Effect of cryogenic grinding on volatile and fatty oil constituents of cumin (*Cuminum cyminum* L.) genotypes

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Abstract Effect of cryogenic grinding on recovery of volatile oil, fatty oil percentage and their constituents in two cumin (*Cuminum cyminum* L.) genotypes have been analyzed. Cryogenic grinding not only retains the volatiles but enhanced the recovery by 33.9 % in GC 4 and 43.5 % in RZ 209. A significant increase (29.9 %) over normal grinding in oil percentage was also observed in genotype RZ 209. This increase was, however, less (15.4 %) in genotype GC 4. Nineteen major compounds were identified in the essential oil of both genotypes. The two grinding techniques had significant effects on dependent variables, viz., volatile oil and monoterpenes. Cuminaldehyde was the main constituent in both genotypes, content of which increased from 48.2 to 56.1 % in GC 4 on cryo grinding. Content of terpenes were found to decrease in cryo ground samples of GC 4 and either decrease or no change was found in RZ 209. Organoleptic test showed more pleasant aroma in cryo ground seeds of both the genotypes. Significant increase was also reported in fatty oil yield due to cryogenic grinding. Fatty acid methyl ester (FAME) analysis showed oleic acid as major FAME content of which increased from 88.1 to 94.9 % in RZ 209 and from 88.2 to 90.1 % in GC 4 on cryogenic grinding. Other prominent FAME were palmitic, palmitoleic and stearic acid. Results indicated commercial potential of cryogenic grinding technology for cumin in general and spices in particular for better retention of flavour and quality in spices.

Keywords Cryogenic grinding · Cumin · Cuminaldehyde · FAME · Seed spice

Introduction

Seed spices group comprises all those annuals whose dried fruit or seeds are used as spices. These are aromatic vegetable products of tropical origin and primarily used for seasoning, flavouring and imparting aroma to the food and beverages. They are characterized by pungency, strong odour, sweet or bitter taste and known for ages as effective therapeutic food. India is known as the ‘Land of Spices’ and is the largest producer, consumer and exporter of raw spices and value added spice products. The states, Rajasthan and Gujarat have together contributed more than 80 % of the total seed spices produced of the country.

Cumin is one of the major seed spice, long associated with man. The seeds of cumin were used by Romans as an alternative to pepper and as a paste to spread over bread and meat. Cumin is mentioned as an essential ingredient of many traditional dishes. In Ayurvedic system of medicine, dried cumin seeds are used for medicinal purposes. It is known for its actions like enhancing appetite, taste perception, digestion, vision, strength, and lactation. It is used to treat diseases like fever, loss of appetite, diarrhea, vomiting, abdominal distension, edema and puerperal disorders (Rathore et al. 2013).

Grinding of spices is an age-old technique like grinding of other food materials. The main aim of spice grinding is to obtain smaller particle size with good product quality in terms of size, flavour and colour. In normal grinding, temperature of the product rises to a level of 42–95 °C (Pruthi 1993), depending upon the oil and moisture content of the spices. This elevated temperature causes loss of

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significant fraction of their volatile flavouring components resulted in loss of flavour and colour of the produce. The fat content in spices poses extra problems, hence, an important consideration in grinding. The losses of volatile oil for different spices have been reported to be in the order of 40 % in coriander (Saxena et al. 2010), 37 % for nutmeg, 14 % for mace, 17 % for cinnamon and 17 % for oregano (Balasubramanian et al. 2015). The loss of volatile oil during grinding of caraway seed has been reported to be 32 % with an increase in grinding temperature from 17 to 45 °C (Wolf and Pahl 1990). This loss of volatile oil can be significantly reduced by adopting cryogenic grinding technique using liquid nitrogen that provides the refrigeration needed for pre-cooling the spices and to maintain the desired low temperature by absorbing the heat generated during the grinding operation (Singh and Goswami 1999). The extremely low temperature in the grinder solidifies oils so that spices become brittle hence, crumble easily permitting grinding to a finer and more consistent size. The earlier work on use of liquid nitrogen for cryogenic grinding of the spices highlights the benefits of cryogenic grinding over the non cryogenic grinding in ambient condition (Saxena et al. 2012, 2015; Sharma et al. 2014, 2015; Singh and Goswami 1999).

