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Pre and post harvest factors effecting yield and quality of seed spices: A review

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ABSTRACT

Coriander *(Coriandrum sativum* L.*),* cumin *(Cuminum cyminun* L.*),* fennel *(Foeniculum vulgare* Mill) and fenugreek *(Trigonella foenum-graecum* L.*)* are the important seed spices of Rajasthan. Seed spices are exported to Western countries whose main requirement is quality. This includes cleanliness, or free from extraneous matter, safe level of moisture, absence of food additives, adequate level of flavouring constituents like volatile oil or pungent principle etc. Various factors like sowing date, seed rate, maturity at harvest, drying, storage practices etc. are important to improve the quality of these spices.

Key words : Harvest factors, Yield, Quality, Seed spices

INTRODUCTION

India, being the land of spices, is the foremost country with regard to production, consumption and export of wide range of spices. More than 60 spices are cultivated in India. The country produces about two million tonnes of spices annually. Rajasthan holds an important position in terms of area and production of spices. Coriander, cumin, fennel and fenugreek are the important seed spices produced by Rajasthan and Gujarat. In developing countries, spices are used in household sectors, while in developed countries food processing industries make use of bulk of spices. The seed spices are exported to Western countries. 80 to 85% of volume of spices is traded in whole ungrounded form. Quality requirements of the buying countries and price competitiveness are the key, which determine our survival in the international market. Improved productivity and quality will increase farmers' income and country's foreign exchange earnings which is much needed for our development. The maximum produce, process and prosper' holds true in the case of exports of spices from India. Export require the clean spices without food additives and extraneous matter, having safe level of moisture and adequate level of flavouring constituents like volatile oil or pungent principle etc. Various factors like climate conditions, maturity at harvest, drying storage practices etc. that affects the quality are discussed to enhance the export. In open field cultivation genetic and cultural components are generally and largely managed by growers but there is no control over abiotic (environmental component) and biotic factors (pests and diseases) . Protected cultivation is one way which can check abiotic (environmental component)and biotic factors partially or fully, but this entirely depends upon the kind of protected structures being used vis-à-vis prevailing environmental conditions in that area. Further, harvesting marks the beginning of the deteriorative process and longer the crop awaits before use, the lower will be its quality. Although post harvest quality and shelf life generally depends upon the quality achieved at the time of harvest (Weston and Barth, 60)

Quality parameters

The main parameter for evaluating the quality is their flavour/aroma, which is due to volatile oil contents and its constituents. The relative importance of these qualities depends upon the end use of the spices. For whole seed entering the grocery trade, the appearance is the primary quality determinant. For extraction purpose, the quantity of volatile oil or pungent principle is important. The seed having luster is preferred. These characters vary from spices to spices. Adulteration of superior quality with inferior grade should be stopped. The spices should be graded according to International Standard Organization (ISO). The quality of any product depends upon the quality of raw materials and the practices adopted in processing, packing, storing and transportation.

Factors influencing seed quality

The major thrust on the production of Indian seed spices has been towards higher productivity, however quality consideration was generally very poor. As the quality picture is slowly getting clear due advent of mono-chromatographic techniques, adequate attention is being paid to quality aspects.

Climate and Soil

Coriander: It is a tropical crop which requires a

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cool and comparatively dry and frost-free climate, particularly at the time of flowering and seed formation stages, for good quality and high yields. Frost following the flowering stage reduces production drastically. High temperature and high wind velocity during anthesis and seed formation enhances sterility and reduces yield. Cloudy weather at the time of flowering increases the number of aphids and diseases. Coriander is grown as an irrigated crop on loamy to moderately heavy soils. It is also cultivated as an unirrigated crop with conserved moisture on black cotton or heavy soil types with high moisture retention capacity. Saline, alkaline and even sandy soils are not suitable for coriander cultivation.

Fennel: It requires cool and dry climate and its cultivation should be avoided in frost prone areas because it is susceptible to frost at flowering stage. Dry as well as moderately cool weather conditions during seed formation stages increase seed yield as well as quality of the produce. Except sandy soil, fennel can be successfully cultivated on all types of soil. Soil containing lime with drainage is better suited for fennel cultivation.

Fenugreek: In India it is grown as a winter season crop for commercial seed production. It needs relatively cool climate and low temperature for better vegetative growth during early stages while a dry and relatively high temperature favours better ripening and high production. It can be grown in all types of soils rich in organic matter with good drainage.

Cumin: Cumin crop requires cool (15-25°C) and dry climate for good growth and production. High humidity, cloudy weather, more dew and unseasonable rain after flowering of the crop are detrimental to cumin crop for irrigated cumin crop, sandy-to–sandy loam soil with adequate organic matter is suitable. It can also be grown in well drained medium black soil under conserved moisture conditions.

