

Sustainable Granulation of Limestone Fertilizers Using Molasses-Vinasse Binder Mixtures: A Circular Economy Approach

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Breaking the Fertilizer Quality-Cost Paradox

Addressing Poland's critical soil acidification through circular innovation

The Problem: Soil Acidification

>50% of Polish arable land is acidic, with some regions exceeding 70%
~2.0 t CaO/ha Required theoretical lime rate
~0.09 t CaO/ha Actual applied rate

The Root Cause: Powdered limestone is highly problematic to handle, transport, and apply without heavy dusting.

Water-only binders: Cheap but highly fragile

Lignosulfonates: Effective but 4-6x cost premium

The Aim: A Paradigm Shift

Objective: Develop a sustainable, highly cost-effective granulation process for milled limestone using circular agro-industrial by-products.

The Raw Material: activCALC

- Neutralizing value: >55
- Reactivity: >98%
- Median particle size (Dv50): 10.2 μm

Formulating the Solution: Materials & Methodology

A systematic framework for process scale-up and validation

Inputs & Binders (The Circular Economy Base)

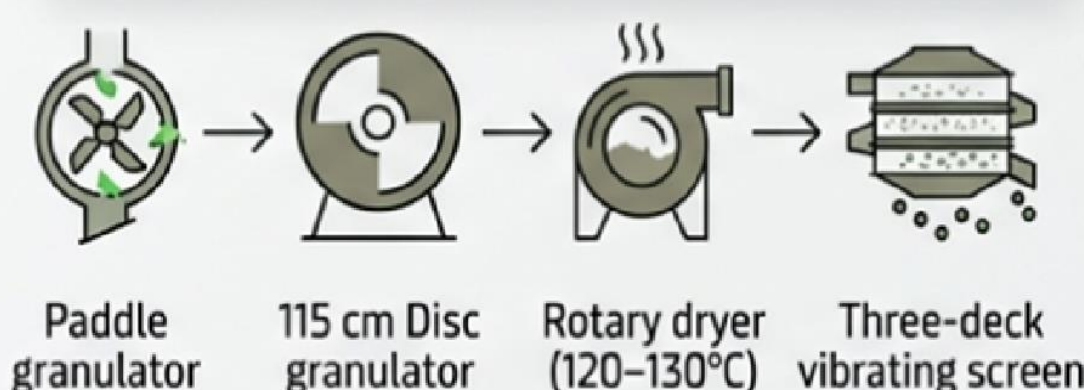
Base Material: activCALC limestone

- Molasses: 80% w/w solution (Sugar industry by-product, ~480 PLN/t)
- Vinasse: 47% w/w solution (Yeast fermentation by-product, ~650 PLN/t)
- Binary Mixtures (M:V dry matter ratio): 3:1 | 1:1 | 1:3 (tested at 10-40% w/w)

References: Water (0 PLN/t) and Na-lignosulfonate powder (~3,300 PLN/t)

Process Scale-Up (The Testing Funnel)

- Phase 1: Laboratory Scale (56 Trials)
 - Ø400 mm disc granulator (16-17 rpm, tilt 30-60°)
 - ~3 kg batches, dried at 105°C for 1 h
- Phase 2: Pilot Scale (9 Trials at Lukasiewicz-INS)
 - Capacity: 160-180 kg/h with SCADA monitoring