In the present investigation seeds of two distinct genotypes of cumin were ground at ambient temperature using normal grinding technique and cryogenic grinding technology using liquid nitrogen. Ground powder from both techniques was analyzed for recovery of volatile oil content and its constituents and changes in fatty oil profile. Effect of grinding technology was studied to see the benefit in terms of better retention of flavour and fatty acids composition in cumin.

Materials and methods

Seeds of two genotypes of cumin (GC 4 and RZ 209) were obtained from seed store of ICAR-NRCSS, Ajmer (Rajasthan), India. Cleaned seeds were used for grinding both, cryogenic and normal grinding. Ground powder was used for extraction of volatile and fatty oil and subsequent analysis.

Grinding of seeds

Cryogenic grinding of seeds was done using a cryogenic grinder (Spectra cryogenics, India) model Fine Impact Mill 100UPZ at National Research Centre on Seed Spices, Ajmer (India). In the process of cryogenic grinding the material is fed into a feeder hopper and dropped into a pre-chilled conveyor. Liquid nitrogen is sprayed and blended directly onto the material. The material is conveyed via a

stainless steel special design auger. The auger not only transports the grinding media, but also mixes it with liquid nitrogen for greater cooling efficiencies. Liquid nitrogen is added until the temperature of the material is reduced to a predetermined set point (−30 °C). Finally the brittle material enters an impact (pin) mill where it is ground to a desired particle size (50–100 microns). The Cryo ground powder was quickly packed in aluminum foil packets using heat sealing machine and opened at the time of analysis. Non cryogenic grinding was done separately by domestic mixer grinder (Sujata, model Dynamix, 810 W). Ground powder was used for volatile and fatty oil extraction.

Oil extraction

Oil content was extracted using Accelerated Solvent Extraction System (Dionex India Pvt. Ltd.). This technique accelerates the traditional extraction process by using solvent at elevated temperatures and pressures. Pressure is maintained in the sample cell to keep the heated solvent in a liquid state during the extraction process. After heating, the extract is rinsed from the sample cell into a collection vessel. Oil was obtained after evaporating the solvent in rotary evaporator. Thirty gram seed powder was utilized for oil estimation.

Chemicals

All reagents and fatty acid standards were procured from Sigma-Aldrich, USA and were analytical or HPLC grade.

Extraction of essential oil

Thirty gram cleaned seeds of each genotype were used for essential oil extraction by hydro-distillation for 3 h using a Clevenger apparatus (Clevenger 1928). After decanting and drying of the oil over anhydrous sodium sulphate the corresponding mild yellowish coloured oil was recovered and calculated in terms of percentage. The oil has a characteristic odour of cumialdehyde and a warm, aromatic flavour.

Gas chromatography–mass spectroscopy

Essential oil profiling

One microlitres of volatile oil was injected to a HP 5 MS column (Agilent, USA, 30 m × 0.250 mm film thickness 0.25 µm) using auto sampler (Agilent 7693). The analysis was carried out under the following conditions: oven temperature was programmed at 50 °C for 3 min followed by raising at 10 °C/min to 180 °C and 45 °C/min to

280 °C, injection port temperature was kept 250 °C; carrier gas: helium; flow rate 1 ml/min, split ratio was 10:1. Authentic standards of major constituents of cumin essential oil were procured from Sigma-Aldrich (USA). These standards were run alone and in combination to get retention time of each constituent. Retention indices of all the constituents were determined by chemstation software (Agilent technologies, USA). The volatile constituents were identified by a comparison of their retention indices and their identification was confirmed by computer matching of their mass spectral fragmentation patterns of compounds in the NIST-MS library and published mass spectra.

FAME analysis

Fatty Acid Methyl Esters (FAME) were prepared according to AOCS Method CE 1–62. Diluted FAME were separated on an Agilent Series GC–MS (Agilent, USA; GC-7820 A, MS-5975) equipped with an HP5 (Universal column) (30 m × 0.32 mm × 0.25 µm); Agilent J&W GC column with an auto sampler. A sample of 1 µL was used in split mode (20:1) with an auto sampler. Helium was used as the carrier gas at a flow rate of 1.0 ml/min. The column temperature was programmed from 50 to 280 °C with equilibrium time of 3 min, held for 30 min. Injector temperature was set at 250 °C. The fatty acids were identified by a comparison of their retention indices and their identification was confirmed by computer matching of their mass spectral fragmentation patterns of compounds in the NIST-MS library and published mass spectra with the help of Chemstation software (Agilent Technologies, USA).

