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Effect of cryogenic and ambient grinding on grinding characteristics of cinnamon and turmeric

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Abstract

In this communication, grinding characteristics of cinnamon (cv. *Nityashree*) and turmeric (cv. *Pratibha*) were investigated under cryogenic and ambient grinding conditions. Grinding of spices was carried out using a laboratory grinder with pin mill set up (M/s Hosakowa Alpine, Germany, Model: 100UPZ). Various grinding characteristics were determined using sieve analysis of the ground spices. The average particle size, volume surface mean diameter, mass mean diameter, volume mean diameter and specific surface of mixture of ambient ground spices were found higher than that of cryogenic ground spices. The average particle size of ground cinnamon and turmeric were 0.356 mm, 0.336 mm in cryogenic condition and 0.454 mm, 0.407 mm in ambient condition, respectively. The energy constants and specific energy consumption under cryogenic grinding were lower than that of under ambient grinding conditions. In case of turmeric, Rittinger's and Kick's constants were 34.8, 39.7 KWh / tonne in cryogenic ground and 58.0, 58.1. In ambient ground powder, respectively. The colour values of cryogenic ground spices were found better than ambient ground spices. The grinding characteristics of cinnamon and turmeric under cryogenic grinding condition were found superior in quality than that of ambient grinding condition.

Key words : Ambient grinding, cinnamon, colour, cryogenic grinding, energy constants, turmeric

Introduction

Spices have pungent flavour, taste and the medicinal properties. These are an integral part of food of agricultural commodities, with consumption not only in households, restaurants and other eateries but also in food processing industry such as pickles, sauces, instant curry powders, ready-to-eat food preparations and so on. Spices can come from almost any part of a plant including seeds, leaves, barks, rhizomes, latex, stigmas, floral buds and modified stems. Spices are essential ingredients imparting taste and flavour to various food preparations. India is the leading producer and exporter of various spices i.e. fenugreek, turmeric, black pepper, coriander, and cinnamon etc.

Cinnamon (C*innmomum zeylanicum)* blume of family *lauraeae* is native to Sri Lanka and India. It has a delicate fragrance and a warm agreeable taste. It is extensively used as a spice or condiment in the form of small pieces or in powder form. It is principally employed in cookery as a condiment and flavouring material. It is being largely used in the preparation of some kinds of desserts, chocolate, candies, tea and liqueurs. Cinnamon is reported to possess antioxidant and antimicrobial properties (Baratta et al., 3).

Turmeric (*curcuma longa linn),* plant of family *Zingberaceae*, is native to India and Southeast Asia. It possesses an appreciable aroma and flavour. It is valued principally for its yellow-orange colouring compound and directly used as a spice or colouring agent in the powder form and also for the preparation of oleoresin. It is used to colour liquor, fruit drinks and cakes.

Grinding is one of the most common unit operations which are used to prepare ground agricultural materials including spice powders for consumption. Spice is converted to powder by the mechanical process of grinding which leads to increase the temperature as high as 43-95°C under ambient or normal conditions which leads to losses of essential oils and quality deterioration of the obtained powder (Singh and Goswami, 10, 11). Cryogenic grinding is a novel and innovative grinding technique which helps in retaining good colour, flavour, aroma and volatile oil of the product (Singh and Goswami, 10). The cryogenic

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grinding of cumin seed and cloves at different conditions was studied and its influence on volatile oil content, particle size distribution, volume mean diameter and specific energy consumption was reported (Singh and Goswami, 10, 11). In a recent report from Saxena *et.al.*,(8) highlighted the benefits of cryogenic grinding of coriander on retention of volatile oil, total oil and antioxidant activity as compare to traditional grinding under ambient conditions. As per published literature, limited research information is available on grinding characteristics of spices under cryogenic grinding conditions. The size reduction theory of spices involves particle size measurement, particle size analysis, power consumption in grinding. Therefore, in present work, grinding characteristics of some spices such as cinnamon and turmeric were investigated under cryogenic and ambient grinding conditions.

