



# Legumes and millets combined, provide a complete quality protein and power-packed nutrients

Smart Food brief 4

Good for you - the planet - the farmer®

## The needs

- Legumes are the most common plant-based protein sources and more affordable than most protein alternatives, but are not a complete protein as they are low in one of the essential amino acids - methionine.
- More than 2 billion people suffer with malnutrition arising from dietary protein and micronutrient deficiencies.
- Plant-based proteins are gaining popularity with vegetarian and vegan diets on the rise in many of the Global North countries.

## The study

The aim was to assess the nutrition levels, complementarity and optimal nutritional combinations of legumes and millets. Two commonly available varieties of two legumes (chickpea and pigeonpea) and two millets (pearl and finger millets) were studied.

Alert: UN World Food Program stated that because of COVID-19 we are on the edge of a hunger pandemic. There is a risk that the need for food will overshadow the need to include nutrition and sustainable agriculture. This can have longer lasting negative impacts and we know that poor nutrition in the first 1,000 days of a child's life impacts physically and mentally in ways that are irreparable. It is very important to incorporate nutrition in strategies.

## Results

Legumes and millets are highly complementary, and when combined, create a powerful nutri-basket with:

- ▶ High levels of protein
- ▶ Complete protein (all essential amino acids)
- ▶ High protein digestibility
- ▶ High levels and wide range of major micronutrients

## Policy recommendations

1. Bring millets back as a 'staple', providing a level playing field with support stretching across the whole value chain from consumer awareness to food entrepreneurs to farm production.
2. To maximize the benefits in nutrition programs:
  - Combine millets and legumes in a 3:1 proportion.
  - Select millets and legumes by type and variety with the highest protein and nutrients.
3. Ensure seed is identifiable and available for the higher protein and nutrient varieties.
4. Support and incentivize food industries and entrepreneurs to scale up products with nutri-dense varieties, and motivate dryland farmers to grow these varieties.

Smart Food Executive Council:





These conclusions are based on the following, for the legumes and millets tested:

- **Legumes are high in protein (14-22%).** A serving of 100 grams provides 50-100% of the Daily Value of protein required by adults and more than 100% of the Daily Value required by an 18-month-old child.
- **Legumes are low in one essential amino acid – methionine; but millets are 100% higher in methionine than legumes.** While methionine in a serving of 100g of legumes meets about 10% of the adult Daily Value, in 100g of millets it meets about 22% of the Daily Value in adults.
- **Millets are high in micronutrients,** especially when selected by type and variety.
- **Protein digestibility of millets were 47 to 95% and legumes were 70 to 88%.** Pearl millet (Dhansakti variety) had highest protein digestibility at 95%.
- **Cooking process increased the protein digestibility for all the millet and legume combinations.**
- **Maximum nutritional benefits accrue when millets and legumes are combined in a 3:1 proportion.** 150g of millets combined with 50g of legumes provides around 100% of the Daily Value of protein for an adult and more than 30% of the Daily Value of methionine for an adult and nearly 100% of an adult's Daily Value of iron or calcium (from pearl or finger millet respectively).

## Published study

Results are based on published study: Anitha S, Govindaraj M, Kane-Potaka J. 2019. Balanced amino acid and higher micronutrients in millets complements legumes for improved human dietary nutrition. Cereal Chemistry. 2019; 00:1–11. <https://onlinelibrary.wiley.com/doi/full/10.1002/cche.10227>



## The study in detail

This is the first study on protein digestibility of finger millet and pearl millet in combination with pigeonpea and chickpea, as past protein studies have focused largely on dairy products and soybean or other crops independently.

The aims of the study were to determine:

- Amino acid composition of high nutrient varieties of commonly used pigeonpea, chickpea, finger millet, and pearl millet varieties and their complementary potential to provide protein and micronutrients
- Protein quality of various legume–cereal combinations by *in vitro* protein digestibility (IVPD) using pepsin; and
- The effect of cooking on the quality of protein and quantity required to meet Daily Value (DV) requirements. For example, comparing both pearl millet cooked simply by boiling in water and pearl millet flour added with water and cooked as a flat bread.

Table 1: Micronutrients, total protein and protein digestibility in each of the legume and millet varieties tested.

Table 2: Provides more details on the protein by each amino acid.

Table 3: Percentage of Daily Value (DV) of amino acids in a combination of 150 g of millet and 50 g of legume.

