Impact of consolidated stresses on wall friction behavior of processed Kodo (Paspalum scrobiculatum) millet flour

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Abstract

Corresponding variation in Kodo millet flour wall friction behavior with respect to consolidated stress (0.25-5.0 kPa) were studied using powder flow tester for roasting, microwave, steaming, hydrothermally and germination processes. At given consolidated stresses, for particle size (3.65-9.35µm), irreversible correlation was established amongst cohesion and angle of internal friction in decreasing order: Native flour (0.164kPa, 23°) > Germination (0.112kPa, 16.34°) > Microwave (0.082kPa, 17.4°) > Steaming (0.045, 14.4°) > Hydrothermally (0.054kPa, 14.02°) > Roasting (0.042kPa, 16.3°) at moisture content 8.7-9.4% d.b. Roasted Kodo flour exhibited lowest cohesion (0.042 kPa) at angle of internal friction (16.3°) exerting depreciation in cohesion behavior at maximum consolidation stress (5kPa), owing to hollow and expanded morphology of particulate flour (9.35µm). Thus compared to raw and varied processes finer roasted Kodo flour depicted lower values of tapped density (534 kgm^{-3}) since the particles attain loose matrix, enhanced inter-particle void fraction (0.927), diminishing superficial contact with adjoining irregular shaped octahedral particles, rendering lowest powder cohesiveness. The compressibility indices (36.67-24.35)% for above processes, were found inversely proportional to particle size (3.65-9.35µm). Particulars on wall friction are helpful in modeling heat and mass transfer, drying quality, predicting diffusional properties of cellular foods, fabrication of silos and hopper angle.

Keywords: Consolidation stress, wall function, compressibility index, hydrothermally, cohesion, internal friction

Introduction

Kodo millet (*Paspalum scrobiculatum*), a monocot, resembles a spheroid shaped, possessing brick red colored seed coat, flourishes well in post-Karif fallows, survives in the warm and dry climate of peninsular India. Its nutritional profile posseses proteins (8%) with glutelins (an antioxidant potent protein fraction) 40.4-52.1%, which forms largest protein fraction, carbohydrate, crude fiber and fat are 66.6, 9, and 1.4g/100g, respectively. Food technologists nowadays are manufacturing low-moisture products containing high contents of dietary fiber and antioxidants owing to the interest of the people in preparing functional foods, where kodo fits suitable. In light of this information, traditional, conventional and novel thermal methods (roasting, steaming, germination, hydrothermal, and microwave treatment) were studied in accordance with their powder flow behavior for adequate storage. Flowability of agro-finished products is prime factor to be considered at post-harvest, to minimize losses, improving material handling, and exercising design of machinery. Determination of these properties is important because it provides adequate knowledge to industrial operations, such as flow in hoppers and silos, blending, transportation and packaging. Particularly for storage structures, knowledge about the flow properties of the coffee in contact with the particular material composing these structures is important for their correct design. Among the main flow properties, internal and external friction coefficients, the angle of internal friction, the effective angle of internal friction, the wall friction angle are highlighted. Such practices would exaggerate prices, exhibit immediate sale and the need to formulate blends

Methodology

- **Germination** of kodo millets at 38.75 ◦C for 36 hrs was carried after steeping for 24 hrs at 30°C. Soaking of grain:water (1:3) ratio was taken. It's simplest and efficient process for increasing nutrient bioavailability by fragmenting carbohydrate chains for easy assimilation. Dried by convective hot air oven at 50°C, till moisture content (m.c) was obtained at 8.5%db (dry basis).
- **Roasting** is a processing technique that uses dry heat, whether an open flame, to enhance the flavor by browning the food's surface. At temperature 230°C for 90 sec with continuous stirring till the end of crackling sound obtaining 7% m.c (db).
- **Hydrothermal** treated flour passed through 70 mesh sieve (ASTM no.70) conditioned at 20% m.c (db) and incubated overnight at 4°C. Further heated at 110 °C for 16 h ensuring 7-8% m.c (db).
- **Microwave** treated sample prepared at 600W for 300sec preconditioned at 20% m.c (db) in domestic microwave (Sharp-R-3801, Japan). Samples were placed inside borosilicate-glass bowl (dia=20.5 cm) at the centre.
- **Steam** treated sample was prepared in autoclave at 121°C for 1200 sec. Dried by convective hot air oven at 50°C, till moisture content (m.c) was obtained at 8.5%db (dry basis).

