

# Microwave Drying of Iron Pellets and Tailings in Pelletization Processes<sup>#</sup>

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## ABSTRACT

Drying is a critical stage in iron production through pelletization, accounting for a substantial share of the total energy demand. Conventional convective drying methods face limitations in efficiency, particularly with larger pellets and moisture-rich tailings. This study investigates the application of microwave technology as an alternative drying method for iron pellets and tailings. Drying experiments were conducted using both convective oven at 300 °C and a 15 kW industrial microwave system operated at different power levels. The results demonstrate that microwave drying dramatically reduces drying time and energy consumption compared to conventional methods. For iron pellets, microwave drying achieved the target residual moisture content more than six times faster and with nearly 30% lower energy usage. For tailings, the improvements were even greater, with drying more than thirteen times faster and energy consumption reduced by over 50%. These findings highlight the potential of microwave technology to enhance the efficiency and sustainability of pelletization processes in iron production.

**Keywords:** drying, iron ore pellets, tailings, convective heating, microwave, energy efficiency

## NONMENCLATURE

### Abbreviations

RMC	Residual Moisture Content
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## 1. INTRODUCTION

The increasing demand for high-quality iron ore has intensified interest in iron pelletization for iron production [1]. Drying is a critical stage in the iron pelletization technique process, as moisture removal must be carefully controlled: excessive or uneven drying can damage the pellets and waste energy, while tailings often contain high moisture content that must be

reduced to improve stability, safety, and environmental compliance [2–4].

Conventional drying methods, which rely primarily on convective heat transfer, face limitations particularly when processing larger pellets or materials with elevated moisture levels. These methods can be energy intensive. For instance, pellet drying alone accounts for more than 25% of the total energy consumed during pellet induration [5]. To address these challenges and move toward more sustainable and energy-efficient practices, researchers and industry professionals are investigating alternative approaches. Among these, microwave technology has shown promising potential [6–8].

Microwave technology has gained increasing attention in mining applications due to its distinctive heating mechanism [9–11]. Under microwave irradiation, molecular dipoles oscillate rapidly, generating heat through friction. The extent and distribution of heating within a material are governed by its complex electrical and magnetic properties, which dictate how much of the microwave energy is absorbed by moisture and the solid matrix, and how much is reflected or lost [12,13]. Water, in particular, exhibits dielectric properties that make it a highly efficient absorber of microwave energy compared to most solid minerals. This characteristic underscores the suitability of microwave technology for drying applications.

Extensive research has investigated microwave drying within the mineral industry, consistently highlighting its superiority over conventional convective techniques. Several studies have shown that microwave drying can be at least twice as effective as conventional approaches. In mining applications, for instance, Lovas et al. [14] demonstrated that microwave irradiation enables considerably faster drying than standard methods. Lv et al. [15] applied the technique to Philippine nickel laterite, reporting that both higher microwave power and smaller particle sizes contributed to improved drying performance. Fu et al. [16] further

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emphasized the role of power, observing a 60% rise in temperature when the input was increased from 385 W to 700 W. More recently, Luo et al. [17] carried out a parametric investigation on hematite pellets, examining initial mass, power level, and pellet size. Their results showed that raising pellet mass from 50 g to 80 g

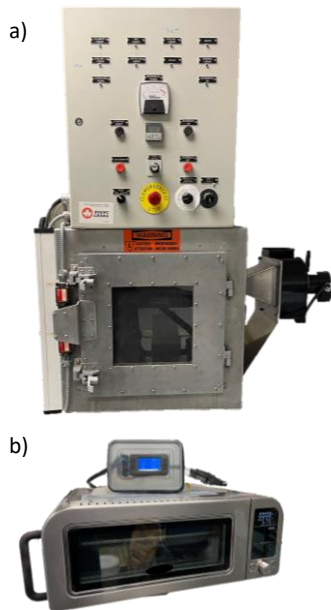


Fig. 1 Experimental equipment used for drying, a) industrial microwave system, and b) convective oven.

increased the drying rate by 62%, and increasing power from 600 W to 1000 W improved it by 35%. In contrast with Athayde et al. [18], however, they found that enlarging pellet size from 10–12 mm to 14–16 mm reduced the drying rate by 10%.

Building on the advancements reported in previous studies, this work explores the application of microwave technology for drying processes in iron production via pelletization with a focus on enhancing energy efficiency and sustainability. Unlike earlier research that primarily examined single-material systems, this study provides a direct comparison of microwave and conventional convective drying for both iron ore pellets and tailings—two critical streams in iron production that significantly influence the overall energy demand. This integrated approach demonstrates a pathway toward more energy-efficient and sustainable iron production, highlighting the potential of microwave technology as a transformative solution for reducing the carbon footprint of the process.