Statistical analysis

Experimental data were analyzed using Microsoft Excel (Microsoft Inc.). Each observation was replicated three times and data were analyzed using Randomized Block Design. Significance of differences between samples was analyzed using analysis of variance (ANOVA).

Results and discussion

Table 1 shows essential and fatty oil percentage of cryo ground, non cryo ground and intact seeds of cumin genotypes. Essential oil percentage in intact seeds of genotype GC 4 was larger (4.0 %) compared to RZ 209 (3.3 %). Non cryo grinding causes a loss of 23.2 % volatile oil in genotype GC 4 and 24.3 % in RZ 209. Interestingly, cryogenic grinding not only retains the volatiles in both the genotypes but enhanced the recovery in order of 33.9 % in GC 4 and 43.4 % in RZ 209. Similar results regarding

higher recovery of essential oil from cryo ground seeds compared to non cryo and even intact seeds were reported by Saxena et al. (2015) when analyzing the effect of cryogenic grinding in nine coriander genotypes. Due to cryogenic temperature during grinding loss of volatile essential oil was minimum or negligible. Recovery of more essential oil than present in intact seeds may be due to the fact that oil bodies in intact seeds became free during grinding process and extraction of oil from oil bodies became easy from powdered samples than intact seeds. Oleoresin content which include non volatile oil fraction of total oil was also higher in GC 4 (15.3 %) compared to RZ 209 (11.5 %) in non cryo ground samples. A significant increase over normal grinding (29.8 %) in oleoresin percentage was observed when seeds of RZ 209 were ground using cryogenic grinding. This increase was, however less (15.4 %) in genotype GC 4. In normal grinding process of cumin, due to high temperature fat is melted and sticks on the grinding surfaces. In cryogenic grinding, extremely low temperature solidifies oils so that the spices become brittle, crumble easily permitting grinding to a finer and more consistent size with minimum or no loss of oil during grinding process. Genotype RZ 209 responded well to cryogenic grinding as compare to GC 4. A significant variation in the yield of the essential oil extracted from various cumin ecotypes have been reported by other researchers were 3.8 % from China (Li and Jiang 2004), 5.3 % from Bulgaria (Jirovetz et al. 2005), 1.6 % from Tunisia (Rebey et al. 2012), 1.4–2.8 % from Turkey (Beis et al. 2000) and 2.0–3.3 % (v/w) from India (Sowbhagya et al. 2008). It is well documented that genetic constitution and environmental condition influence the yield and composition of volatile oil produced by medicinal plants (Ramezani et al. 2009; Omidbaigi 2007).

Nineteen major compounds belonging to the group of monoterpenes and oxygenated terpenes were identified in essential oil extracted from cryo and non cryogenically ground seeds of cumin genotypes (Table 2; Figs. 1, 2). Percentage of compounds in volatile oil from cryo and non cryo ground seeds of both genotypes was ranging from 99.60 to 99.75 % and 97.28 to 99.60 % respectively. Both genotypes from diverse origins showed difference in essential oil constituents whether ground by either technique. Monoterpene, cuminaldehyde was the main constituent in both genotypes, content of which increased from 48.2 to 56.1 % in GC 4 due to cryogenic grinding. Genotype RZ 209 showed significantly high cuminaldehyde content as compared to GC 4 being observed 69.7 % in non cryo and 71.6 % in cryo ground samples. Cuminaldehyde is a constituent of the essential oils of eucalyptus, myrrh, cassia, cumin and others. It has a pleasant smell and contributes to the aroma of these oils. It is used commercially in perfumes and other cosmetics. Seeds of

Table 1 Essential oil and oleoresin percentage of cumin genotypes

Variety	Essential oil				Oleoresin		
	Cryo ground (%)	Non cryo ground (%)	Intact seed (%)	% Increase in cryo over non cryo grinding	Cryo ground (%)	Non cryo ground (%)	% Increase in cryo over non cryo grinding
GC 4	4.1 (±0.15)	3.0 (±0.15)	4.0 (±0.07)	33.9	17.7 (±0.43)	15.3 (±0.73)	15.4
RZ 209	3.6 (±0.09)	2.5 (±0.15)	3.3 (±0.03)	43.5	14.9 (±0.13)	11.5 (±0.49)	29.8

n = 3, value in parenthesis is standard deviation

Table 2 Composition of volatile constituents of cumin genotypes after grinding with cryo and normal grinding techniques

