Wrocław University of Science and Technology

Conversion technology of anaerobic digestates from biogas plants to fertilizer formulation

Mateusz Samoraj[a,b], Krzysztof Trzaska[a], Dawid Skrzypczak[a], Katarzyna Chojnacka[a]

[a]Department of Advanced Material Technologies, Wrocław University of Science and Technology, Smoluchowskiego 25, 50-372 Wrocław, Poland

[b]EKOPLON Sp. z o.o. sp. k., Grabki Duże 82, 28-225 Szydłów, Poland

mateusz.samoraj@pwr.edu.pl

Introduction

- The fertilizer industry is currently facing a crisis due to the availability and price of raw materials.
- Population growth rate exceeds grain yield by three times, crop area remains the same. The global crisis has made the situation much worse, millions of people are at risk of starvation.
- Waste materials are invaluable alternative source of nutrients. A promising raw material is the digestate from biogas production
- Today, the main goal is to improve the efficiency of fertilizer ingredients while reducing the environmental impact of their use.

Biomethane plants - future and challenges

Currently, in Poland there are 126 registered agricultural biogas plants with a total production capacity of **600 million m³/year**.

Even though the number of biogas plants has decreased since last year, their total capacity has **increased by 13%** (from 532 million m³/year to 600 million m³/year).

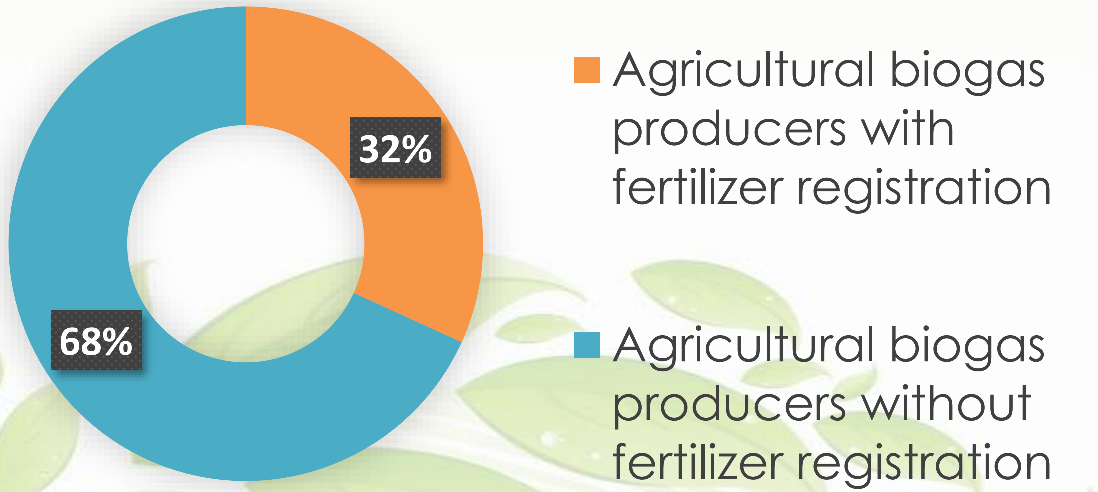


Figure 1. Participation of agricultural biogas producers with fertilizer registration in 2019.

Figure 1. Number of biogas plants in Poland (source: Register of Agricultural Biogas Producers, KOWR)

Raw material selection

ANAEROBIC DIGESTATE

Sugar beet from sugar factory
Südzucker Polska S.A.

REJECTED

Rejected on the basis of lower nitrogen content <0.5%

Plant parts and food (bread) from agricultural biogas plant
EPPO Sp. z o.o.

REJECTED

Solid biomass digestate

Rejected on the basis of lower nitrogen content <0.5%

Figure 2. The materials obtained, combined with the selection of the optimal

Composition of anaerobic digestates

Table 1. Composition of anaerobic digestates -macronutrients, micronutrients and toxic elements.

Materials	Macronutrients							
	C [%]	N [%]	P_2O_5 [%]	K_2O [%]	CaO [%]	MgO [%]	Na_2O [%]	SO_3 [%]
SUGAR BEET DIGESTATE	1.53 ±0.15	0.486 ±0.049	0.0298 ±0.0045	0.0157 ±0.0023	0.0182 ±0.0027	0.0216 ±0.0032	0.0172 ±0.0026	0.0325 ±0.0049
PLANT AND FOOD DIGESTATE	2.61 ±0.26	0.808 ±0.081	0.577 ±0.087	0.303 ±0.046	0.352 ±0.053	0.417 ±0.063	0.334 ±0.050	0.629 ±0.094

