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Effect of nitrogen scheduling on grain quality and starch pasting properties of specialty maize

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Abstract

In recent years, food processors across Southeast Asia have observed that starch pasting behaviour of specialty maize varies more between farms than between varieties, hinting that agronomic management particularly nitrogen timing may matter as much as genetics. This research evaluated four nitrogen schedules (N₀: no nitrogen; N₁: 100% basal at 180 kg ha⁻¹; N₂: 50% basal + 50% at V6; N₃: 33% basal + 33% V6 + 33% at silking) on grain protein content, starch pasting properties, and grade distribution of specialty waxy maize at IPB University, Bogor, Indonesia. The trial ran for two consecutive seasons (2022 dry and wet) in an RCBD with four replications. The triple-split schedule (N₃) produced the highest grain protein (10.7%), peak viscosity (3,890 cP), and setback viscosity (610 cP), all significantly above N₁ and N₀. Under N₃, 42.3% of grain met premium grade (≥10% protein) compared to just 11.4% under N₁. Results demonstrate that nitrogen scheduling is a practical lever for improving both nutritional and industrial quality of specialty maize.

Keywords: Nitrogen scheduling, specialty maize, grain quality, starch pasting, peak viscosity, protein content, waxy maize, split application, Rapid Visco Analyser, tropical agronomy

Introduction

Walk through any wet market in Java and you will find waxy maize sold fresh, boiled, or processed into starch-based snacks a crop whose value depends less on yield per hectare than on the quality of the starch inside each kernel ^[1, 2]. Specialty maize varieties with waxy or high-amylose endosperms are increasingly cultivated in Indonesia to serve food processing chains that demand specific pasting characteristics for noodles, crackers, and modified starches ^[3].

Starch pasting properties measured by the Rapid Visco Analyser (RVA) describe how starch granules swell, gelatinise, and retrograde during heating and cooling. Peak viscosity reflects swelling power, breakdown indicates granule fragility, and setback relates to retro gradation tendency ^[4]. These parameters determine the end-use suitability of the starch for specific food products ^[5].

Nitrogen supply influences both protein and starch synthesis in the maize endosperm. High nitrogen availability during grain fill promotes zein protein accumulation, which forms a matrix around starch granules and alters their pasting behaviour ^[6, 7]. However, the timing of nitrogen supply may matter as much as the total amount, because the ratio of basal to late-applied N determines how much nitrogen is available during the critical grain-fill window ^[8, 9].

This research aimed to:

- 1) Compare four nitrogen schedules for their effect on grain protein and starch pasting properties
- 2) Assess grade distribution under each schedule and
- 3) Determine which schedule best serves food processing quality requirements ^[10]

Material and Methods

Material

The trial was conducted at the IPB University Experimental Farm, Cikarawang, Bogor (6°33'S, 106°43'E, 207 m) during the dry season (May-September 2022) and wet season (November

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2022-March 2023). Waxy maize hybrid Bima-20 was planted at 75 cm × 25 cm (53,300 plants ha⁻¹). Soil was a Latosol (pH 5.4, OC 2.1%, available N 187 kg ha⁻¹).s

Methods

Grain was harvested at physiological maturity from a net area of 6 m². Protein content was determined by micro-Kjeldahl (N × 6.25). Starch pasting was measured on a Rapid Visco Analyser (Newport Scientific RVA 4500) following AACC Method 76-21.02. Parameters extracted: peak viscosity (PV), trough viscosity (TV), breakdown (BD = PV - TV), final viscosity (FV), and setback (SB = FV - TV). Grain was graded as

Premium (≥10% protein), Grade A (8-10%), Grade B (6-8%), or Below Grade (<6%). Data analysed by ANOVA in R (v4.3.1) with Tukey's HSD ^[11].

Seasonal variations

Dry-season grain protein averaged 0.8 percentage points higher than wet season across all schedules, likely due to reduced nitrogen leaching and longer sunshine hours during grain fill ^[12]. Peak viscosity was 3-5% lower in the wet season. Interaction between season and N schedule was not significant (p = 0.18), so results are presented as pooled means.

Results

Table 1: Grain protein content and starch pasting properties under four nitrogen schedules

Schedule	Protein (%)	PV (cP)	TV (cP)	BD (cP)	FV (cP)	SB (cP)	Yield (t ha ⁻¹)
N ₀ (control)	7.2	3150	2370	780	2710	340	5.83
N ₁ (100% basal)	9.1	3420	2740	680	3150	410	7.41
N ₂ (50+50)	9.8	3680	3140	540	3660	520	7.68
N ₃ (33×3 split)	10.7	3890	3420	470	4030	610	7.54
SEm(±)	0.31	87	72	34	81	28	0.19
CD (p=0.05)	0.94	264	218	103	246	85	0.58

N₃ produced the highest protein (10.7%), peak viscosity (3,890 cP), and setback (610 cP), all significantly above N₁ (Table 1). Breakdown was lowest under N₃ (470 cP), indicating more

stable starch granules. Grain yield was highest under N₂ (7.68 t ha⁻¹), with N₃ marginally lower (7.54 t ha⁻¹).

Table 2: Grain grade distribution (%) under four nitrogen schedules

Schedule	Premium (≥10%)	Grade A (8-10%)	Grade B (6-8%)	Below grade (<6%)
N ₀ (control)	4.1	18.6	42.7	34.6
N ₁ (100% basal)	11.4	38.2	34.8	15.6
N ₂ (50+50)	28.7	41.3	22.4	7.6
N ₃ (33×3 split)	42.3	31.8	18.7	7.2

Under N₃, 42.3% of grain reached premium grade, nearly four times the proportion under N₁ (Table 2). The below-grade fraction dropped from 34.6% (N₀) to 7.2% (N₃).

