

INTRODUCTION

Milling is a mechanical process for size reduction of solid materials into smaller particles¹ and is the first important step that is undertaken before the extraction of active principles from medicinal plants². It allows an increase in surface area and concentration gradient, hence increasing extraction efficiency³. Conventionally, size reduction of plant materials is carried out by impact or cut milling. The relatively new conical screen mill is reported to achieve higher throughput rates compared to conventional milling processes, in addition to the advantages of lower dust and noise production⁴. While milling has been studied with great interest in the pharmaceutical industry, it has received little attention in the size reduction of raw plant materials for extraction, especially with the use of conical screen mill. Other than the milling mechanism, different process variables such as feed weight, milling speed and the types of screens or impellers used can affect the efficiency of the milling process and subsequently the particulate and bulk properties of the milled material⁵.

OBJECTIVES

- To study the influence of different milling mechanisms under different conditions for a model plant material, magnolia bark.
- To select an efficient milling method for extraction of barks based on the resultant bulk properties of the milled material.

METHODOLOGY

- Sliced magnolia bark was used as the model plant material.

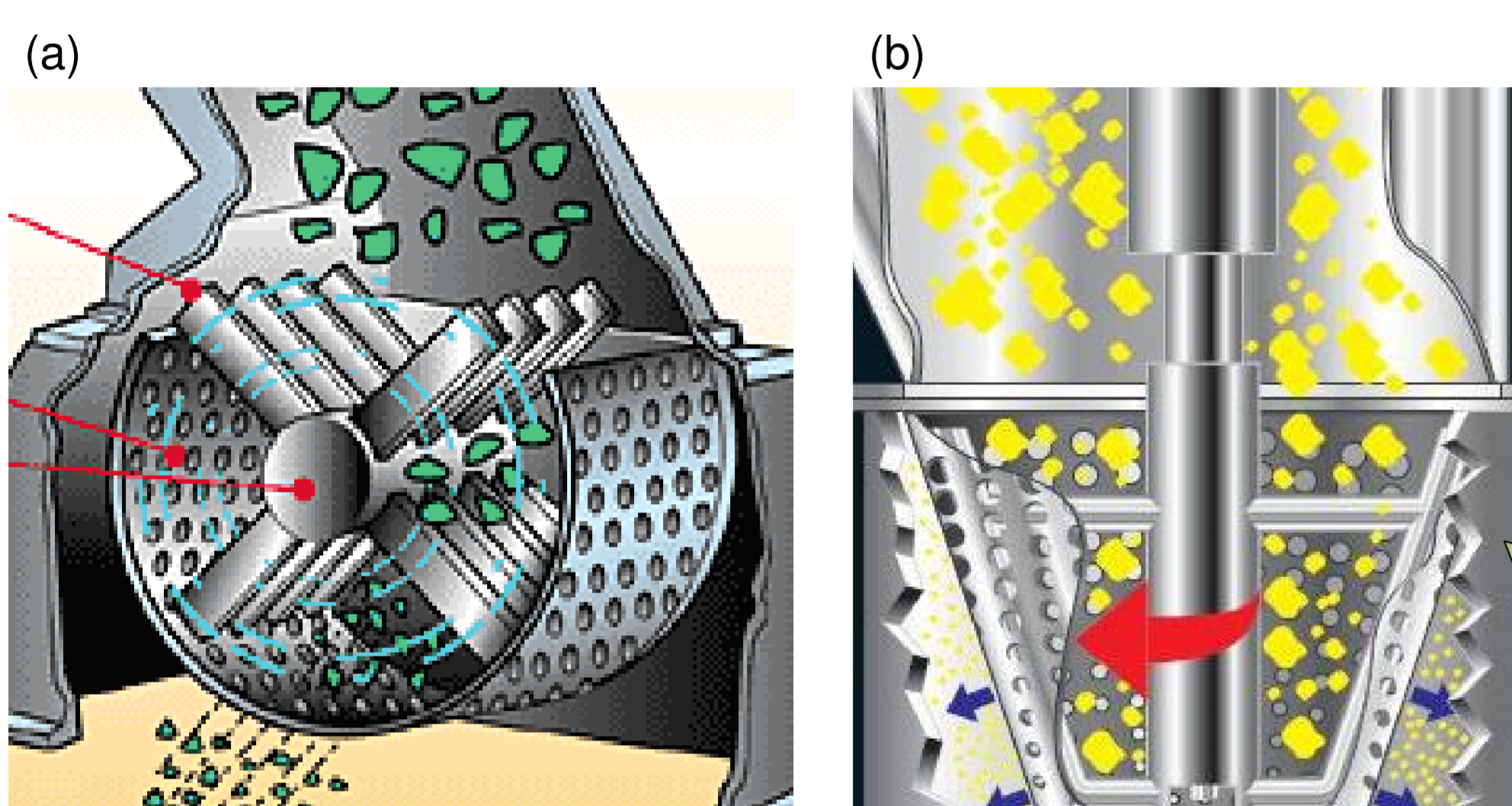


Figure 1. (a) Rotary hammer mill (Fitzmill Comminutor M5A, Fitzpatrick Company Ltd, USA) (b) Conical screen mill (Quadro Comil Model 197S, Canada)