Materials	Micronutrients						Toxic elements					
	B [mg/kg]	Co [mg/kg]	Cu [mg/kg]	Mn [mg/kg]	Mo [mg/kg]	Zn [mg/kg]	Cd [mg/kg]	Cr [mg/kg]	Pb [mg/kg]	Ni [mg/kg]	As [mg/kg]	Hg [mg/kg]
SUGAR BEET DIGESTATE	10.9 ±1.6	0.967 ±0.145	3.20 ±0.48	15.5 ±2.3	4.24 ±0.64	7.66 ±1.15	0.427 ±0.064	1.36 ±0.20	4.14 ±0.62	8.24 ±1.24	18.6 ±2.8	0.0230 ±0.0035
PLANT AND FOOD DIGESTATE	3.34 ±0.50	0.125 ±0.019	2.41 ±0.36	13.2 ±2.0	3.00 ±0.45	16.8 ±2.5	0.477 ±0.072	1.65 ±0.25	<LOD	6.73 ±1.01	<LOD	0.0480 ±0.0072

Selection of hydrolysis conditions

Table 2. Composition of anaerobic digestates divided into macronutrients and micronutrients

Sample	Macronutrients [%]								Micronutrients [mg/kg]					
	C	N	P_2O_5	K_2O	CaO	MgO	Na_2O	SO_3	B	Co	Cu	Mn	Mo	Zn
Acid hydrolyzate	1.60±0.16	**0.703**±0.070	2.45±0.37	1.29±0.19	1.49±0.22	1.77±0.27	1.42±0.21	2.67±0.40	7.24±1.09	1.04±0.16	1.47±0.22	9.85±1.48	<2.50	11.2±1.7
Alkaline hydrolysate	2.33±0.23	0.508±0.051	0.518±0.078	0.273±0.041	0.317±0.047	0.375±0.056	0.300±0.045	0.566±0.085	2.09±0.31	0.442±0.066	3.22±0.48	11.7±1.8	<2.50	19.0±2.9

Table 3. Concentration of amino acids in the hydrolysate after acid and alkaline hydrolysis [mg/L]

Amino Acids	Alanine	Arginine	Aspartate	Aspartic acid	Cysteine	Glutamic acid	Glycine	Histidine	Leucine	Lysine	Methionine	Phenylalanine	Proline	Serine	Threonine	Tyrosine	Valine	TOTAL
	Ala	Arg	Asn	Asp	Cys-Cys	Glu	Gly	His	Leu	Lys	Met	Phe	Pro	Ser	Thr	Tyr	Val	
Acid hydrolyzate	1819 ±55	11.0 ±0.3	8.00 ±0.24	10.6 ±0.3	15.0 ±0.5	7.28 ±0.22	19.2 ±0.6	12.6 ±0.4	7.24 ±0.22	-	38.3 ±1.1	9.13 ±0.27	9.47 ±0.28	5.91 ±0.18	4.09 ±0.12	1.12 ±0.03	3.54 ±0.11	**1981**
Alkaline hydrolysate	18.2 ±0.5	9.01 ±0.27	9.72 ±0.29	10.9 ±0.3	13.3 ±0.4	12.7 ±0.4	9.86 ±0.30	13.1 ±0.4	20.9 ±0.6	14.3 ±0.4	8.98 ±0.27	12.1 ±0.4	8.17 ±0.25	-	5.84 ±0.18	9.33 ±0.28	9.85 ±0.30	**186**