Sowing Time

Coriander: Ideal season for sowing coriander is last week of October to first week of November for seeds (Sharma and Israel, 53). The seed yield was found to be highest with heavier seeds when sown during this period (Das *et al.,* 18). Essential oil yields were also found to be higher when sowing is carried out during the same period (Bhati and Shaktawat, 9). Crops sown in mid-October have been observed to produce maximum essential oil, which declines with delay in sowing (Maurya, 36). It is observed that early plantings (October end - Early November) reduce the incidence of major insect pests (Jain and Yadav, 28). Incidence and severity of powdery mildew *(Erysiphe polygonz)* is also reduced when the crop is sown early in October (Kalra *et al.,* 31). Therefore delay in owing has to be avoided for coriander crop cultivated for essential oil. Singh et *al.,* (54) obtained the best yield from coriander when seeds were sown in mid- October at 10 kg seeds/ ha receiving 90 kg N/ha. Bhati and Shaktawat (9) obtained the highest seed yield and higher essential and fatty oils in coriander when the crop was sown on 31st October with a row spacing of 30 cm on loamy sand soil.

Cumin: The ideal date of sowing is from 15 October to end of November at an interval of 10 to 20 days. The best time varies from third week of October to first week of November. The temperature below 30°C is essential for better germination. Maurya *et al.,* (38) reported that higher germination can be obtained by soaking the seeds with 100 mg of potassium nitrate/litre of water followed by ammonium nitrate and urea solution of 1000 mg/litre water.

Fennel Optimum sowing time of fennel is from mid-September to end of October. Delayed sowing reduces the yield. In transplanted crop, nursery is raised in the month of June or July; the seedlings of 45-60 days are transplanted in the field in the month of August.

Fenugreek: First week of October to first week of November is the best sowing time for fenugreek in Northern India. In southern part it is grown in both *kharif* and *rabi* seasons. In *kharif,* yield is lesser than *rabi.* Sowing should be done from second fortnight of June to end of July in *kharif* and in *rabi* season fortnight of October is the best sowing time.

Seed Rate and Spacing

Corriender: About 8 kg of seed is required for sowing one-hectare land (Dimri and Narayana, 19). An increased seed rate of 15-20 kg/ha has been found ideal for early as well as delayed sowing (Singh *et al.,* 54). Fruits are split into halves before sowing, since sowing whole fruit delays germination. Profuse branching habit of S-33 demands more space between the rows. The seeds are sown in rows 50-60 cm apart whereas a row spacing of 30 cm has been found suitable for obtaining higher seed yield (Bhati and Shakawat, 9). Germination generally takes place within 10 days. Seedlings are thinned after a month of sowing maintaining a distance of 30-45 cm between the plants. To achieve optimum plant density in irrigated condition, a seed rate of 12-15 kg/ha is required. Sowing should be done 30 cm apart in lines with plant-to-plant distance of 10 cm, whereas in heavy soils or fertile soils 40 cm spacing between rows is recommended.

Fennel: To achieve optimum plant density in direct sowing, a seed rate of 10-12 kg/ha is required. For transplanted crop, a seed rate of 3-4 kg/100 m^2 in nursery is sufficient for transplanting one hectare. Optimum sowing time of fennel is from mid-September to end of October. Delayed sowing reduces the yield. In transplanted crop, nursery is raised in the month of June or July, the seedlings of 45-60 days are transplanted in the field in the month of August.

Cumin: To protect the crop from seed and soil borne diseases, seeds should be treated with a fungicide @ 3 g/kg seeds. Delay and slow germination are constraints in cumin cultivation; therefore farmers use higher seed rate to achieve maximum plant population in field (Lal, 35, Anon., 3). Chandola *et al.,* (14) and Sharma (52) advocated 10-12 kg as optimum seed rate of cumin while Sharma *et al.,* (53) suggested 12-15 kg good quality seeds/ha for optimum plant population. In Gujarat recommended seed rate is 16 to 20 kg/ha. However, seed rate varies with type of soils, water and method of sowing:

Fenugreek: To achieve optimum plant population a seed rate of 25 kg/ha is sufficient. Seeds should be treated with, rhizobium culture before sowing. Line sowing should be done 30 cm apart with plant-to-plant distance and depth of seed should be around 5.0 cm. Randhawa et *al.,* (47) investigated the effects of sowing date, plant spacing and fertilizers (N at 0,20,30,40, or 50 kg/ ha; P at 0, 20 or 40 kg/ha) on seed yield. Highest yield was obtained when seeds were sown between the last week of Oct. and the first week of November in rows 22.5 cm apart using 30 kg seeds/ ha.

