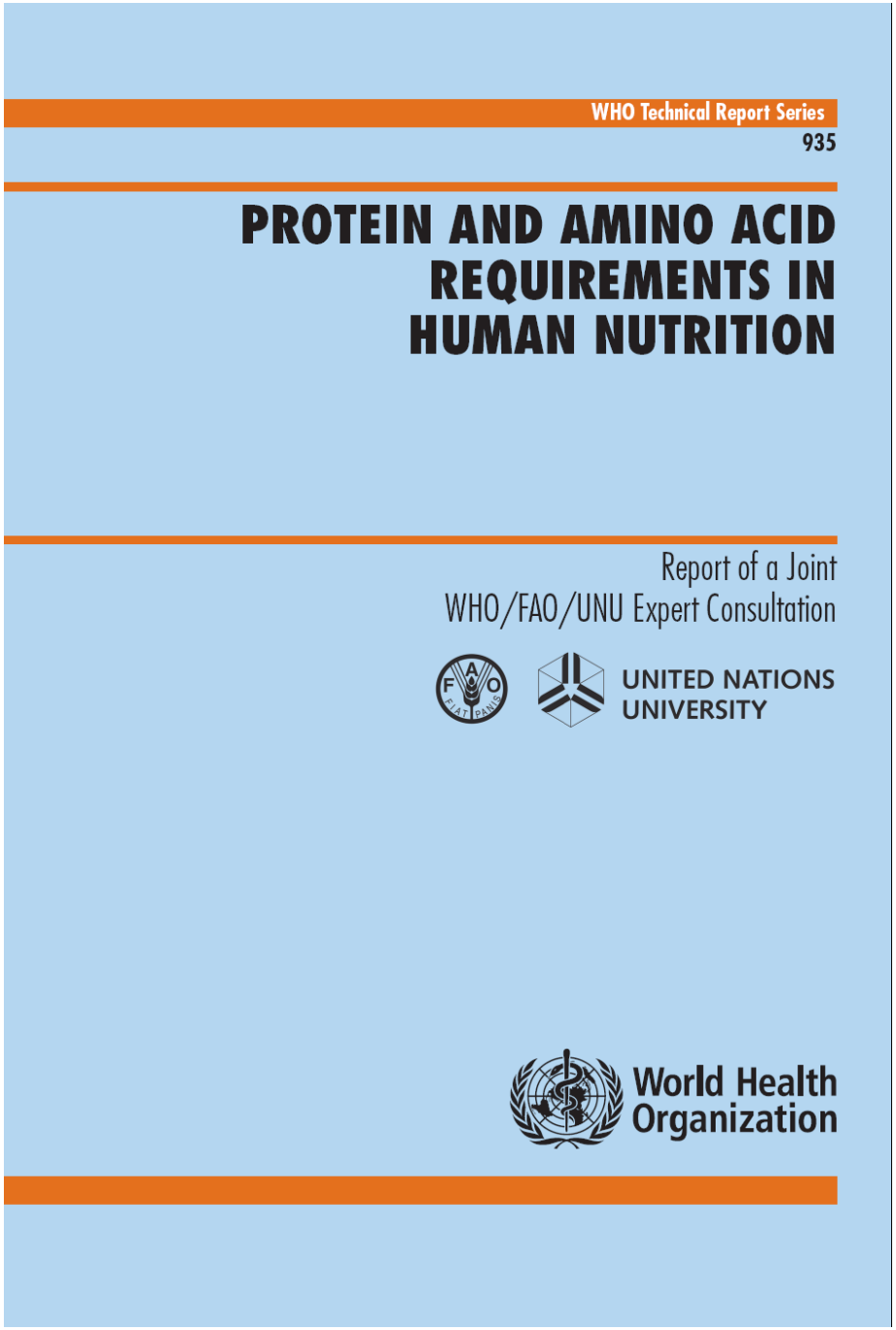
Protein (and more)
Within a nutrition-agriculture framework

Anura Kurpad

St John's Medical College,
Bengaluru



Released in 2007

Just beginning to impact policy

New Amino Acid Requirements

Amino Acid	WHO/FAO/UNU 2007 mg/kg/d	WHO/FAO/UNU 1985 mg/kg/d
Isoleucine	20	10
Leucine	39	14
Valine	26	10
Lysine	30	12
TSAA	15	13
TAA	20	14
Threonine	15	7
Tryptophan	4	3.5
TOTAL EAA	179	84

Amino Acid Scoring Patterns for Different Foods

	Amino Acid Score based on	
Protein Source	**FAO/WHO/UNU 1985**	**FAO/WHO/UNU 2007**
Wheat	>100	60
Rice	>100	78
Sorghum	>100	53
Millet	>100	50
Nuts / Seeds	>100	77
Vegetables	>100	96
Legumes	>100	>100
Animal Protein	>100	>100

What did this mean?

- Protein intake is not a function of the calories eaten
- One needs high quality protein foods in the diet
- The risk of 'quality' protein deficiency is real
- Implications for growth, muscle mass/ diabetes/ aging, and pregnancy

Protein:

Added dimension of digestibility (and the environment)

- Per capita food availability does not reveal the whole picture.
- Further losses (Maillard reaction) and wastage while cooking and preparation.
- Even further loss … Digestibility
- Digestibility is a function of
  - **digestive enzymes** (interacts with undernutrition)
  - **absorptive surface** (interacts with the environment)

Digestibility and the Amino Acid Score

	Amino Acid Score based on			
Protein Source	**FAO/WHO/UNU 1985**	**FAO/WHO/UNU 2007**	**Digestibility %**	**PDCAAS**
Wheat	>100	60	86	52
Rice	>100	78	88	69
Sorghum	>100	53	79	42
Millet	>100	50	79	40
Nuts / Seeds	>100	77	94	73
Legumes	>100	>100	78 (Beans) 95 (Soy PI)	~95 (Beans)
Animal Protein	>100	>100	95	

THE AMERICAN JOURNAL OF CLINICAL NUTRITION
Vol. 22, No. 11, November, 1969, pp. 1476-1482
Printed in U.S.A.

