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Grinding performance of cryogenic spice grinding system for coriander

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Abstract

Grinding performance of cryogenic spice grinding system was evaluated for grinding of coriander seeds. Coriander seeds were ground at 10°C and -50°C with varying conveyor screw speeds of 5, 10 and 15 rpm in pin mill (6500 rpm). The coriander seeds ground at -50°C contained higher amount of volatile oil (0.66 ± 0.01%), total phenolics (85.94 ± 0.58 mg GAE g^{-1}), flavonoids (24.78 ± 0.88 mg QE g^{-1}) and antioxidant (38.56 ± 1.67 BHTE g^{-1}), which was significantly ($p \leq 0.05$) higher than the corresponding values of above constituents in coriander powder obtained at 10°C. The particle size varied from 0.450 ± 0.038 to 0.529 ± 0.005 mm and significantly affected ($p \leq 0.05$) due to variation in temperature and screw speed. The L-value, *a* –value, b-value, hue, chroma and browning index of ground coriander seeds varied significantly from 58.21 ± 0.53 to 61.27 ± 0.95, 5.20 ± 0.46 to 6.76 ± 0.28, 23.92 ± 1.11 to 28.05 ± 0.60, 75.53 ± 1.04 to 77.99 ± 0.53, 24.21 ± 1.47 to 28.73 ± 0.60 and 54.77 ± 4.31 to 71.65 ± 2.61, respectively with variation in temperature and screw speed. The high quality cryogenically ground coriander would have domestic as well as international market.

Key words : Antioxidant content, colour, cryogenic grinding, essential oil, particle size.

Introduction

Coriander is a major seed spice crop grown, throughout the sub continent for either green leaf purpose or seeds and has prime position in flavouring foods. In India, major coriander growing states are Rajasthan, Gujarat, Andhra Pradesh, Uttar Pradesh, Madhya Pradesh, Himachal Pradesh etc. The most common use of coriander seed is in curry powders, where it is the bulkiest constituent, often rough ground, to give a crunchy texture. The most important constituents of coriander seeds are the essential oil which varies between 0.03- 2.6%. Other constituents such as crude protein, fat, crude fibre and ash contents vary from 11.5-21.3%, 17.8-19.15%, 28.4-29.1% and 4.9-6.0%, respectively (Akgul,1993; Diederichsen,1966; Kaya *et al.,* 2000; Ramadan and Morsel, 2002).

The essential oil and various extracts from coriander have been shown to possess antibacterial, antidiabetic, anticancerous, antimutagenic, antioxidant and free radical scavenging activities (Sreelatha *et al.,* 2009; Zoubiri and Baaliouamer, 2010). In addition to its culinary value, coriander is known for its wide range of healing properties. It is generally used in gastrointestinal complaints such as anorexia, dyspepsia, flatulence, diarrhea, griping pain and vomiting. Coriander fruit is also reputed as refrigerant, tonic, diuretic and aphrodisiac, while, the oil is considered useful in flatulent colic, rheumatism, neuralgia, etc. Coriander is also used as antiedemic, anti-inflammatory, antiseptic, emmenagogue, antidiabetic, antihypertensive, lipolytic and myorelaxant, and possess nerve-soothing property (Jabeen *et al.,* 2009).

Grinding is one of the most common operations used to produce coriander powder for consumption. However in ambient grinding of spices, temperature rises to the extent of 42-93°C as grinding is the most power consuming operation because only 1% of the energy imparted into the material is utilized for loosening the bond between particles, whereas almost 99% of input energy is dissipated as heat, rising the temperature of the ground product etc. The rise in temperature causes the loss of volatile oil and flavouring constituents; for high oil bearing material, oil comes out from oil bearing material during grinding, which makes ground product gummy, sticky and results in chocking of sieves through which the product passes (Singh and Goswami, 1999). The loss of volatile oil,

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moisture, and colour can be significantly reduced by a cryogenic grinding technique. Liquid nitrogen at -195.6°C provides the refrigeration needed to pre-cool the spices and maintain the desired low temperature by absorbing the heat generated during the grinding operation.

From the aforesaid statements, there seems enough justification for cryogenic grinding of spices in order to obtain high quality ground spices products. Theoretically, cryogenic grinding of spices is better than ambient grinding. Therefore, in the present study, cryogenic spice grinding system was evaluated for grinding of coriander seeds to analyse the various parameters affecting grinding of coriander.

Materials and methods

Sample preparation

The coriander seeds were procured from local market of Ludhiana, India. The seeds were cleaned manually to remove all foreign matter, dust, dirt, broken and immature seeds. The initial moisture content of the seeds was determined by vacuum oven method (temperature 70 ºC and pressure 100 mm Hg) until a constant mass was obtained (Singh and Goswami, 2000) and was 8.0% dry basis (db).