Sowing method

Fennel: Sowing should be done in rows of 45-60 cm apart with plant-to-plant distance of 20 cm. Seeds should be placed 1.5 to 2.0 cm deep in case of direct sowing. In some areas broadcasting method is adopted when it is taken as mixed crop with chillies or any cole crops. Seeds are broadcasted in the beds after the seedlings of chillies or cole crops are established in the field preferably at weeding and hoeing and after sowing is done the field are irrigated. Sowing in the third week of October (rather than first week of October or November) gave the highest seed and biological yield (Yadav *et al*., 61).

Cumin: It is normally sown by broadcasting. According to Jat (30) line sowing at 30 cm row spacing is best for cumin. On the other hand, Bhargava *et al.,* (8), Lal (35), Chandola *et al.,* (13) ,Sharma (52) reported that line sowing at 30 cm row spacing was superior over both broadcasting as well as wider row spacing of 45 cm. However, Choudhary (17) and Bhati *et ai.,* (10) observed non-significant differences between these two methods. It was also reported that line sowing facilitates hand weeding at faster rate as well as to check the spreading of wilt disease.

Fenugreek: Line sowing should be done 30 cm apart with plant-to-plant distance10 cm and depth of seed should be around 5.0 cm.

Irrigation

Coriander: Crop requires frequent light irrigations until the crop comes to full blooming after that frequency of irrigation is reduced and totally stopped before harvesting (Dimri and Narayana, 19). In areas like Madhya Pradesh four irrigations are essential for good crop growth (Ali *et al.,* 2)

Fennel : is a long duration crop and requires more irrigation than other seed spices. As the germination is slow in fennel, to facilitate germination one or two light irrigations are required depending on the climatic conditions. Water stress during flowering and seed formation stages may reduce seed formation and the grain yield. So care must be taken at this stage not to subject the plants to water stress. Consumptive use of water associated with increase in the number of irrigations was highest (293.1 mm) when irrigation was applied at the crown stage, main umbel development stage and seed setting stage (Yadav *et al.,* 61). Seed yield and biological yield were also highest (24.0 q/ha and 154.5 q/ha) with 3 irrigations, followed by 2 irrigations (one at the crown stage and second at the umbel development stage).

Cumin: Generally light irrigation is given immediately after sowing and at 8-10 days after sowing. Subsequent irrigations are given at 15-25 days interval depending upon environmental conditions. Jangir and Singh (29) concluded that 5 irrigations *i.e*. first at sowing and 10, 30, 55 and 80 days after sowing produced highest seed yield of 764 kg/ha. Singh and Rao (57) indicated that nitrogen requirement with water supplied to the crop. The treatment combination, 480 mm of water and 87 kg N/ha, produced seed yield of 1467 kg/ha. The studies further concluded that to obtain the yield goal of 1500 with least cost, combination of water and nitrogen should be 455 mm and 100 kg N/ha.

The crop requires 10-12 days for germination and therefore two irrigations are required for good germination. To save one irrigation, water soaked seeds should be kept in cotton six days for sprouting. These pre-sprouted seeds give good germination within six days and require one irrigation immediately after sowing.

Fenugreek: About 5-7 irrigations are required depending upon the climatic conditions, moisture retention capacity of soil and variety used. To obtain the best results in sandy loam soil, the crop should be irrigated at IW / CPE ratio of 1.00. First irrigation should be applied 30 DAS, second at 45-50 DAS, third at 70-75 DAS, fourth at 85-90 DAS, fifth at 105-110 DAS, Special care should be taken to avoid water stress at pod and seed development stages.

Fertilizer application

Coriander: Judicious use of fertilizers has also been shown to benefit to the volatile coil contents as well as fruit yield of coriander (Prakash Rao *et a1*. 44). Seed and essential oil yields were found to improve with increase in doses of nitrogen and phosphorus (Tiwari and Banafar,

58) While higher *seed* and essential oil yields could be obtained upto 100 kg N (Rao *et* 48; Baboo and Rama, 4). At the time of field preparation about 10-20 tonnes/ha FYM or compost should be applied. In addition to this 20 kg nitrogen, 30 kg phosphate and 20 kg potash per hectare should be applied at the time of sowing in irrigated as well as in unirrigated crop.

In irrigated coriander an additional dose of 40 kg nitrogen/ha should be applied in two equal splits first at 30 days and second at 75 days after sowing. Badgujar *et al.,* (5) observed the response of foliar application of urea at 20 DAS. It was reported that treatment with 0.25% urea gave the highest yield *viz.* 8.38 q/ha, compared with 3.38 q/ha in the untreated control. Maurya (37) studied the effect of micronutrients on yield and essential oil content of coriander and found that the best results were obtained with $CuSo_4$ in all the treatments. Ughreja and Chundawat (59) reported that increasing N application resulted in increased plant height, number of branches, number of seed/primary umbel, seed and straw yield and essential oil content.