Results and Discussion

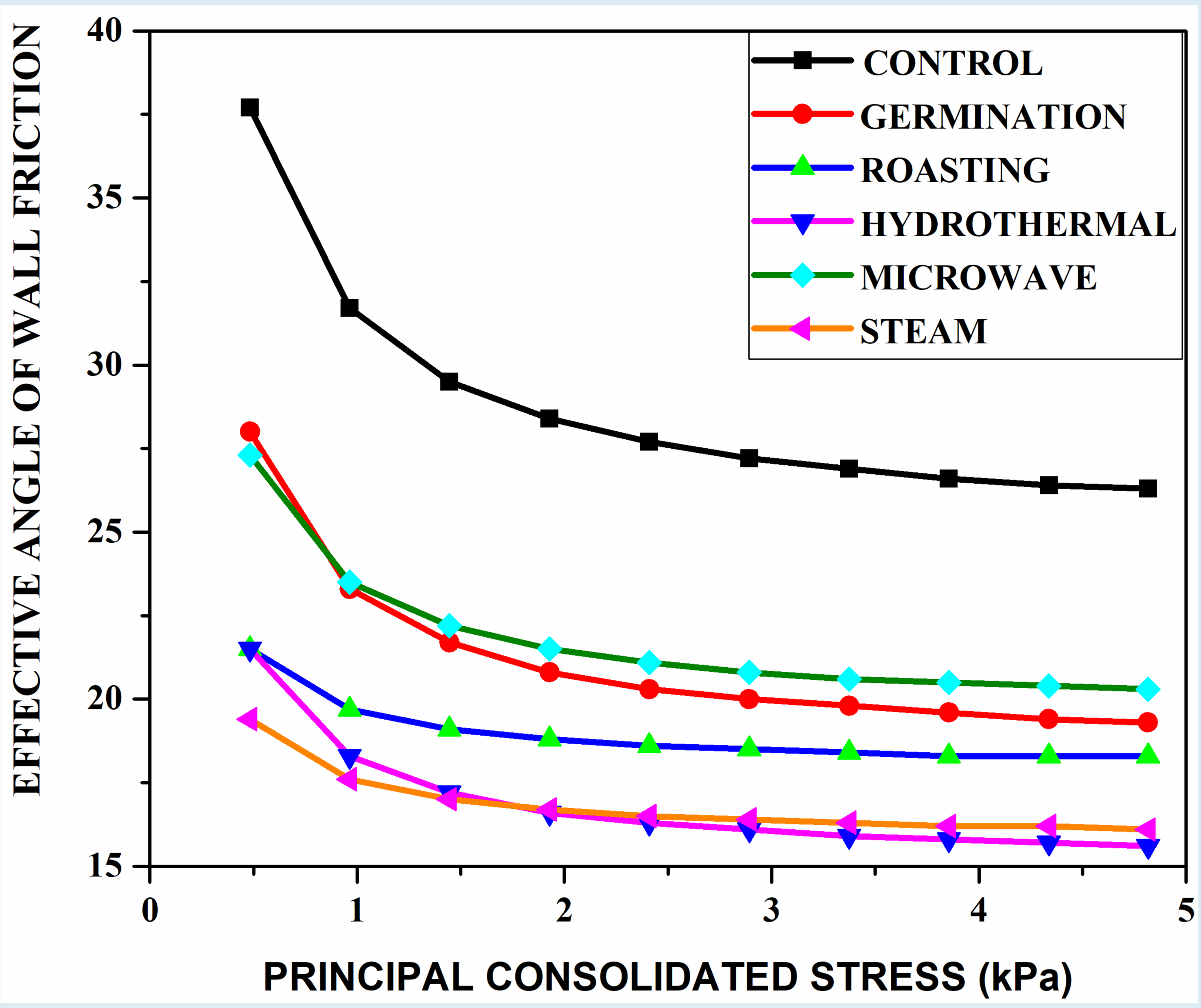