± - measurement error resulting from the method

Comparison of granulation methods

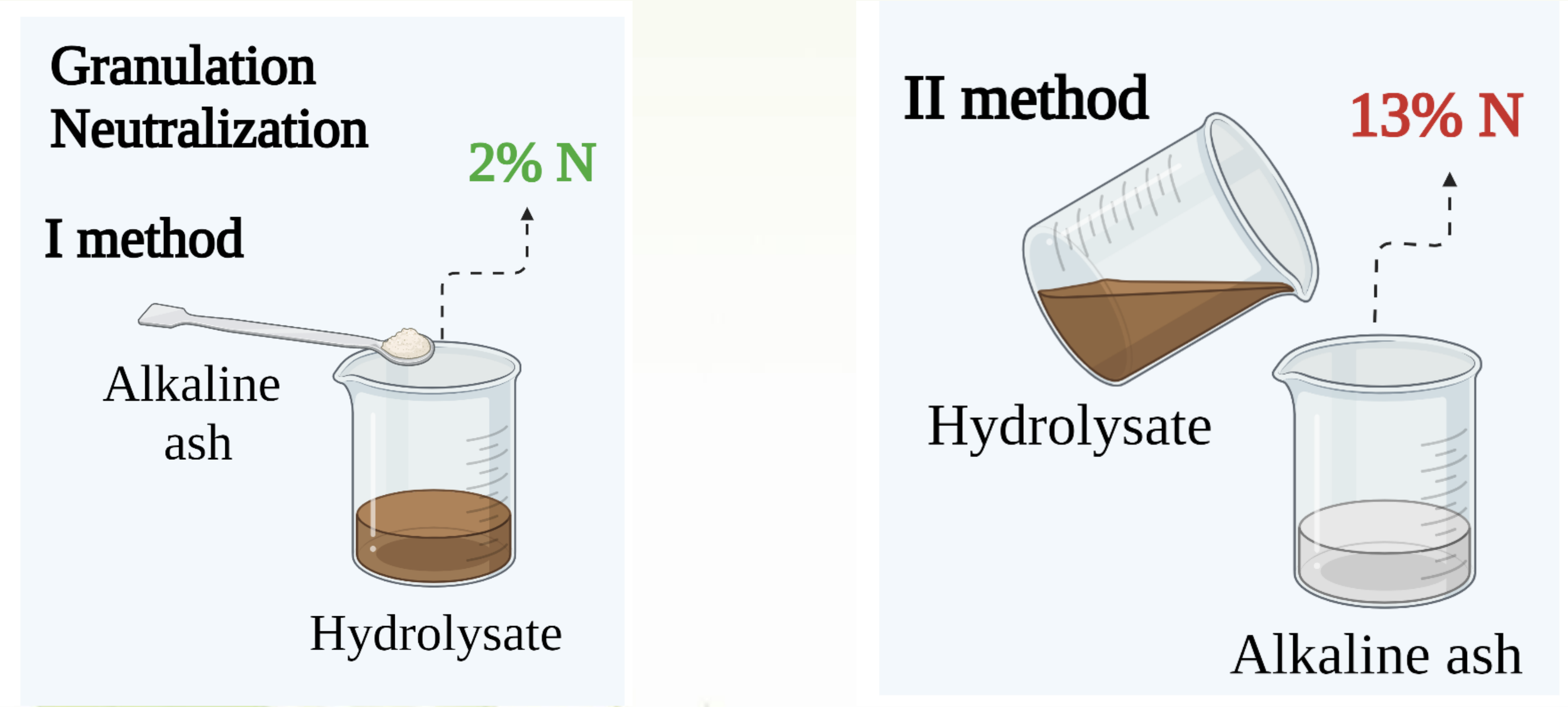


Figure 3. Comparison of nitrogen losses in two granulation methods combined with neutralization