Exocrine Pancreatic Function in Protein–Calorie Malnutrition Disease of Adults[1]

B. N. TANDON, M.D.,[2] P. K. GEORGE, M.B.B.S.,[3] S. K. SAMA, M.D.,[4] K. RAMACHANDRAN,[5] AND P. C. GANDHI, B.SC.[6]

- 90 units of pancreozymin, followed 10 min later by 80 units of secretin
- IV
- Duodenal intubation and collection

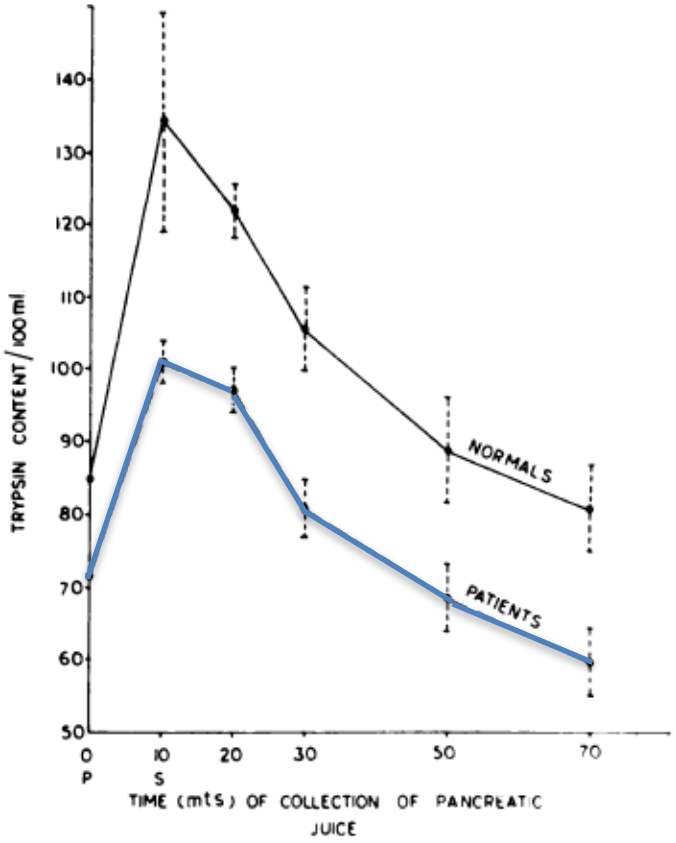


FIG. 2. Data of trypsin studies in the duodenal juice.

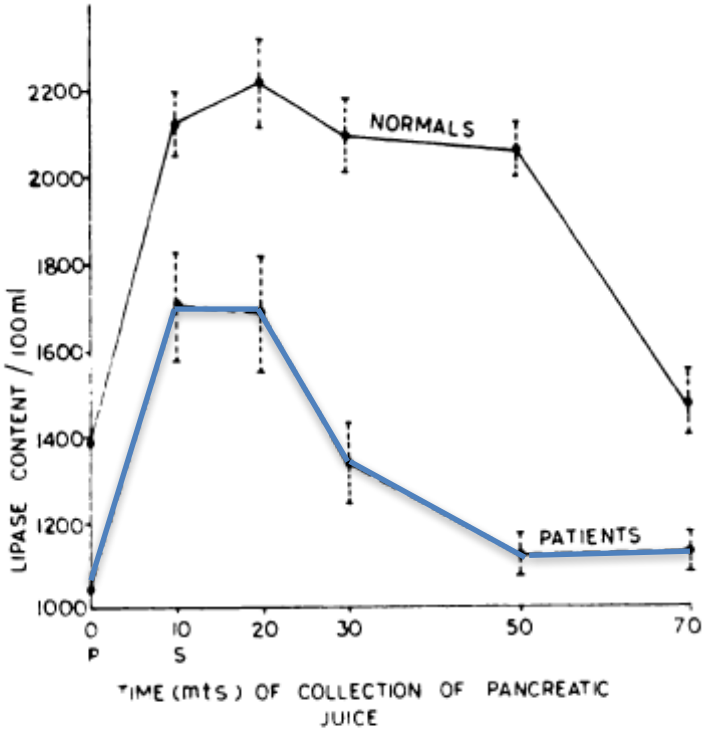


FIG. 3. Results of lipase study in the duodenal juice.

Exocrine pancreatic function and protein-calorie malnutrition in Dakar and Abidjan (West Africa): silent pancreatic insufficiency[1,2]

Jean-François Sauniere, MD, and Henri Sarles, MD, DSc

Am J Clin Nutr 1988;48:1233–8. Printed in USA.

	Dakar	France	Abidjan
Age (y)	1.0	1.0	3.6
Amylase (U/ml)	49.8	**197.8**	54.2
Lipase	24.6	**1077.7**	164.4
Trypsin	2.0	**15.6**	6.2
Chymotrypsin	12.6	**116.2**	27.8

Environmental Enteric Dysfunction

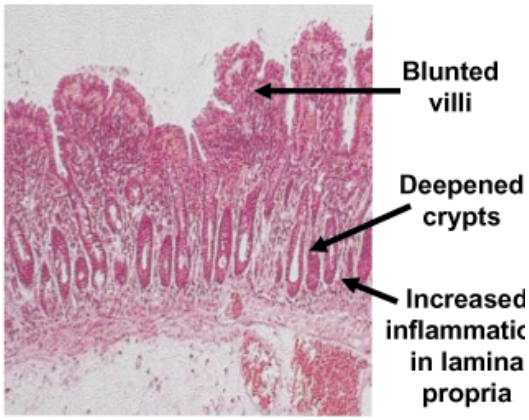
Crane et al, Food Nutr Bull, 2005

- Environmental enteropathy, first noted in the 60's.
- Characterized by the blunted and shortened villi, crypt hyperplasia, and lymphocytic infiltration of the lamina propria.
- Non-specific

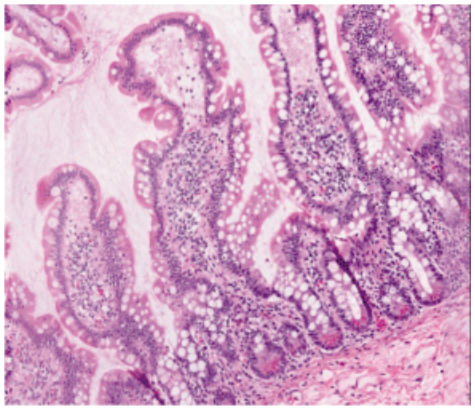
- Impaired barrier function results in luminal contents crossing the gut wall itself and activating the immune system.

