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PROTEIN YIELD GAP IN PULSES: WHY INDIA GROWS LEGUMES BUT STILL FACES PROTEIN DEFICIENCY

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ABSTRACT

India is the world's largest producer of pulses, yet protein deficiency remains widespread, highlighting a significant protein yield gap. This gap extends beyond grain production to include protein quality, digestibility, post-harvest losses, affordability, consumption patterns, and inefficiencies in the pulse value chain. Biological, agronomic, socioeconomic, and policy factors further influence this challenge. This article explores the multiple dimensions of the protein yield gap in Indian pulses and discusses integrated strategies to enhance pulse production, nutritional quality, accessibility, and consumption for improved food and nutrition security.

KEYWORDS: Anti-nutritional factors, DIAAS, Legumes, Protein deficiency, Protein quality, Protein yield gap, Pulses

INTRODUCTION

India occupies a unique and paradoxical position in global protein nutrition. On one hand, it is the world's largest producer of pulses, growing chickpea (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), lentil (*Lens culinaris*), black gram (*Vigna mungo*), and green gram (*Vigna radiata*) across approximately 29-30 million hectares and producing over 24 million tonnes annually (Agriculture.Institute, 2026). On the other hand, it is home to one of the largest protein-deficient populations in the world, with estimates suggesting that over 70% of Indians do not meet their daily protein requirements (ORF, 2021).

A recent analysis by the Council on Energy, Environment and Water (CEEW, 2025) found that while Indians consume an average of 55.6 g of protein per day, nearly 50% of this protein comes from cereals such as rice and wheat - foods with an inherently poor amino acid profile - while pulses, dairy, and eggs remain significantly under-consumed. The richest 10% of the Indian population consumes 1.5 times more protein than the poorest, revealing a deep inequality in protein access (CEEW, 2025).

Understanding why this production-nutrition paradox persists demands a multi-dimensional analysis of the protein yield gap - defined here not just as the difference between potential and actual pulse yields, but as the full gap between what India's pulse sector could deliver in terms of digestible, high-quality protein per person and what it actually does deliver.

UNDERSTANDING THE PROTEIN YIELD GAP IN PULSES

The protein yield gap in pulses operates on two distinct levels that must be addressed simultaneously:

- Quantity gap: The difference between potential pulse grain yield per hectare (under optimal management) and actual farm-level yield. India's pulse productivity stands at only 889 kg/ha, well below the global average of 964 kg/ha (Agriculture.Institute, 2026).
- Quality gap: Even when pulses are produced, the digestible protein available for human absorption is reduced by anti-nutritional factors, poor amino acid profiles (particularly deficiency of sulfur amino acids methionine and cysteine), and processing-related protein losses.

Table 1: Protein Yield Gap Analysis of Major Indian Pulse Crops

Pulse Crop	Potential Protein Yield (kg/ha)	Actual Protein Yield (kg/ha)	Yield Gap (%)	Limiting Amino Acid	DIAAS Score
Chickpea	420-480	180-230	~55%	Methionine + Cysteine	0.56-0.68
Pigeon Pea	380-440	160-200	~58%	Methionine + Cysteine	0.52-0.65
Lentil	400-460	185-220	~53%	Methionine + Cysteine	0.58-0.72
Black Gram	360-420	155-195	~57%	Methionine + Tryptophan	0.50-0.63
Green Gram	350-400	160-190	~54%	Methionine + Cysteine	0.53-0.67

Source: Compiled from ICRISAT, FAO, and Herreman et al. (2020) data

The protein quality of pulses, when assessed by the Digestible Indispensable Amino Acid Score (DIAAS) - the internationally recommended method - ranges from 0.47 to 0.75, well below scores of 1.0 or higher seen in animal-based proteins (Herreman et al., 2020). This means that even when pulses are consumed, their usable protein content is substantially lower than crude protein figures suggest.

KEY DRIVERS OF THE PROTEIN YIELD GAP

1. *AGRONOMIC YIELD GAP: RAINFED CONDITIONS AND LOW INPUTS:* About 85-90% of pulse cultivation in India occurs under rainfed conditions, making these crops highly vulnerable to rainfall variability, drought stress, and waterlogging (Lybbert et al., 2024). Unlike rice and wheat, which receive the majority of irrigation, fertilizer subsidies, and institutional support, pulses are predominantly grown on marginal soils with minimal external inputs. This results in a massive agronomic yield gap - the difference between what pulse crops could yield under best management practices and what farmers actually achieve.
2. *PROTEIN QUALITY GAP: ANTI-NUTRITIONAL FACTORS:* Raw pulses contain a range of anti-nutritional factors (ANFs) including phytic acid, tannins, trypsin inhibitors, haemagglutinins (lectins), and oxalates that significantly reduce protein digestibility and mineral bioavailability (Samtiya et al., 2020). Phytic acid alone can reduce iron absorption by 50-80% and zinc absorption by 15-35%. While traditional cooking methods (boiling, soaking, fermenting, and sprouting) can reduce ANF content by 50-90%, inadequate processing, especially among rural and low-income households, means that the full protein value of pulses is rarely realized.
3. *STRUCTURAL INEQUALITY: PRICE, ACCESS, AND AFFORDABILITY:* Pulses have historically been among the most price-volatile food commodities in India, with retail prices of arhar (pigeon pea) dal frequently exceeding ₹150-200 per kg during periods of production shortfall. This price volatility effectively prices out the most protein-deficient segments of the population - the poor - from adequate pulse consumption. Lybbert et al. (2024) demonstrated that domestic pulse production in India has consistently lagged behind demand growth since 1995, with consumption growing at 2.3% annually against production growth of only 1%, forcing heavy reliance on imports.
4. *CONSUMPTION PATTERNS AND AWARENESS GAP:* The CEEW (2025) analysis, based on the 2023-24 NSSO Household Consumption Expenditure Survey, revealed that while average protein intake figures appear adequate at 55.6 g/day, the quality and diversity of protein sources are deeply inadequate. Cereals supply nearly 50% of protein intake - far above the National Institute of Nutrition's recommended 32% - crowding out high-quality protein sources like pulses. The "Protein

Paradox" study further identified three key barriers: paucity of knowledge, psychological misconceptions, and pinch of affordability (ORF, 2021).

