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Study on quality aspects of cryogenic grinding of ginger

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Abstract
In India, ginger is a popular spice that is used in both culinary and traditional medicine. In the form of powder, ginger is frequently utilized. The temperature of the product was raised during the traditional method of grinding ginger with a hammer mill, resulting in the loss of oleoresin content, and colour value. The cryogenic grinding system has been attempted to resolve this problem. Dry ginger was cryogenically ground at temperatures of -40℃, -55℃, -70℃ grinding at ambient temperature was used as control. The results showed that oleoresin content was preserved at a higher level in the ground sample 7.67 per cent at -70℃ while the lowest level was 6.95 per cent at ambient grinding. The lowest and greatest L^* values were discovered to be 61.56 at ambient ground powder and 68.95 at -70℃, respectively. The brightness is indicated by the L^* Value.

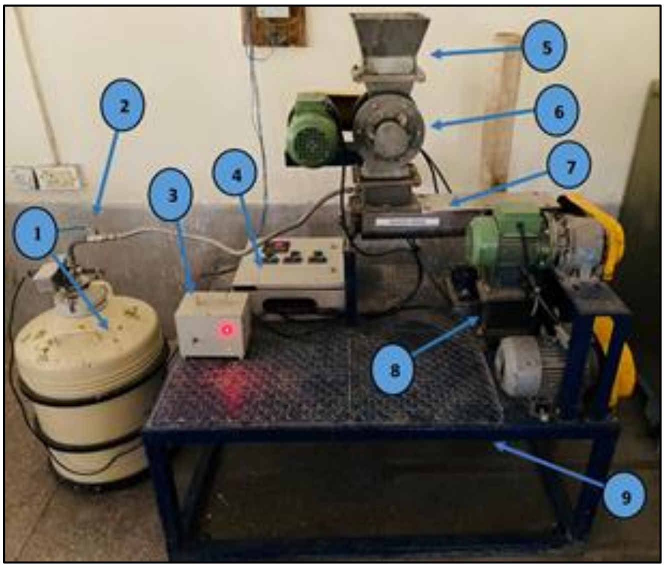
Keywords: Ginger, cryogenic grinding, oleoresin content, colour value, ambient ground

Introduction
Ginger (*Zingiber officinale*) is a flowering plant whose rhizome, also known as ginger root or ginger, is a popular spice and folk medicine. The rhizome of the plant, which belongs to the *Zingiberaceae* family, is used as a spice, either fresh or dried (Pruthi, 1993) [7]. Grinding is a high-energy operation that uses just 1 or 2 per cent of the input energy to reduce particle size and wastes the rest as heat (Jung *et al.*, 2018) [4]. In ambient grinding (Bera *et al*., 2001) [2], product temperatures of up to 90°C were measured. Cryogenics is a method of cooling materials by direct contact with fluids with extremely low boiling temperatures. It can freeze materials and make them brittle. The material to be ground is cryogen-precooled before being transferred to grinding, where cryogen is employed to keep the temperature constant (Russo, 1976) [10]. The fat and oil content of the spice will be frozen, and no evaporation or melting will occur, preventing filter clogging. The goal of this study was to see how temperature affected the physio-chemical characteristics of ginger powder during cryo-grinding.

Materials and Methods
Selection of raw material
For this study, ginger (*var. Indian Ginger*) was purchased at a local market in Udaipur, Rajasthan. They were dried in a tray dryer at 60℃ after cleaning, partial peeling, and cutting into 2.5 mm thick slices to achieve storage moisture content.

Traditional grinding of dried ginger in hammer mill
Traditional grinding is a grinding in that takes place at room temperature with no temperature control or cooling. Grinding took at room temperature and the temperature will rise during the grinding. The trails were taken at 21℃.

Low temperature grinding
A cryogenic grinder was used to ground the dried ginger samples at a low temperature (Spectra Cryogenic System Pvt. Ltd.). The cryogenic grinder consists of a hammer mill, cryo-screw conveyor, feed hopper, temperature controller, heater, rotary valve, and cryo-can (51.5-liter capacity) with liquid nitrogen valve and collecting pan. The rotary valve, screw conveyor, and grinding mill are all powered by three induction motors. The liquid nitrogen pipe is connected to the cryo-screw conveyor. The ground product is collected in the collection pan, which is located at the bottom of the grinding mill.