Figure 1: A comparison of the amino acids available in legumes and millets compared to common protein foods, milk, eggs, soybean and chicken, shows that legumes and millets have comparatively reasonable levels of protein in all the essential amino acids except methionine.



## Future research priorities

### Testing more crops and varieties

- **More legumes and all types of millets should be tested** to identify varieties and combinations that maximize protein quantity and quality and micronutrients. This should include most commonly grown varieties.
- **Test geography-specific combinations** in order to pick the most nutritious combinations of legumes and millets based on the type and varieties locally available. These can be mapped for easy referencing.

### Research recipe and product development

- Customize more nutritious **meals/recipes** based on the optimal combination information, for use in school and other feeding programs. Include sensory and socio-cultural acceptability testing.
- Create more nutritious **food products** from unexplored complementary combinations of legumes and millets to cater to niches such as weaning foods, ready to eat therapeutic foods and sports foods. Include sensory and socio-cultural acceptability testing.
- Research **how different types of processing and cooking affect** nutrition levels and bioavailability in millets and legumes.

- Use these combinations to further identify **industrial protein isolate usages**.

### Health testing

- Test these new food combinations of legumes and millets for **bioavailability** and **gut microbiome** benefits.

### Breeding and on-farm research

- **Breeding programs** need more attention on selection by nutrition elements e.g. protein levels and broken down by amino acids, protein digestibility and other nutrients.
- A **systematic classification** of crops and varieties by nutrition levels (e.g. high, medium and low) and producing a nutrition priority index for each crop.
- **Study optimal combinations of diversity on farm with diversity in diets:** Study different agro-ecologies and how combinations of crops can maximize on-farm income, provide environmental benefits as well as consumption benefits in terms of nutrition.

### Economic

- Analyses of **cost-efficiency** along the whole value chain.
- Identify the most viable business model for **scaling-out**.





Table 1 Major nutrition profile and Protein digestibility of legumes and millets.

Crop	Line/variety	Parameters tested				
		Iron (Fe) (mg/100g)	Zinc (Zn) (mg/100g)	Calcium (Ca) (mg/100g)	Total protein (%)	Average protein digestibility (SD)
Pigeonpea	Maruthi	4.08	3.55	191.93	17.00	70.22 (±0.04)
	Asha	3.48	2.63	117.07	16.72	80.36 (±5.06)
Chickpea	JG11	5.50	3.24	205.50	22.31	80.80 (±0.88)
	Jaki	5.40	3.42	162.92	14.47	88.98 (± 2.42)
Pearl millet	Dhanshakthi	8.48	5.54	30.04	10.53	95.36 (±6.26)
	Proagro9444	4.73	4.32	22.44	9.06	57.35 (±16.41)
Finger millet	VR847	2.86	2.00	359.79	6.34	47.29 (±5.13)
	GPU28	2.64	2.02	450.33	6.31	47.70 (± 3.98)

Table 3: Percentage of Daily Value (DV) of amino acids with the combination of 150g of millet and 50 g legume.

Millet-legume combinations	Essential amino acids (DV%)								
	Histidine	Lysine	Leucine	Isoleucine	phenylalanine	valine	Threonine	Tryptophan	Methionine
150g pearl millet with 50g chickpea	120	73	127.7	97.3	91.5	91.5	146.1	78.1	32.9
150g pearl millet with 50g pigeonpea	130.8	69.4	51.5	89.6	105.7	90.1	105	59.4	32.9
150g Finger millet with 50g Chickpea	90	59.2	70.7	74.2	70	70.3	83.1	62.5	34.2
150g Finger millet with 50g pigeonpea	100.8	55.7	65.7	66.5	84.2	68.9	80	43.7	34.2

Varieties used: Pearl millet - Dhanashakti; finger millet – GPU 28 ; chickpea, JG 11 and pigeonpea - Maruthi.