A cryogenic spice grinding system (capacity: 30 to 50 kg/h, depending on type of spice) has been designed and developed (Anon., 2013; 2014) at ICAR-CIPHET, Ludhiana, India . It consists of a pre-cooling unit, grinder unit, spice powder collection unit, grading unit (sieving system) and a control (operator) panel. The pre-cooling unit (capacity: 30-50 kg h^{-1}; feed material size: 1 to 10 mm) consists of screw conveyor assembly, self pressurized liquid nitrogen (LN_2) cylinder (185 litre capacity), and power transmission systems. All spice contact parts were made of stainless steel (AISI 304) whereas not-contact parts made of mild steel such as frame of the grinding system etc. The grinder unit consists of a grinder / dual mill (pin mill and provision of hammer mill) of 30-50 kg h^{-1} capacity with variable grinder speed. There is a provision for collection of ground spice product (spice powder) through cyclone system and immediate sieving system for different grades of the powder. This developed cryogenic spice grinding system was employed for the grinding of coriander seeds. The coriander seeds were ground in developed cryogenic spice grinding system at 10°C and -50°C with varying conveyor screw speed of 5, 10 and 15 rpm in pin mill (6500 ppm) in duplicates. All the above ground coriander samples were packed in sealed, moisture free and water proof flexible polythene bags for further analysis of quality characteristics.

Particle size of coriander powder

Particle size of coriander powder, ground at variable screw speed (5, 10 and 15 rpm) and variable temperature (10°C and -50°C) was determined in duplicates using a vibratory sieve shaker with a set of Bureau of Indian Standards (BIS) sieves. Average particle size (D_p) of ground coriander were calculated using following equation (Sahay and Singh, 2004):

$$\text{Average particle size, } D_p = \left[\,0.135 \times (1.366)^{FM}\,\right] \qquad \ldots(1)$$

where FM is fineness modulus.

Colour attributes of ground coriander

Colour (*L*, *a* and b) values of ground coriander were determined by using Hunter Colorimeter (model no. 45/0 L, U.S.A). '*L*' is known as the lightness and extends from 0 (black) to 100 (white). The other two coordinates '*a*' and '*b*' represents redness (+*a* values) to greenness (-*a* values) and yellowness (+*b* values) to blueness (-*b* values), respectively. Hue angle (h°) is the attribute of the colour by means of which the colour is perceived. Chroma value (C^*) is the attribute of colour used to indicate the degree of departure of the colour from gray of the same lightness. Browning index (BI) is the intensity of pure brown colour. The values of h°, C^* and BI were computed by using the following formulae (Gupta *et al.,* 2011) :

$$\text{Chroma value, } C^* = \sqrt{\left(a^2 + b^2\right)} \qquad \ldots(2)$$

$$\text{Hue Angle, } h^\circ = \tan^{-1}\left(\frac{b}{a}\right) \qquad \ldots(3)$$

$$BI = \left[\frac{100(x - 0.31)}{0.17}\right] \qquad \ldots(4)$$

$$x = \left[\frac{(a + 1.75)}{(5.645L + a - 3.012b)}\right] \qquad \ldots(5)$$

Chemical properties

Essential oil

Essential oil was extracted from the coriander powder by hydro distillation using Clevenger apparatus lighter than water type. Oil was quantified as volume by weight percentage (Saxena *et al.,* 2015).

Total phenolic content

The ground coriander sample (10 g) was extracted with 50 ml methanol twice. Supernatant from both extraction were pooled and methanol was evaporated in rotary evaporator. This crude extract was used for determination of the total phenol and flavonoids concentration, as well as antioxidant activities. Total phenol concentrations were determined using a Folin-Ciocalteu assay, as described by Amin *et al.,* (2006). An aliquot of 0.1 ml from 1,000 ppm crude methanol extract was taken in a test tube and made the volume 1 ml by adding solvent. Three ml of 10 % sodium carbonate was added. Previously 10-fold diluted Folin-Ciocalteu reagent was added to the mixture. The mixture was allowed to stand at room temperature for 90 min and then absorbance was measured at 710 nm. Gallic acid was used as the standard phenol. The amount of phenolic content was calculated by using the standard curve of Gallic acid having R^2 value ranged from 0.96 to 0.99 and was expressed as mg Gallic Acid Equivalents g^{-1} crude seed extract. (mg GAE g^{-1})

Total flavonoid content

Total flavonoid concentration was determined by using method as described by Chang *et al.,* (2002). One ml of crude extract was taken in a test tube and 100 μl aluminum chloride (1 M) solution was added carefully from the side wall of the test tube followed by addition of 100 μl potassium acetate. The total volume was made 4 ml by adding 2.8 ml of solvent in the test tube. After 30 min incubation of reaction mixture at room temperature stable yellow colour was developed. Absorbance was measured at 415 nm. Quercetin was used as the standard flavonoids. The amount of flavonoid was calculated by using the standard curve of quercetin having R^2 value ranged from 0.96 to 0.99 and was expressed as mg Quercetin Equivalents g^{-1} crude seed extract. (mg QE g^{-1}).

