

Workshop 4

Topic “Development of digestate for the fertilizer market in the
Baltic Sea Region”

Digestate granulation: experimental setup

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Limitations and Challenges of Using Raw Digestate

Digestate has significant potential as an organic fertilizer, helping to improve soil fertility and reduce dependence on mineral fertilizers. However, in practice, farmers face several challenges that limit its effective use.



Main challenges:

- Strong odor during storage and application
- Difficult to apply effectively
- Social concerns in rural communities
- Particularly problematic in densely populated areas

Seasonality and Storage



Figure 1 – Chemical profile of solid digestate samples.

Source: <https://doi.org/10.3390/fuels6020032>

Issues:

- Digestate use is limited by crop growth periods
- Long-term storage adds costs and risks
- Risk of greenhouse gas emissions if sorted poorly

Granulation: A Practical Way Forward

- Makes storage and handling easier
- Reduces environmental risks
- Enables year-round use

Advantages of Digestate Granules



Granulating digestate makes it easier to transport and store. The compact granules don't clump, can be bagged or packed in big sacks, and reduce logistics costs, even allowing long-distance transport or export.

Granules also preserve nutrients. Nitrogen, phosphorus, potassium, and micronutrients remain stable and available for plants, providing long-lasting fertilizing effects and supporting higher crop yields.

Finally, granulation reduces odor and environmental risks. Unlike raw digestate, granules have minimal smell and release nutrients gradually, lowering the chance of leaching into groundwater. This makes them suitable for use near communities.

Study conducted on digestate from two Ukrainian biogas plants: Teofipil Energy Complex (Khmelnyska Oblast) and Hals Agro (Lynyvitsya, Chernihiv Oblast).



Figure 2 – Laboratory granulation setup for digestate pellets

Digestate Conditioning for Granulation

Digestate was pre-ground prior to granulation to achieve an optimal particle size of 0.5–1 mm. Granulation was performed using a matrix granulator with 6 mm holes. Besides particle size, the initial moisture content of the digestate significantly influences granule quality.

Effect of Initial Moisture on Granule Quality

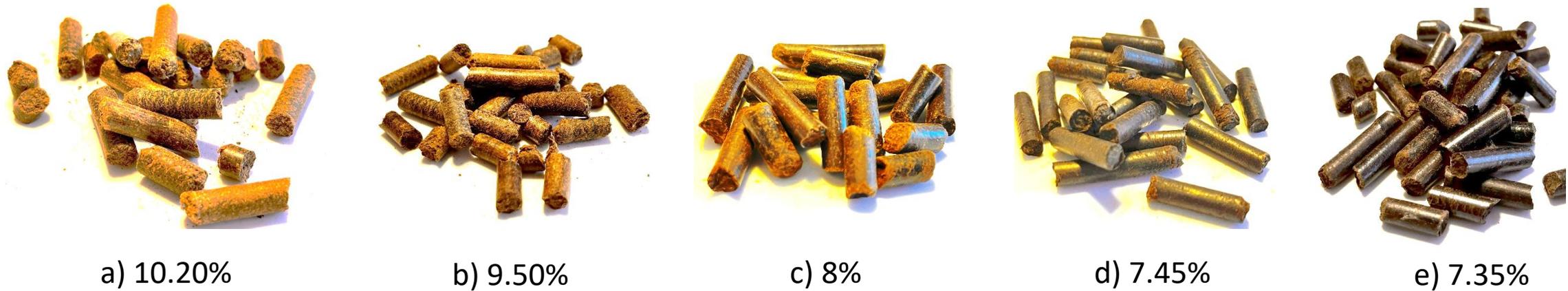


Figure 3 – Chemical profile of solid digestate samples. Source: <https://doi.org/10.3390/fuels6020032>

The optimal initial moisture content for producing strong digestate granules is 7–8%. If the moisture is too low, the granulation process consumes excessive energy, making it economically inefficient. On the other hand, excess moisture can hinder granule formation, reduce durability, and create handling difficulties. High moisture levels may also promote microbial growth, affecting storage stability.

Table 1 – Chemical profile of solid digestate samples

Indicator	Analysis results			
	Sample 1		Sample 2	
	as received	dry basis	as received	dry basis
Total nitrogen (N), %	0.46	2.57	0.63	2.21
Total phosphorus (as P ₂ O ₅), %	0.35	1.95	0.54	1.83
Water-soluble phosphorus (as P ₂ O _{5vat}), %	0.25	1.39	0.13	0.46
Total potassium (as K ₂ O), %	0.27	1.51	0.35	1.23
Calcium (as CaO), %	0.54	3.01	0.87	3.06
Magnesium (as MgO), %	-	-	-	-
Moisture content (H ₂ O), %	82.08		71.53	
Cadmium content, mg/kg	< 0.5			
Lead content, mg/kg	< 5.0			
Arsenic content, mg/kg	< 1.0			
Sulfur (as S), %	0.03	0.17	0.07	0.25
Sulfur trioxide (as SO ₃), %	0.08	0.44	0.17	0,60
Dry matter content, %	17.92		28.47	
Ash content, %	-	5.60	-	5.98
Organic matter content, %	-	89.40	-	91.02
Iron (as Fe ₂ O ₃), %	0.02	0.10	0.04	0.13
pH	9.25		8.95	
Organic carbon content, %	14.50	80.92	26.88	94.43

Chemical Analysis and NPK Enrichment of Digestate

The analysis of granulated digestate shows low carbon, phosphorus, and potassium contents. To improve its agronomic value and reduce application rates, the digestate can be enriched with ammonium sulfate, monoammonium phosphate, potassium chloride, or biochar to achieve a balanced NPK ratio of 5:5:5. Our organo-mineral digestate samples (with ammonium sulfate or biochar) demonstrated a more balanced NPK composition.

