



Comparative study on ambient and cryogenic grinding of fenugreek and black pepper seeds using rotor, ball, hammer and Pin mill



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ABSTRACT

The suitability of a grinder based on their performance, fenugreek and black pepper seeds were ground under ambient and cryogenic grinding condition with the help of rotor, ball, hammer and pin mills. Rotor, hammer and pin mills were found to be good for small scale grinding at a feed rate of 22.5 g min^{-1} under ambient conditions and at 24.5 g min^{-1} for cryogenic grinding (continuous process) whereas the ball mill could be used for a lower feed rate of 1.56 g min^{-1} under ambient grinding; and 2.08 g min^{-1} under cryogenic grinding (batch processes). Time taken in grinding an equal amount of sample to a definite size in various grinders was found to be in the order: ball mill > rotor mill > pin mill > hammer mill; order of feed rate: hammer mill > rotor mill > pin mill > ball mill; order of power consumptions: pin mill > hammer mill > rotor mill > ball mill; and order of surface area created: rotor mill > hammer mill > pin mill > ball mill. Out of the above selected grinders, the rotor mill was found to be the most suitable for grinding fenugreek and black pepper spices. Power consumption was found to be increasing with an increasing specific surface area. This study will be useful for food process industries while considering spice-grinding applications; and also in academic field to understand suitability of grinders, their grinding mechanism.

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1. Introduction

Grinding is the process of reduction of grains or seeds to powders by the application of various forces, especially by rubbing, compression, shearing and impact between two hard surfaces [1–3]. Different types of grinders such as pin, ball, hammer and rotor mills can be used for grinding grains and seeds [4] depending on the hardness, stickiness and brittleness of seeds. Whole seeds cannot be consumed as such in human diet and therefore need to be ground in fine particle size. Further, seeds or grains in powder form can easily be packed, stored and consumed [2].

Grinding is an age-old practice of the human civilization. Ambient grinding refers to grinding carried out at normal atmospheric temperature and pressures, while cryogenic grinding refers to grinding performed with the help of a cooling agent such as liquid nitrogen (LN_2) at temperatures much lower than ambient. There are several benefits with cryogenic grinding such as better retention of volatile oils, better appearance, and reduced discolor of the products [5]. Grinding is an energy intensive operation where only 1% of total applied energy is used in grinding operation and remaining 99% is dissipated as heat [4,6]. In understanding the grinding process, we have to study the

particle size distribution, granulation, particle agglomeration, adhesive and cohesive nature of particles, and sticking properties of powder [7].

Rotor, ball, hammer and pin mills are the most common types of grinders used in the milling of agricultural materials and food processing. These grinders are easily available at a reasonable price and are simple to operate and maintain. These grinders can also be used for cryogenic grinding with suitable modifications.

However, very little information is available in the literature on the relative performance of different grinders operating at ambient and cryogenic temperatures.

The main objective of this work is to study the relative performance of different types of grinders for ambient and cryogenic grinding of the fenugreek and black pepper seeds. The time required for grinding, feed rate, overall power consumption, specific power consumption, specific surface area created after grinding, moisture content before and after grinding and color change were determined in this study for the above materials, the details of which are presented in the following sections.

2. Materials, methods and equipment

2.1. Materials

The fenugreek and black pepper seeds were used as the grinding materials for evaluating the performance of different grinders. Liquid nitrogen was used as cooling medium in cryogenic grinding.

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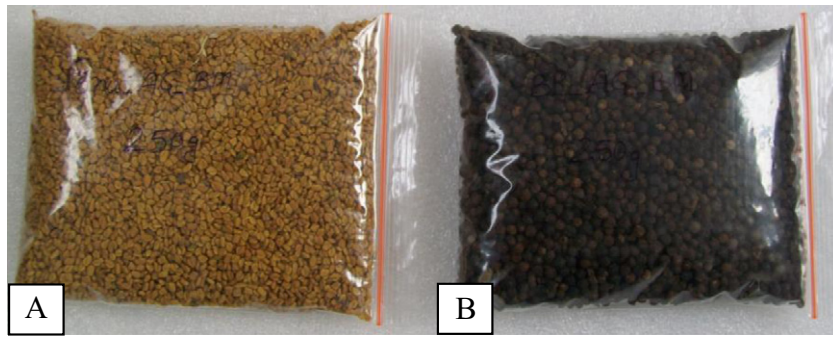


Fig. 1. Pictorial view of fenugreek (A) and black pepper (B) samples.

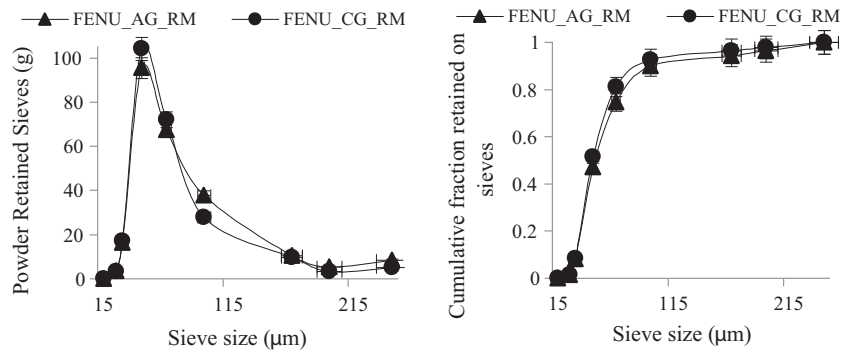


Fig. 2. Particle size analysis of fenugreek ambient and cryogenically ground powder (rotor mill).

2.2. Sample preparation

The fenugreek and black pepper seed samples were obtained from their major production centers in India [1,2,9]. The fenugreek and black pepper seeds were manually cleaned and sieved with a 600 μm mesh sized sieve before they were ground. 250 g samples of the fenugreek and black pepper were used in each grinding trail. After the grinding operations the ground powders were allowed to reach thermal equilibrium with the ambient before different chemical analyses and physical properties' determination were carried out. Fig. 1(A) and (B) shows a pictorial view of the typical fenugreek and black pepper samples used.

2.3. Mills used

The details of the different mills used in this study are described below.

2.3.1. Rotor mill

A rotor mill is a compactly designed grinder and can be used to grind spices such as black pepper and fenugreek. It can be used for continuous grinding as well as a batch grinding process depending on the requirements. In addition, most rotor mills have a metering mechanism that allows control of the feed rate.

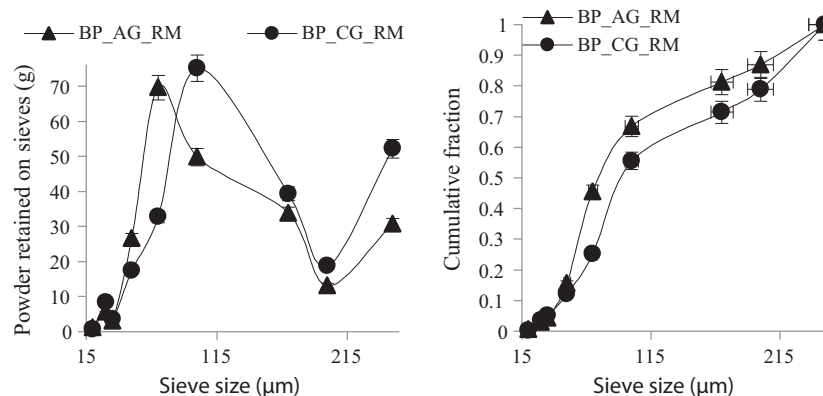


Fig. 3. Particle size analysis of ambient and cryogenically ground black pepper powder (rotor mill).

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