- **Decreased surface area for nutrient absorption – relevant for poor growth.**

Environmental enteropathy



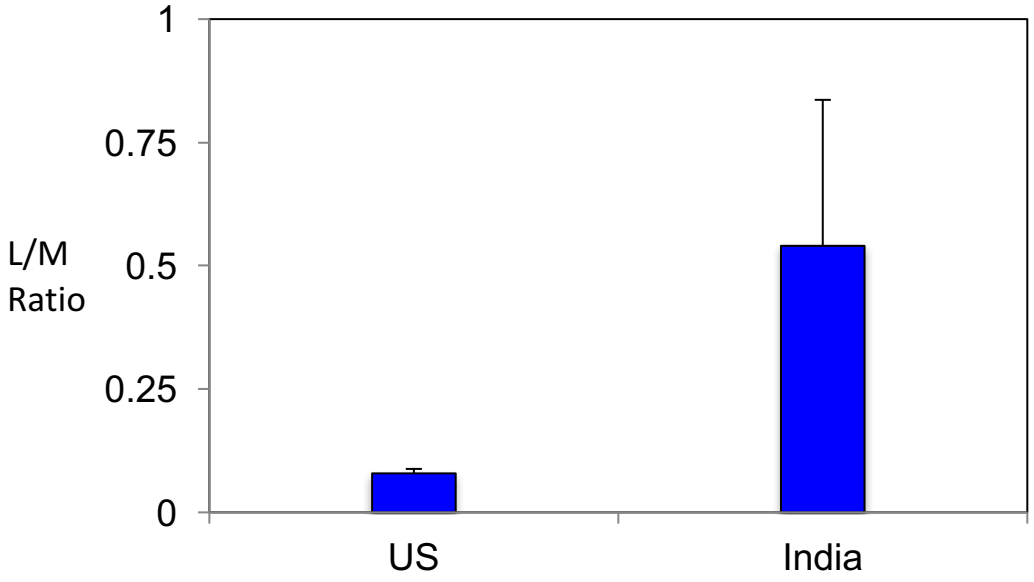
Normal intestinal mucosa

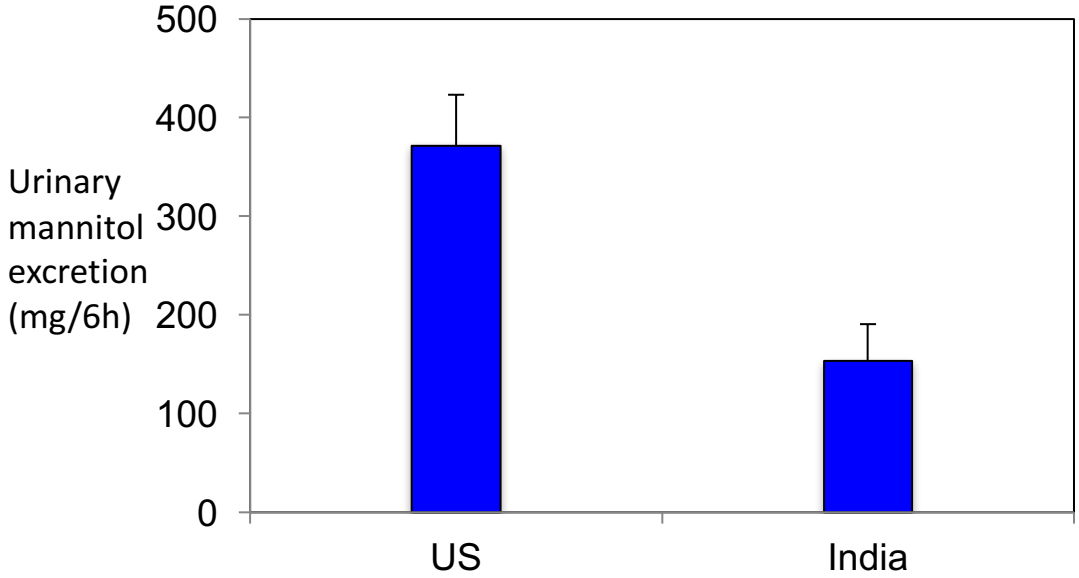


Nutr Rev 2012

Poor gut function – the L:M test

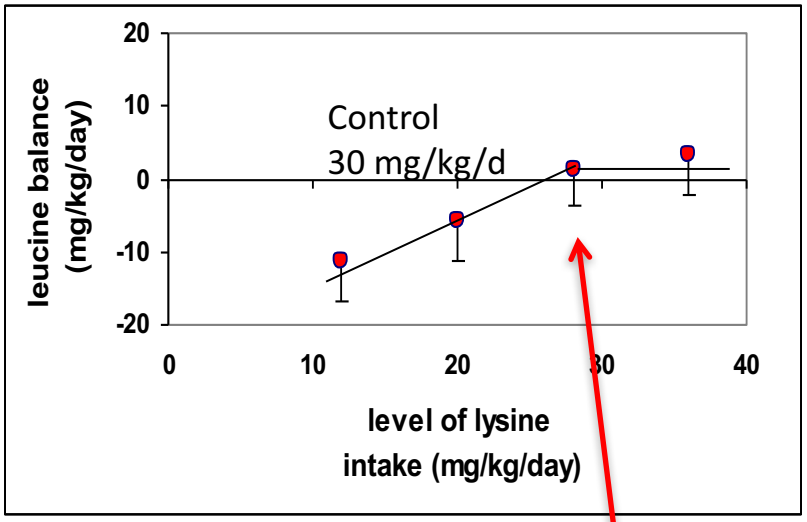
- 10 young non-pregnant non-lactating women in Houston & Bangalore
- Lactulose / mannitol absorption & excretion
- Index of absorptive capacity and gut permeability

