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Cryogenic technique in value addition of spices

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Abstract
Traditional grinding techniques can be used to grind the spices but because of the increase in the temperature during grinding process natural flavour and aroma will be lost. Cryogenics is the study of low temperature and behaviour of material under low temperature conditions. Precooling of the raw spice and the continuous low temperature maintained within the cryogenic system reduces the loss of volatile oil and moisture. Cryogenic grinding technology retains colour, antioxidant activity, aroma and flavour properties of the materials thereby improves the product quality.

Keywords: cryogenics, precooling, techniques, flavour, spices

Introduction
Spices play an important role in enhancing the flavour and taste of the processed foods. These spices are also used in the medicines because of their stimulating and digestive properties. These properties are enhanced by the process of grinding 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 flavour and colour.

Long time ago, when human beings started processing their food, they discovered that some plants can be stored longer and also tasted nicer if they were pounded with stones. Some of the commercial grinders are hammer mills, impactors, rolling and compression machines, attrition mills, ball mill and tumbling mills.

In India traditionally plate mills and hammer mills are used for spice grinding. But in these mills there is heavy loss of volatiles and production of lower quality of spice powder in terms of flavour, colour and medicinal value. At commercial scale pin mills are used for grinding of spices, which produces better quality of powder as compared to hammer and plate mills. However a significant amount of volatiles are also lost in pin mill grinding. In the normal grinding process, heat is generated when energy is used to fracture a particle into a smaller size. Food species are ground when their requirement is in the form of powder. Referring to journals on Food Engineering has shown that species consist of fat or oil in them. This fat comes out of the seeds when they undergo ambient grinding operation. Due to the rubbing action between the seeds and grinder there produces certain temperature inside the grinder which may vary to certain extent (42^0C to 92^0C). The rise in the temperature inside the grinder reduces the flavouring ingredients of the species. There by adopting cryogenic grinding technique, flavouring ingredients of species can be saved by attaining cryogenic temperatures.

Cryogenics
- Cryogenics is the study of low temperature and behaviour of material under low temperature conditions. The word cryogenics originates from the Greek word "cryo" which means creation or production by means of cold.
- It deals with temperature as low as below -150 ^{0} C
- A person who studies elements that have been subjected to extremely cold temperature is called cryogenicist.

Table 1: Cryogens: It means low temperature boiling liquids

Nitrogen (LN_2)	Carbon dioxide (LCO_2)
Helium (LHe)	Methane (LCH_4)
Hydrogen (LH_2)	Oxygen (LO_2)

