

Straw-type biomass as a clean reductant in magnetized roasting of Bayan Obo

X.L. He¹, Y. Zhou², X.X. Xue^{1,*}, H. Yang¹

¹School of Metallurgy, Northeastern University, Shenyang, Liaoning, 110169, China

²College of Materials Science and Engineering, Taiyuan University of Technology, Taiyuan, Shanxi, 030024, China

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Presenting author email: hexinglu001@foxmail.com

Since the mining of the Bayan Obo mine, the main use of iron resources has been iron. There are still more iron, rare earth, niobium, and other resources in the tailings separated by magnetic separation to be recycled as secondary resources (Zhang et al. 2022). At present, research on the recovery process of iron resources in Bayan Obo tailings is mainly based on coal-based (Yang et al. 2013), gas-based magnetisation roasting or carbothermal reduction of iron (Zhou et al. 2020) followed by magnetic separation. Since this process relies on fossil fuels, such as coal, as a reductant either directly or indirectly in the reduction reaction, it is essential to seek lower-carbon and environmentally friendly alternatives to promote sustainable development. Researchers have investigated the use of biomass fuel as a reducing agent in magnetization roasting. Studies have been conducted on refractory-grade oolitic iron ores (Sahu et al. 2023), iron tailings (Deng et al. 2022), and hematite iron ore (Cao et al. 2021) using biomass fuel as a reducing agent, yielding encouraging results. This paper explores the use of straw-type biomass as a reducing agent for the magnetization roasting and magnetic separation of iron from Bayan Obo tailings. It examines the effects of reaction temperature and the dosage of biomass fuel on the magnetization roasting process. The findings provide valuable insights for the future development of clean utilization technologies for tailings.

The Bayan Obo tailings used in this study were supplied by the Baotou Iron and Steel Group, and their composition is detailed in Table 1. The straw powder utilized was sourced from Jiangsu Province, China, with its composition presented in Table 2.

Table 1. Chemical composition of the sample of Bayan Obo tailings (wt. %).

TFe	FeO	REO	Nb ₂ O ₅	CaO	SiO ₂	BaO	MgO	Al ₂ O ₃	MnO	TiO ₂	F	P
13.06	2.10	7.09	0.103	30.34	11.71	4.13	3.32	1.39	1.15	0.64	12.5	1.39

Table 2. Preliminary analysis of the straw-type biomass.

	M _{ad}	A _{ad}	V _{ad}	FC _{ad}	C	H	O
Wt%	7.39	19.81	65.32	7.48	37.35	2.48	44.9

Tailings and biomass were mixed and formed into briquettes to create a sample. This sample was then placed in a tube furnace for magnetization and roasting. The temperature in the furnace was gradually increased to a predetermined temperature at a rate of 10°C per minute, and then held steady for one hour under a nitrogen atmosphere. After the holding period ended, the samples were slowly cooled to room temperature within the furnace under a nitrogen atmosphere. They were then crushed using a vibration sample crusher. Approximately 10g of the crushed samples were taken and dispersed in 100 mL of water to create a slurry. The slurry was processed through a weak magnetic separator with a magnetic field strength of 125 mT to separate the magnetic concentrate from the tailings.

Characterisation indicators for magnetisation roasting and magnetic separation include magnetisation rate, iron grade, and recovery rate. The definitions of magnetisation rate and iron recovery rate are as follows:

$$\eta_1 = \frac{\omega_{FeO}}{\omega_{TFe}} \times 100\% \quad (1)$$

$$\eta_2 = \frac{\omega_c \times m_c}{\omega_0 \times m_0} \times 100\% \quad (2)$$

In this context, η_1 represents the magnetization rate, while ω_{FeO} denotes the mass fraction of ferrous oxide in the roasted sample. The term ω_{TFe} indicates the mass fraction of total iron. Additionally, η_2 is the iron recovery rate; ω_0 refers to the mass fraction of total iron in the magnetic separation feed; ω_c represents the mass fraction of total iron in the magnetic separation concentrate. Lastly, m_c and m_0 denote the qualities of the magnetic separation concentrate and the magnetic separation feed, respectively.

As shown in Figure 1, the magnetization rate increases with the amount of biomass added. However, when the biomass addition exceeds 5%, the iron grade of the concentrate decreases, while the recovery rate remains largely unchanged. The increase in biomass addition contributes to the over-reduction of iron oxides, which leads to a higher magnetization rate. Additionally, the ash produced from the biomass during the roasting process has a low density, causing it to enter the concentrate during magnetic separation and ultimately reducing the iron grade. In conclusion, a biomass addition of 5% is identified as the optimal amount.