- Impact and cut milling were carried out using the rotary hammer mill (Fig. 1a) while conical screen milling was carried out using the conical screen mill (Fig. 1b).
- Both mills were fitted with retention screens of aperture size 4750 μm .
- Milling was carried out in triplicates under different combinations of process variables.
 - Feed weight: 200 g, 400 g
 - Milling speed: 2000, 3000, 4000 rpm
- Different screen and impeller types were employed in conical screen milling.
 - Screen type: round-bore, grater-bore
 - Impeller type: rectangular-bar, round-bar with teeth
- Milling efficiency was determined by the amount of material milled and lost as dust, as well as the milling time.
- Characterization studies of the milled material were carried out as follows.

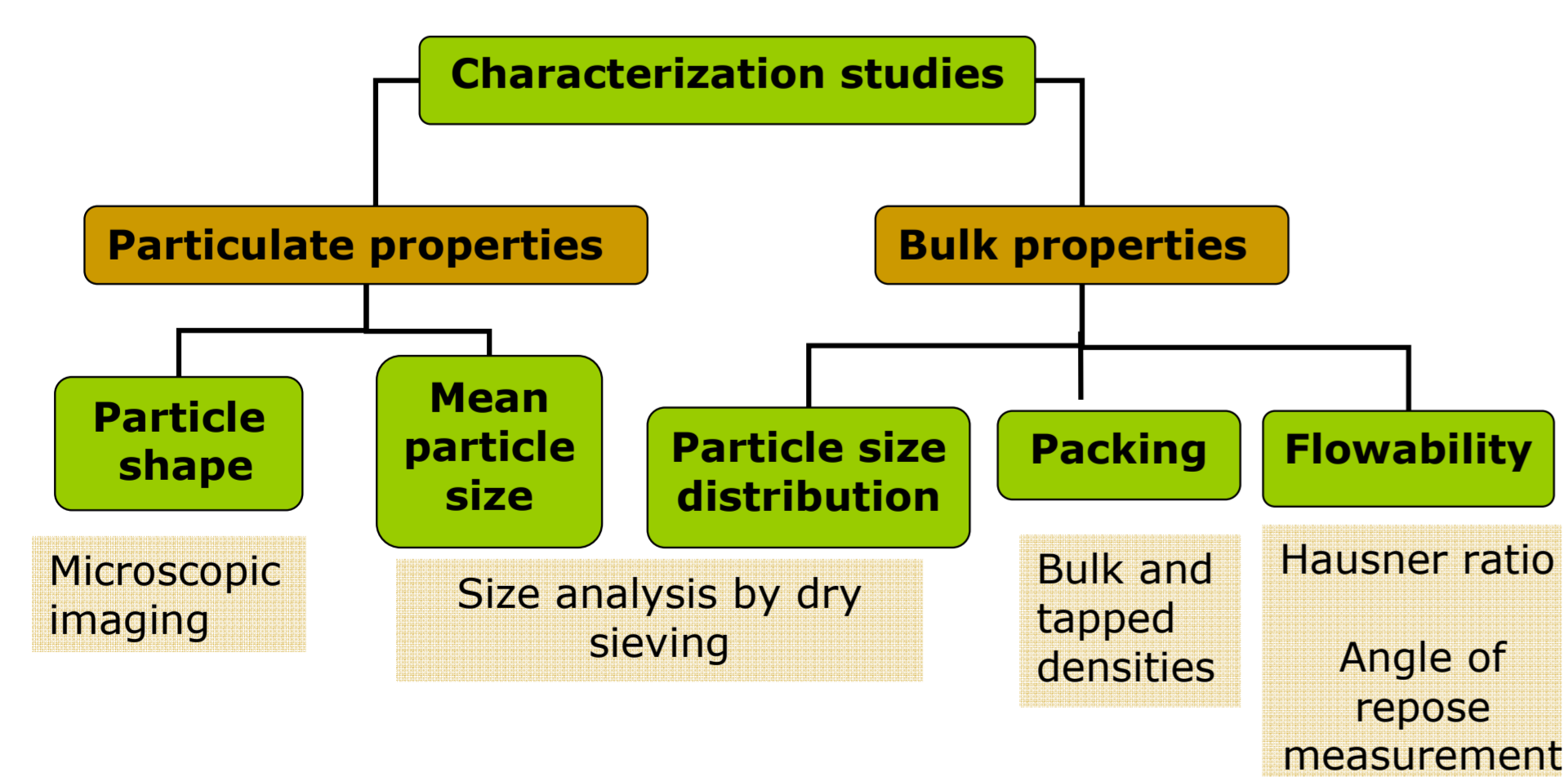


Figure 2. Characterization studies to determine the particulate and bulk properties of the milled material.

RESULTS AND DISCUSSION

Particle shape

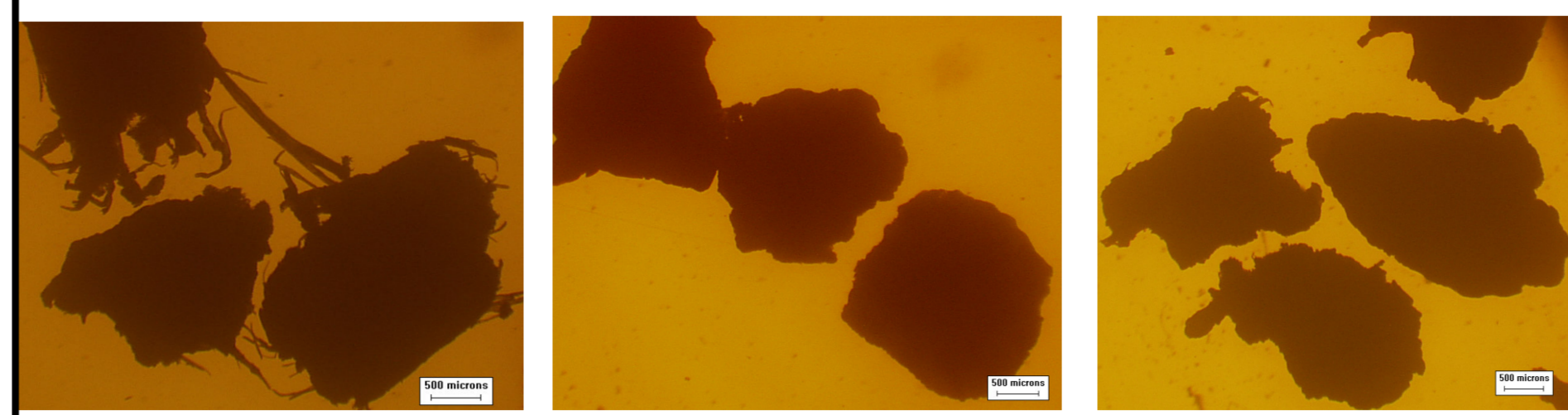


Figure 3. Microscopic images illustrating the particle shape of milled particles using (a) impact mill (b) cut mill and (c) conical screen mill.

- Impact mill:** battered appearance with fibrous strands protruding outwards; uneven cut surfaces
- Cut mill:** broad and cuboidal with even and smooth cut surfaces
- Conical screen mill:** irregular and jagged surfaces; less fibrous and more even in shape than those produced by impact milling