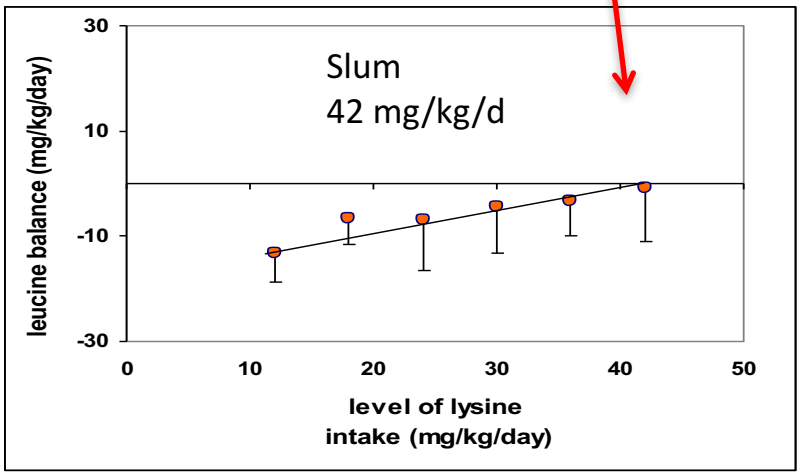


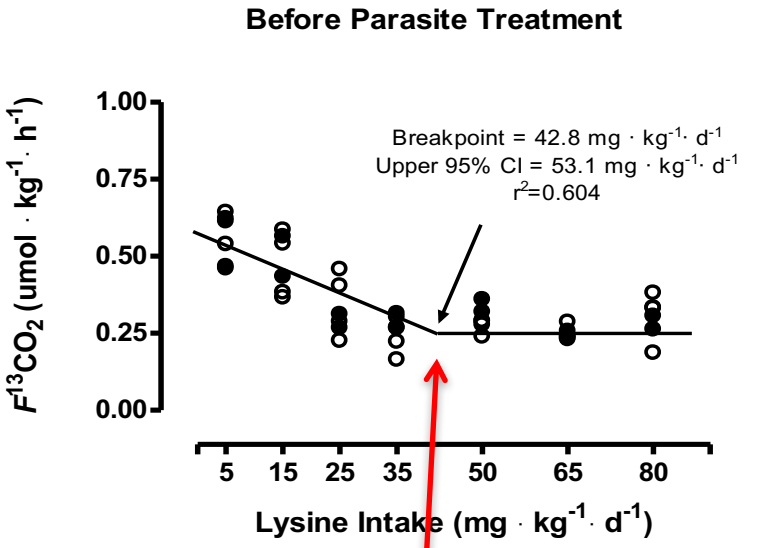


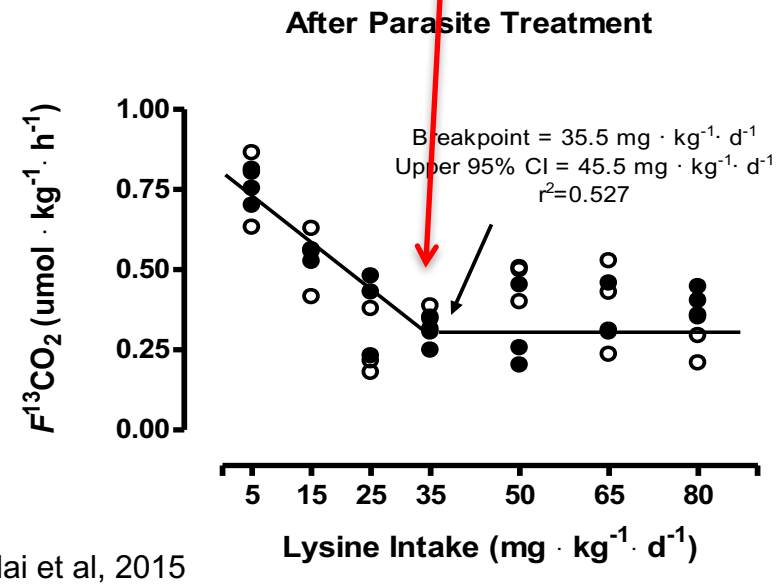
Kao, Kurpad et al, J Nutr 2015

Effect of intestinal parasites on lysine requirement – Indian adults and children





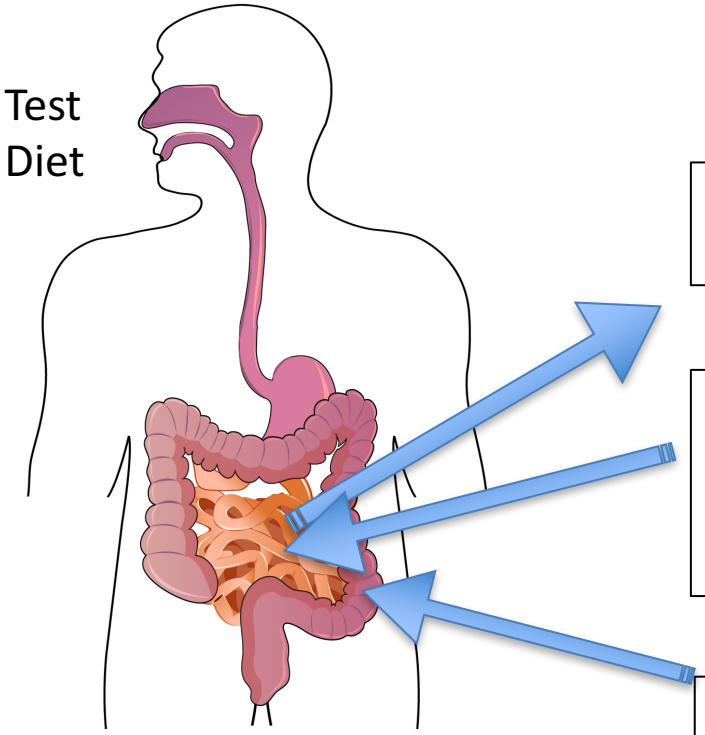




From: Kurpad et al, 2002,2003; Pillai et al, 2015

How do we measure digestibility? Oro-fecal

Oro-fecal balance
Rats, humans



Fecal-Digestibility

Minus
- Amino acids

Plus
- Digestive juices
- Sloughed off cells
- Mucins

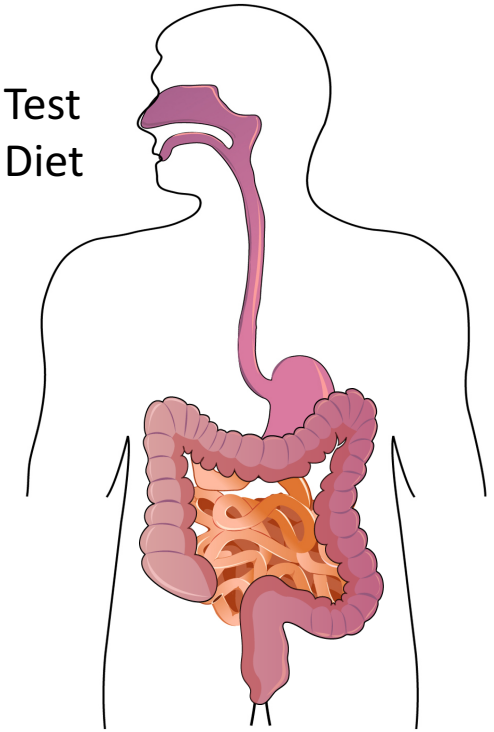
Plus
- Bacterial protein
- Recycled N
- Especially with high CHO diets

- *An Ileal Digestibility term was required for EACH amino acid*

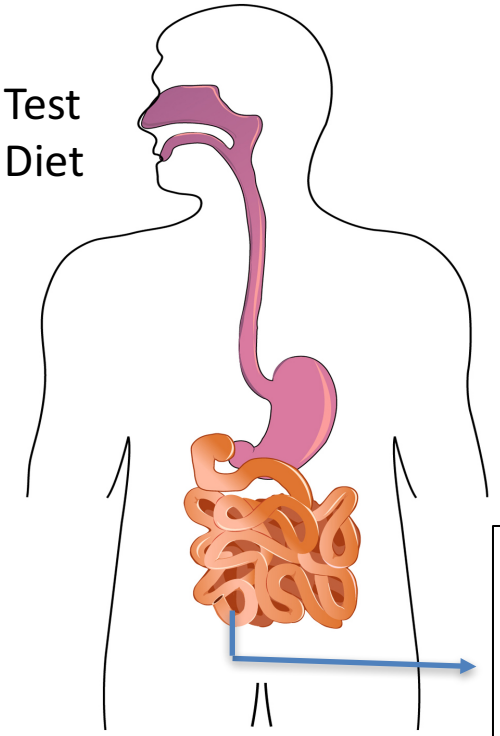
- A new index has been proposed:
- Digestible Ileal Amino Acid Score: *DIAAS*

- *Use the most limiting one as the index*

Measuring Ileal digestibility?