1. Cryo can
2. Valve
3. Heater
4. Temp indicator
5. Feed hopper
6. Rotary valve
7. Cryo-Screw Conveyor
8. Grinding hammer mill
9. Collector pan

Quality attributes of the grounded ginger powder

Determination of moisture content

The oven drying method was used to test the moisture level of raw ginger slices before drying and after drying.

Oleoresin content

The oleoresin content of dried ginger powder was determined using solvent extraction (Kapoor *et al*., 2014) [14] in the Soxhlet apparatus.

$$\text{Oleoresin (\%)} = \frac{\text{Weight of extracted material}}{\text{Weight of sample}} \times 100$$

Particle size analysis

The ground product was sieved using a sieve shaker in accordance with BSS 460. A stack of BSS sieve No. 100, 48, 28, 16, 8, and 4 with pan and cover was set in a mechanical shaker serially. A 100g ground product sample was inserted in the top most sieve, and the set was shaken for 5 minutes using a sieve shaking machine (Sahay and Singh 1996) [11]. The average diameter of the particle (DP) in pulverized ginger powder was determined by weighing the mass retained on each screen.

The average Dp was calculated by using the Equations

$$FM = \frac{\text{Total percent retained on sieve}}{100}$$

$$D_p = 0.135\,(1.366)^{FM}$$

D_p = average particle size in mm

Color

The appearance of the sample was used to assess its quality. As a result, Hunter colour Lab was used to determine the colour of the sample, which scans the visible spectrum from 400 to 700 nm with a 10 nm resolution for reliable colour measurement. The colour of ground ginger powders at various temperatures, as well as control samples with L*, a*, and b* values displayed on the screen, were studied.

Angle of repose

The angle of repose is used to determine the flow ability of the powder (Geldart *et al*., 2012) [3]. The powder is allowed to descend through a small opening from a funnel and create a conical pile on a horizontal surface. The angle of repose was determined as follows:

$$\Theta = \tan^{-1}\frac{h}{r}$$

Where,

Θ= Angle of repose, degrees

h = Height of pile, cm

r = Radius of the base circle of pile formed, cm

Water activity (a_w)

The water activity of cryogenically ground ginger powder was measured using a digital water activity meter. The sample cup was filled with powder samples. Water activity values were recorded by keeping the filled sample cup in contact with the sensor probe of a water activity meter (Beaudry *et al*., 2004) [1].

Results and Discussion

Dry ginger slices were cryogenically ground at temperatures of -40°C, -55°C, -70°C grinding at ambient temperature was used as control. For the grounded sample oleoresin content, colour value, sieve analysis, water activity, and angle of repose were examined.

Initial Moisture Content

The oven dry method was used to determine the initial moisture content of fresh ginger. The initial moisture content of fresh ginger was discovered to be 426.00 per cent on average (DB).

The fresh ginger was dried in a tray dryer at 60°C until it reached a storage moisture content. After drying for 8 hours, the moisture content was determined using the oven dry method. The dried ginger was found to have a moisture content of 10.1%. (WB).

Characteristics of ginger powder ground using the traditional grinding method

The various quality criteria of ginger powder such as moisture content, oleoresin content, and colour values ground at ambient temperature have been estimated. The quality of the ground powder was compared with raw sample, as shown in Table 1.

The moisture content of ginger powder was found to be 16.43 per cent lower than the raw sample. This reduction in moisture content might be due to evaporation of moisture during grinding i.e., as a result of temperature rise from room temperature.

A visible variation in the amount of oleoresin content in ginger powder was observed. The loss in oleoresin content was 12.13 per cent when compared to the raw sample. This might be due to the oleoresin and fat contents melting at high temperatures inside the grinder and sticking to the walls, causing losses and potentially sieve clogging (Singh and Goswami, 1999) [13].

The difference in colour values revealed that the ambient ground powder had a poor appearance. The drop in L* value (which represents lightness) compared to the raw sample indicates that the ambient ground product has become less light in colour, the increase in a* value indicates that it has become more reddish, and the decrease in b* value suggests that the blueness has increased.