Variety/compound	RI ^a (iu)	GC-4		RZ-209	
		Cryo	Normal	Cryo	Normal
α -Thujene	902	0.07 (±0.004)	0.1 (±0.019)	0.1 (±0.109)	0.1 (±0.015)
<i>p</i> -Mentha-1(7),3-diene	993	–	–	0.03 (±0.004)	0.39 (±0.077)
Camphene	943	0.18 (±0.025)	0.03 (±0.001)	–	–
B-Pinene	943	9.44 (±0.062)	17.24 (±0.573)	6.71 (±0.766)	7.21 (±0.556)
α -Pinene	948	0.6 (±0.016)	0.9 (±0.059)	0.50 (±0.169)	0.51 (±0.206)
Myrcene	958	0.06 (±0.0045)	0.22 (±0.106)	0.03 (±0.025)	0.21 (±0.054)
γ -Terpinen	998	3.07 (±0.116)	4.35 (±0.945)	2.08 (±1.410)	5.38 (±0.727)
Terpinolene	1023	0.16 (±0.016)	0.26 (±0.025)	0.09 (±0.020)	0.03 (±0.013)
<i>p</i> -Cymene	1042	13.6 (±0.206)	15.4 (±0.885)	5.49 (±0.312)	5.23 (±0.338)
4-Isopropylanisole	1117	0.24 (±0.009)	0.15 (±0.029)	0.27 (±0.045)	–
2-Caren-10-al	1136	–	0.06 (±0.017)	5.07 (±0.946)	–
<i>o</i> -Cuminol	1149	–	1.26 (±0.083)	2.99 (±0.372)	–
<i>m</i> -Cuminol	1149	0.19 (±0.020)	0.16 (±0.038)	0.87 (±0.049)	0.13 (±0.025)
4-Allyl anisole	1172	0.75 (±0.071)	1.31 (±0.669)	0.82 (±0.267)	1.30 (±0.185)
Anethol + Estyragol	1190	5.61 (±0.70)	7.37 (±0.031)	1.94 (±0.608)	7.02 (±0.498)
Cuminaldehyde	1230	56.1 (±0.648)	48.2 (±0.474)	71.6 (±1.750)	69.7 (±1.252)
<i>p</i> -Cuminol	1254	9.42 (±1.774)	2.07 (±0.304)	–	–
Carvacrol	1262	–	–	0.60 (±0.109)	–
Geranyl acetate	1352	0.13 (±0.0625)	0.15 (±0.045)	0.27 (±0.089)	0.01 (±0.003)
Total		99.75	99.48	99.60	97.28

n = 3, value in parenthesis is standard deviation

^a Estimated nonpolar retention index (*n*-alkane scale)

genotype RZ 209 contained significantly more cuminaldehyde than GC 4 while other important monoterpene, cymene is found more in GC 4 as compared to RZ 209. Upon organoleptic test, oil of RZ 209 appeared more spicy and pungent than GC 4. Turpentine note in oil of both the genotypes may be due to presence of significant amount of β -pinene and γ -terpinene as described by Ramasamy et al. (2007) and Saxena et al. (2015) in case of coriander essential oil. Quantity of terpenes like α -pinene, β -pinene, myrcene, γ -terpinene, terpinolene was found to decrease in cryo ground samples of GC 4 and either decrease or no change was observed in RZ 209. This decrease was associated with reduced turpentine note thus increased pleasantness of oil from cryo ground seeds of both the genotypes. Genotype GC 4 showed presence of cumin alcohol which increases significantly from 2.0 % in

non cryo ground samples to 9.4 % in cryo ground seeds. This compound was not detected in ground samples of RZ 209 in either cryo or non cryo ground samples, however, Behtoei et al. (2012) reported presence of cumin alcohol in significant proportion (13.0 %) in Parsi Jira (*Bunium persicum*). Occurrence of the same compound in cryo ground seeds of genotype GC 4 is possible because *Bunium persicum* and *Cuminum cyminum* though belong to different species but share homogenous genetic makeup (Sheidai et al. 1996). Oxygenated terpenes such as *p*-cymene and anethol/estragol are also reduced in cryo ground samples of GC 4.