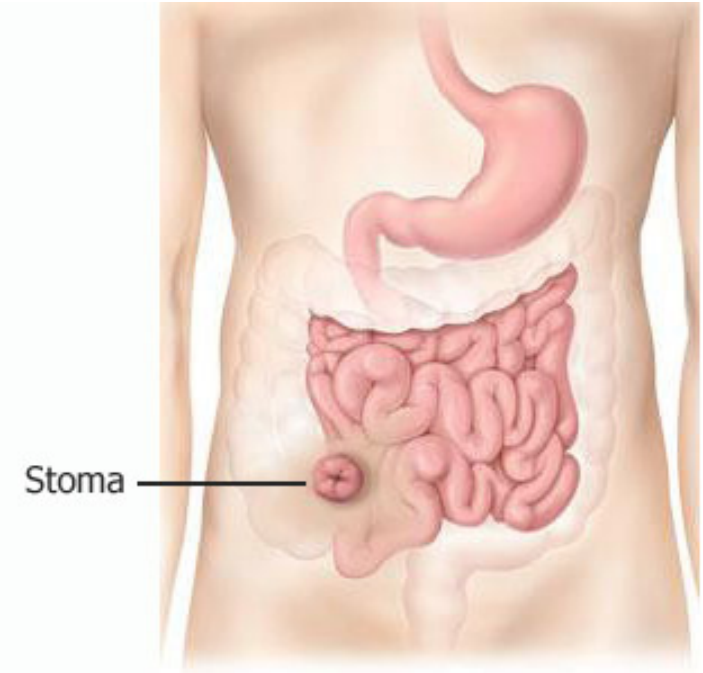
Fecal-Digestibility



Ileal-Digestibility

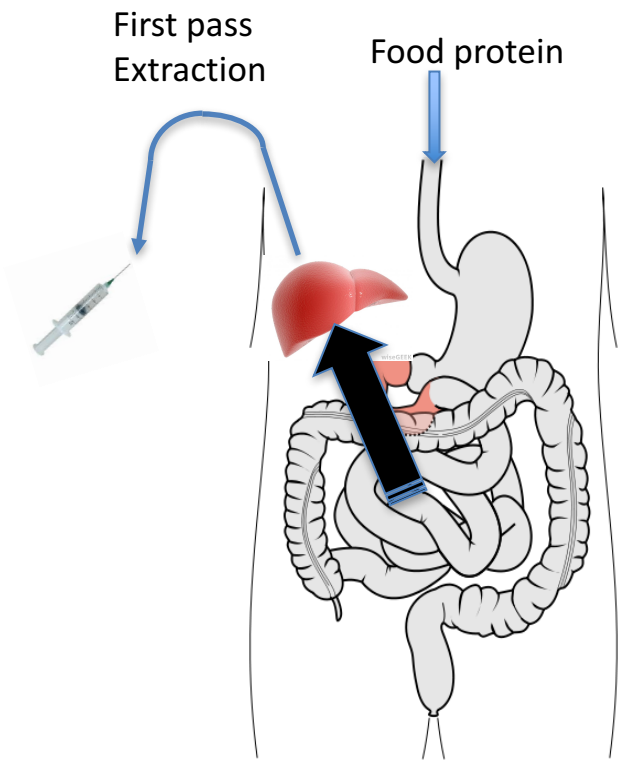
- Need to collect ileal effluent
- Control for secretions, sloughed cells and mucins
- Pig model

Ileostomy



Growth of bacteria into the stoma
Other morbidities

Dual isotope method and intrinsic labeling of plant protein



^{2}H-labeled test protein

+

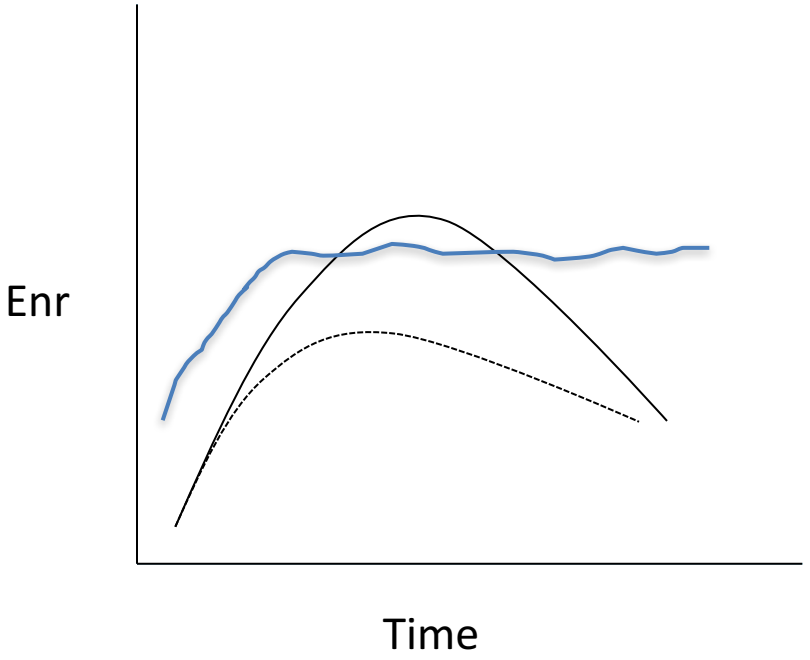
^{13}C-reference protein

- The ratio of isotope species in the blood is an index of digestibility
- Does not get affected by liver/splanchnic extraction

Eventually

Digestibility: For each indispensable amino acid in the test protein, digestibility is calculated from the AUC of AA enrichment from the test protein relative to AA enrichment in the reference protein:

$$100 \times \frac{\text{AUC } {}^{2}\text{H-AA}}{\text{AUC } {}^{13}\text{C-AA}} \times \frac{\text{test meal } {}^{13}\text{C-AA}}{\text{test meal } {}^{2}\text{H-AA}}$$