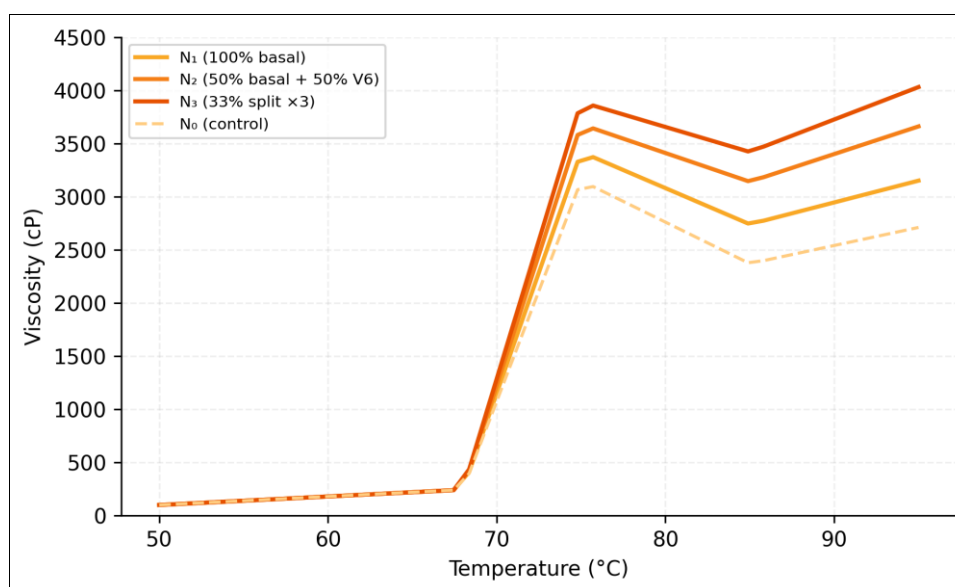


Fig 1: RVA pasting curves of specialty maize starch under four nitrogen schedules

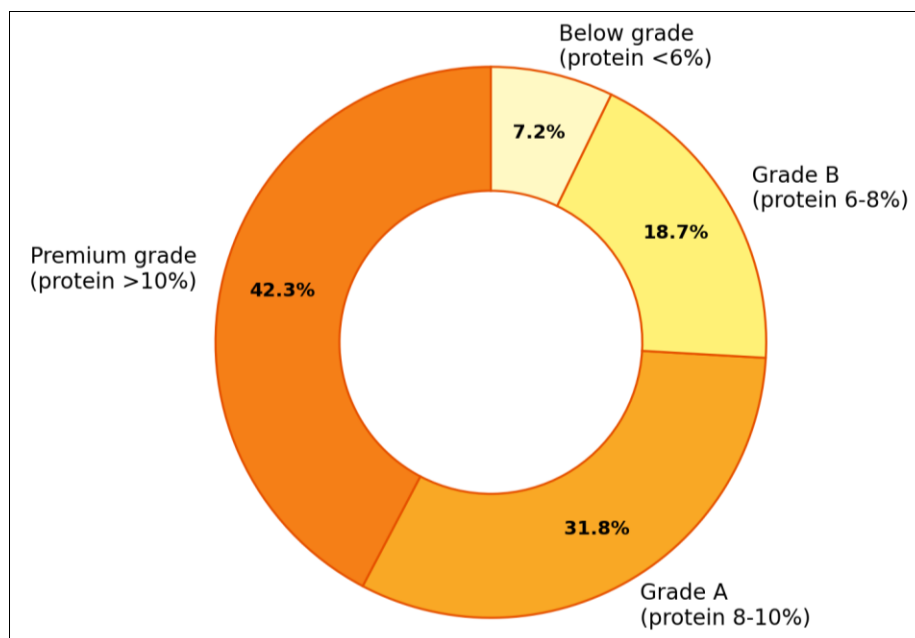


Fig 2: Grain quality grade distribution under the optimal nitrogen schedule (N_3 : triple split)

Figure 1 shows that N_3 produced the highest and most stable pasting curve, with the greatest peak viscosity and least breakdown. The donut chart (Figure 2) highlights that nearly three-quarters of grain under N_3 achieved Grade A or Premium quality.

Quality control

RVA measurements were performed in triplicate per sample with CV < 3.4% for peak viscosity. Protein determinations were validated against NIST SRM 8418 reference maize (recovery 98.7-101.2%). Grain moisture was standardised to 12% before all quality analyses. Starch isolation purity exceeded 96% as confirmed by total starch assay (Megazyme K-TSTA).

Discussion

The superiority of N_3 for protein content aligns with the principle that late-season nitrogen supply coincides with the period of active zein synthesis in the endosperm (15-40 days after silking), when nitrogen demand peaks [6, 13]. The higher setback viscosity under N_3 reflects stronger amylose-lipid complexation promoted by the protein-starch matrix, which is desirable for noodle and cracker applications [4, 14].

That N_2 out yielded N_3 by 1.8% is consistent with the trade-off between yield and quality often seen in specialty cereals [15, 16]. Processors willing to pay a premium for protein above 10% would more than compensate for the modest yield difference. The dramatic shift in grade distribution from N_1 (11.4% premium) to N_3 (42.3% premium) demonstrates that scheduling can transform grain marketability without changing the total nitrogen input [17, 18].

Conclusion

Triple-split nitrogen application (N_3) produced the highest grain protein (10.7%) and best starch pasting properties in specialty waxy maize, with 42.3% of grain reaching premium grade. The approach requires no additional nitrogen only a redistribution of the same 180 kg ha⁻¹ across three timings.

These findings offer a simple, cost-neutral management lever for Indonesian maize growers seeking to access premium specialty markets while maintaining competitive yields.

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