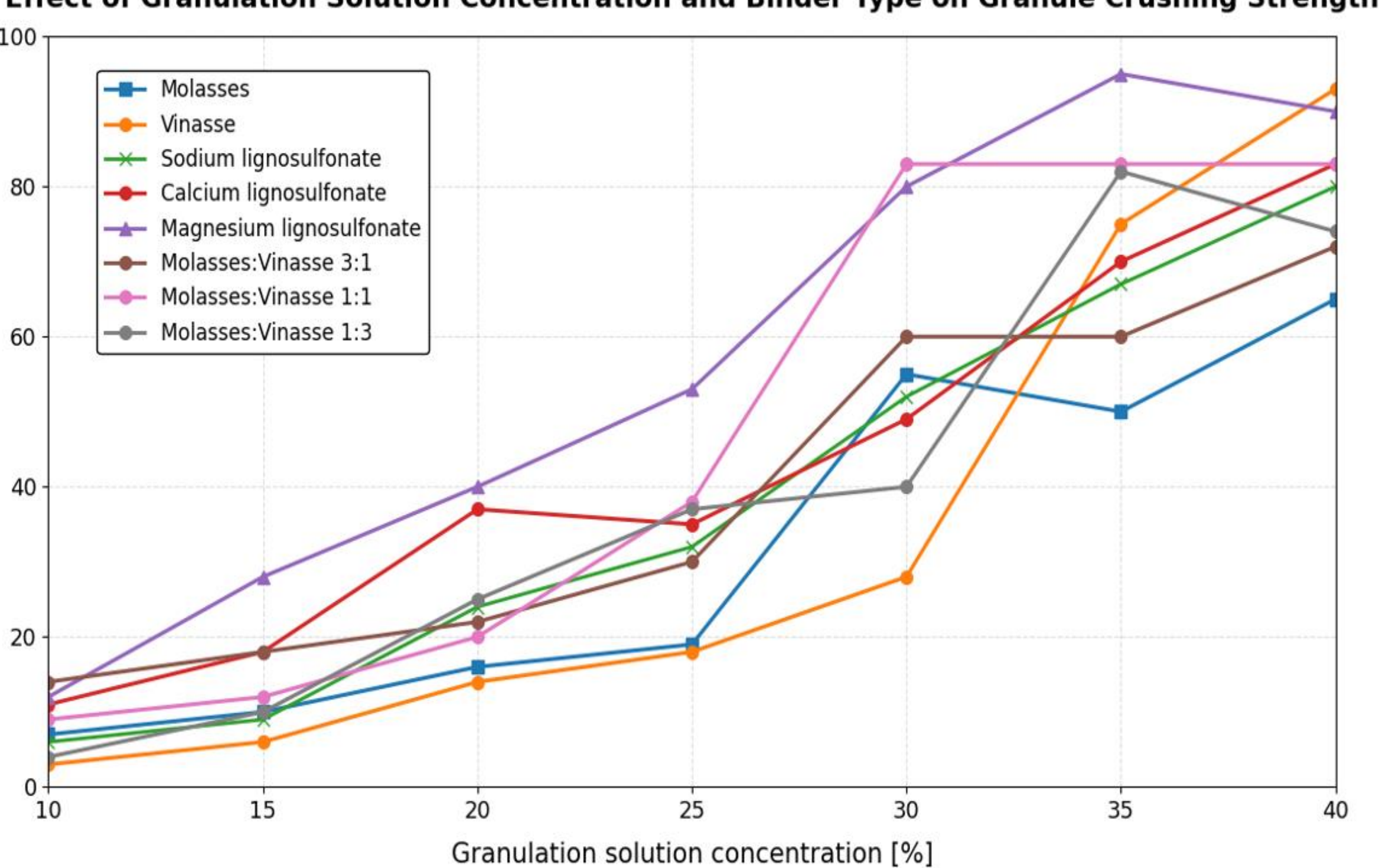
Rigorous Evaluation (The Metrics)

- Crush strength (ERWEKA TBH 225)
- Abrasion loss (ERWEKA TAR)
- Particle size distribution (PN-EN 1235)
- Wet sieving stability (PN-EN 15704)
- Reactivity (PN-EN 13971)