Chemical Profile of Organo-Mineral Digestate Granules

Both granule samples show a balanced macronutrient profile:

- Nitrogen: 4.80–5.00%
- Phosphorus (P_2O_5): 3.50–5.90%, largely water-soluble for immediate plant uptake
- Potassium (K_2O): 4.50–4.70%
- Moisture content (4.07–4.97%) supports long-term storage stability.
- High dry matter ($\geq 95\%$) and organic matter (67.60–72.94%) indicate structural integrity and bioactive potential, while ash content (27.06–32.40%) reflects stable inorganic components.
- These results show that digestate, combined with mineral additives or biochar, improves nutrient availability, supports soil health, and offers a sustainable reuse pathway for biogas residues, reducing dependence on synthetic fertilizers.

Table 2 – Chemical composition of organo-mineral fertilizer granules (NPK 5:5:5)

Parameter	Analysis results	
	Sample 1	Sample 2
Total nitrogen (N), %	5.00	4.80
Total phosphorus (as P_2O_5), %	5.90	3.50
Water-soluble phosphorus (as $P_2O_{5,s.r.}$)	4.00	2.70
Total potassium (as K_2O), %	4.70	4.50
Calcium (as CaO), %	1.90	1.40
Magnesium (as MgO), %	1.60	1.00
Moisture content (H_2O), %	4.07	4.97
Sulfur (as S), %	0.80	0.40
Sulfur (as SO_3), %	1.90	1.10
Dry matter content, %	95.93	95.03
Ash content, %	32.40	27.06
Organic matter content, %	67.60	72.94
pH value	7.00	7.10

Granulated Digestate as Fuel Pellets

Granulated digestate can be used to produce fuel pellets for solid-fuel boilers, offering energy recovery and sustainable waste management.

- **Waste-to-energy:** reduces fossil fuel use; provides local heat/electricity
- **Lower greenhouse gas emissions:** controlled drying/pelletizing limits methane losses
- **High calorific value:** 15–17 MJ/kg (higher in wood blends)
- **High bulk density:** $\sim 700\text{--}1100\text{ kg/m}^3$ → cheaper transport & compact storage
- **Standardized form:** easy to dose, package, and sell
- **Diversified revenue:** fuel as a product + long-term storage
- **Reduced odor & pathogens:** thermal treatment lowers microbiological risks
- **Ash management:** minerals (P, K, Ca) can be returned to soil
- **Co-generation/local heat:** suitable for mini-boilers, grain dryers, greenhouses
- **Seasonal flexibility:** produced in summer → utilized in winter; less need for liquid storage



Table 3 – Characteristics of digestate fuel pellets according to standard ISO 17225-6:2021

Parameter	Unit	D1	D2	ISO 17225-6:2021
Diameter	mm	6.00	6.00	6.00
Length	mm	7.50-28.50	8.00-29.40	3.15–40.00
Moisture content	%	6.16	6.35	≤ 12.00
Ash content	%	4.40	5.20	≤ 6.00
Bulk density	kg/m ³	710.00	706.00	≥ 600.00
Mechanical durability	%	97.67	97.74	≥ 97.50

Digestate Pellet Parameters

Table 4 – Gross and Net calorific value of digestate fuel pellets

Sample	Moisture content [%]	Calorific value [MJ/kg]	
		Gross	Net
D1	6.16	18.65	17.07
D2	6.35	18.71	17.11

Table 5 – The physico-chemical parameters of the digestate fuel pellets and threshold values according to ISO 17225-6:2021

Sample	[%] dry matter					[mg/kg] dry matter											
	C	N	O	H	P	S	K	Cl	Ca	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
D1	43.4	1.6	35.4	5.3	0.1147	0.1303	0.296	0.0700	0.305				3	2		3	44
D2	45.2	1.8	26.4	5.1	0.1230	0.1330	0.285	0.0650	0.280				4	1		2	52
ISO 17225-6:2021		≤ 1.5				≤ 0.2		≤ 0.1		≤ 1	≤ 0.5	≤ 50	≤ 20	≤ 10	≤ 0.1	≤ 10	≤ 100

Conclusions

- **Granulation is an effective way to use digestate:** improves handling, storage, and transport.
- **Enhances nutrient availability:** preserves N, P, K and allows enrichment for balanced fertilizers.
- **Reduces odor and pathogens:** safer and more acceptable near communities.
- **Enables fuel production:** granules can be used as pellets for energy, adding value and diversifying revenue.
- **Supports sustainable agriculture and circular economy:** transforms waste into useful products while reducing dependence on synthetic fertilizers and fossil fuels.