Comparison of nitrogen balances

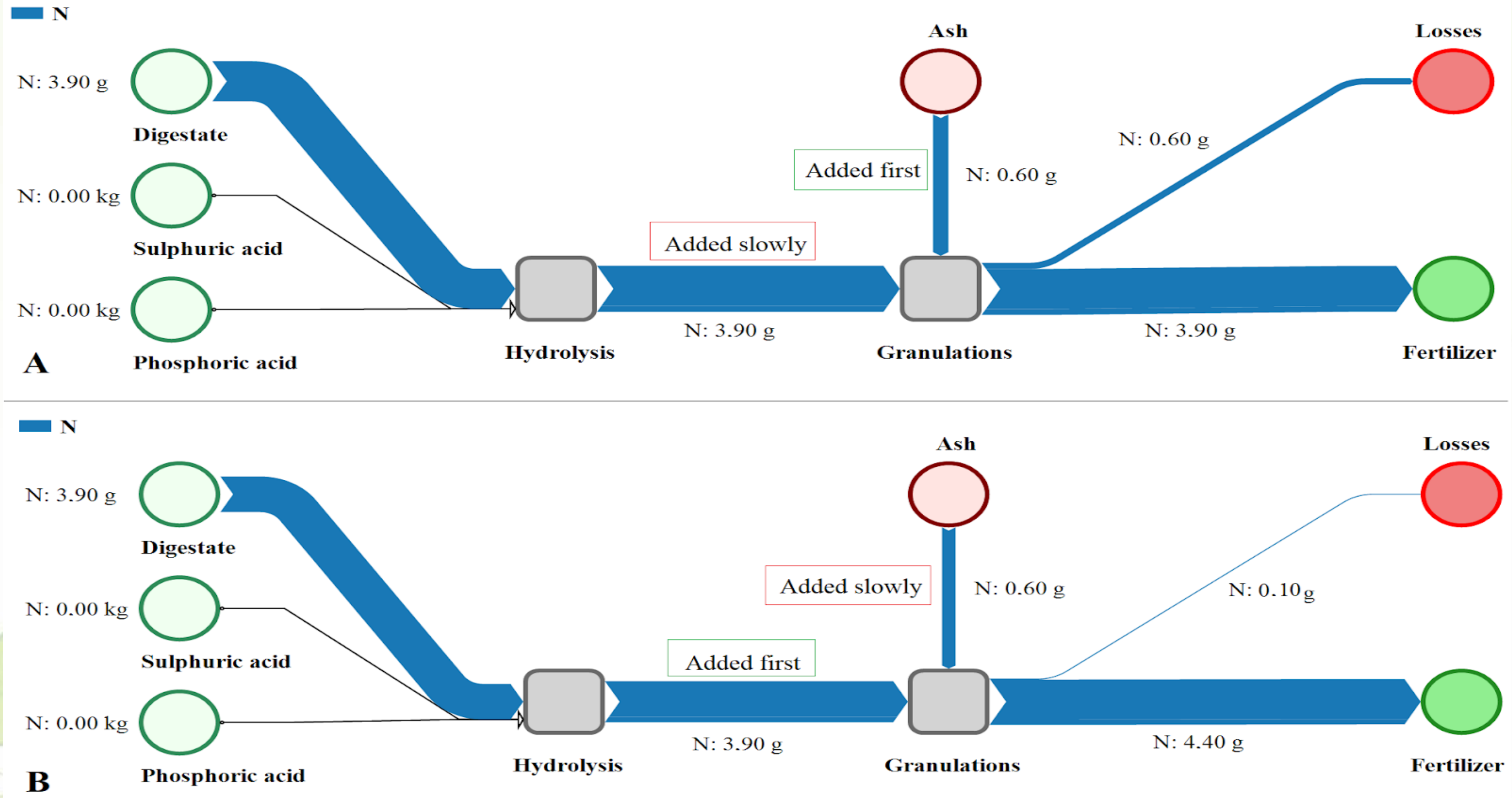


Figure 4. Nitrogen (N) Balance for the Standard Production Process of Fertilizer (A) and Granulation with Slow Ash Addition (B) per 1 kg of Formulations, Accounting for 15% Measurement Error

Microbiological analysis

Table 4. Microbiological Characteristics of Digestate , Hydrolyzed Digestate, and Fertilizer in Colony-Forming Units per mL for Digestate and Hydrolyzed Digestate, and per g for Granular Fertilizer (TNM, the total number of microorganisms; TNY, the total number of yeasts; TNF, the total number of moulds; ND, not detected)

Sample	TNM	TNY	TNF	*Salmonella* sp. [in 25 g]	*Escherichia coli*	Coliforms
DIGESTATE (per ml)	3.7×10^5	<10	4.0×10^1	ND	<10	7.1×10^4
HYDROLYZED DIGESTATE (per ml)	<10	<10	<10	ND	<10	<10
GRANULAR FERTILIZER (per g)	7.9×10^3	<10	<10	ND	<10	<50