The Synergistic Effect: Lab-Scale Performance

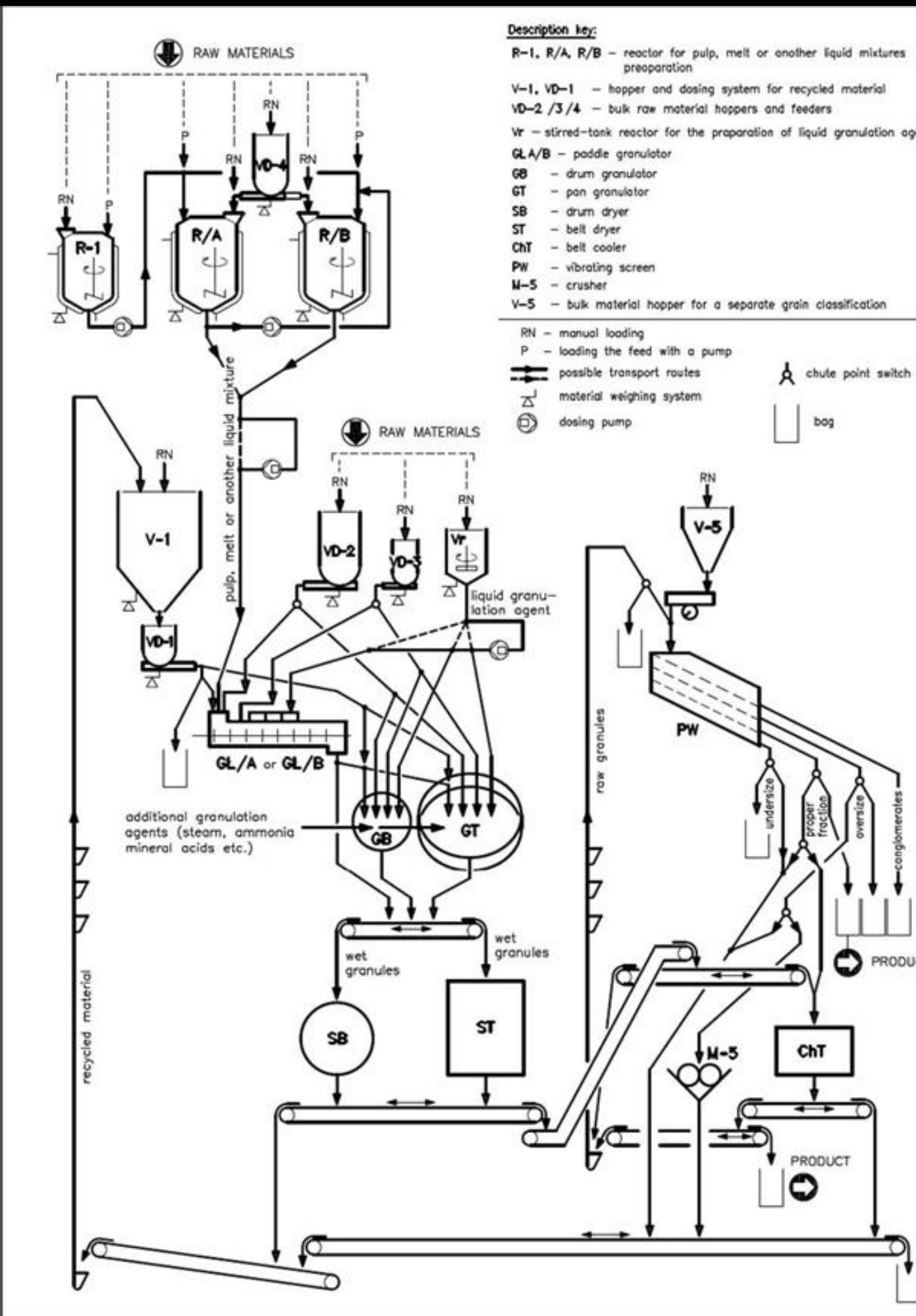