Milling efficiency: milling time

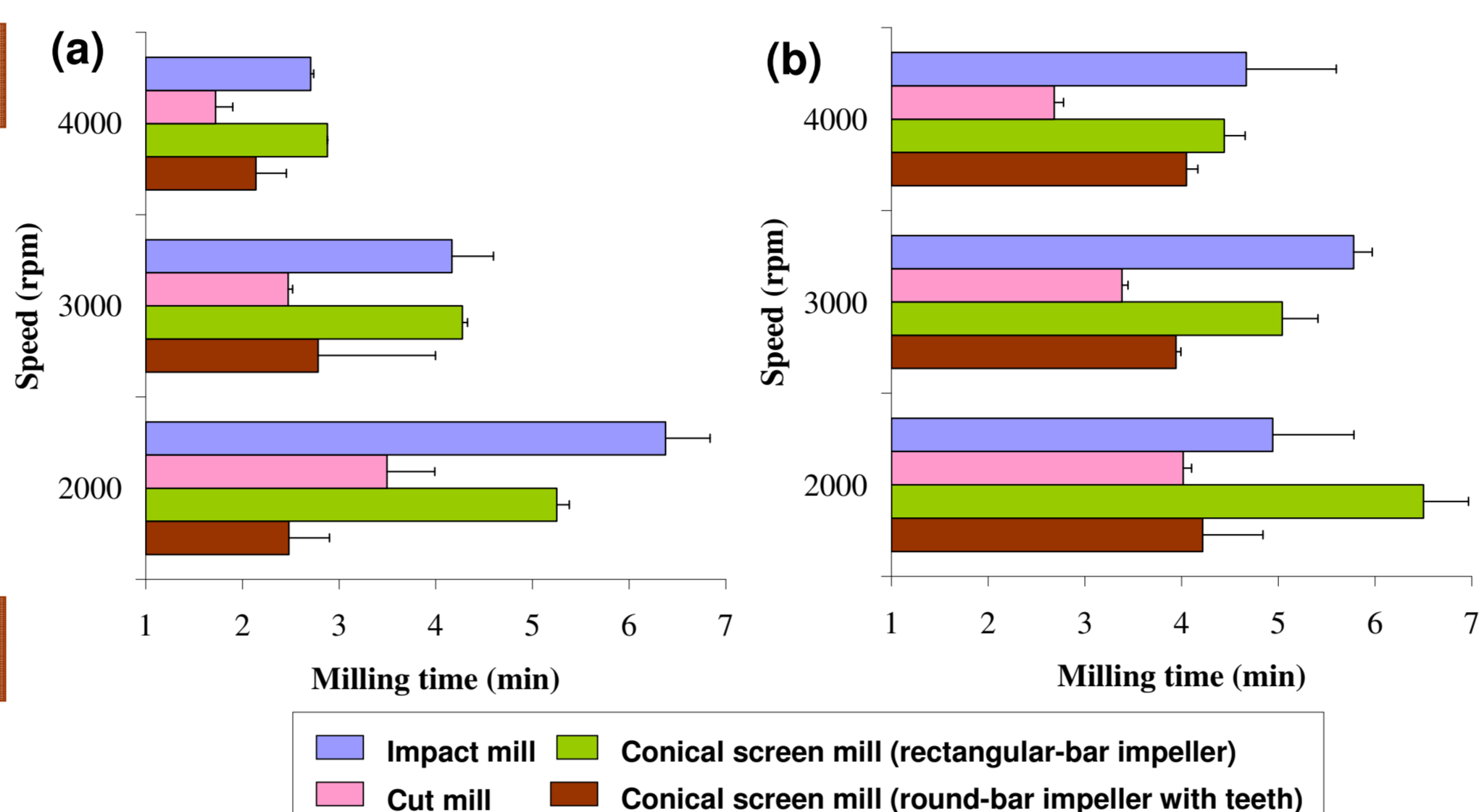


Figure 4. Comparison of milling time for different mill types for feed weight of (a) 200 g and (b) 400 g.

- Conical screen milling using the round-bore screen was unsuccessful. However, conical screen milling using grater-bore screen was the most efficient as it resulted in the highest throughput and least amount of material lost as dust.
- Impact milling and conical screen milling using the rectangular-bar impeller took a longer time than cut milling and conical screen milling using the round-bar impeller with teeth.
- Feed weight and speed exerted more significant effects on impact milling and cut milling.

- In **impact milling**, a blunt force is applied across a wide area. It is inefficient for the milling of fibrous material⁶, hence producing particles with irregular shapes and fibrous protrusions.
- Fibrous material requires a high concentration of **shear forces** that could be provided by the sharp-edged blades in **cut milling** and additional fracturing by the grater-bore screen as well as the teeth on the round-bar impeller in **conical screen milling**.
- Also, the **discharge** of milled material was inefficient for **impact and cut milling**.
- The larger impeller-screen clearance and spaces in between the blades allowed milled material to slide around the housing, hence decreasing throughput and increasing dust generation due to increased residence time of material.
- In the **conical screen mill**, the **vortex flow pattern** generated and the **small impeller-screen clearance** allowed material to be pushed through the screen bores as soon as they were size-reduced appropriately⁷. Hence, the residence time was reduced and throughput was increased. This also led to milled material with narrow size distribution and minimal fines generation.