Materials and methods

Sample preparation

Cinnamon barks (cv. *Nityashree*) and turmeric rhizomes (cv. *Pratibha*) were procured from Indian Institute of Spices Research (IISR), Kozhikode, Kerala, India. The spices were cleaned manually by removing adhered foreign matter etc. The initial moisture content of the cinnamon bark and turmeric rhizomes were determined (AOAC, 1) and found to be 8.8 and 7.3 % w.b., respectively. Initially, the size of cinnamon barks and turmeric rhizomes were reduced manually and graded using sieves BSS No. 6 and 10. The cinnamon and turmeric samples, retained between BSS No. 6 and 10, were used for grinding purpose.The spice of 400 g each samples at its initial moisture content were used for experimental purpose.

Grinding of samples

The experiments were conducted at Central Institute of Post Harvest Engineering and Technology (CIPHET) Ludhiana, Punjab, India. A laboratory grinder with pin mill set up (M/s Hosakowa Alpine, Germany, Model: 100UPZ) was employed for the grinding of spices under cryogenic and ambient conditions. For cryogenic grinding condition, liquid nitrogen (LN_2) dewar of 50 litre capacity was attached and LN_2 was supplied at the entry of feed screw conveyor in the pre-cooler to bring the feed material to low temperature (-50 °C or lower). Feed material from pre-cooler enters at the centre of the pin mill through feed chute. Grinding of spice (graded cinnamon and turmeric) was performed (feed screw speed: 4 rpm, and pin mill speed: 10000rpm) and the final ground product was collected at pin mill outlet. Control panel was used to record the various parameters such as feed screw speed (rpm), electric current (Amp) and pin mill speed (rpm). The grinder was run at no-load condition and value of electric current was recorded from the control panel. The value of electric current was also recorded at on load condition i.e. during the grinding of sample.

Computation Procedure

The various expressions used for computations of grinding characteristics are presented in Table 1 (Sahay and Singh, 7; Singh and Goswami, 8; Balasubramanian *et al.*, 2; Mridula *et al.*, 5).

Average size (geometric mean diameter) of graded cinnamon and turmeric sample was determined by measuring the three linear dimensions viz., length (L), width (W) and thickness (T) of randomly picked spice graded sample and by using following expression (Sahay and Singh, 7):

Geometric mean diameter $\left(D_g\right) = \sqrt[3]{L \times W \times T}$ …(1)

Sphericity (Φ) was calculated by using following equation:

$$\Phi = \frac{\left(L \times W \times T\right)^{\frac{1}{3}}}{L} \quad \ldots(2)$$

Sieve analysis of ground spices was carried out (Sahay and Singh, 7) to determine its fineness modulus.

$$FM = \frac{\text{Total percent retained on sieve}}{100} \quad \ldots(3)$$

The value of FM was used to calculate the average particle size (Table 1).

True density (ρ_t) was determined by using gas (nitrogen) pycnometer (make IQI, USA, Model2: *Hymipyc*). The volume surface mean computed, mass mean diameter and volume mean diameter were computed using expressions given in Table 1. The Rittinger's constant and Kick's constants were also determined using standard expressions (Table 1).

The colour of ground spices (powder) were measured using HunterLab labScan XE (Hunter Associates laboratory Inc., Reston, Virginia, USA) in terms of lightness (*L*), redness (*a*) and yellowness (*b*). The hue angle (h^0) and chroma (C) were computed using standard expressions (Mridula *et al.,* 5) as given in Table 1.

The weight of one ground particle, assuming spherical shape, was determined by following expression.

Weight of one particle = $(4/3)\pi(D_m/2)^3\rho_t$

Where, ρ_t and D_m are true density and mass mean diameter of ground product, respectively.

Energy consumption during grinding operation (ΔW) was calculated by following expression

$$\Delta W = W_{OL} - W_{NL} = V \times \left(I_{OL} - I_{NL}\right)$$

Where, V is operational voltage and I_{OL} and I_{NL} are the current recorded at on load and no load conditions, respectively.

Feed rate (f, kg/h) was calculated as a ratio of weight of the feed (M_s) to time consumed during the operation of grinding (t).

$$f = \frac{M_s}{t}$$

The values of specific surface of mixture, number of particles/g and specific energy consumption were computed using expressions given in Table 1 and presented in Table 2.