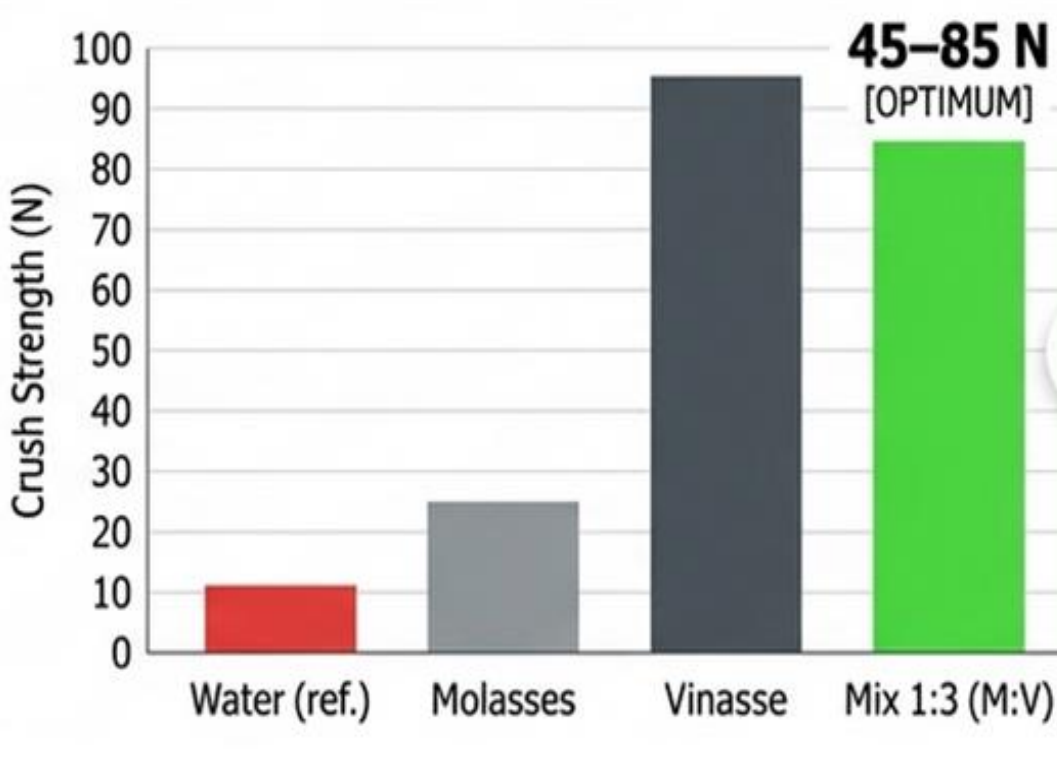
Binary mixtures yield superior physical properties at a fraction of commercial costs