## 2. METHODOLOGY

### 2.1 Sample description

Drying experiments were performed on iron ore pellets and iron ore tailings. The pellets were composed primarily of hematite, representing approximately 84% of their mineral content. Their initial moisture content was measured at 8.82%, with about 92% of the fraction falling within the 9–16 mm size range. Each experiment was conducted using 1000 g of pellet samples.

The iron ore tailings, sourced from beneficiation processes, exhibited particle sizes ranging from 38 μm to 800 μm and an initial moisture content of approximately 22.5%. Similar to the pellets, tailings were prepared in 1000 g batches for the drying experiments.

### 2.2 Drying procedure

#### 2.2.1 Conventional drying

Conventional drying was conducted using a convective-based oven (Fig. 1) operating at 300 °C, representing the standard temperature commonly applied in industrial drying of iron pellets. Each 1000 g batch was weighed prior to drying, subjected to the designated exposure time, and then reweighed after treatment to determine the final mass.

#### 2.2.2 Microwave drying

Microwave drying was carried out using a 15 kW industrial microwave system (Fig. 1). Each 1000 g sample was weighed prior to treatment and exposed to microwave irradiation at specified power levels and durations. Following drying, the samples were reweighed to determine the remaining moisture content.

### 2.3 Evaluation criteria

The effectiveness of both microwave and conventional drying methods was evaluated by determining the residual moisture content (RMC) of the treated samples. The RMC was calculated using Eq. (1) as follows:

$$\text{RMC (\%)} = \frac{W - W_d}{W_d} \quad (1)$$

where W is the weight of the sample after drying and  $W_d$  is the dry weight obtained from complete oven drying.

## 3. RESULTS AND DISCUSSION

This study addresses two key processes requiring drying in iron production through the pelletization technique: the drying of iron pellets and the drying of tailings.

For both iron pellets and tailings, drying experiments were performed using 1000 g samples. Each sample was dried under both convective oven and

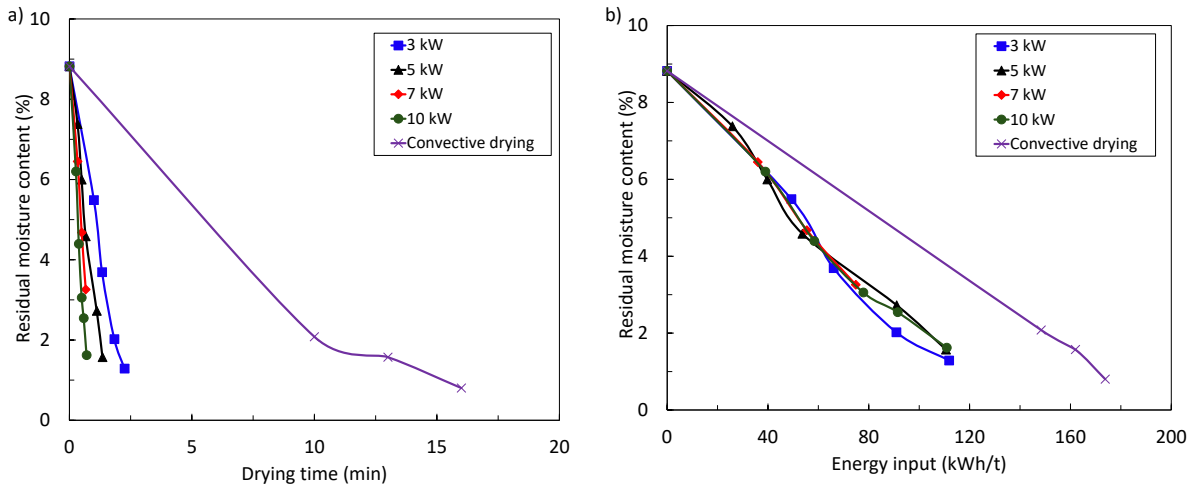


Fig. 2 Drying of iron pellets using convective oven and microwave system showing residual moisture content as a function of a) drying time, and b) energy input.

microwave conditions. While the convective oven provided a constant temperature throughout the process, the microwave system was operated at different power levels. The results are presented in Figs. 2 and 3, showing RMC as a function of energy input and drying time for pellets and tailings, respectively.

The results for iron pellet drying are presented in

pronounced compared to the substantial gain observed when shifting from convective to microwave drying.