Antioxidant content

The antioxidant content of crude extract was evaluated on the basis of its activity in scavenging the stable DPPH radical using the method described by Shimada *et al.,* (1992). Crude seed extract was diluted in methanol to give at least 5 different concentrations. An aliquot (1, 1.5, 2, 2.5 ml) of the extract of each concentration was mixed with 1 ml of 1 M DPPH solution. The mixture was then homogenized and left to stand for 30 min in the dark. The absorbance was measured at 517 nm against a blank of methanol using a spectrophotometer. DPPH solution plus methanol was used as control and Butyl hydroxyl toluene (BHT) was used as a standard reference synthetic antioxidant with R^2 value ranged from 0.95 to 0.99. Results were expressed as mg Butyl hydroxyl toluene (BHT) Equivalent g^{-1} crude seed extract. Results were expressed as a mean standard deviation from three replicate measurements. The percent scavenging effect was calculated as follows :

$$\textit{Scavenging effect}\ (\%) = \frac{A_{517}\text{ of control} - A_{517}\text{ of extract}}{A_{517}\text{ of control}} \times 100 \qquad \ldots(7)$$

Statistical analysis

Analysis of variance for quality characteristics were carried out using LSD of AgRes Statistical software (Version 3.01, Pascal International Software Solution, USA).

Results and discussion

Average particle size of coriander powder

Table 1 represents the variation of average particle size of coriander powder with screw speed and temperature, which increased with increasing screw speed irrespective of temperature. This may be due to the fact that at high feed rate owing to; overloading coarser particles were pushed out before further crushing as more coriander seed entered the shearing area of the disk plate (mill), which results in coarser grinding at higher screw speeds. In addition a higher particle size was obtained at 10°C irrespective of screw speed, which may be attributed due

Table 1. Effect of screw speed and temperature on particle size of coriander powder.

S.No.	Average particle size (mm)		
	Screw speed (rpm)	Temperature	
		10°C	-50°C
1	5	0.469±0.029^{a}	0.450±0.038
2	10	0.523±0.019^{b}	0.466±0.037
3	15	0.529±0.005^{b}	0.478±0.019
	F-values	8.97^	1.10^
	$CD_{0.05}$	0.04	0.04

Mean values with the same superscript letters within the same column do not differ significantly (p > 0.05) to the fact that at ambient grinding due to generation of heat there is increase in temperature and the moisture and oil content in the spice sample remains in liquid state which leads to a sticky mass if grinding continues. This results in deterrence of smaller particle size (Singh and Goswami, 1999). The average particle size varied significantly with screw speed and temperature (Table 1).

Colour parameters

The colour parameters i.e *L*, *a*, b, hue, chroma and browning index of coriander ground at variable screw speed and temperature are illustrated in Table 2. It was depicted that the colour parameters L (indicator of lightness), *a*- value, b-value, hue, chroma and browning index (intensity of brown colour) were found to be varied significantly with screw speed and temperature. However a brighter and lighter coloured coriander was obtained at -50°C. This may be due to the fact that in case of grinding at 10°C, due to rise in temperature powder turns into dark in colour and lost its brightness. On the other hand, in cryogenic grinding (-50°C), a light and vivid powder obtained due to preservation of brightness and natural lust of powder (Meghwal and Goswami, 2010).

Essential oil

Essential oil content in the spice powder is a measure of its aroma and flavour, and hence its quality. Higher the volatile oil content in spice powder, the higher is its market value in financial terms since spices are valued for their aroma and flavour (Gopalkrishnan *et al.,* 1991). The essential oil content of coriander powder was found to be varied significantly with the grinding temperature whereas non significant with screw speed (Table 3) . Higher values of essential oil content was observed in cryogenically ground (-50°C) coriander as compared to coriander ground at 10°C (Table 3). This may be due to the fact that at10°C, mass transfer increased due to increase in vapour pressure which resulted in a loss of volatile oil. The results are in agreement with the findings of Saxena *et al.* (2015) who reported a significant increase in volatile oil content of cryo-ground coriander of different genotypes.