Effect of grinding temperature on moisture content

The amount of moisture in a product has a significant impact on its shelf life. The maximum moisture content figure was 9.73 percent at -70°C, while the lowest was 8.44 percent (WB) at the 21°C. The results demonstrate that as the grinding temperature was reduced, the moisture content increased. The cold and inert environment formed by liquid nitrogen during cryogenic grinding prevents moisture from evaporating from the product. The temperature has a substantial effect on the moisture content of the material. (Jung, *et al.* 2018) [6] Discovered a similar effect, finding that maintaining a low temperature inside the mill prevents moisture content losses. The statistical analysis shows that P-value less than 0.0500 indicate model terms are significant. Fig.1 depicts the change in moisture content as a result of various cryogenic treatments.

Effect of grinding temperature on recovery of oleoresin

The highest and lowest percentages of oleoresin found were 7.67 and 6.95 percent, respectively. A grinding temperature of -70°C yielded the maximum amount of oleoresin, while a normal grinding temperature yielded the lowest amount. The yield of oleoresin tended to increase as the grinding temperature was reduced. Sharma *et al*., (2014) [12] previously demonstrated increased oleoresin content of 28.28 percent in cumin seeds by use of a cryogenic grinder. The statistical analysis shows that P-value less than 0.0500 indicate model terms are significant. The oleoresin retention in several cryogenic ground samples is shown in Fig 2.

Effect of grinding temperature on particle size

The particle size of ginger powder was in the range of 0.308 to 0.248 mm. The higher grinding temperature, the particle size was large. Similarly, at a low temperature of grinding the average particle size was also small. The particle size of a powder reflects its fineness, and the smaller the value, the finer the powder. Ground spice's tiny particle size aids in the easy release of taste and aroma. As the temperature drops from -40°C to -70°C, the particle size decreases. Singh and Goswami (1999) [13] found a decrease in particle size of the ground product as the grinding temperature was reduced from -70°C to -160°C in their studies using cumin seeds. The statistical analysis shows that P-value less than 0.0500 indicate model terms are significant. Fig.3 shows the variation of particle size with different temperatures.

Effect of grinding temperature on the colour of ginger powder

One of the first things that attract a customer's attention is the colour of the spice powder. Spice powder's eye-catching colour gets a nice premium for the maker. The lowest and greatest L* values were discovered to be 61.56 at ambient temperature and 68.95 at -70°C, respectively. The brightness is indicated by the L* value. It ranges in intensity from dark to light (0 to 100 and 100 indicates white). The lightness was observed to increase as the grinding temperature was reduced. When the ginger was ground at the lowest grinding temperature, the best L* values were discovered.

6.62 and 3.93 were found to be the highest and lowest a* values, respectively. The highest value of a* at the ambient ground and the lowest at -70°C. The redness of the powder is indicated by a* value. The yellowness of the powder is indicated by the b* value. For a grinding temperature of -70°C, the maximum value was found to be 30.31. The lowest value found was 26.48 at ambient grinding. The effects of cryogenic and ambient grinding on the colour of turmeric had also produced a similar result, according to Pesek and Wilson (1986) [8]. The statistical analysis shows that P-value less than 0.0500 indicate model terms are significant. The colour values of cry ground ginger powder are shown in Table 2.

Angle of repose

To better understand the flow qualities of ginger powder, its angle of repose was investigated. The angle of repose is maximum at -70°C and lowest at ambient grinding. The highest value of angle of repose was 50.2 and the lowest was 48.2 degrees. This range of flow ability places a powder in the passable or poor category. The statistical analysis shows that P-value less than 0.0500 indicate model terms are significant. Fig. 4 shows the variation in the angle of repose of ginger powder at different temperatures.

Water activity (a_w)

When the grinding temperature is reduced, the water activity is shown to increase. The highest and lowest water activity (a_w) found were 0.598 and 0.524, respectively. A grinding temperature of -70°C yielded the maximum amount of water activity, while a normal grinding temperature yielded the lowest amount. This may be related to the fact that moisture content retention increased at lower temperatures. (Mallappa *et al.*, 2015) [5] Found a similar effect of grinding temperature on water activity. The statistical analysis shows that P-value less than 0.0500 indicate model terms are significant. Fig. 5 shows the variation of the water activity of ginger powder at different temperatures.