Particle size, size distribution, fines generation and flowability

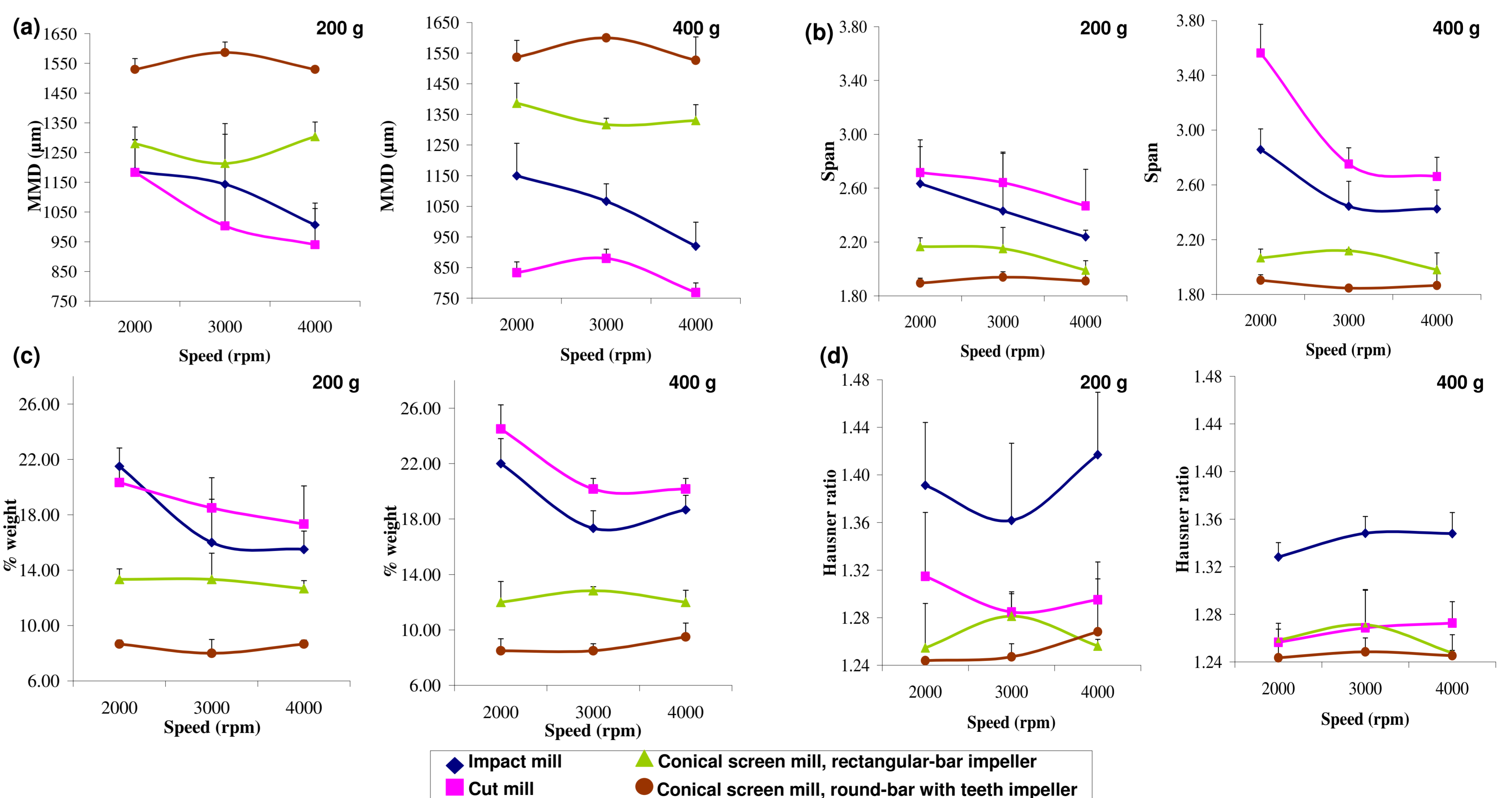


Figure 6. Comparison of (a) MMD (b) span (c) percentage fines and (d) Hausner ratio between different mill types.

- Conical screen milling using the round-bar impeller with teeth produced the coarsest particles but generated the least amount of fines. The milled materials showed the narrowest size distribution (lowest span value) and best flow properties (lowest Hausner ratio).
- Cut milling produced the greatest size reduction but generated the most fines, resulting in wide size distribution. Impact milling produced particles with the worst flow properties.
- Feed weight and speed exerted more significant effects on impact milling and cut milling, and affected the impeller types differently.

CONCLUSION

- Different mill types employ different milling mechanisms and this affected the milling efficiency as well as the particulate and bulk properties of the milled materials to different extents.
- Feed weight and milling speed exerted significant effects on particle size reduction by impact and cut milling, while the type of screen and impeller employed affected the process in conical screen milling more significantly.
- Conical screen milling was the most efficient process with high throughput, low dust generation and produced milled material that possessed more desirable and consistent bulk properties.
- Conical screen milling is more suitable than impact and cut milling for the size reduction of barks for extraction processes.

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