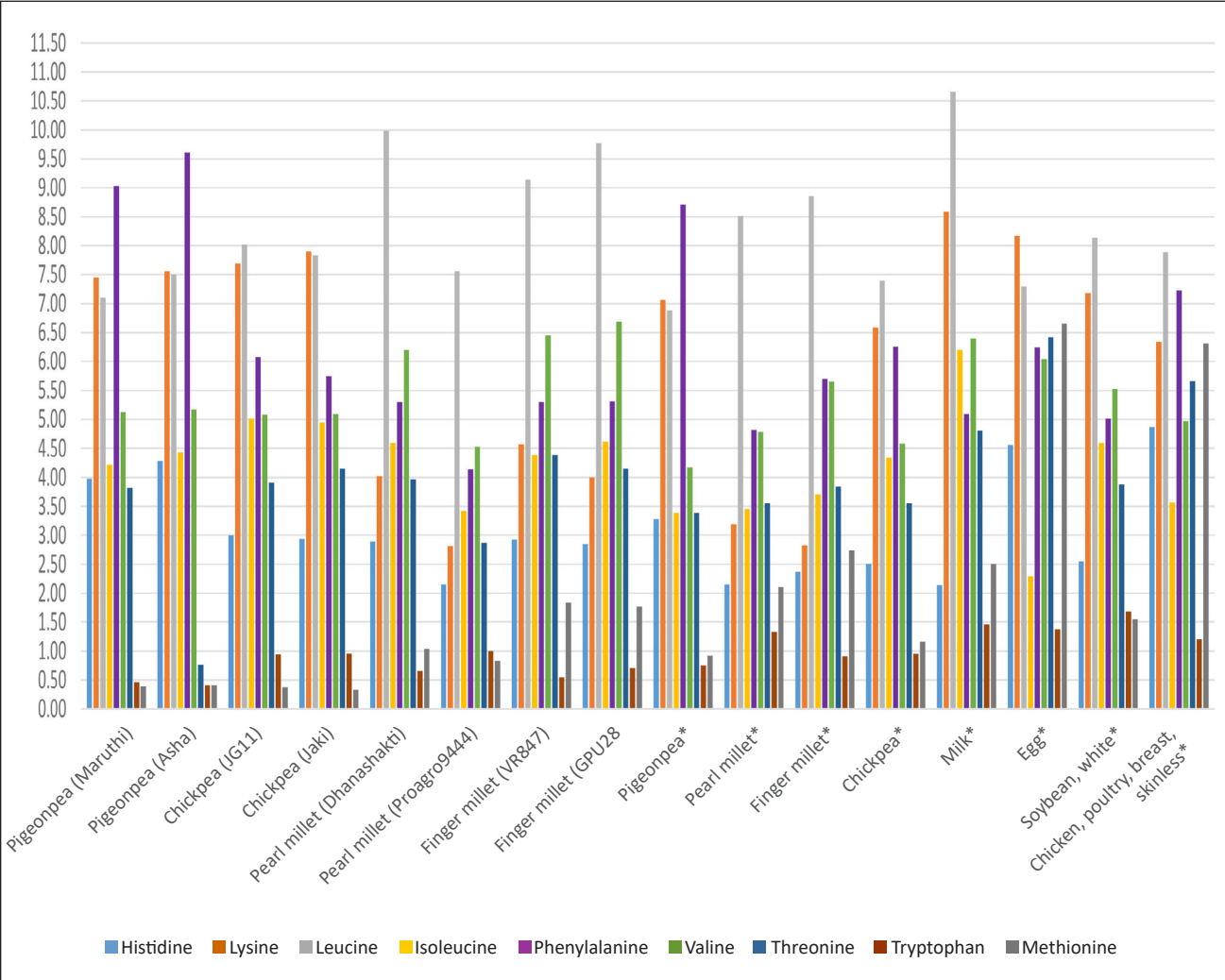


Figure 1: Amino acid profile of tested legumes and millets in comparison to available reference data.

Table 2: Percentage Daily Value (%DV) of essential amino acids that an adult weighing 60 kg and an 18 month-old child weighing 10.8 kg can obtain from 100 g of millets and legumes on dry weight basis.