Results and discussion

The grinding characteristics of cinnamon and turmeric are presented in Figure 1. For ground cinnamon, the average particle size, volume surface mean diameter, mass mean diameter and volume mean diameter were found as 0.356 mm and 0.454 mm, 0.351 mm and 0.360 mm, 0.300 mm and 0.374 mm, and 0.277 mm and 0.309 mm for cryogenic and ambient grinding conditions, respectively (Figure 1a) for ground turmeric the average particle size, volume surface mean diameter, mass mean diameter and volume mean diameter were found as 0.336 mm and 0.407 mm, 0.335 and 0.351 mm, 0.328 mm and 0.379 mm, and 0.259 mm and 0.270 mm, for cryogenic and ambient grinding conditions, respectively (Figure 1b). In general, the average particle size, volume surface mean diameter, mass mean diameter and volume mean diameter were found lower in cryogenic grinding as compared to ambient grinding, as expected (Meghwal and Goswami, 4; Singh and Goswami, 8, Murthy and Bhattacharya, 6). It may be due to fine powder obtained in cryogenic grinding as the feed material becomes brittle under cryogenic conditions.

The energy values of cinnamon and turmeric are presented in Figure 2. In cinnamon sample, energy values i.e Rittinger's constant and Kick's constant were found as 26.8 and 29.6 KWh / tonne, and 54.0 and 50.7 KWh / tonne for cryogenic and ambient grinding conditions, respectively (Figure 2a). For turmeric sample the energy values i.e Rittinger's constant and Kick's constant were found as 34.8 and 39.7 KWh / tonne, and 58.0 and 58.1 KWh / tonne for cryogenic and ambient grinding conditions, respectively (Figure 2b). The value of Rittinger's constant and Kick's constant were found lower in cryogenic grinding in comparison to ambient grinding as expected (Meghwal and Goswami, 4).

For ground cinnamon, colour values such as *L, a, b*, hue angle and chroma were found 55.8 and 48.0, 9.6 and 19.6, 22.3 and 67.3, 67.0° and 73.3°, and 25.2 and 62.0 for cryogenic and ambient grinding conditions, respectively. The value of L was higher whereas *a, b*, hue angle and chroma values were lower in cryogenic ground sample in comparison to ambient ground. It means cryogenically ground samples are better in colour as expected 0(Meghwal and Goswami, 4). For ground turmeric the colour values e.g. *L, a, b,* hue angle and chroma were found as 35.0 and 36.0, 28.6 and 27.4, 58.7 and 58.0; 66.1° and 67.8° and 68.3 and 65.1 for cryogenic and ambient grinding conditions, respectively.

The values of specific surface of mixture, number of particles/g and specific energy consumption for cinnamon and turmeric under cryogenic and ambient conditions are presented in Table 2. For cinnamon and turmeric, the values of specific surface of mixture and number of particles/g were higher in cryogenic grinding conditions in comparison to ambient grinding conditions. The specific energy consumption for cinnamon and turmeric was lower in cryogenic grinding conditions in comparison to ambient grinding conditions as expected (Meghwal and Goswami, 4).

Conclusion

From present study on cinnamon and turmeric, the average particle size, volume surface mean diameter, mass mean diameter and volume mean diameter were found lower in cryogenic grinding as compared to ambient grinding. For cinnamon sample, energy values (Rittinger's and Kick's constants) were found as 26.8 and 29.6, and 54.0 and 50.7 KWh / tonne for cryogenic and ambient grinding conditions, respectively. It is also concluded that less specific energy consumption was found for cryogenic grinding in comparison to ambient grinding.