Selection of mineral nitrogen source

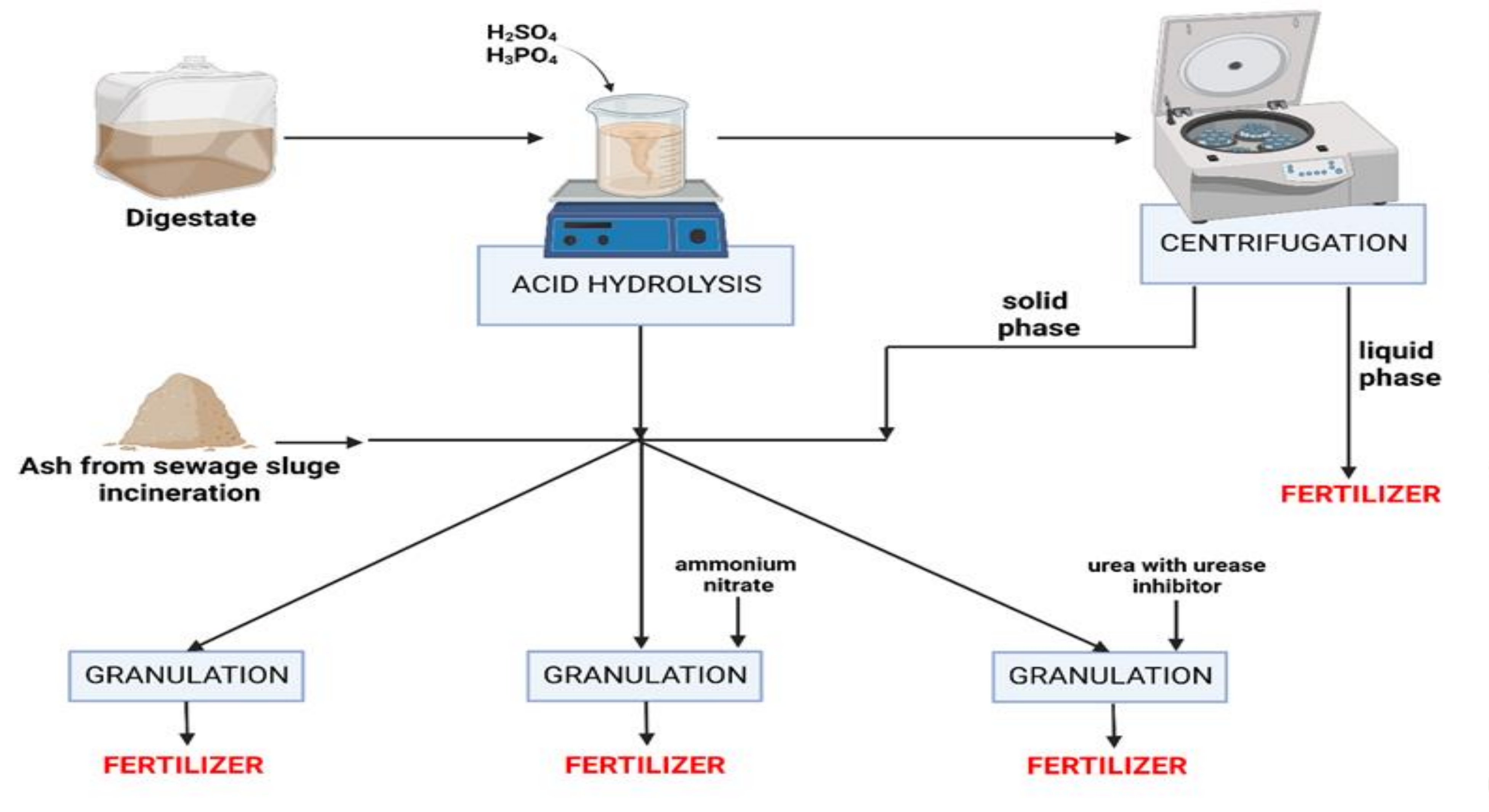


Figure 5. Schematic diagram of the process of selection of the optimal mineral nitrogen source