Reports have shown that some of the medicinal and aromatic plant characteristics can be affected by genetic (cultivar or landrace) and ecological factors including precipitation, temperature, plant competition and nitrogen

Fig. 1 Chromatogram of major essential oil constituents of essential oil extracted from non cryogenic ground cumin seeds of genotype RZ 209

Fig. 2 Chromatogram of major essential oil constituents of essential oil extracted from cryogenic ground cumin seeds of genotype RZ 209

concentration in the soil (Letchamo et al. 1995; Ghasemi Pirbalouti et al. 2011). Apart from these factors grinding technique also has a significant effect on medicinal and aromatic characteristics of the final product. In an earlier communication, Sharma et al. (2014, 2015) analyzed effect of cryogenic grinding and found a significant increase in total phenolic, flavonoid content and antioxidant properties of cumin and ajwain genotypes. The composition of the essential oil of cumin therefore may vary with genetic, environmental conditions, extraction method and geographic origin including climate, edaphic factors, elevation and topography. Li and Jiang (2004) found 37 constituents in cumin essential oil, representing 97.9 % of the oil. Cuminal (36.3 %), cuminic alcohol (16.9 %), γ -terpinene (11.1 %), safranal (10.8 %), *p*-cymene (9.8 %) and β -pinene (7.7 %) were the major components. Safranal was also reported by Hashemian et al. (2013) in green cumin (*Cuminum cyminum* L.) of Iran and Oroojalian et al. (2010) in Razavi Khorasan

accession of cumin in the range of 16.8–29.0 and 9.4 % respectively. Safranal is an organic compound responsible for the aroma of saffron, the spice consisting of the stigmas of crocus flowers (*Crocus sativus*). In another study Wanner et al. (2010) when compared chemical composition of cumin oils originated from Iran, Egypt, India and Europe did not find safranal in any of the oil, instead reported *p*-mentha-1,3-dien-7-al and *p*-mentha-1,4-dien-7-al, isomers of safranal. Similarly in present investigation safranal was not detected in both genotypes but terpinolen, an isomer of safranal was detected in trace amount. This may be due to the fact that safranal is a degradation product of the carotenoid zeaxanthin via the intermediacy of picrocrocin and only detected in green cumin. Ripen seeds of cumin in India and Indian sub-continent are having dark brown colour with no green pigment. Hence, safranal may not be detected in Indian cumin but cuminaldehyde content was reported significantly more in cumin from India.

Effect of cryogenic grinding on volatile constituents was same in genotype RZ 209. Content of terpenes like α -pinene, β -pinene, myrcene, γ -terpinene were reduced in cryo ground samples while terpinolen was detected only in cryo ground seeds of RZ 209. Content of oxygenated terpenes showed a significant increase in cryo ground samples of RZ 209. 2-Caren-10-al and *o*-cuminol were detected in cryo ground samples only, being observed 5.0 and 2.9 % respectively (Table 2). Significant genotypic variation in volatile oil constituents of genotypes taken in present analysis may be due to distinct morphology of two genotypes. Genotype RZ 209 is a selection from state Rajasthan, India, having erect growth habit, branched with less leaves biomass and comparatively bold seed size while GC 4 is a variety from state Gujarat, India, probably exotic selection from Mediterranean region having bushy appearance, more leaf biomass and small sized seeds. Some constituents like 2-caren-10-al and *o*-cuminol were detected only in cryo ground samples of RZ 209. In GC 4, the compound like cuminal alcohol, showed significant increase from 2.0 to 9.4 % in non cryo and cryo ground samples of GC 4 respectively. The loss of monoterpenes (i.e.- cuminaldehyde in cumin) was high in ambient grinding, as there was a loss of volatile oil in terms of every monoterpene compounds. Cryogenic grinding technique was superior to ambient grinding in terms of monoterpenes retention in the powder. Sensory assessment of the ground samples indicated that cryogenically ground samples were distinctly high in top notes which represented freshness, while marginally high in basic notes. The two grinding techniques had significant effects on dependent variables,

viz., volatile oil and monoterpenes content that is cuminaldehyde content in case of cumin. In the present study cryogenic grinding technique has been adopted which successfully proves that cryo-ground seed powder of cumin provides a better cuminaldehyde percentage which is a major constituent responsible for the quality of cumin oil as compared to conventionally ground powder of cumin.