Fennel: At the time of field preparation, about 10-15 tons of well decomposed FYM or compost is applied. In addition to this 90 kg N/ha in three equal splits, first as basal dose at the time of sowing, second at 30 DAS and third at 60 DAS with irrigation is applied to obtain good yield. Increasing phosphorus fertilizer rate had a strong effect on fennel yield.

Cumin: Cumin was considered to be non-responsive to inorganic fertilizers. Recent studies have indicated, it is responsive to application of nitrogen, phosphorus and to some extent to potash. Mishra (40), Sankla and Mathur (51), Bhati *et al.,* (12) and Choudhary and Gupta (16) reported 20-30 kg N/ha as optimum dose for cumin. Studies conducted earlier indicated 45 kg N/ha as optimum dose of N application. Bhargava *et al.,* (8), Lal (35), Chandola *et al.,* (13) and Fageria *et al,* (20) recorded maximum yield of cumin by application of 50-60 kg N/ha. Application of nitrogen as top dressing in two equal splits, one at the time of sowing and after days after sowing resulted in a good crop of cumin. (Bhati *et al*., 11, 12).

Fenugreek: at the time of field preparation about 10-15 tonnes/ha FYM or compost should be applied. A basal dose 25 kg N and 40 kg P_2 O per ha should be applied in the soil at the time of sowing. If soil fertility is more, dose of nitrogen maybe reduced. Banafar *et al.,* (6) studied the response of fenugreek to nitrogen and phosphorus and reported that seed yield increased from 806 to 1200 kg/ ha at N application rates of 0 and 80 kg/ ha, respectively (excluding basal applications) and from 776 to 1105 at P application rates of 0 and 45 kg/ ha, respectively.

Weed Control

Coriander: Seed yield recorded under the combination of hand weeding once at 50 DAS and herbicidal treatment of fluchloralin @ 0.75 kg /ha or oxyfluorfen @ 0.15 kg/ ha (8.17 q / ha) or pendimethalin @ 1.0 kg/ ha (8.50 q/ ha) or pendimethalin @ 1.0 kg/ ha (8.50 q /ha) was at par with weed free condition (9.41 *q/* ha) and hand weeding twice. Crop should be kept free from weeds. Weeding is done at least twice; 15 and 30 days after germination. Pendimethalin (0.75kg/ha) provides 76.5% weed control and essential oil yields comparable to weed free control (Kothari *et al.,* 34).

Fennel: The fennel crop faces severe weed competition at early stages because of slow germination wider row spacing and frequent use of light irrigation for its germination, favouring the growth of weeds. At the time of thinning (30 DAS), first hoeing and weeding should also be done. Pre-emergence application of Pendimethalin at the rate of 1.0 kg/ha supplemented with one hand weeding 50 DAS gives better control of weeds.

Cumin: weed is a serious problem in cumin crop. In addition to contaminating seed, it also shares nutrients and moisture from cumin crop. Weeding should be done at 15 and 30 DAS. Mishra (40) reported Zeeri (*Plantago pumila;* wild) Bathua *(Chenopodium album),* Khartua *(Chenopodium murale),* Piaji (*Lodellus tenifolius);* while Choudhary and Gupta (16) in addition also observed *Heliotropium :cumin,* Pilisanjee *(Melilotus indica),* as common weeds in the crop. Due to Zeeri *(Plantago pumila),* contamination a serious cumin weed, the crop fetches poor prices in the market (Singh and Joshi, 55).

Favourable response has been reported by using herbicidal spray as pre-sowing (Bhati *et al.,* 11; Choudhary, 15; Choudhary and Gupta, 16; Rathore,*et al.,* 49) . Gupta (24) reported that Zeeri *(Plantago pumila)* could be controlled by spraying of fluchloralin 0.75 to 1.00 kg/ ha. Rathore, (49) indicated that Pendimethlin is the best herbicide for controlling weeds in cumin crop. (Chandola *et al*., 13) reported that zeeri can be controlled with pre plant spraying of flucloralin @ 0.77 to 1.0 kg/ha.

Fenugreek: Hoeing and weeding are required to keep the crop well aerated and free from weeds. First hoeing and weeding should be done at the time of thinning *i.e*. 25-30 DAS and second at 50-60 DAS. Preplant application of fluchloralin @ 0.75 kg/ ha supplemented with hand weeding at 50 DAS could keep the crop free from weeds.