Effect of Granulation Solution Concentration and Binder Type on Granule Crushing Strength



Visualizing the Synergy

The Scientific Breakthrough: The 1:3 Molasses:Vinasse ratio at 30% concentration exhibits a powerful synergistic binding effect.
 Maximum Impact, Minimal Input: Achieving up to 85 N/granule strength requires only ~3% dry-matter addition to the total mass.
 Post-Granulation Boost: Granule strength continues to increase significantly during a 24-h seasoning period due to ongoing cross-linking within the organic matrix.



Industrial Validation: Pilot-Scale Highlights

Scaling up to 160-180 kg/h confirms massive improvements in quality and yield

[THE BASELINE] WATER ONLY REFERENCE

~69%

Target Fraction Yield (2-6mm) (Inefficient, requires heavy recycling)

~31%

Abrasion Loss (Highly fragile; inadequate for transport or field spreading)

✓ Critical Agronomic Validation

Standard wet sieving (PN-EN 15704) confirmed complete disintegration in water for all organic binder products—meeting essential agronomic reactivity requirements. (Leading competitor products often show incomplete disintegration).

[THE BREAKTHROUGH] OPTIMUM MIX 1:3 M:V at 30%

98.4% 0.07%

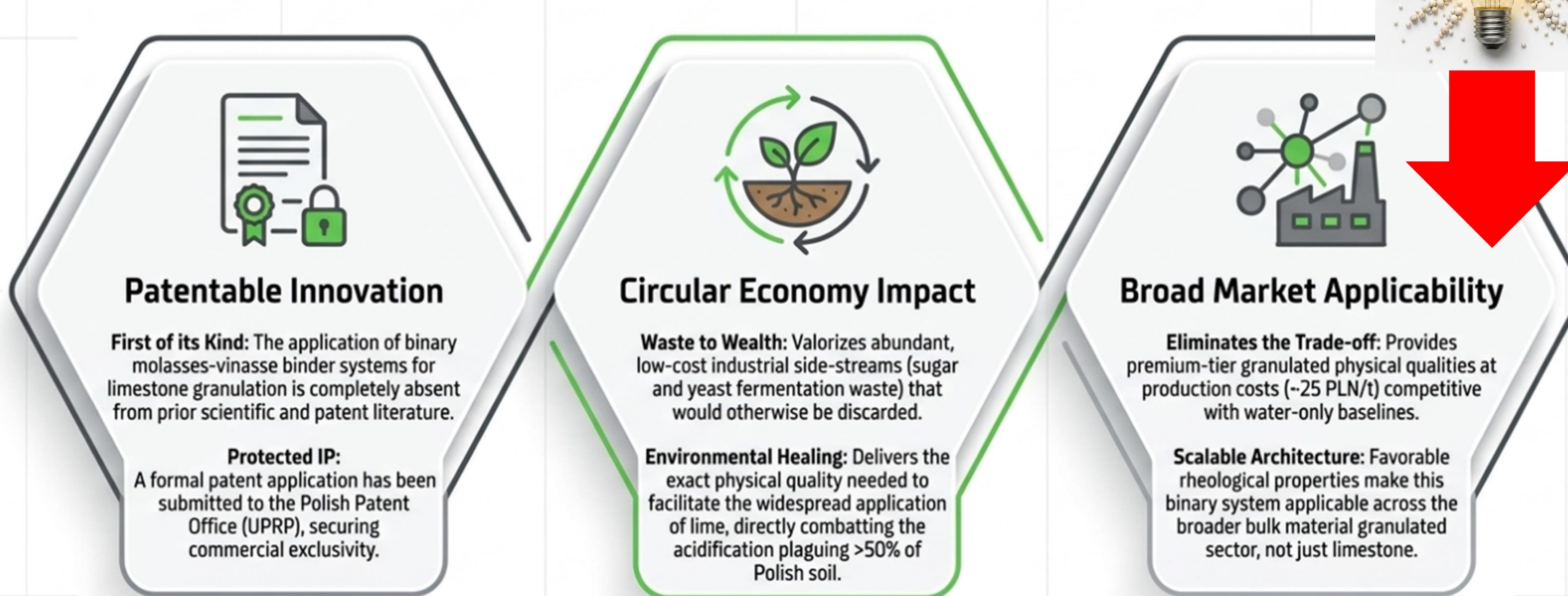
Target Fraction Yield (2-6mm) (Near-perfect manufacturing yield) Abrasion Loss (Exceptional durability)

Crush Strength: 5-20 N/gran. (Rises substantially after 24-h seasoning)

Moisture Content: 1.0-2.0% w/w (Achieved keeping drying temps <100°C to prevent steam fractures)

Redefining Fertilizer Granulation

A patentable shift toward circular, cost-effective agriculture



Patentable Innovation

First of its Kind: The application of binary molasses-vinasse binder systems for limestone granulation is completely absent from prior scientific and patent literature.

Protected IP:

A formal patent application has been submitted to the Polish Patent Office (UUPRP), securing commercial exclusivity.

Circular Economy Impact

Waste to Wealth: Valorizes abundant, low-cost industrial side-streams (sugar and yeast fermentation waste) that would otherwise be discarded.

Environmental Healing: Delivers the exact physical quality needed to facilitate the widespread application of lime, directly combating the acidification plaguing >50% of Polish soil.

Broad Market Applicability

Eliminates the Trade-off: Provides premium-tier granulated physical qualities at production costs (~25 PLN/t) competitive with water-only baselines.

Scalable Architecture: Favorable rheological properties make this binary system applicable across the broader bulk material granulated sector, not just limestone.

Final Conclusions & Next Steps

Delivering a comprehensive, ready-to-scale granulation technology

Summary of Impact

- ✓ **Exceptional Quality:** Organic binders from agro byproducts fundamentally transform the physico-chemical quality of limestone granulates.
- ✓ **The Optimum Formula:** A 1:3 Molasses-Vinasse mixture at 30% concentration is the definitive winner.
- ✓ **Unbeatable Metrics:** Delivers 45-65 N/granule crush strength, <1% abrasion loss, and over 98% target size achieved.



✓ **Agronomic Success:** Achieves complete water disintegration, ensuring rapid soil neutralization upon application.

✓ **Disruptive Economics:** Total land-in cost is only ~25 PLN/ton product, directly breaking the market's historical quality cost barrier.

Status & Path Forward

Ready for Industry: Comprehensive process datasets and upscaling guidelines have been entirely finalized

Next Step: Commencing Stage III Industrial Trials at MKG PROMYK facility.