Table 1: Various quality parameters of ambient ground and raw sample

Quality parameter		Raw sample (Ginger slices)	Ginger powder (Obtained by normal grinding)
Moisture content (% W.B.)		10.10	8.44
Oleoresin content (%)		7.91	6.95
Colour values	L*	65.23	61.56
	a*	5.26	6.62
	b*	30.18	26.48

Table 2: Colour values of cry ground ginger powder

Grinding temperature (°C)	Hunter colour values		
	L *	A*	B*
21	61.56	6.62	26.48
-40	67.23	4.23	29.88
-55	68.39	3.98	30.09
-70	68.95	3.93	30.31

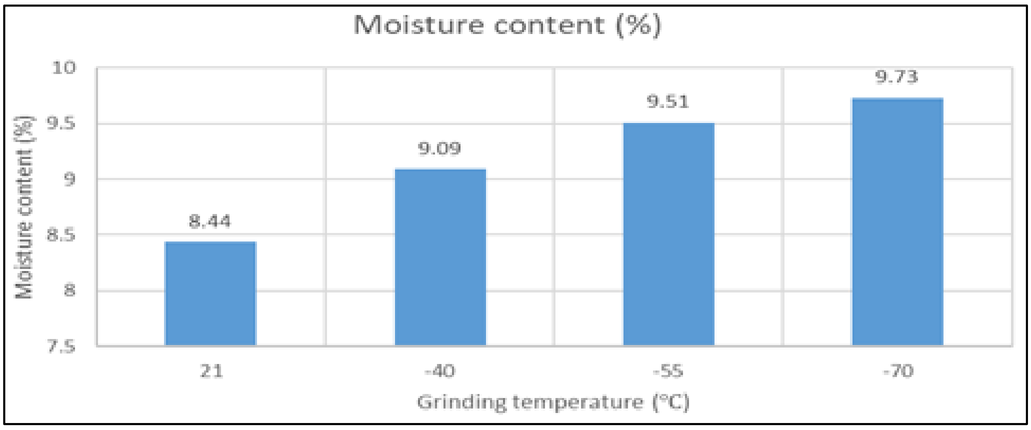


Fig 1: Change in moisture content of ginger powder at different temperature

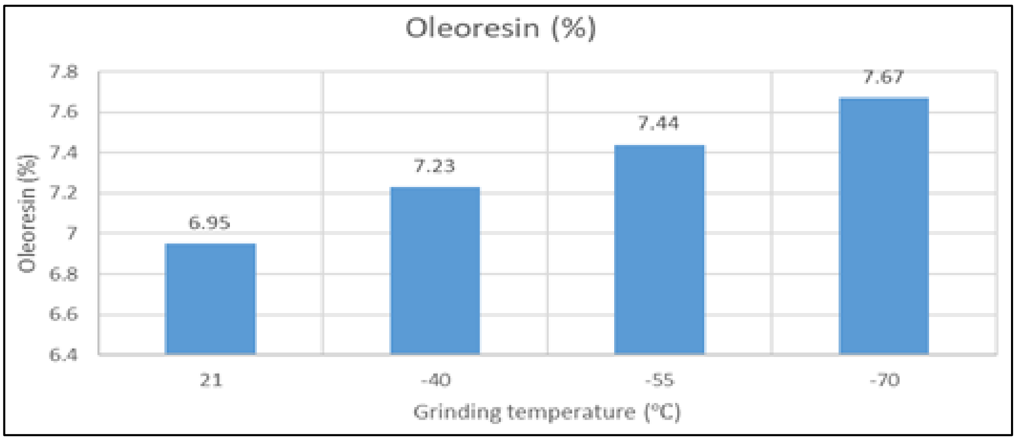


Fig 2: Oleoresin recovery of ginger powder at different temperature