Pest

Coriander: Among the insect - pests, aphids *Aphis gossypii* (Ghetiya and Butani, 42) and *Hydaphis coriandri* are the major problems in coriander cultivated for essential oil. They damage at the time of flowering

stage and in the essential oil rich flowering the incidence is greater (Jain and Yadav, 27). Aphids can be controlled by monocrotophos or rogor (Dimri and Narayana, 19).

Cumin: Insects are one of the limiting factors for higher production of cumin. Six pests namely Surface grass hopper, Lucern caterpillar, Cotton aphid, Green peach aphid, Onion thrips and Brown mite are reported. Among these, cumin aphid *(Myzus persicae)* was found to be a major pest damaging the crop by sucking the cell sap of inflorescence (umbels) from February till second week of March. Due to high population and continuous desapping of flowers, the seed formation gets very much reduced. Meena (39) reported that adopting spraying schedule and use of resistant varieties can control aphid. Gupta and Yadav (22) reported least appearance of aphid, when cumin crop was sown on 1-16 Nov. Later sown crop showed heavy infestation. Gupta (25) suggested that spraying of monocrotophos at 0.04 or 0.06% at seed initiation stage effectively controlled the aphid (green peach), whereas Gupta *et al.,* (23) reported spraying of 0.03 or 0.05% phosphamidon to control the aphid, effectively.

Fennel: Aphid *(Hyadaphis coriandri)* sucks the sap of the plant from tender parts and flowers. The infected plants turn yellow and produce shrivelled and small seeds and thus reduce the yield as well as quality of the produce. While using insecticides for controlling the aphids, we must consider that the insecticides should not harm pollinators (honey bees) in fennel and it should have very low residual toxicity as the insecticide residual standards are strictly regulated in fennel particularly in International market. Damage by aphids can be reduced when fennel is sown in September.

Fenugreek: Fenugreek is attacked mainly by aphids namely *Acrythosiphon pisum, Aphis craccivora. Hydaphis coriandri,* and *Myzus persicae, which* suck the sap of plant from tender parts and flowers. With the attack of aphids the plants turn yellow and results in shriveling of seeds and reduction in seed yield as well as quality. Spraying endosulfan (0.07%) or monocrotophos (0.1%) 400-500 lit/ ha can control aphids. (Ravindran *et al.,* (50). Leaf Eating Cater pillar and Pod Borer *(Spodoptera litura)* can be controlled by spraying 0.05% quinolphos or endosulfan @ 0.075% or Monocrotophos (0.04%) (Ravindran *et al.,* 50).

Disease management

Seed spices are susceptible to various diseases, which cause heavy loss of yield and deteriorate quality. Blight and powdery mildew are controlled chemically. Screening of lines against cumin wilt under artificial/field conditions indicated that RZ-19, UC-198 and UC-199 have shown fairly good tolerance to wilt. In Coriander, RCr-41 was found to be less susceptible to wilt and completely free from stem gall disease. Wilt can be reduced by three years crop rotation practice.

Coriander

Wilt (*Fusarium oxysporum* f. sp *corianderi*): Root infection results in dropping of terminal shoots, followed by withering and drying of leaves. Partial infection shows yellow to pink foliage (Prakasam *et al.,* 43);. Spray the foliage twice with Carbendazim (Bavistin, (0.1%) at the age of one and two month). Use tolerant lines Sindhu, Co3, RCr-41, GCr-1 & GCr-2.

Powdery mildew (*Erysiphe polygoni*): Infection occurs as whitish circular patches on leaves and stems and later white powdery mass appears. Affected inflorescences dry up or get shrivelled. Total loss of crop occurs in case of death of plants. (Raju *et ai.,* 46). Use tolerant varieties-Sindhi, Co3, RCr-41, GCr-1 and GCr-2. Apply 2 rounds of spray with Karathane (0.1%) at the start of the disease and again with Carbendazim (0.1%) 10-15 days after the first round.

Stem gall (*Protomyces*)*:* Stem gall of coriander is another major problem causing tumour like swelling on stems, petioles, pedicels and vein of leaves and affecting the yield up to 33-96% seed (Naqvi, 41 and Kalra *et al.,* 33). Efforts for chemical control been really successful on control of this disease by treating seed with aptafol and thiram @ 250g/ 100 kg (Bhardwaj and Shrestha, 7).

Grain moulds *(Alternaria, Fusarium, Curuularia, Helminthosporium)*: Fungal infestation occurs in the semi-mature and mature grains when they are still intact on panicles. Reduction in the yield, quality and appearance take place. Spray Carbendazim (0.1%) 20 days after seed-set.

