

# Pelletizing of digestate-based mineral-organic fertilizers: effect of die L/D ratio and utilization of frictional heat

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The LIFE DIMITRA project develops technological routes for valorising anaerobic digestates into solid and liquid bio-fertilisers for climate-friendly agriculture. Among tested granulation methods, pressure pelletizing proved most effective, as other techniques did not provide sufficient mechanical strength for digestate-based fertilizers (Tumuluru et al., 2011). A modular mobile granulation line was therefore designed around a Nawrocki flat-die mini pelletiser (18 kW), equipped with interchangeable dies to study the effect of compression ratio (L/D) and frictional heat on pellet formation (Benders et al., 2026).

This work focuses on the pelletizing step, analysing how increasing die thickness from 30 to 40 mm (L/D 5.0–6.7, at 6 mm diameter) influences pellet quality and energy balance. Feedstock consisted of dewatering digestate fractions with mineral additives. Key questions addressed were whether higher L/D improves pellet strength and density, and to what extent frictional heat can support in-situ water evaporation, reducing external drying demand.

The novelty lies in applying a detailed mass and energy balance to digestate pelletizing using real data from an 18 kW unit, combined with die geometry optimisation. Unlike biomass or feed materials, digestates differ significantly in composition and behaviour, making standard design rules uncertain. The approach treats die geometry as a key variable in a modular system intended for distributed biogas plants.

The system was designed for 200–300 kg/h feed (50% moisture), producing 125–188 kg/h pellets (20% moisture) with ~25% recirculation. For 200 kg/h feed, 75 kg/h of water must be removed. Including recirculation, pelletiser throughput reaches ~231 kg/h. Two die variants were analysed: 30 mm (L/D=5.0) and 40 mm (L/D=6.7), both used in the same pelletiser.

Table 1. Technical parameters of the Nawrocki flat-die mini pelletiser (18 kW) and die variants used in LIFE DIMITRA pelletizing concept.

Parameter	Variant A (shorter die)	Variant B (longer die)
Die hole diameter, mm	6	6
Die thickness, mm	30	40
Compression ratio L/D	5.0	6.7
Installed motor power, kW	18	18
Effective mechanical power ( $\eta = 0.85$ ), kW	15.3	15.3
Typical bulk density of pellets, kg/m <sup>3</sup>	600–700	700–800
Typical crushing strength, N/granule	15–20	25–35
Specific energy (wet basis), kWh/t	≈60	≈80

Pellet quality assessment showed that both dies produced acceptable granules, but the longer die (Variant B, L/D=6.7) consistently delivered higher bulk density and crushing strength, clearly above the 20 N/granule. The shorter die (Variant A, L/D=5.0) produced pellets in the 15–20 N/granule range, which may be sufficient for gentle handling but is less robust for mechanical spreading and transport. This trend is consistent with literature on biomass densification, where increasing L/D increases residence time and back-pressure, promoting particle rearrangement and consolidation at the expense of higher resistance and specific energy.

The energy balance accounted for conversion of mechanical power into frictional heat within the die channels. For both variants, the effective mechanical power available at the die was estimated as 15.3 kW (18 kW motor, 85%

mechanical efficiency). Assuming that 80% of this power is dissipated as heat in the material–die interface, the frictional heat generation is about 12.2 kW, corresponding to 44 MJ/h. At a throughput of 200 kg/h (wet basis) and an average specific heat capacity of 2.8 kJ/(kg·K) for the moist digestate-based feed, approximately 6.2 kW is needed to raise the material temperature from 20°C to 60°C. The remaining 6.0 kW can theoretically be used for water evaporation, allowing evaporation of about 9.6 kg/h of water directly in the pelletiser. This value refers to a single pass through the pelletiser; however, the material may be recirculated and processed multiple times (e.g. double pass), increasing the total amount of water evaporated during pellet formation.

This internal evaporation accounts for roughly 13% of the total water removal requirement (75 kg/h) at the considered operating point, reducing the water load to be handled by the downstream dryer to about 65.4 kg/h. With a latent heat of 2.26 MJ/kg and a dryer thermal efficiency of 70%, the corresponding thermal power demand is about 58.7 kW. In a reference scenario without exploitation of frictional heat, the full 75 kg/h would have to be evaporated in the dryer, requiring approximately 67–70 kW of thermal power, depending on preheating, which implies a reduction of external thermal demand of around 10–15% due to in-situ evaporation in the pelletiser. Under favourable conditions, the final drying stage can be conducted as ambient air drying under a sheltered condition, provided that periodic turning (mechanical agitation) is applied to account for the specific properties of these products.

From a process-engineering perspective, these results demonstrate that increasing die thickness from 30 to 40 mm at constant 6 mm hole diameter, thereby raising L/D from 5.0 to 6.7, significantly improves pellet integrity and enables meaningful utilisation of frictional heat for internal drying. The trade-off is higher specific mechanical energy ( $\approx 80$  kWh/t wet feed) and a tendency towards lower throughput, which must be considered when designing modular mobile granulation lines for different digestate compositions and moisture levels. The results suggest that an L/D threshold of approximately 6 may represent a practical compromise between pellet quality and energy efficiency for digestate-based materials.

In conclusion, the study confirms that die geometry and frictional heat utilisation are key design levers for pelletizing digestate-based mineral-organic fertilizers in compact 18 kW mini pelletisers. Optimisation of the L/D ratio not only improves pellet mechanical properties but also contributes to lowering external thermal energy demand, thereby supporting the climate-mitigation objectives of LIFE DIMITRA and providing a robust technological basis for mobile granulation units at biogas plants.

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### **References**

- Tumuluru, J.S., Wright, C.T., Hess, J.R. and Kenney, K.L. (2011), A review of biomass densification systems to develop uniform feedstock commodities for bioenergy application. *Biofuels, Bioprod. Bioref.*, 5: 683-707. <https://doi.org/10.1002/bbb.324>
- Benders, R. T., Dijkman, J. A., Bastiaansen, T. M., Fix, R., van der Gucht, J., & Thomas, M. (2026). A temperature dependent framework to predict and control physical pellet quality in biomass extrusion. *Chemical Engineering Journal*, 173569.