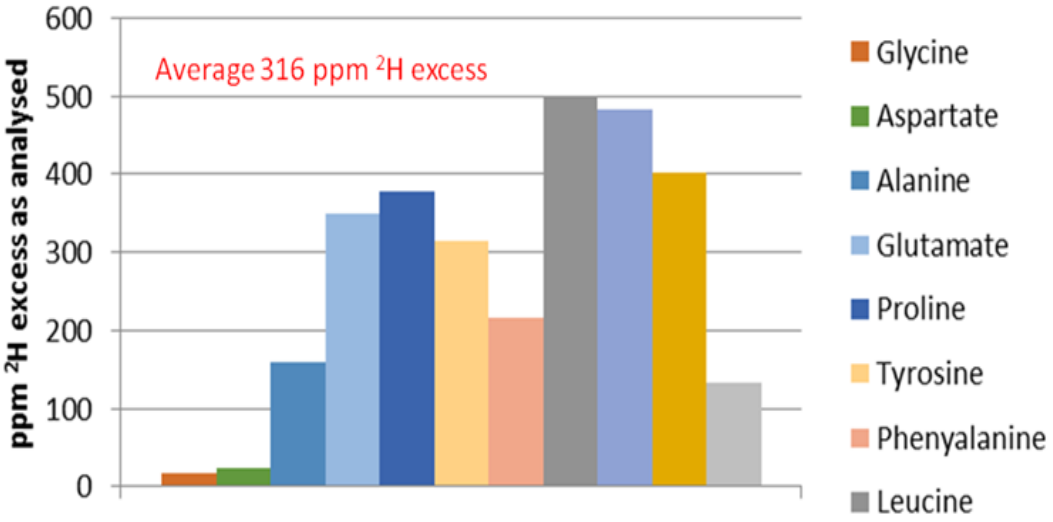


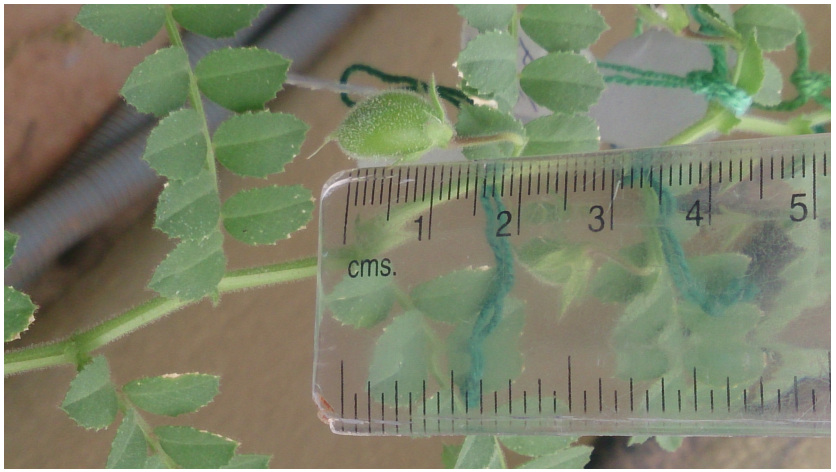
Measure digestibility for different AA

- Within products
- As a biological metric of intestinal function

Intrinsic labeling of pulse protein

Chickpea and mung bean at the University of Agricultural Sciences





To create a reference protein Spirulina digestibility

IAA	MEAN	SD
MET	85.9	7.9
PHE	94.0	2.1
THR	87.7	9.9
LYS	81.1	8.8
LEU	87.5	3.7
I-LEU	83.5	4.1
VAL	84.8	4.2
Mean	**86.4**	

Measured against a mixture of crystalline ^{2}H labelled IAA

Using spirulina as a reference for legume digestibility

IAA	Chick Pea	Whole mung bean	De-hulled mung bean
Methionine	59.8	60.6	64.1
Phenylalanine	60.5	65.2	69.4
Threonine	53.8	43.6	47.2
Lysine	44.4	56.5	57.5
Leucine	68.5	62.3	72.3
I-Leucine	68.8	76.0	80.3
Valine	64.1	64.5	78.7
Average IAA	**60.0**	**61.2**	**67.1**

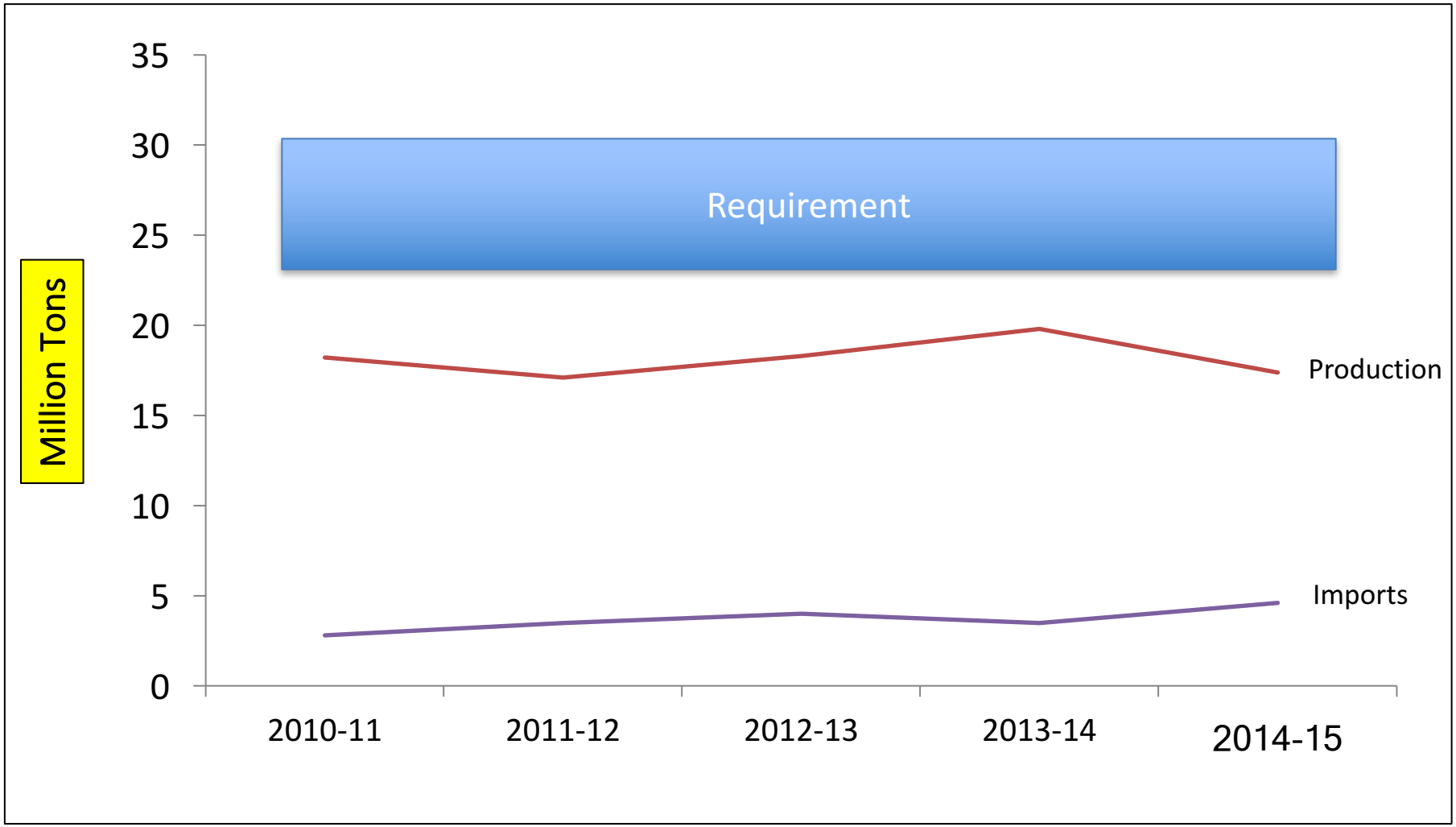
A public health nutrition view

Pulses: how much do we need?