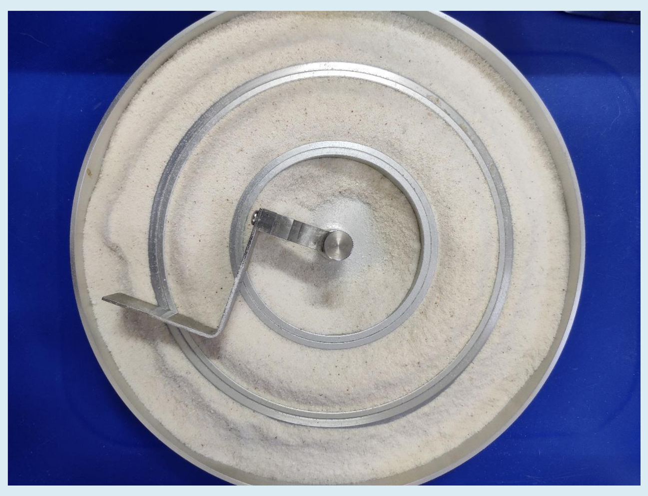
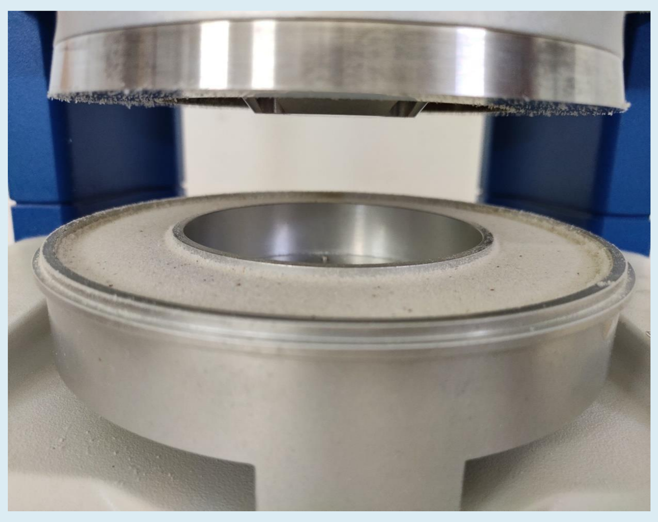