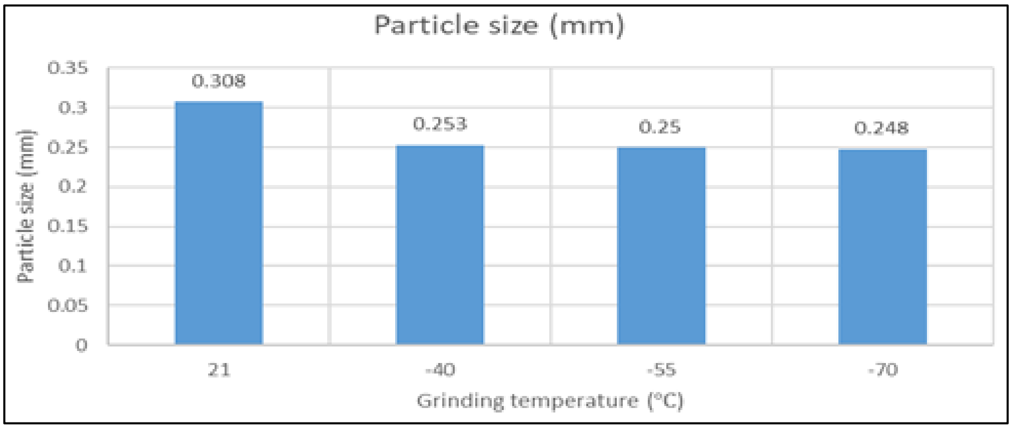


Fig 3: Change in particle size of ginger powder at different temperature

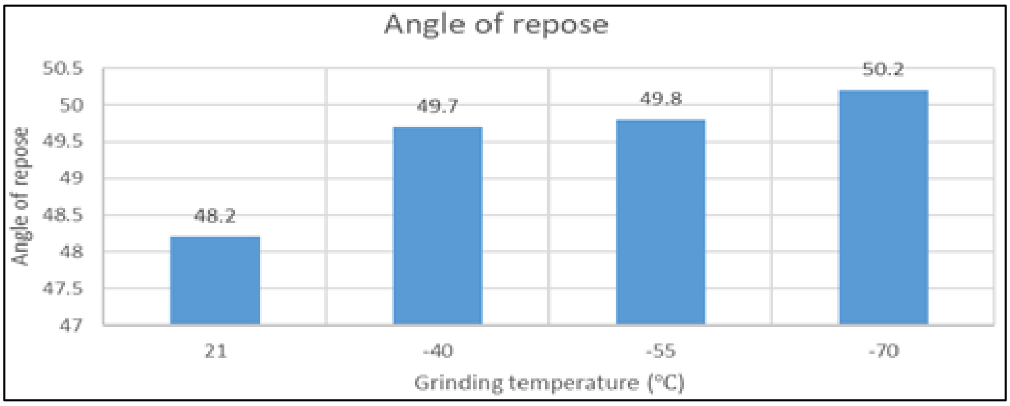


Fig 4: Change in the angle of repose of ginger powder at different temperature

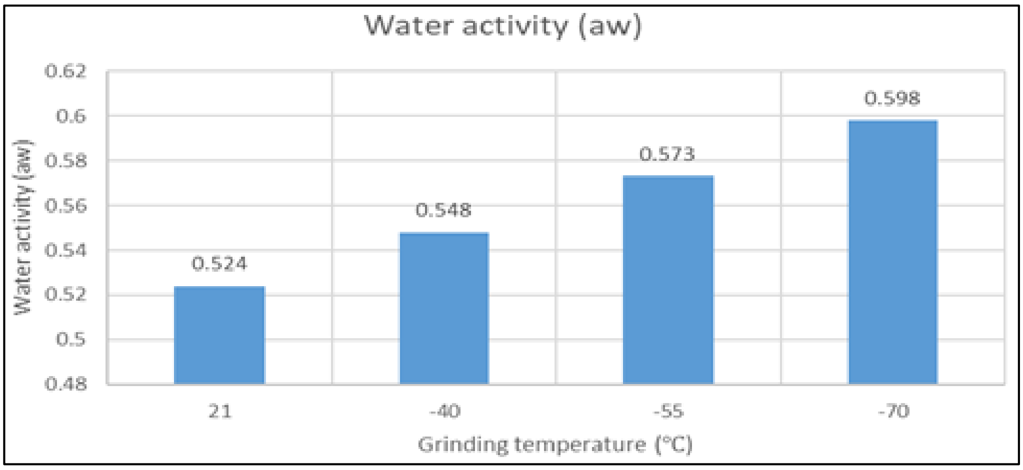


Fig 5: Change in water activity of ginger powder at different temperature

Conclusions

According to the results of the research, cryogenic grinding produces a higher quality product than ambient temperature grinding. Cryogenic grinding is a promising technology that delivers a powder with reduced quality deterioration and good grinding characteristics of ginger.

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