Crops	Variety	Histidine % DV		Lysine % DV		Leucine % DV		Isoleucine % DV		Phenylalanine % DV		Valine % DV		Threonine % DV		Tryptophan % DV		Methionine % DV		Methionine + Cysteine %DV	
		Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Pigeonpea	Maruthi	109.17	409.38	68.06	255.21	50.00	201.72	57.92	239.66	99.33	346.51	54.17	222.37	70.00	262.50	31.25	108.70	10.83	28.26	107.93	422.35
	Asha	111.67	418.75	65.83	246.88	50.21	202.59	57.92	239.66	100.33	350.00	51.92	213.16	13.33	50.00	27.08	94.20	10.83	28.26	102.87	402.55
Pearl millet	Proagro	32.50	121.88	14.17	53.13	29.27	118.10	25.83	106.90	25.00	87.21	26.28	107.89	28.89	108.33	37.50	130.43	12.50	32.61	184.48	721.86
	Dhanashakti	50.83	190.63	23.61	88.54	45.09	181.90	40.42	167.24	37.33	130.23	41.99	172.37	46.67	175.00	29.17	101.45	18.33	47.83	168.30	658.57
Chickpea	JG 11	87.50	328.13	75.00	281.25	60.04	242.24	73.33	303.45	71.00	247.67	57.05	234.21	76.11	285.42	68.75	239.13	10.83	28.26	114.40	447.64
	JAKI	73.33	275.00	65.56	245.83	50.00	201.72	61.67	255.17	57.33	200.00	48.72	200.00	68.89	258.33	58.33	202.90	8.33	21.74	92.84	363.27
Finger millet	VR 847	26.67	100.00	13.89	52.08	21.37	86.21	20.00	82.76	19.33	67.44	22.44	92.11	26.67	100.00	12.50	43.48	16.67	43.48	272.26	1073.18
	GPU 28	30.83	115.63	14.44	54.17	27.14	109.48	25.00	103.45	23.00	80.23	27.88	114.47	30.00	112.50	18.75	65.22	19.17	50.00	247.89	969.99
T statistics		-5.27**		-4.28**		-8.52**		-6.37**		-4.59**		-8.43**		-5.34**		-5.23**		-9.40**		-6.53**	

\*\* = p<0.001; %

# Nutrition levels of the optimal combinations of millets and legumes in 3:1 are:

Note that: The legumes tested had high protein levels (14-22%), and the millets had moderate protein levels (6.3-10.5%).

## Pearl millet and chickpea combination:

150 g of pearl millet variety Dhanashakti and 50 g of chickpea variety JG 11 can provide:

### High Protein

- > 100% of the Daily Value of 8 (of the 9) essential amino acids and >85% of the 9th essential amino acid, methionine, for an 18-month-old child (Table 3).
- 70-110% of the Daily Value of 8 essential amino acids and >30% of methionine for an adult.

### High Iron

- >100% of the Daily Value of iron for an 18-month-old child (taking bioavailability of 7.5% into account)
- > 100% of the Daily Value of iron required for adult men and children under 10 years, >70% of the Daily Value of iron required for adult women and adolescent children, 10-17 years, (taking bioavailability of 7.5% into account).

## Pearl millet and pigeonpea combination:

150 g of pearl millet variety Dhanashakti and 50 g of pigeonpea variety Maruthi can provide:

### High Protein

- > 100% of the Daily Value of all the essential amino acids required by an 18-month-old child (Table 3).
- 60-125% of the Daily Value of 8 of the 9 essential amino acids and >30% of methionine for an adult.

### High calcium

- > 100% of the Daily Value of iron required for adult men and children under 10 years.
- >65% of the Daily Value of iron required for adult women and adolescent children (10-17 years), taking bioavailability of 7.5% into account.

## Finger millet and pigeonpea combination:

150 g of finger millet variety GPU 28 and 50 g of pigeonpea variety Maruthi can provide:

### High Protein

- > 100% of the Daily Value of all the essential amino acids required by an 18-month-old child (Table 3).
- 40-96% of the Daily Value of 8 of the 9 essential amino acids and >30% of methionine for an adult.

### High Iron

- >100% of the Daily Value of calcium for an adult or children (taking absorption of 30 to 40% into account).



## Finger millet and chickpea combination:

150 g of finger millet variety GPU 28 and 50 g of chickpea variety JG 11 can provide:

### High Protein

- > 100% of the Daily Value of 8 of the 9 essential amino acids and >85% of methionine for an 18-month-old child (Table 3).
- 55-90% of the Daily Value of 8 essential amino acids and >35% of methionine for an adult.

### High calcium

- >100% of the Daily Value of calcium for an adult or children (taking absorption of 30 to 40% into account).

# School feeding studies with millet and legumes

## In India

Approximately 1,500 adolescent school children were provided a mid-day meal based on millet, pigeonpea and vegetables and approximately 1,500 school children as the control group were fed the standard school meal of fortified rice and sambar.