Cumin

Wilt: *(**Fusarium oxysporum* f. sp. *Cumini***): Foliar yellowing ,drooping and root rot are symptoms. Partially infected plants show stunting, poor seed-set and death. If root rot is severe crop loss is heavy. Select healthy seeds. Treat seeds with hot water at 54°C for 15 minutes. Treat the seed with Carbendazim @ 2g/kg seed. Cultivate resistant/tolerant varieties-RZ 19, Gujarat Cumin 1 and Gujarat Cumin 2 and MC-43, RZ-209 and GC-4.

Powdery mildew *(Erysiphe polygoni)* : Whitish or greyish specks on lower leaves which spread to entire leaf covered with whitish powdery mass. Give two rounds of sulphur dust, Karathane (0.1%) with the onset of disease during November. Integrated disease/pest management schedule for powdery mildew, blight and aphid consists of round of 0.2% Captafol, II round of 0.2% Captafol + Karathane (0.1 %) + Dimethoate (0.01%), III round of Captafol + Karathane and IV round of sulfur dust @ 25kg/ ha in October-November according to first appearance of the disease.

Blight *(Alternaria burnsii)*: symptoms include necrotic spots on leaves especially in tips with stem infection as dark streaks which later spreads to blossoms.For blight alone treat the seed with Dithanon @ 2g/kg or spray plants with Mancozeb thrice (0.2%).

Fenugreek

Powdery mildew *(Erysiphe polygoni)*: On leaves it appears as discoloured patches and later spreads to whole plants as a powdery mass causing reduction in yield. Dust plant with sulphur 300 mesh, @ 25kglha or spray with wettable sulphur (0.25%) or Dinocap (0.25%) at 15 days interval after the first appearance of the disease.

Root rot *(Rhizoctonia solani)* : Infected plants show varying degrees of foliar yellowing and root rot 30-40 days after sowingand they wither and dry up. If disease is severe, drench the soil twice with Carbendazim (0.1 %) at 15-days interval.

Maturity indices

Harvest the crop only when it is fully mature. Maturity in most of the crops is indicated by the drying up of the plant including the base of the stem. While harvesting care should be taken not to cause any damage to the seeds. Any product depends upon the quality of raw material and the practices adopted in grading, storing and transportation. Injudicious harvest and in appropriate post harvest technology probe potential threat for low quality. At harvest, a moisture content of the seed is around 20%, which should be dried to a safer limit of 8-9%. If the fruits are not thoroughly dried, they absorb moisture, which results into the deterioration of colour and flavour of spices.

Coriander: The crop of coriander matures in 90 to 135 days. The stage of maturity of fruit at harvest is when central umbels are about to attain yellow colour. At this stage, shining and volatile oil contents of fruits are highest. Harvesting is done when about 60% of the fruits mature and turn brown (Dimri and Narayana, 19). The harvested plants are dried and threshed to separate seeds. The stage of maturity is of paramount importance; immature fruits contain higher essential oil than the ripened fruits, over ripening however, should be avoided as it leads to splitting of fruits causing loss of essential oil. At harvest moisture content should be around 20% and it should be reduced to 9-10%. S-33 takes around 120-123 days to mature in southern regions (Rahman *et al.,* 45) and 130 days in northern regions (Kalra *et al.,* 32). Coriander seeds are harvested at a stage when 50 percent grains turn yellow. At this stage, seeds are having maximum luster and volatile oil contents (Agrawal and Sharma 1).

Immature fruit contains a higher volatile oil contents than ripe fruit but aroma of immature fruit is generally considered disagreeable because of its high aldehyde content which are responsible for fetid like aroma. The harvested material should be dried in shade to retain seed colour and quality. If it is not possible then material should be bundled and kept up side down to avoid direct sun rays on the seeds and to avoid bleaching. After drying, the seeds are separated by light beating with sticks and winnowing.

Cumin: Cumin is harvested in about 100 to 110 days. The right time for harvesting is usually done in morning hours to avoid shedding losses. Cumin should be harvested by cutting rather the uprooting the plants to overcome the problem of contamination. Zderkiewiej (62) found that the quality and quantity of volatile oil improved with ripeness. Physiological maturity (complete yellowing of plant) is the best stage for harvest to get high oil content in seeds, with good color and higher yield. Delayed harvesting showed negative results for all above three parameters. It is also observed that sun drying of harvested material for long time before threshing is also advantageous for quality of cumin.

The crop is kept in field for drying in a bunch. To separate the seeds from plant, the crop is beaten with wooden rod. Quality also depends upon the practices adopted in processing; packaging storing and injudicious harvest and inappropriate post harvest operation may be potential threat. Processing consists of drying, cleaning, sorting and grading. Sun drying is done on clean floor or tarpaulin. This will avoid the direct contact of seed with soil. Cleaning, sorting and grading is done with the help of different machines like Spiral Separator, Magnetic seed separator, our sorter, Destoner, Rotary knife cutter etc. Commercially, cumin is cleaned using separator.