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References

1. AOAC .1995. Official Methods of Analysis. In Williams, S. (Ed), Association of Official Analytical Chemists, Inc., Arlington,Virginia.
2. Balasubramanian, S., Kumar, R., Singh, K.K., Zachariah, T. J., and Vikram. 2013. Size reduction characteristics of black pepper. *Journal of Spices and Aromatic Crops*. **22 (2)**:138–147.
3. Baratta, M.T., Dorman, H.J.D., Deans, S.G., Figueiredo, A.C., Barroso, J.G., and Ruberto, G. 1998. Antimicrobial and antioxidant properties of some commercial essential oils. *Flavour and Fragrance Journal*. **13**: 235–244.
4. Meghwal, M., and Goswami, T.K. 2010. Cryogenic grinding of spices is a novel approach whereas ambient grinding needs improvement. *Continental Journal of Food Science and Technology.* **4(3):**24 – 37.
5. Mridula, D., Singh, K.K., and Barnwal P. 2010. Development of omega-3 rich energy bar with flaxseed. *J. Food Sc. Technol.* **50(5)**: 950-957.

Table 1. Expressions used for determination of grinding characteristics of spices

S.No.	Grinding characteristics	Expression used
1.	Average Particle size (D_p)	$D_p = \left[0.135 \times (1.366)^{FM}\right]$
2.	Volume Surface Mean Diameter (D_{vs})	$D_{vs} = \dfrac{1}{\sum_{i=1}^{n} \left(\dfrac{m_i}{D_{pi}}\right)}$
3.	Mass mean diameter (D_m)	$D_m = \sum_{i=1}^{n} (m_i D_{pi})$
4.	Volume Mean Diameter (D_v)	$D_v = \left[\dfrac{1}{\sum_{i=1}^{n} \left(\dfrac{m_i}{D_{Pi}^3}\right)}\right]^{\frac{1}{3}}$
5.	Rittinger's law constant (C)	$E = C\left[\dfrac{1}{x_p} - \dfrac{1}{x_f}\right]$
6.	Kick's law constant (C_k)	$E = C_K \ln(x_p / x_f)$
7.	Hue angle (h^0)	$h^0 = \tan^{-1} (b/a)$
8.	Chroma (C)	$C = v\ (a^2 + b^2)$
9.	Specific surface of mixture (Ass)	$Ass = \left[\dfrac{1}{(D_{VS}¤°_t)/6}\right]$
10.	Number of particles	$= \dfrac{Weight\ of\ one\ seed}{Weight\ of\ one\ ground\ particle}$
11.	Specific energy consumption (ΔE)	$\Delta E = \dfrac{\Delta W \times 3.6}{f}$

Where, m_i, and D_{pi} are mass retained and mean diameter in each increment, respectively;
x_f and x_p are the diameter of feed and product, respectively and E is the amount of work required to reduce a unit mass of feed from x_f to x_p.

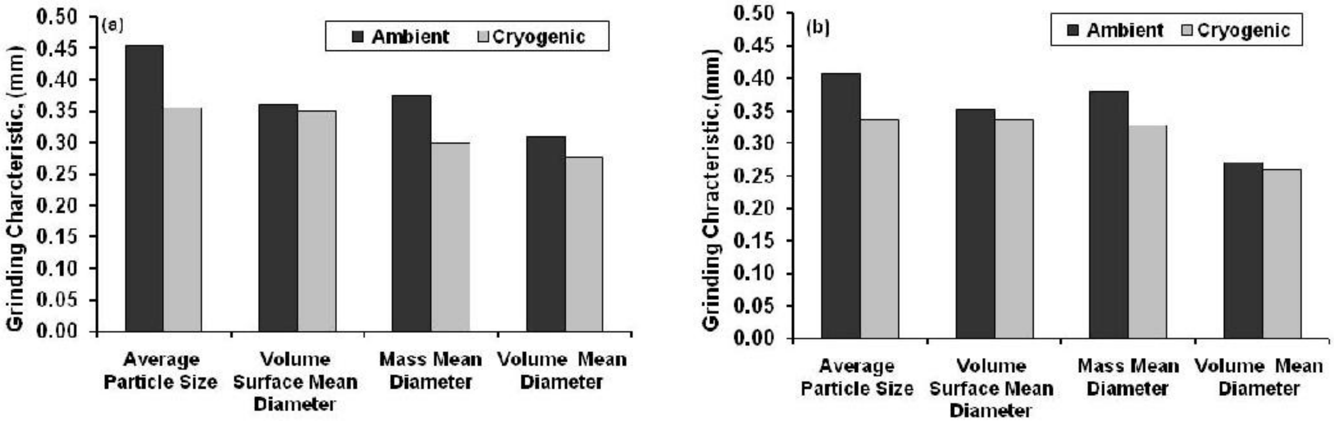

Figure 1. Grinding characteristics of spices under different grinding conditions (a) cinnamon and (b) turmeric