The energy analysis for iron pellet drying shows a similar trend to the time-based results when comparing convective and microwave methods. Microwave drying demonstrates greater energy efficiency due to its selective heating mechanism. For example, achieving

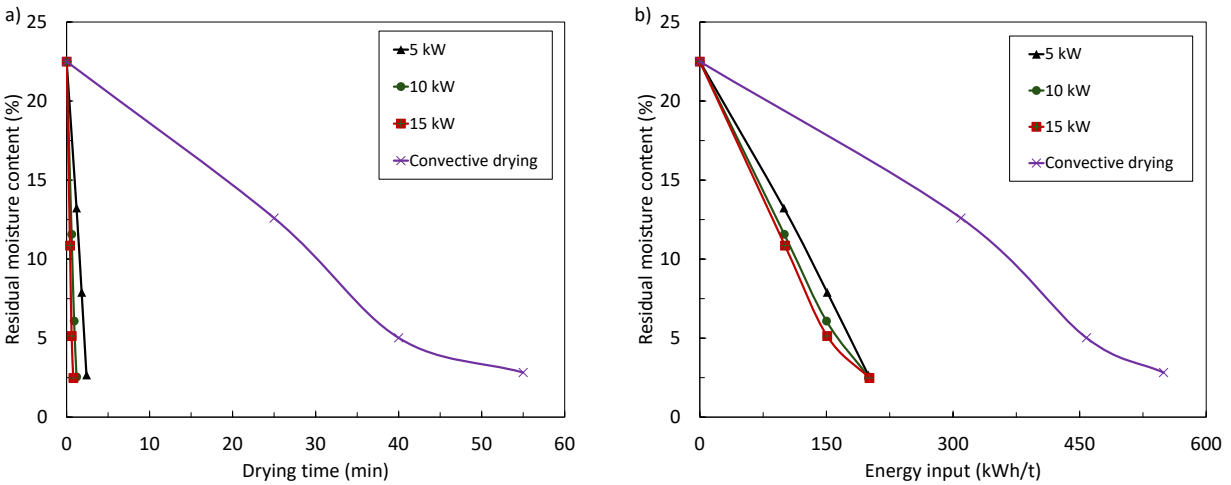


Fig. 3 Drying of tailings using convective oven and microwave system showing residual moisture content as a function of a) drying time, and b) energy input.

Fig. 2. The target RMC for pellets was approximately 1%. The findings indicate that microwave drying offers a significant advantage in terms of drying time. Under convective drying at a constant temperature of 300 °C, it required about 15 minutes to reach the desired moisture level, whereas microwave drying achieved the same result in less than 2.5 minutes, more than six times faster. The drying rate increased further with higher microwave power; however, the improvement was less

approximately 1% RMC for iron pellets with convective drying required about 170 kWh/t, whereas microwave drying achieved the same result with less than 120 kWh/t, representing nearly a 30% reduction in energy consumption. It should be noted, however, that the effect of microwave power level is less pronounced in this case: while higher power reduces drying time, it does not result in a substantial improvement in overall energy consumption.

A similar analysis was carried out for the drying of tailings, as shown in Fig. 3. The improvements in both drying rate and energy consumption were even more pronounced than those observed for pellet drying. The initial moisture content of the tailings was 22.5%, with a target range of 5% to 8%. Using convective drying at a constant temperature of 300 °C required approximately 55 minutes to reach this range, whereas microwave drying achieved the same result in less than 4 minutes (over 13 times faster drying). In terms of energy consumption, convective drying demanded more than 525 kWh/t, while microwave drying required less than 200 kWh/t, representing an improvement of more than 50% in energy efficiency. Similar to pellet drying, increasing microwave power accelerated the drying rate; however, unlike the pellet case, the effect of higher power levels on energy consumption was also significant. The results indicate that, at elevated microwave powers, less total energy is required to achieve the RMC.

#### 4. CONCLUSIONS

This study investigated the use of microwave technology for drying in iron production through pelletization, focusing on both iron pellets and tailings. The results showed that microwave drying significantly outperforms conventional convective methods in terms of both drying rate and energy efficiency. For pellets, microwaves reduced drying time by more than sixfold and lowered energy consumption by nearly 30%, while for tailings, drying was accelerated over thirteenfold with energy savings exceeding 50%. These improvements stem from the selective heating mechanism of microwaves, which enables rapid moisture removal. Although higher microwave power further increased drying rates, its effect on energy efficiency varied between pellets and tailings, underscoring the need for process optimization. Overall, microwave drying demonstrates strong potential as an energy-efficient and time-saving alternative to conventional methods, offering a pathway toward more sustainable practices in iron production.

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