### A random sample of 10% of the children showed:

- » 50% faster growth than those eating fortified rice-based meals.
- » The children rated the meals 4.5 or higher out of 5 for taste, including eating little millet as rice.
- » Laboratory testing of the recipes showed they were significantly higher in protein, fibre, total fat, iron zinc, calcium, magnesium and energy.

For more information on this study and results, see: <https://tinyurl.com/yaggk6af>



## In Tanzania

Over 2,800 students in four schools were provided finger millet and pigeonpea based meals. Fifteen months after the study period, 681 students (26%) were surveyed showing:

- » 80% and 70% changed their negative perception of finger millet and pigeonpea respectively.

- » More than 95% of the students wanted to eat the finger millet and pigeonpea dishes at school.
- » 84% of the students wanted to include pigeonpea 2-7 times a week and 80% of the students wanted to include finger millet on all seven days in school meal.
- » All meals were higher in protein, energy, fats, calcium, magnesium, iron and zinc than previous maize based meals.



For more information on this study and results, see: <https://www.smartfood.org/activities/tanzania/>



## Comments from the Experts

“This new data further emphasises the need to diversify our staples and our diets. These foods and combinations can open new markets for millets, pigeonpea and chickpea in Africa and further afield.”



**Dr Tshilidzi Madzivhandila**  
Chief Executive Officer ad interim  
The Food, Agriculture and Natural Resources Policy  
Analysis Network (FANRPAN)

“These crops are resilient and climate smart, and survive well in the drylands. Their contribution to agriculture and food and nutrition security in the dry zones is significant.”



**Dr Jacqueline d'Arros Hughes**  
Director General, International Crops Research  
Institute for the Semi-Arid Tropics (ICRISAT)



“Protein has been studied for a long time but typically on dairy products and soybean or other crops independently. This is the first study looking at combinations of millets and legumes which have shown valuable results in creating complete and quality proteins as well as a good range of micronutrients.”

**Dr Anitha**  
Nutritionist, International Crops Research Institute for  
the Semi-Arid Tropics (ICRISAT)



“This study shows the need and opportunity to incorporate protein and essential amino acids in future breeding pipelines in the respective crops. Protein and micronutrient deficiencies are increasing threats to public health. Therefore, donors should invest breeding programs to develop cultivars with nutrition beside good yield potential.”

**Dr M Govindaraj**  
Senior Scientist, Crop Improvement, International Crops  
Research Institute for the Semi-Arid Tropics (ICRISAT)



“This study helps towards understanding and achieving nutrition security, especially protein security. ICAR and IIPR have the scientific skills and reach across India to make this happen and bring the right partners and government support in India.”

**Dr NP Singh**  
Director ICAR-Indian Institute of Pulses Research (IIPR)



“This opens opportunities for the food industry entrepreneurs and new product development. It also supports bringing millets back as the staples. IIMR has the vision to work across the whole value chain to create the needed links in India.”

**Dr Vilas Tonapi**  
Director, ICAR-Indian Institute of Millet Research (IIMR)



“In so many ways, millets and legumes are the foods of the future, helping build more economic, environmental, and social sustainability in communities in India and around the world. These foods are not only important sources of nutrition, but they provide income, especially for women farmers. They're a win-win-win for people, planet, and farmers.”

**Danielle Nierenberg**  
President, Food Tank



“There is a rising global popularity of plant based proteins, yet few people are aware of whether it is a complete protein with all the essential amino acids. Food combinations like millets and legumes have the advantage of not only being a complete and quality protein but also a powerful nutri-basket.”

**Joanna Kane-Potaka**  
Assistant Director General – External Relations,  
ICRISAT Executive Director - Smart Food

Smart Food executive council is led by:



@SmartFoodGlobal  
@SmartFoodIndia  
@SmartFoodESA  
@SmartFoodWCA



Smartfood Global



SmartFood\_India



Smart Food Global

Smart Food Kenya



SmartFood India



Smart Food Global  
Smart Food Kenya  
SmartFoodIndia

Efforts in India are coordinated in association with



Citation: ICRISAT, 2019, Legumes and millets combined provide a powerful nutri-basket, Smart Food brief 4, Hyderabad, India.

Writers: Joanna Kane-Potaka and Parkavi Kumar; Design: Vengala Reddy Ch; Editing: Smitha Sitaraman

[www.SmartFood.org](http://www.SmartFood.org)