Fatty oil analysis

Both the genotypes yields substantially good amount of fatty oil being observed 11.5 % in RZ 209 and 15.2 % in GC 4. Cryogenic grinding significantly increased oil yield registered 14.8 % in RZ 209 and 16.2 % in GC 4. FAME analysis of fatty oil was carried out to find out major constituents of cumin oil. Non cryo seeds of both genotypes showed almost similar composition of FAME. Most abundant was oleic acid methyl esters found 88.1 and 88.2 % in RZ 209 and GC 4 respectively. Other prominent FAME were palmitic, palmitoleic and stearic acid found 7.5, 1.2 and 1.1 % respectively in RZ 209 and 7.4, 1.2, 1.5 % in GC 4. Oleic acid is a common monounsaturated fat in human diet and has been associated with decreased low-density lipoprotein (LDL) cholesterol, and possibly increased high-density lipoprotein (HDL) cholesterol. Palmitic acid, or hexadecanoic acid in IUPAC nomenclature, is the most common fatty acid (saturated) found in animals, plants and microorganisms (Kokatnur et al. 1979). Upon cryogenic grinding oleic acid content was increased from 88.1 to 94.9 % in RZ 209 while palmitic and stearic acid reduced significantly from 7.5 to 2.6 and

Table 3 Effect of cryogenic grinding on fatty acid composition (%) of cumin genotypes

Fatty acids methyl esters	RI ^a (au)	RZ-209		GC-4	
		Non cryo	Cryo	Non cryo	Cryo
Total oil (%)		11.5 (± 0.37)	14.8 (± 0.44)	15.2 (± 1.06)	16.2 (± 1.20)
Undecylic acid	1471	0.12 (± 0.15)	–	0.05 (± 0.003)	0.05 (± 0.003)
Myristic acid	1769	0.24 (± 0.01)	0.05 (± 0.003)	0.17 (± 0.01)	–
Palmitoleic acid	1886	1.23 (± 0.06)	0.18 (± 0.01)	1.22 (± 0.05)	1.12 (± 0.10)
Palmitic acid	1968	7.53 (± 0.40)	2.61 (± 0.25)	7.46 (± 0.45)	6.62 (± 0.46)
Cis-10-heptadecaenoic acid	1986	0.23 (± 0.01)	0.08 (± 0.009)	0.22 (± 0.05)	–
Heptadecanoic acid	2067	0.05 (± 0.004)	0.03 (± 0.007)	–	–
Cis-6,9-octadecadienoic acid	2093	0.26 (± 0.01)	0.17 (± 0.02)	0.15 (± 0.01)	–
Stearic acid	2167	1.15 (± 0.05)	0.83 (± 0.05)	1.59 (± 0.22)	1.35 (± 0.04)
Oleic acid	2175	88.1 (± 0.94)	94.9 (± 0.49)	88.2 (± 1.12)	90.1 (± 0.95)
α -Linoleic acid	2183	0.05 (± 0.003)	–	–	–
Linoleic acid	2183	0.41 (± 0.04)	0.11 (± 0.03)	0.36 (± 0.02)	0.78 (± 0.07)
α -Linolenic acid	2191	–	0.98 (± 0.10)	0.01 (± 0.003)	0.01 (± 0.003)
Arachidic acid	2366	0.20 (± 0.02)	–	–	–

n = 3, value in parenthesis is standard deviation

^a Estimated nonpolar retention index (*n*-alkane scale)

1.1 to 0.8 respectively. Genotype GC 4, however, showed marginal increase in oleic acid and decrease in palmitic acid content (Table 3).

The biosynthesis of fatty acids common in all plant species involves a carbon elongation and desaturation process, that is largely determined by the genes coding for the enzymes involved and is therefore specific for a particular variety (Takagi et al. 2012). Conversion of palmitic, palmitoleic and stearic acid into oleic acid under cryogenic grinding may be the result of activity of desaturation and carbon elongation related enzymes which otherwise degraded during normal grinding procedure.

Conclusion

Present study suggested that sufficient genetic variation existed for essential oil and its constituents in cumin. Quality of aroma and fatty oils can be improved for desired characters by selecting grinding technology. Cryogenic grinding of spices in general and cumin in particular produces better quality ground powder in terms of retention of more pleasant flavour, desirable fatty acids and enhanced antioxidant properties. Major constituents of essential oil, cuminaldehyde showed a significant increase in cryo ground seed powder of both genotypes. Some constituents were only recovered in cryo ground samples while others are either increased or decreased upon cryogenic grinding. This grinding technology can significantly increase the recovery of essential oil with superior quality and thus has a tremendous commercial application.

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