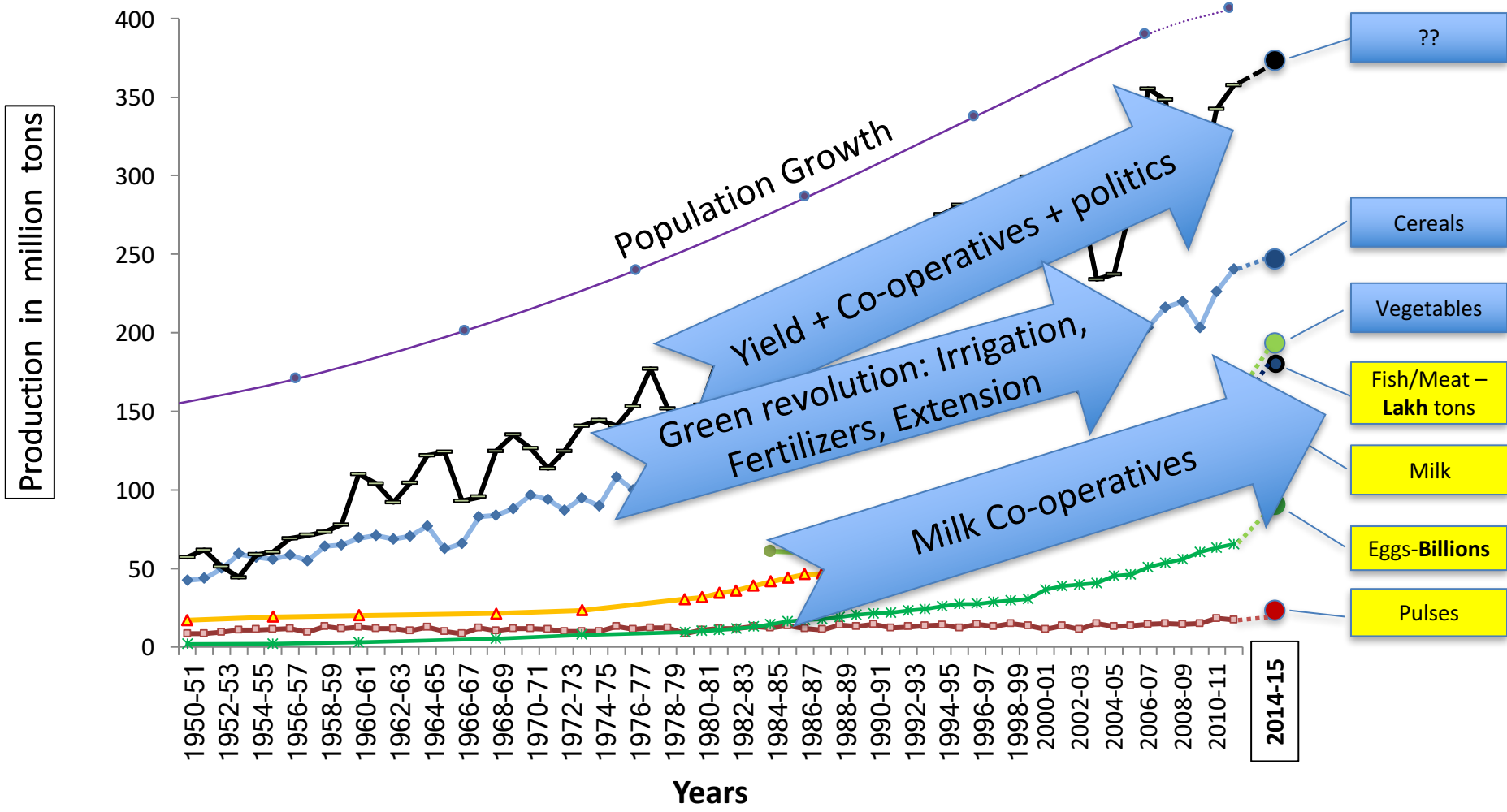
	Energy = 2370 kCal	
Food group	Per day (g)	
Cereals	400	
Animal Food	60	
Pulses	80	
GLV	50	
Other Veg	150	
Roots/Tubers	100	
Fruits	100	400
Milk	300	
Nuts/	25	

- Population: 1.25 billion
- Children – 35%
- Total pulses requirement: 30 million tons/year
- At least…

Pulses: Production and need gap



India - Trends in food groups production 1951 - 2015



- http://eands.dacnet.nic.in/PDF/Agricultural_Statistics_At_Glance-2015.pdf
- http://dahd.nic.in/sites/default/files/BAH_%26_FS_Book.pdf