Comparison of nitrogen balances

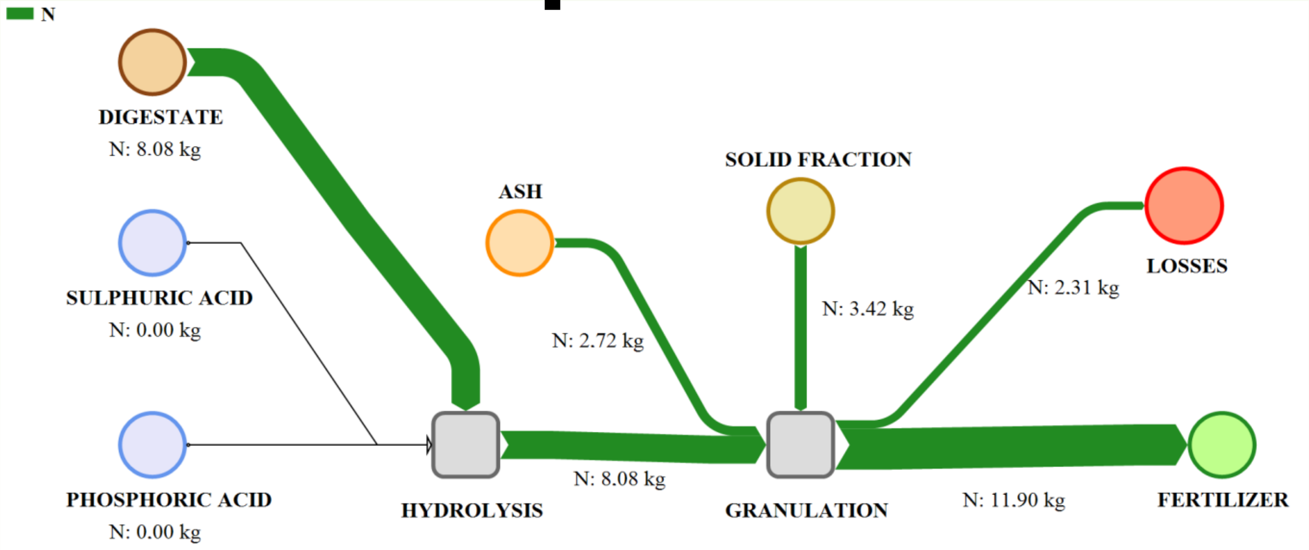


Figure 6. Nitrogen balance of the preparation of 1kg of granular fertilizer

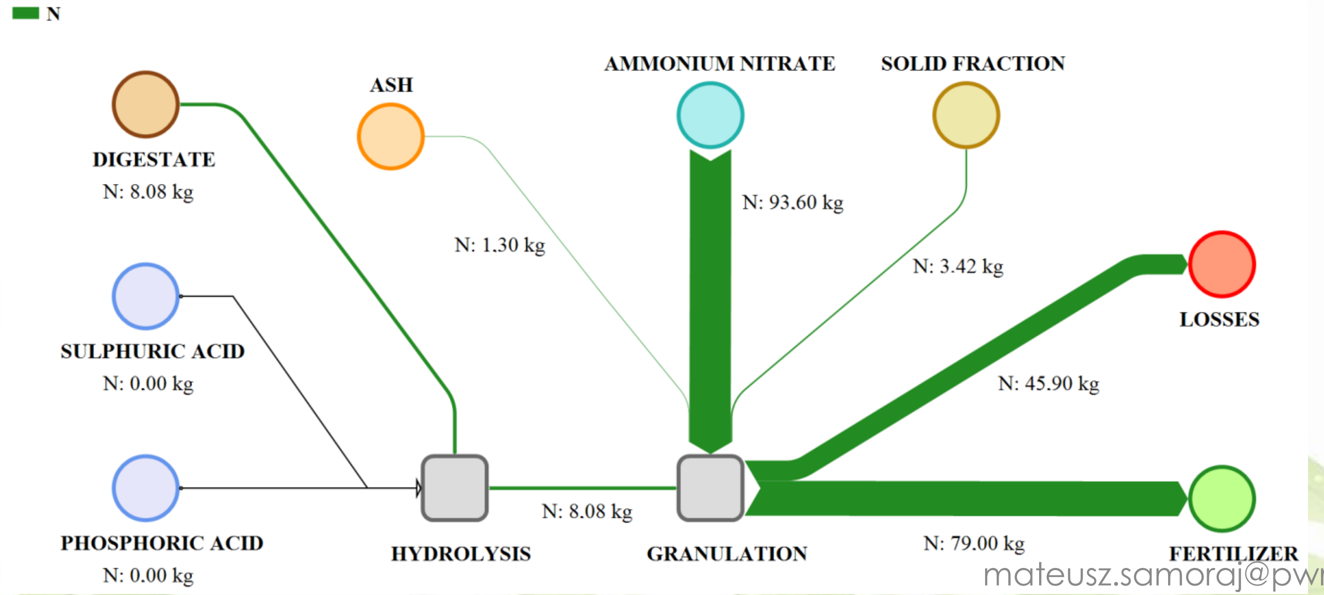


Figure 7. Nitrogen balance of the preparation of 1kg granular fertilizer with ammonium nitrate

Comparison of nitrogen balances

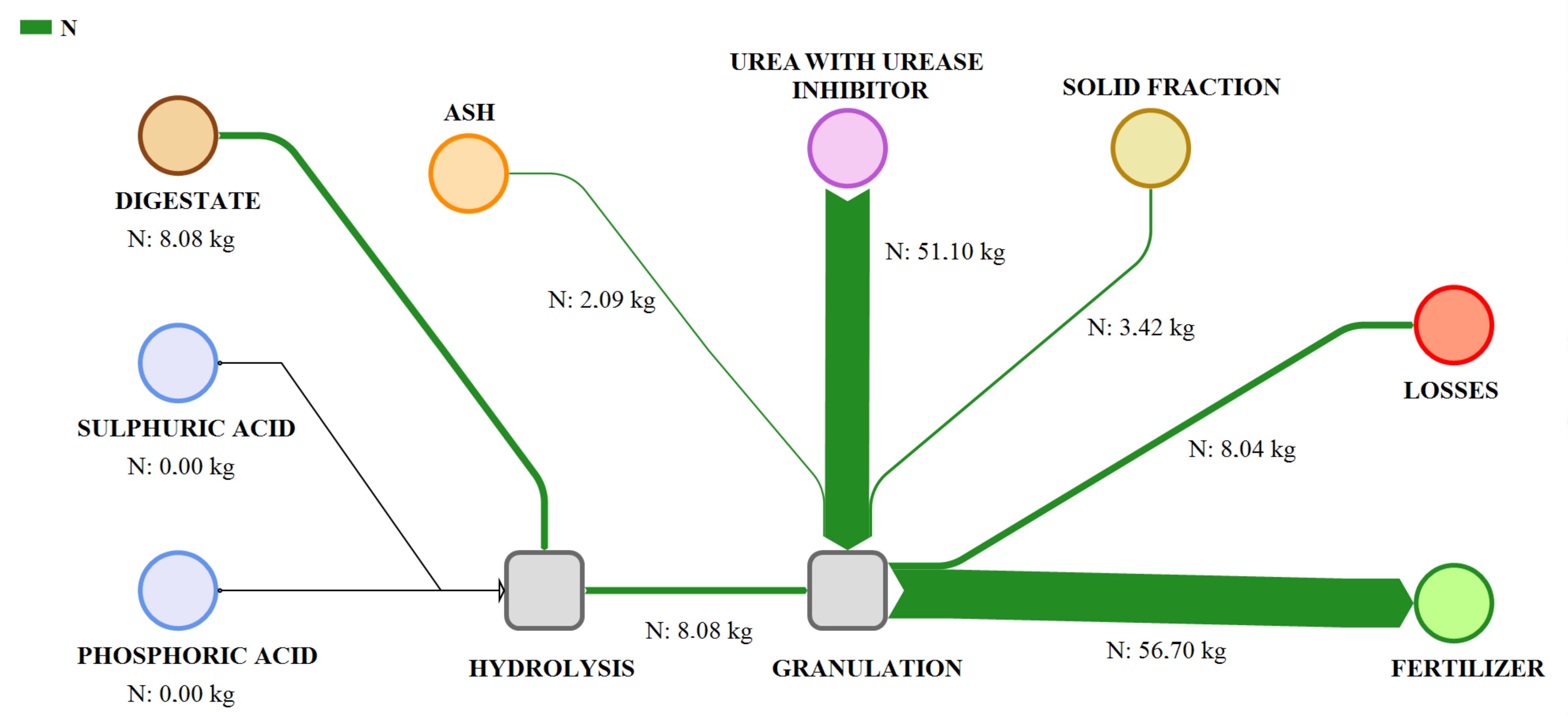


Figure 8. Nitrogen balance of the preparation of 1kg granular fertilizer with urea