Figure 1. Effective angle of wall friction and applied consolidated stress for various flour treatments



Flour preparation in powder flow analyzer



Flour leveling in powder flow analyzer

Consolidated stress applied to flour in powder flow analyzer

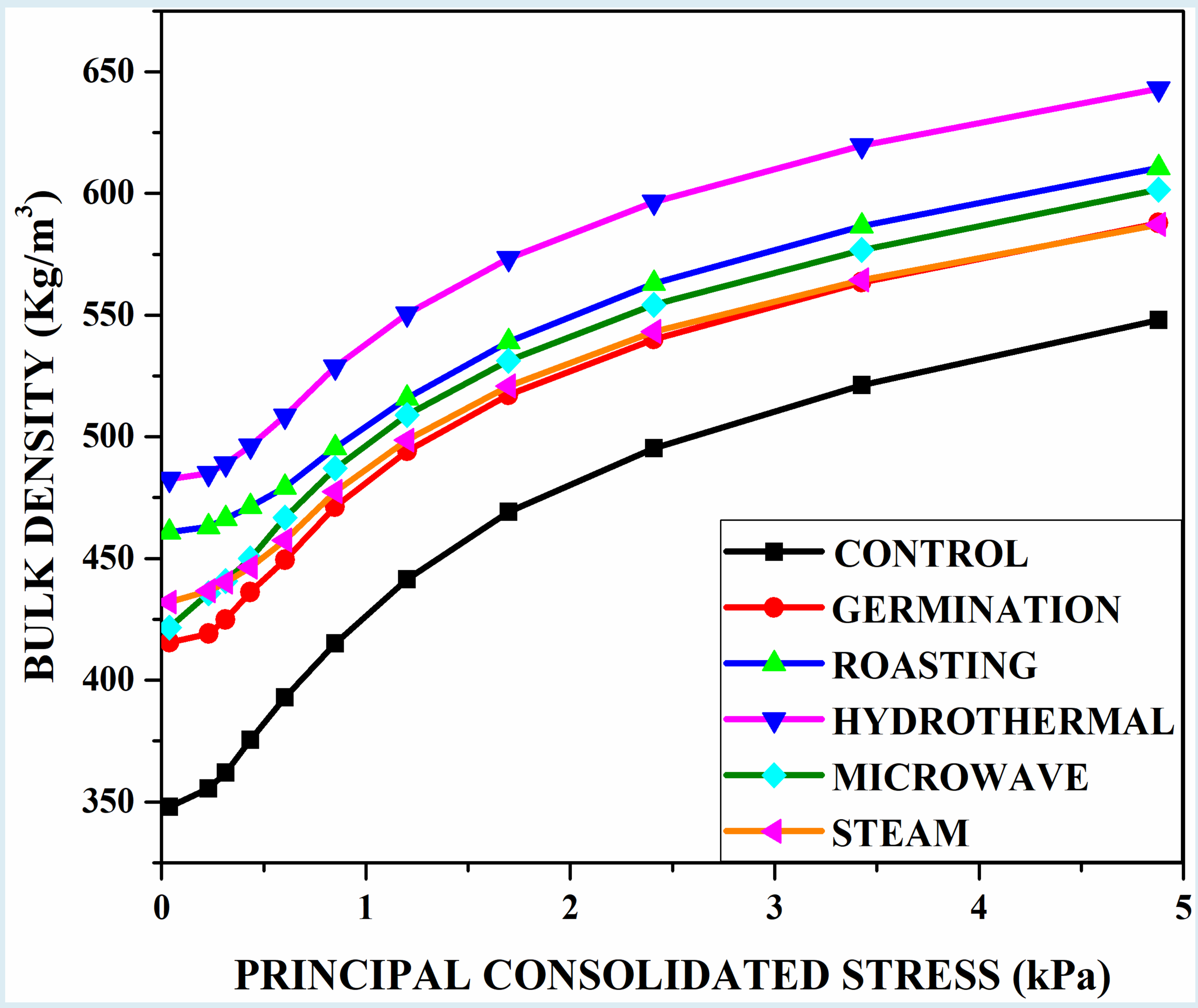


Figure 2. Effective bulk density and applied consolidated stress for various flour treatments