Total flavonoids, phenolic content and antioxidant content

The total flavonoids, phenol content by Folin-Ciocalteu reagent method and antioxidant content by DPPH free radical scavenging % are shown in Table 3. The total flavonoids, total phenolic content and antioxidant content were found to increase with increase in screw speed which may be attributed due to high feed rate i.e lower residence time in grinder leading to retention of these medicinal constituents. Similar results have been reported by Gopalkrishnan *et al.* (1991) for ambient grinding of cardamom. The coriander powder, ground at -50°C, retained higher amount of the total flavonoids, total phenols and antioxidant content (Table 3). As phenolics are quite heat unstable and reactive compounds (Cheynier, 2005) and during grinding at 10°C there is temperature rise leading to reduction in phenols which can be appreciatory reduced in grinding at -50°C. The enhanced retention of total

Table 2. Effect of screw speed and temperature on colour parameters of coriander powder

Temp.	Screw speed (rpm)	*L*-value	*a*-value	*b*-value	Chroma value	Hue angle (°)	Browning index
10°C	5	59.74±0.57^{a}	5.84±0.39^{ab}	24.45±0.70^{a}	25.14±0.68^{a}	76.54±0.93^{a}	58.68±2.29^{a}
	10	58.87±0.19^{b}	5.57±0.27^{b}	26.25±1.08^{b}	26.83±1.08^{b}	77.99±0.53^{b}	64.47±3.21^{b}
	15	58.21±0.53^{c}	6.21±0.43^{a}	28.05±0.60^{c}	28.73±0.60^{c}	77.51±0.85^{b}	71.65±2.61^{c}
	F-values	21.38*	5.86*	38.49*	38.30*	7.04*	45.13*
	$CD_{0.05}$	0.48	0.38	0.85	0.85	0.82	2.84
-50°C	5	61.27±0.95^{a}	5.20±0.46^{a}	23.92±1.11^{a}	24.21±1.47^{a}	77.74±0.75^{a}	54.77±4.31^{a}
	10	60.14±1.20^{b}	6.45±0.34^{b}	25.09±1.33^{b}	25.91±1.29^{b}	75.53±1.04^{b}	60.81±4.73^{b}
	15	58.50±0.60^{c}	6.76±0.28^{b}	26.28±1.13^{b}	27.14±1.07^{c}	75.54±1.02^{b}	66.68±3.40^{c}
	F-values	16.83*	39.22*	7.74*	10.17*	14.33*	16.17*
	$CD_{0.05}$	0.99	0.39	1.04	1.02	0.99	4.35

Mean values with the same superscript letters within the same column do not differ significantly (p > 0.05)

Table 3. Effect of screw speed and temperature on essential oil, total flavonoids, total phenolic content and antioxidant content of coriander powder

Temp.	Screw speed (rpm)	Essential oil (%)	Total flavonoids (mg QE g^{-1})	Total phenolic content (mg GAE g^{-1})	Antioxidant content (BHTE g^{-1})
10°C	5	0.49±0.01	13.35±0.82	54.50±3.12	25.14±0.68
	10	0.49±0.01	14.82±1.40	57.32±1.89	26.83±1.08
	15	0.49±0.01	16.97±0.97	62.94±0.58	28.73±0.60
	F-values	0.76^{NS}	32.57*	13.24^{NS}	30.51^{NS}
	$CD_{0.05}$	0.02	1.43	9.82	4.93
-50°C	5	0.66±0.01	19.96±2.84	79.32±6.74[a]	36.13±1.04
	10	0.66±0.01	23.45±1.03	82.56±3.23[b]	37.24±1.44
	15	0.66±0.01	24.78±0.88	85.27±7.32[c]	38.56±1.67
	F-values	0.85^{NS}	23.78^{NS}	46.32*	36.72^{NS}
	$CD_{0.05}$	0.03	7.85	1.91	3.87

NS=Non-significant; Mean values with the same superscript letters within the same column do not differ significantly (p > 0.05)

flavonoids, total phenolic content and antioxidant content may be due to the fact that in cryogenic grinding the vaporization of liquid nitrogen to the gaseous state creates an inert and dry atmosphere which ultimately reduces the loss of quality parameters of spices (Singh and Goswami, 1999). Higher flavonoid content, phenolic content and antioxidant content was also found in cryo-ground coriander and fenugreek genotypes (Saxena *et al.,* 2012).

Conclusions

The coriander seeds ground at -50°C contained higher amount of volatile oil (0.66±0.01%), total phenolics (85.94±0.58 mg GAE g^{-1}), flavonoids (24.78±0.88 mg QE g^{-1}) and antioxidant (38.56±1.67 BHTE g^{-1}), which was significantly ($p = 0.05$) higher than the corresponding values of above constituents in coriander powder obtained at 10°C. The particle size varied from 0.450±0.038 to 0.529±0.005 mm and significantly affected ($p \leq 0.05$) due to variation in temperature and screw speed. The better quality cryogenically ground coriander would fetch the domestic as well as international market.

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