Balance of macronutrients

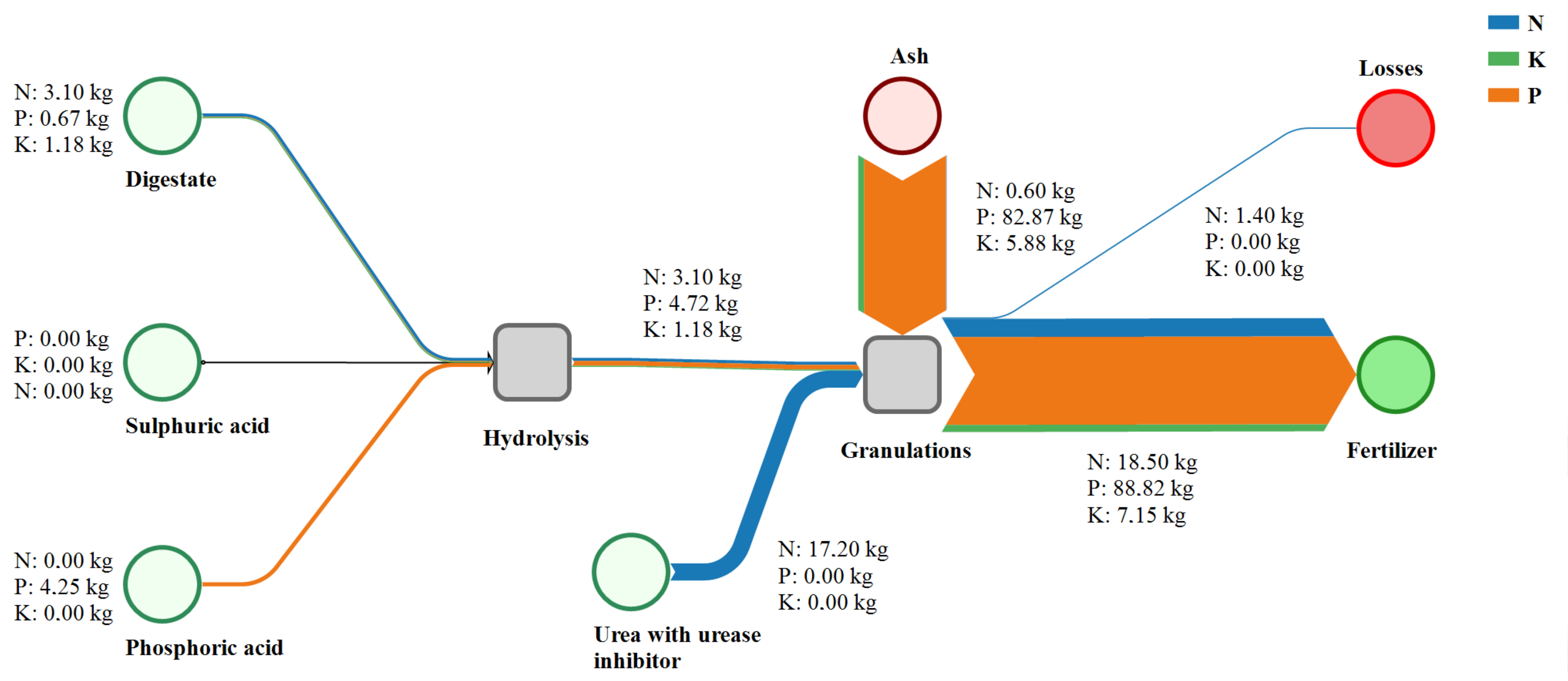


Figure 9. Balance of Macronutrients (NPK) in Urea Enriched Fertilizer Production Process per 1 Ton of Formulation, with 15% Measurement Uncertainty According to ISO 17025 Quality Management System

Granules fraction

Figure 10. Comparison of 3 granule fractions. 0.75mm-1mm fraction (A.) 1mm-2mm fraction (B.) 2mm-4mm fraction (C.)

Table 5. Amino acid content of different types of fertilizers and hydrolysates. The results are presented in mg/kg for solid products and mg/L for liquid products.

AMINO ACIDS		ACID HYDROLYSATE Amino acid concentration (mg/L)	GRANULAR FERTILIZER Amino acid content (mg/kg)
Alanine	Ala	1819±55	**469±15**
Arginine	Arg	11.0±0.3	27.4±0.8
Aspartate	Asn	8.00±0.24	21.8±0.7
Aspartic acid	Asp	10.6±0.3	22.0±0.7
Cysteine	Cys-Cys	15.0±0.5	**48.6±0.8**
Glutamic acid	Glu	7.28±0.22	25.6±0.9
Glycine	Gly	19.2±0.6	13.8±0.5
Histidine	His	12.6±0.4	30.6±1.3
Leucine	Leu	7.24±0.22	27.5±0.2
Lysine	Lys	-	28.7±0.9
Methionine	Met	38.3±1.1	**61.1±1.7**
Phenylalanine	Phe	9.13±0.27	31.5±0.9
Proline	Pro	9.47±0.28	18.8±0.7
Serine	Ser	5.91±0.18	15.4±0.6
Threonine	Thr	4.09±0.12	15.3±0.9
Tyrosine	Tyr	1.12±0.03	1.46±0.04
Valine	Val	3.54±0.11	-
TOTAL		**1981**	**883**

Final formulation

Table 6. Elemental composition of macronutrients of fertilizer granulated with blood as a nitrogen source and modified granulating agent to peat with ash addition.