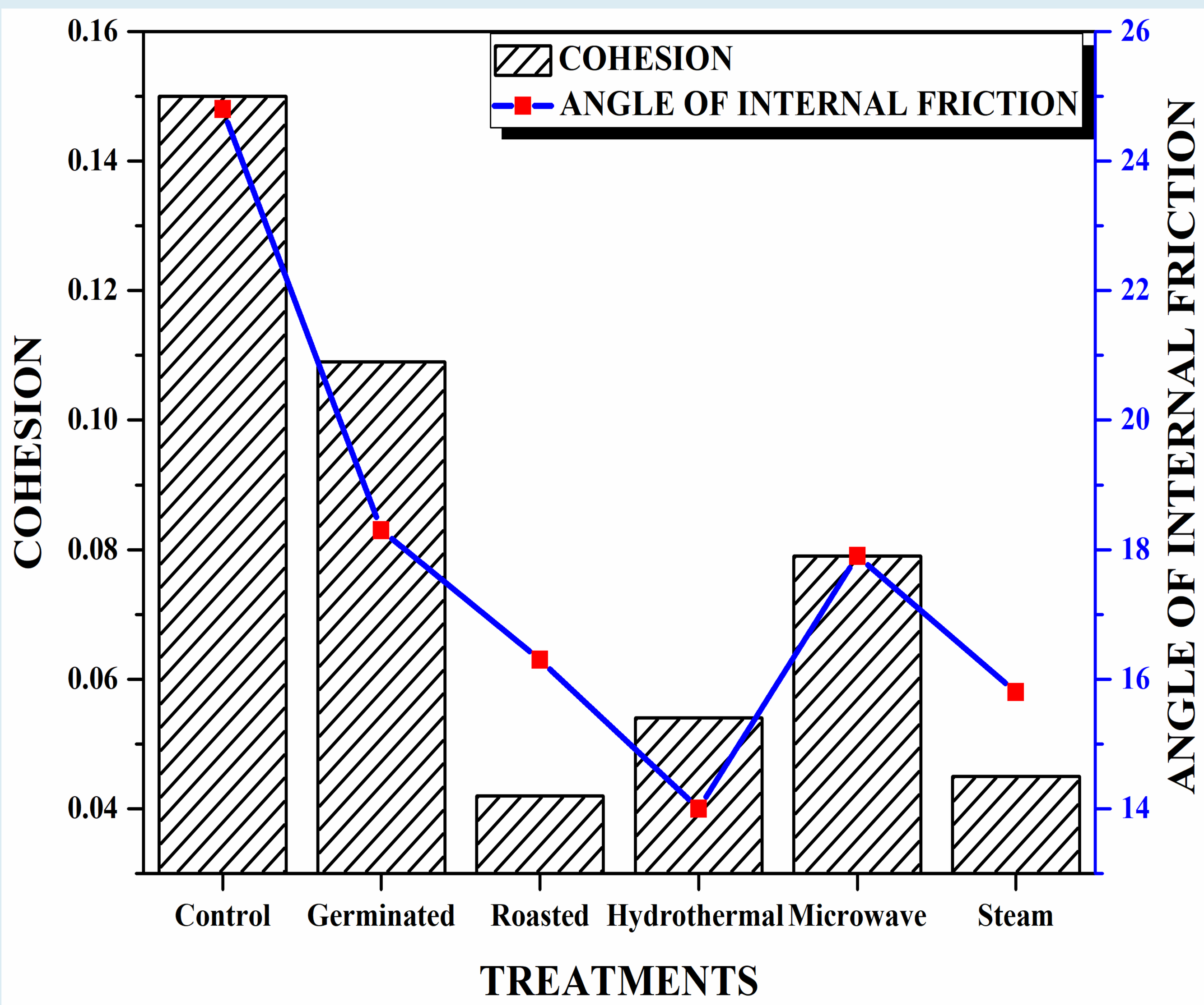


Figure 3. Cohesion recorded against effective angle of internal friction for various flour treatments