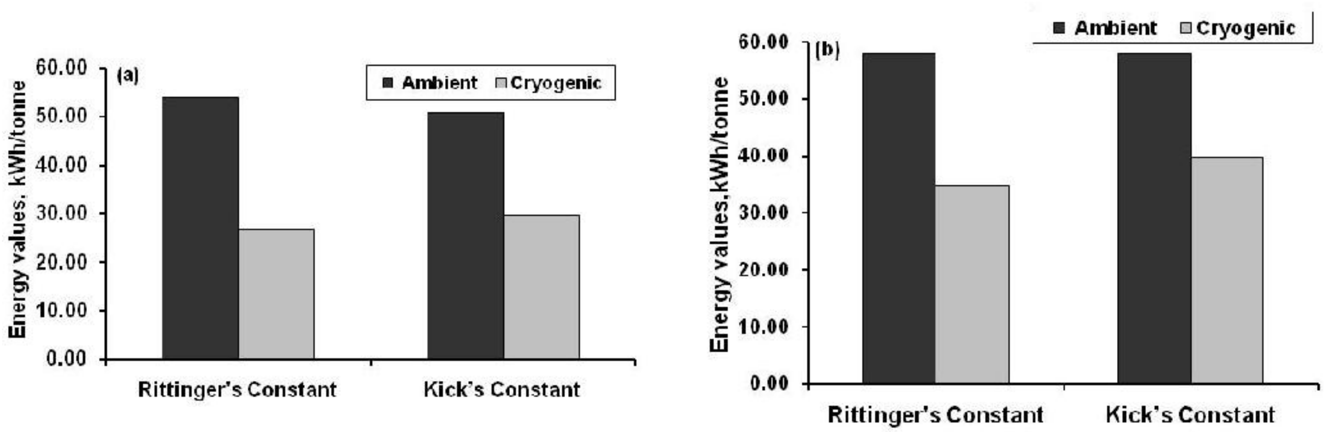

Figure 2. Energy Values of spices under different grinding conditions (a) cinnamon and (b) turmeric

Table 2. Some grinding parameters of cinnamon and turmeric under different grinding conditions

Spice	Grinding conditions	Specific surface of mixture (Ass), (mm^2/g)	Number of particles/g	Specific energy consumption (kWh/tone)
Cinnamon	Ambient	16183	23988	103.33
	Cryogenic	41890	41478	67.50
Turmeric	Ambient	13955	23127	126.32
	Cryogenic	18222	51224	93.82

6. Murthy, C.T., and Bhattacharya, S.2008**.** Cryogenic grinding of black pepper. *J. Food Eng.* **85**: 18-28.

7. Sahay, K. M., and Singh, K. K. 2001. Unit Operations of Agricultural Processing, 2nd Ed., Vikas Publishing House Pvt. Ltd., New Delhi.

8. Saxena, S. N., Sharma, Y. K., Rathore, S. S., Singh, K. K., Barnwal, P., Saxena, R., Upadhyaya, P. and Anwer, M. M. 2013. Effect of cryogenic grinding on volatile oil, oleoresin content and anti-oxidant properties of coriander (*Coriandrum sativum* L.) genotypes. J. of Food Sci. and Tech. DOI 10.1007/s13197-013-1004-0

9. Singh, K.K., and Goswami, T.K. 1997. Studies on cryogenic grinding of spices. IIT Kharagpur, India.

10. Singh, K.K., and Goswami, T.K.1999. Design of a Cryogenic Grinding System for Spices. *Journal of Food Engineering.* 39(10): 359-368.

11. Singh, K.K., and Goswami, T.K. 2000. Thermal properties of cumin seed. *J. Food Engg*. 45:181–187.

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