Fennel: In fennel, all the umbels do not mature at the same time; hence picking of umbels is done when seeds are fully developed but still green. Fennel takes 170 to 175 days to mature. Harvesting is done before the fruits are fully ripe and completes in three pickings at an interval of 10-12 days. At this stage, the umbel attains a slightly garnish yellow colour. Umbels harvested are dried in 1-2 days and then in shade for 8-10 days. At this stage, the umbel attains a slight greenish yellow colour with highest volatile oil content (Bhati 12). Longer exposure to sun changes the colour and luster of seeds and reduces quality. Over-ripening of umbels should be avoided as it reduces the marketable quality. Chewing type “Lukhnavi” fennel is produced by harvesting the umbels 30-40 days after pollination. At this stage size of the seeds is just half of the fully developed seeds and then dried in shade. If reduces the yield but gives high net return as compared to crop harvested at full maturity. Crude fibre content at this stage is 11 % as compared to 15% in the normal fennel (Bhati *et al.,* 11). On ripening of the fruit, fiber

content increases which decreases the quality. Average yield of fennel is about 12-13 q/ha. However, when improved varieties and package of practices are properly adopted, yield as high as 20-25 q/ha can be obtained.

Quality of seed spices also depends upon the practices adopted in processing, packaging, storing and transportation. Injudicious harvest and inappropriate post harvest operations may be potential threat for low quality. Processing of fennel consists of drying, sorting and grading. Harvested umbels are left in field for two to three days and then in a shady place for 8-10 days for complete drying. Crop should not be kept in the sunlight for longer periods, as the colour of seed gets faded.

Most of the contamination in fennel is due to microbes during sun drying or from soil and air. In order to avoid the dependence on weather and to reduce the microbial contamination, mechanical drying may be used. Separation of cleaned and uniform seed purities is based on differences in physical properties between desirable seeds and undesirable. Dried seeds are cleaned to get rid of extraneous matter. Spiral separator is used to separate seeds. Magnetie seed separator or electrostatic seed separator is used to separate identical seed from product. Electronic colour sorter is used to separate discoloured seed to enhance value product. Gravity separator/ distoner is used to separate undesirable material on the basis of seeds relatively free from major diseases.

Fenugreek: Fenugreek is harvested within three months after planting when the colour of leaves and pods turn yellow. Harvesting should be done when the lower leaves started shedding and the pods have become yellowish. Harvesting should be done by cutting the plants with sickles. Delay in harvesting leads to shattering of seeds. The harvested plants are tied in bundles and allowed to dry for 4-6 days. Threshing should be done on clean cemented floor or tarpaulin. The grains are separated by beating followed by winnowing or threshing which may be done by mechanical threshers. The average yield of fenugreek is 10-11 q/ha. Under good management condition and use of high yielding varieties, an average yields of 15-20 q/ha can be obtained.

Post Harvest Processing

The quality of spices depends upon the practices adopted in processing, packaging storing and transportation. Injudicious harvest and inappropriate post-harvest operation may be potential threat for low quality.

Processing

Processing of coriander, cumin fenugreek and fennel consist of drying and cleaning. Sun drying is done on clean-cemented yards or other suitable clean surfaces. The material is occasionally turned over to ensure uniform drying. The material should be heaped and covered during nighttime to ensure protection from rain. No coloring material should be used to improve the appearance of the product as chemicals and artificial colours are highly objected by the importing countries.

Storage Precautions

Cleaned, dried seeds are filled in bags and stored in damp-free aerated storehouses. On commercial scale seeds are cleaned with the help of vacuum gravity separator and destoner and spiral gravity separator. To get good price and easy marketing, the produce should be categorized in different grades and stored properly. The material should be stored ensuring protection from dampness. Drainage should be provided to stack the packed bags to prevent moisture ingress from the floor. Care should be taken to stack the bags 50 to 60 cm, away from the wall. Under any circumstances, no insecticide should, be used directly on the dried material. Stored material should be subjected to periodic fumigation for which only authorized persons should be engaged. Insects, rodents and other animals should be effectively prevented from getting access to the premises where the material is stored. Stored product should be periodically exposed to the sun. If care is taken in all stages of cultivation, harvesting, post harvest handling, processing, packing, storage and transportation by following sound methods and practices we will be able to prevent contamination in any farm produce and ensure consumer satisfaction.