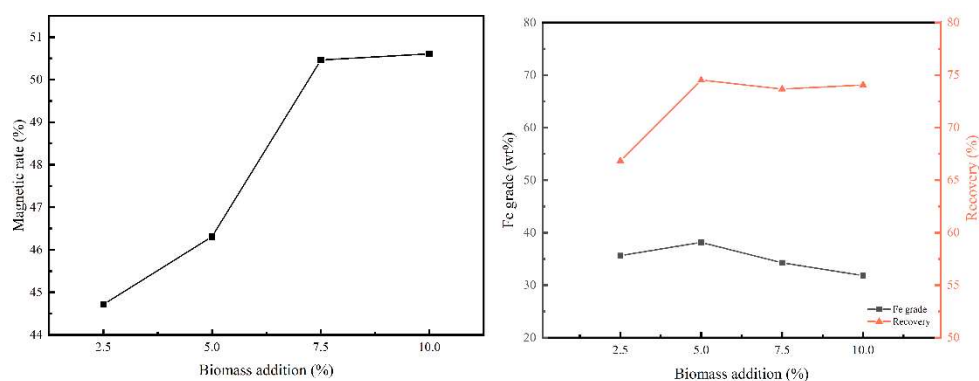


Figure 1. Effect of biomass addition on magnetisation rate, iron grade and recovery rate (650°C) (a) magnetisation rate (b) iron grade and recovery rate

The data presented in Figure 2 indicate that the magnetisation rate generally increases with rising temperature, alongside an increase in the recovery rate. However, there is a notable drop in iron grade observed within the temperature range of 550°C to 650°C. This decrease may be attributed to over-reduction occurring at these elevated temperatures. The higher recovery rate could be explained by the penetration of volatile tar from the roasting tube into the sample during the cooling process, which may have carried some super-reduced iron minerals into the concentrate after cooling. To achieve a higher grade of iron ore concentrate, 550°C is identified as the optimal roasting temperature.

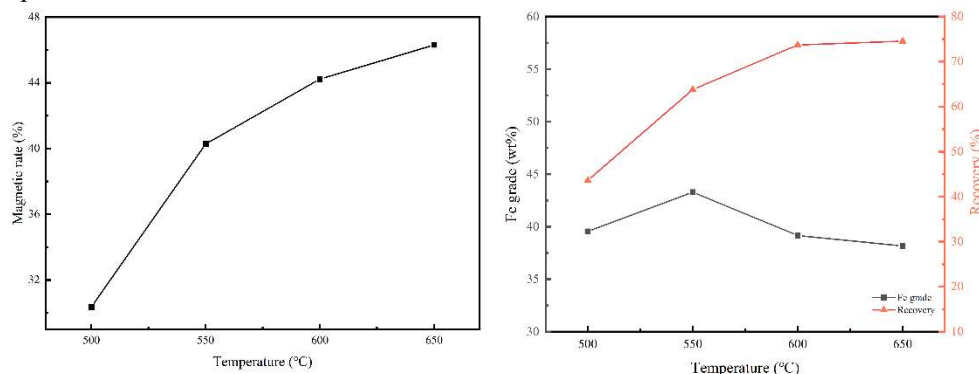


Figure 2. Effect of magnetisation roasting temperature on magnetisation, iron grade and iron recovery rate (5% biomass addition) (a) magnetisation rate (b) iron grade and recovery rate

The magnetization roasting and magnetic separation test was conducted on Bayan Obo tailings using straw-type biomass as the reducing agent. The samples, which had a 5% biomass addition and were roasted at 550°C for one hour, yielded an iron concentrate powder with an iron grade of 43.19%, and an iron recovery rate of 63.81%. However, higher additions of biomass can lead to excessive iron reduction, resulting in low-density ash that becomes mixed with the tailings during the subsequent magnetic separation process, thereby decreasing the iron grade of the concentrate. Additionally, increasing the magnetization roasting temperature can further promote iron over-reduction. Prolonged cooling time can cause tar to infiltrate the sample from the furnace, leading to the adhesion of mineral particles. This results in increased recovery rates but a lower grade of the iron concentrate.

- [1] Zhang B, Xue X, Yang H (2022) A novel process for recovery of scandium, rare earth and niobium from Bayan Obo tailings: NaCl-Ca(OH)₂-coal roasting and acid leaching. *Minerals Engineering* 178:107401.
- [2] Yang H, Rong Y, Tang R, Xue X-X, Li Y (2013) Recovery of iron from Baotou rare earth tailings by magnetizing roast. *Rare Metals* 32:616–621.
- [3] Zhou Y, Xue X, Yang H, Song S, Huang X (2020) Novel Harmless Utilization of Bayan Obo Tailings: Separation and Recovery of Iron and Rare Earth. *Industrial & Engineering Chemistry Research* 59:13682–13695.
- [4] Sahu SN, Meikap BC, Biswal SK (2023) Reduction in fossil fuel consumption by exploiting separation of refractory grade oolitic iron ores using black plum leaf litter via magnetization roasting & pelletization; a small step toward decarbonization & sustainability. *Separation and Purification Technology* 311:123327.
- [5] Deng J, Ning X, Shen J, Ou W, Chen J, Qiu G, Wang Y, He Y (2022) Biomass waste as a clean reductant for iron recovery of iron tailings by magnetization roasting. *Journal of Environmental Management* 317:115435.
- [6] Cao Y, Sun Y, Gao P, Han Y, Li Y (2021) Mechanism for suspension magnetization roasting of iron ore using straw-type biomass reductant. *International Journal of Mining Science and Technology* 31:1075–1083.