Materials	Macronutrients						
	C [%]	N [%]	P_2O_5 [%]	K_2O [%]	CaO [%]	MgO [%]	SO_3 [%]
FINAL FORMULATION	38,3 ±3,8	8,57 ±0,86	3,40 ±0,51	2,02 ±0,30	1,99 ±0,30	0,471 ±0,071	6,44 ±0,97
REQUIREMENT OF EU 2019/1009 REGULATION	>7,5%	>2%					

Table 7. Elemental composition of micronutrients of fertilizer granulated with blood as a nitrogen source and modified granulating agent to peat with ash addition.

Materials	Micronutrients				Toxic elements				
	Cu [%]	Fe [%]	Mn [%]	Zn [%]	As [mg/kg]	Cd [mg/kg]	Cr (VI) [mg/kg]	Ni [mg/kg]	Pb [mg/kg]
FINAL FORMULATION	0,376 ±0,056	0,343 ±0,051	0,0470 ±0,0070	1,23 ±0,18	35,0±5,2	1,73±0,26	<0,500	6,97±1,04	<6,00
REQUIREMENT OF EU 2019/1009 REGULATION					40	<3	2	50	120

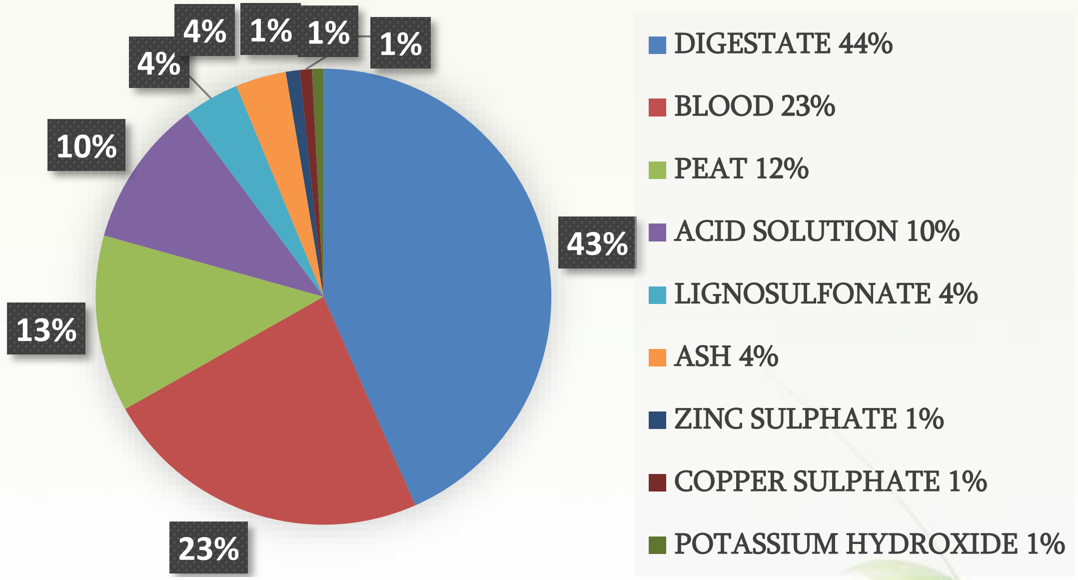


Figure 11. Proportions of raw materials (%m/m) in fertilizer granulated with blood as a nitrogen source and modified granulating agent to peat with ash addition.

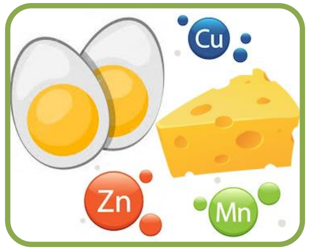
Next steps

Scale up to pilot plant

transfer of verified technology to pilot-scale

Tests on plants

utilitatian tests in field conditions



Biofortification

verification if increased doses of micronutrients in plants will allow for biofortification of animal products

This work was financed by European Union's Horizon2020 Research & Innovation Programme under grant agreement No 696356 and from the Executive Agency for Higher Education, Research, Development and Innovation Funding - UEFISCDI (Romania), the National Centre for Research and Development - NCBR (Poland), Agenda Estatal de Im/estigación - AEI (Spain), and the Ministry of Agriculture and Forestry- MMM (Finland).

Thank you for your attention!

Mateusz Samoraj, PhD
Department of Advanced Material Technologies,
Wrocław University of Technology
Smoluchowskiego 25,
50-372 Wrocław, Poland
mail: mateusz.samoraj@pwr.edu.pl
Tel. +48 71 320 3437