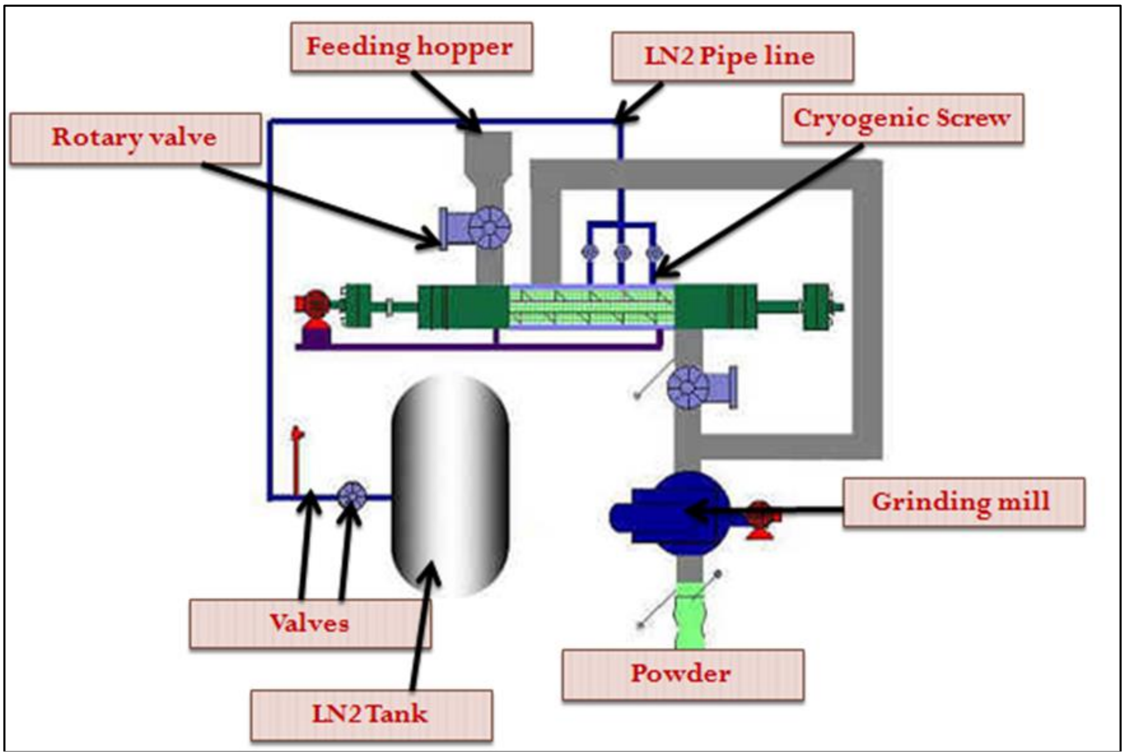

Fig 1: Cryogenic grinding system

Working of cryogenic grinding system

- Material is fed into the feed hopper.
- LN_2 is sprayed directly into the material.
- Material conveyed via stainless steel special design auger
- LN_2 absorbs heat from the material and vaporizes to gaseous state.
- LN_2 is added until the temperature of the material is reduced to predetermined set point.
- Cryogens make spices brittle, separate its fiber and solidify the fat.
- Grinding zone temperature will be maintained below -73^o C. At this temperature spices crumble and permits finer grinding.

Uses of cryogenic grinding in spices

- To obtain fine particle size
- To retain colour and flavour
- To maintain physico-chemical quality
- Promotion of export

Advantages of liquid nitrogen as cryogen

- Faster reduction in temperature
- Higher retention of volatile oils
- Prevention of oxidation and rancidity
- Increased throughput
- Less consumption of electricity
- Reduction in microbial load
- Possibility of fine grinding of difficult spices
- Controls gumming up
- Uniformity in final product

Table 2: Comparison of product quality between traditional and cryogenic grinding process

Parameter	Cryogenic grinding	Traditional grinding
Energy consumption	Low	High
Throughput	High	Low
Mill clogging	No clogging	Frequent
Volatile losses	Minimum	Higher
Grinding of soft material	Possible	Not possible
Control on particle size	Effective	No control
Fire risk	No	High
Microbial load	Does not exist	Possible

Table 3: Superiority of cryogenic grinding over ambient grinding with respect to essential oil content

Spices	Unground (ml/100g)	Ambient grindin (ml/100g)	Cryo grinding(ml/100g)	% increase
Black pepper	3.35	2.65	3.10	36
Cardamom	8.75	5.58	8.40	50.50
Turmeric	5.50	3.50	5.50	57
Cloves	17.00	9.30	11.00	29.50
Coriander	0.60	0.40	0.60	50
Cumin	3.50	2.26	3.30	46

Three genotypes of fenugreek namely AM 1, RMT 305 and RMT 1 were taken and seeds were ground to fine powder using conventional grinder and cryogenic grinder. Result revealed that in fenugreek total sapogenin content was varying from 9.35 per cent in genotype RMT 1 to 10.78 per cent in genotype RMT 305 in cryo ground seeds, while in non cryo ground seeds it varied from 6.61 per cent in RMT 1 to 8.10 per cent in AM 1 genotype. Diosgenin percentage was significantly more in all three genotypes. In non cryo seeds it was ranging from 1.3 to 1.5 per cent while increased significantly in cryo ground samples and ranged from 2.1 to 2.5 per cent (Saxena *et al*., 2013) [6] .