Storage

The dried seeds are usually packed into sacks and stored in cool dry room. It should be stored at room temperature (25°-28°C) where the critical moisture level and relative humidity should not be more than 13-19 percent and 81 percent, respectively. During prolonged storage of spices, free fatty acids are increased by lipolytic action on fixed oil. This value is a good indicator of the period of storage. The spice seed can be stored in gunny bags for one year without significant loss of volatile oil contents. The loss of volatile oil content is fairly rapid in powdered spices. The deterioration in quality of coriander powder can be reduced by storing in aluminium foil bags. No insecticide should, under any circumstances, be used directly on spices. Stored material should be subjected to periodic fumigation for which only authorized persons should be engaged.

PROCESSING TECHNOLOGY

Spice Grinding

Spice-grinding techniques should be studied in more detail in order to evolve efficient methods which prevent changes taking place in ground spices with respect to flavour and pungency. It is known that temp above 35°C, during grinding, cause deterioration of delicate

flavour. Modern pre-crushing techniques such as the Cryomill process or sieveless fine grinding by Contralex wide-chamber mill with stud disks permit spices to be milled to desired fineness, without risk of metallic contamination. The cast grinding mills that yield spice powder contaminated with iron dust, and are still being used.

Spice Products Technology

Spice concentrates, oleoresins and essential oils have become more in demand as exportable item as flavouring agents in pharmaceutical preparations, beverages, and commercial or household food. Methods should be standardized for extraction and recovery of these concentrates, removal of traces. Developmental work on tailor-made oleoresin blends should be initiated after the survey of international markets.

Packaging Technology

As a means of increasing the shelf-life of food, in general and of spices and condiments in particular, has gained considerable importance. The development of new and improved transparent plastic films, foils, high-speed film-sealing machines, gas flushers, etc., has created new opportunities for food spices, condiments, and new spice products such as instant spices, liquid spices spice concentrates, liquid spice pastes, spice powders, and encapsulated soluble dry seasonings are therefore generally costly; they require attractive, efficient, and comparatively inexpensive packaging for retail marketing in western countries, where attractively packed spices fetch a premium price.

Unit Packages

Factors such as compatibility between packaging materials and products, and migration of compound packaging materials into products and vice versa, should be considered before any packaging material is selected. With increasing consumers' insistence on fair practices in packaging and labelling and also with increasing costs of packing materials, the packages should be of minimum requisite size to contain products. Cardboard cartoons with a flexible bag inside can provide chemical and mechanical protection required for spices. Such lined, folding cartons can hold liquids, pastes and powders and are suitable for gas packaging and reclosure facilities. Compared to other forms of rigid containers, these cartons are light in weight and occupy less space, but they require more packaging time. For powdery spices and blends, composite containers made of cardboard bodies and seamed metal tops with suitable coatings or linings could also be tried. The production of moulded aluminium containers should be increased. as the trend is towards export of essential oils and oleoresins.

Bulk Packages

Bulk packages such as jute sacks are sometimes used without any lining material but the addition of kraft paper and polyethylene film would prevent sifting, and the film, to some extent, would protect commodities against moisture and also against insect attack. Woven plastic and multiwall paper sacks with plastic or bituminized liners may be tried for ground and whole spices, as these materials possess adequate physical strength and low permeability to water vapour. Wooden containers used for shipment of spices are rather heavy and are subject to insect attack. Corrugated and solid fibre-board containers are available in various sizes, and they can be filled and closed rapidly. Insect infestation can be reduced by incorporation of insect repellants in sealing tapes and adhesives between plies at the conversion stage.

Other Packaging Requirements

High-density polyethylene film has better barrier properties and more rigidity than low-density polyethylene film. Films of polyvinyl chloride, regenerated cellulose and polyropylene, either singly or laminated with other suitable packaging films, have varying degrees of barrier properties to prevent passage of water vapour, gases, organic volatiles and migration of fats. Since may of the indigenously availability of new packaging materials such as polyester and nylon would facilitate design of more functional packages.

CONCLUSION

India dominates in seed spices and spice oils and oleoresins. Our growth in spices export is remarkable. However, we are facing in stiff competition from other exporting countries like China, Guatemala due to their higher productivity and low unit cost. Research has to be intensified to evolve more high yielding, pest and disease resistant varieties with better overall quality attributes and to suggest effective control measures against pest and diseases and to evolve package and practices to be adopted under varied agroclimatic situations. There is also a need for standardization and grading of packing materials, reduction in variety of containers, rationalized net weights of packages and their tolerances, uniformity in essential features of labelling, classification of packaging hazards. and objective methods of assessment of or testing of packages. Suitable coverage of these subjects in a logical and flexible manner should bring about economy in use of materials and a reasonable growth of relevant industries. This will also help to co-ordinate work of package designers, laboratory technicians, exporters and distributors of spices and spice products, standards-setting bodies and certifying authorities .There is a need to establish a export house and lab recognised for analysing the produce acceptable to foreign markets.

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