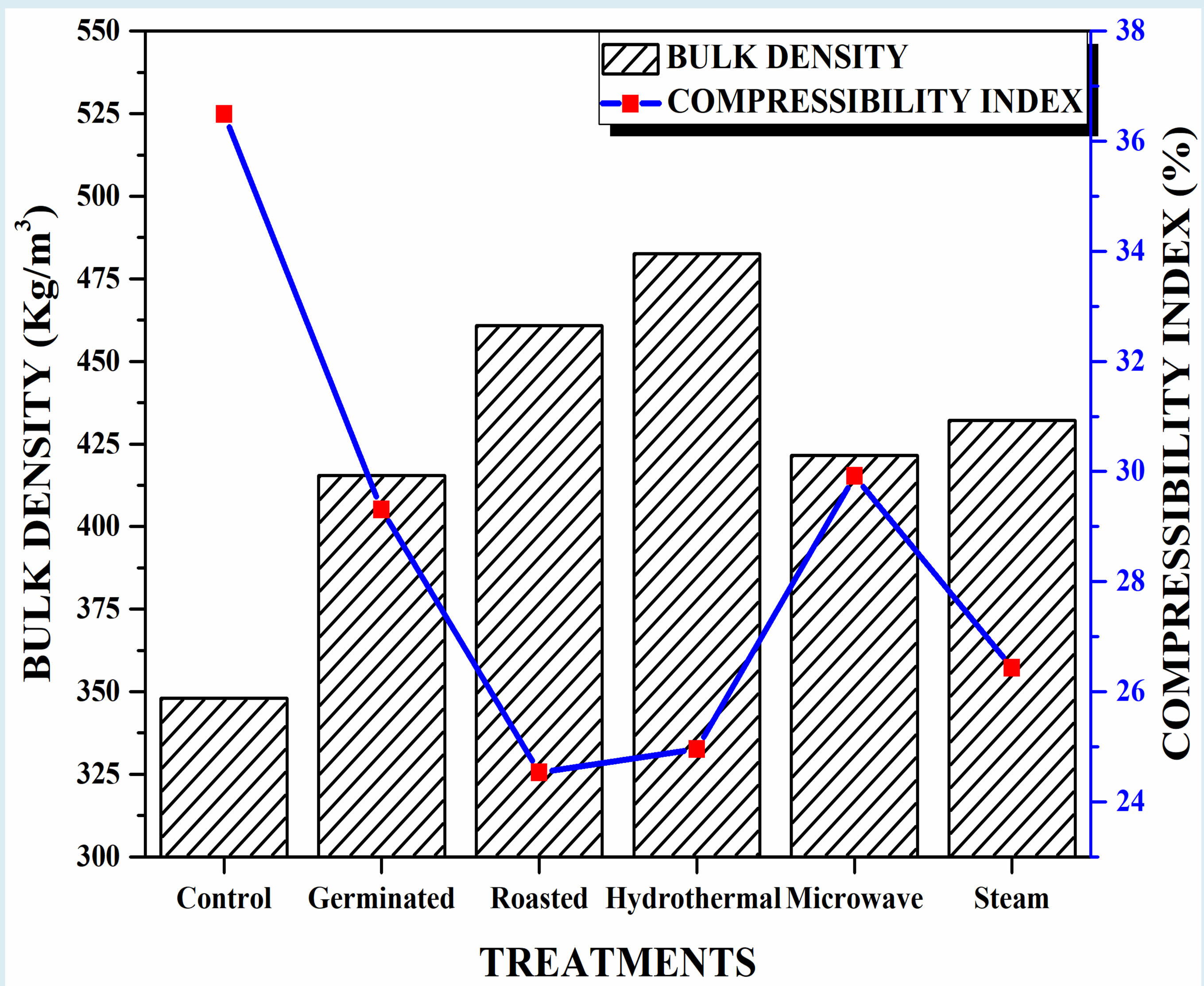


Figure 4. Bulk density and compressibility index for various flour treatments

Conclusion

Control flour cohesive flow behavior may be overcome in material handling with dry heat treatments. With obvious increase in bulk density higher material handling is possible with lower wall friction and compressibility index (%). Subjected to elevated consolidated stresses hydrothermally treated flour exhibited least changes in angle of wall friction thus achieving the feat of high packaging density. Thus these process enhances material handling resisting rat-hole shaped arch formation inside mega-silos, and saving lives of many workmen during their clean-In-place (CIP) or fumigation.

References

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