Saxena *et al*., (2017) [8] reported that, traditionally ground cumin powder retained 2.03 per cent volatile oil whereas cryo-ground cumin powder retained 3.30 per cent. Hence, there was 62.56 per cent more retention of volatile oil observed in cryo-ground cumin powder as compare to traditionally ground.

The oleoresin content in cryogenically ground seeds of coriander showed significant increase over non cryogenically ground seeds. In non cryogenically ground seeds oleoresin content was ranging from a minimum of 5.39 per cent in Swati genotype to a maximum of 15.53 per cent in Sindhu genotype, while cryogenically ground seeds exhibited a minimum 13.80 per cent in ACr 1 to a maximum of 19.58 per cent in Australian genotype. In cryogenically ground seeds total phenolic content was significantly higher in all the genotype. It was ranging from a minimum of 32.44 mg GAE/g in RCr 41 to a maximum of 92.99 mg GAE/g crude seed extract in genotype Sindhu closely followed by the genotype RCr 436 (87.08 mg). Total flavonoid content in these samples was ranging from a minimum of 15.28 mg QE/g in genotype Sindhu to a maximum of 20.85 mg QE/g crude seed extract in genotype Swati. (Saxena *et al*., 2015) **[7]**

Barnwal *et al*., (2014) [1] reported that 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. The colour values of cryogenic ground spices were found better than ambient ground spices.

The percentages of α-pinene, *β*-pinene, γ-3-carene, *β*-caryophyllene and limonene in black pepper were increased by 2.56, 0.51, 1.97, 0.26 and 1.33 per cent respectively, when pepper was cryogenically ground. Those same compounds in white pepper were increased by 14.05, 14.08, 3.65, 11.83 and 8.16 per cent respectively, when cryogenic grinding was performed (Liu *et al*., 2013).

Barnwal *et al*., (2014 [2] reported that maximum volatile oil (5.18%), oleoresin (13.28%) and curcumin (5.17%) content were observed in cryo-ground turmeric powder compared to ambient ground samples (4.27, 10.12, 4.17 % respectively).

Mallappa *et al.* (2015) [4] noticed higher retention of capsaicin in cryogenic grinder (0.017%) followed by low temperature pulverizer (0.012%) and chilli pulverizer (0.007%). The colour values in cryogenic grinder was also higher and was found to be much better than low temperature pulverizer indicating superior quality powder.

In ajwain total phenolic content was maximum (109.75 mg GAE ml^{-1} crude seed extract) in methanol crude seed extract of cryo ground samples of genotype AA-2, closely followed by DMSO seed extract (102.89 mg GAE ml^{-1} crude seed extract). Whereas, maximum total flavanoid content (797.17 mg QE ml^{-1} crude seed extract) was observed in hexane crude seed extract of AA-2 followed by methanol (589.80-1 mg QE ml^{-1} crude seed extract), DMSO (304.49 mg QE 1 ml^{-1} crude seed extract) (Sharma *et al*., 2015) [9].

Sharma *et al*, (2014) [10] observed significant increase (28.28%) in oleoresin when seeds of RZ 209 were ground using cryogenic grinding. Total phenolic and flavonoid content was also more in cryogenically ground seeds of both the genotypes. Antioxidant content was increased in cryo ground seeds by 11.78 and 8.9 mg BHT E/100000 ppm extract in GC 4 and RZ 209 variety of cumin respectively.

The average volatile oil yield in cryogenic grinding was 1.7 ml/ 100 g. whereas, it was 0.9 ml/100 g for ambient system. The gas chromatographic analysis of volatile oil revealed that the ratio of monoterpenes to sequiterpenes varies from 1.35 to 1.85 in the case of cryogenic grinding, whereas, the ambient ground samples have a very low ratio (0.22–0.31). (Murthy and Bhattacharya, 2008.) [5]

Conclusion

By adopting cryogenic grinding technology the leading spice industries of our country will earn considerably more foreign exchange by exporting value added spices, in place of exporting whole spices in crude form. As the cost of raw materials and energy is increasing day by day, it is very necessary to make its efficient use to get quality spice at a reasonable cost. There is ever increasing demand for value added quality spices not only in domestic market but also in global spice market.

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