5. *POST-HARVEST LOSSES:* Post-harvest losses in the Indian pulse value chain are estimated at 8-12% of total production, primarily due to inadequate storage infrastructure, insect pest infestation (pulse beetle, *Callosobruchus maculatus*), and moisture-related deterioration. Beyond quantitative losses, storage damage also degrades protein quality through denaturation, Maillard browning reactions, and amino acid cross-linking, further widening the effective protein yield gap.

Table 2: Dimensions of the Protein Yield Gap in Indian Pulses and Corresponding Interventions

Dimension of Gap	Key Cause	Scale of Impact	Recommended Intervention
Agronomic yield gap	Rainfed conditions, poor inputs	High (889 vs 964 kg/ha)	Irrigation, HYV seeds, fertilization
Protein quality gap	Anti-nutritional factors	Moderate-High (reduces DIAAS by 25-40%)	Processing, biofortification, variety selection
Digestibility gap	Limiting amino acids (Met, Cys)	Moderate (DIAAS 0.5-0.75)	Complementary feeding: pulse + cereal
Access and affordability gap	Price volatility, low farm profitability	High among poor households	MSP support, buffer stocks, PDS inclusion
Awareness gap	Low protein literacy	Population-wide	Nutrition education, campaigns
Post-harvest loss gap	Storage, pest, and moisture losses	8-12% of production	Hermetic storage, cold chains, processing hubs

BRIDGING THE PROTEIN YIELD GAP: AN INTEGRATED APPROACH

- *CLOSING THE AGRONOMIC GAP: TECHNOLOGY AND POLICY:* India's National Food Security

- Mission (NFSM)-Pulses has made significant strides in expanding pulse cultivation, with production growing from 16.3 million tonnes in 2015-16 to 24.5 million tonnes in 2023-24 through area expansion and improved variety adoption (Agriculture Institute, 2026). Scaling up micro-irrigation in pulse-growing zones, expanding distribution of climate-resilient short-duration varieties, and ensuring stable Minimum Support Price (MSP) procurement are essential to sustain this momentum and narrow the agronomic yield gap.
- *IMPROVING PROTEIN QUALITY: PROCESSING AND BIOFORTIFICATION:* Traditional and innovative processing methods can dramatically improve the nutritive value of pulses. Germination (sprouting) increases lysine and reduces phytic acid; fermentation improves digestibility by 20-30%; and roasting reduces trypsin inhibitors. Samtiya et al. (2020) comprehensively reviewed how these simple processing techniques can raise the effective protein quality of pulses to levels competitive with many animal-based sources. Simultaneously, breeding programs at ICRISAT and IARI are developing pulse varieties with higher methionine content and reduced ANF levels, directly addressing the amino acid quality gap.
- *DIETARY COMPLEMENTARITY: PULSES + CEREALS:* A powerful and culturally aligned strategy is the promotion of pulse-cereal complementarity. When pulses (rich in lysine but low in methionine) are consumed together with cereals (rich in methionine but low in lysine), the combined DIAAS of the meal increases significantly. Han et al. (2021) demonstrated that pulse-cereal blends can achieve DIAAS values of 0.85-0.95, approaching the protein quality of animal-based foods. India's traditional diet of dal-roti and dal-chawal intuitively embodies this complementarity principle - the challenge is ensuring adequate pulse quantities in these combinations.
- *POLICY REFORMS: PDS AND NUTRITION LABELLING:* Including pulses in the Public Distribution System (PDS) at subsidized rates for Below Poverty Line (BPL) households is one of the most direct policy levers available to bridge the access gap. Several state governments have already piloted this, with positive outcomes for household protein intake. Simultaneously, mandatory protein quality labelling (displaying DIAAS or PDCAAS scores on packaged dal) would empower consumers to make informed dietary choices - a step aligned with India's evolving food labelling regulations.

CONCLUSION

India's protein paradox - being the world's largest pulse producer while hosting one of the largest protein-deficient populations - is not an accident of fate but the cumulative outcome of agronomic underperformance, protein quality reduction, structural inequalities in access, and insufficient policy integration of nutrition goals into agriculture. The protein yield gap in pulses is therefore not one gap but many - an agronomic gap, a quality gap, an access gap, an awareness gap, and a policy gap. Closing it requires an equally multi-dimensional strategy: expanding irrigated pulse cultivation, deploying biofortified and high-protein varieties, scaling up processing technologies that reduce ANFs, leveraging the power of pulse-cereal dietary complementarity, and integrating pulses into public food safety nets. India has both the agronomic capacity and the traditional food wisdom to solve its protein paradox. What is needed is the political commitment and institutional coordination to transform pulse production into genuine protein security - not just for production statistics, but for every plate across the nation.

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