Varadaharajan, Kurpad et al, APJCN, 2014

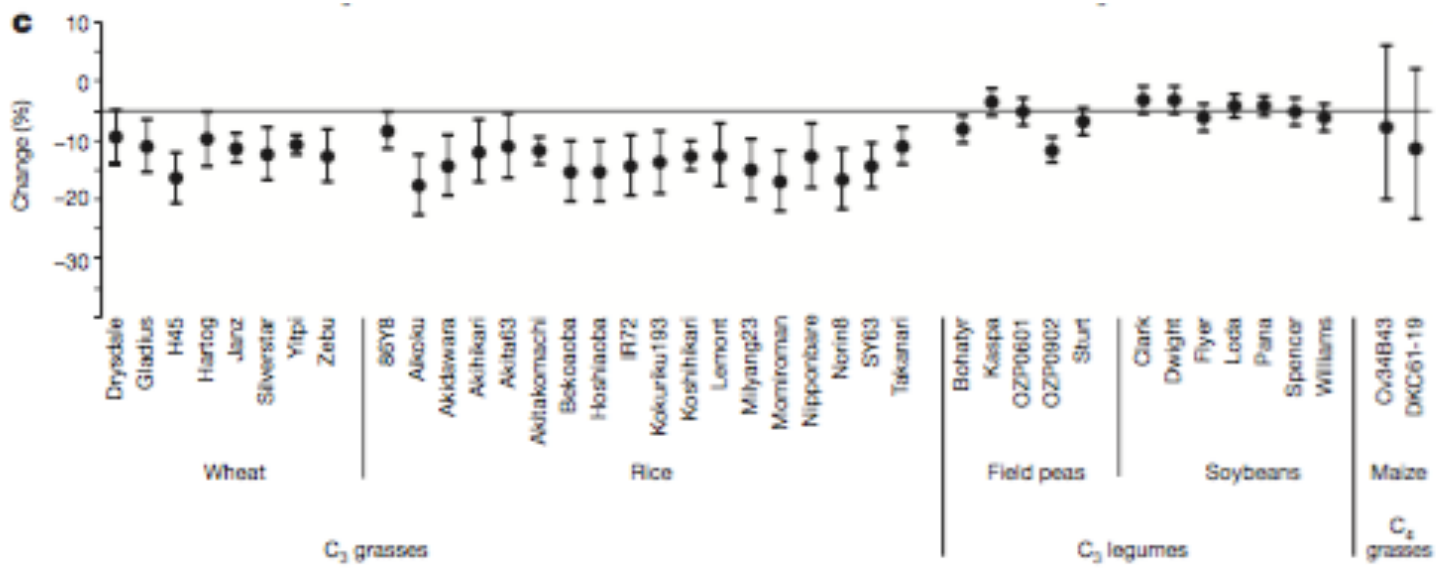
LETTER

doi:10.1038/nature13179

Increasing CO_2 threatens human nutrition

Samuel S. Myers[1,2], Antonella Zanobetti[1], Itai Kloog[3], Peter Huybers[4], Andrew D. B. Leakey[5], Arnold J. Bloom[6], Eli Carlisle[6], Lee H. Dietterich[7], Glenn Fitzgerald[8], Toshihiro Hasegawa[9], N. Michele Holbrook[10], Randall L. Nelson[11], Michael J. Ottman[12], Victor Raboy[13], Hidemitsu Sakai[9], Karla A. Sartor[14], Joel Schwartz[1], Saman Seneweera[15], Michael Tausz[16] & Yasuhiro Usui[9]

Change in protein at CO_2 conc ~550 ppm



Pulse yield (ton) / hectare

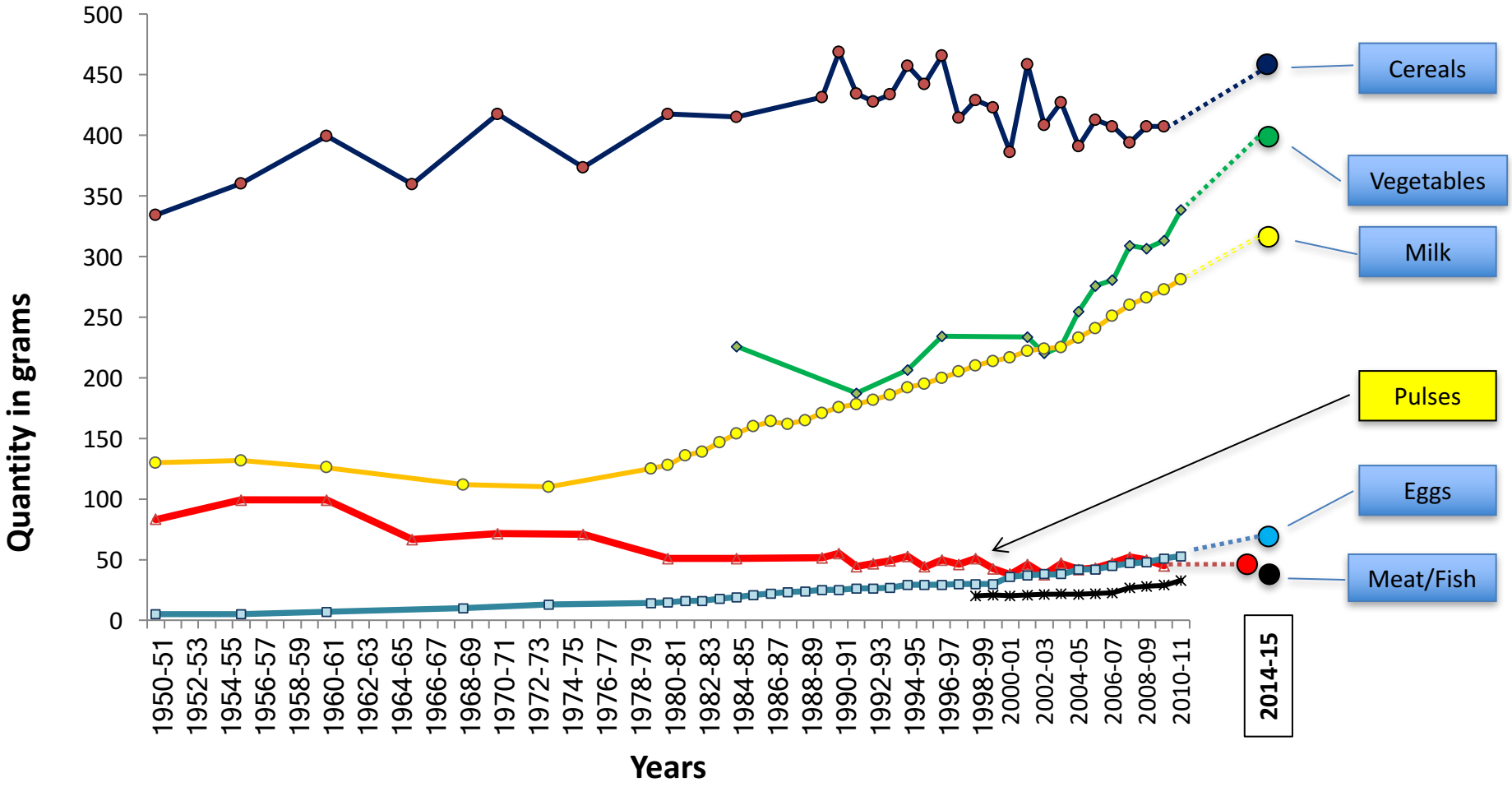
50 years of change

Source: FAO

Country/Year	1961	2012
China	0.9	1.4
Burma	0.4	1.3
Canada	1.1	1.9
Brazil	0.7	1.1
India	0.5	0.6

- Cereals: 3-4 ton/hectare: 5-7 fold higher
- Sugarcane: 75 ton/hectare: 100 fold higher

India - Trends in per capita availability 1951 - 2015



- http://eands.dacnet.nic.in/PDF/Agricultural_Statistics_At_Glance-2015.pdf
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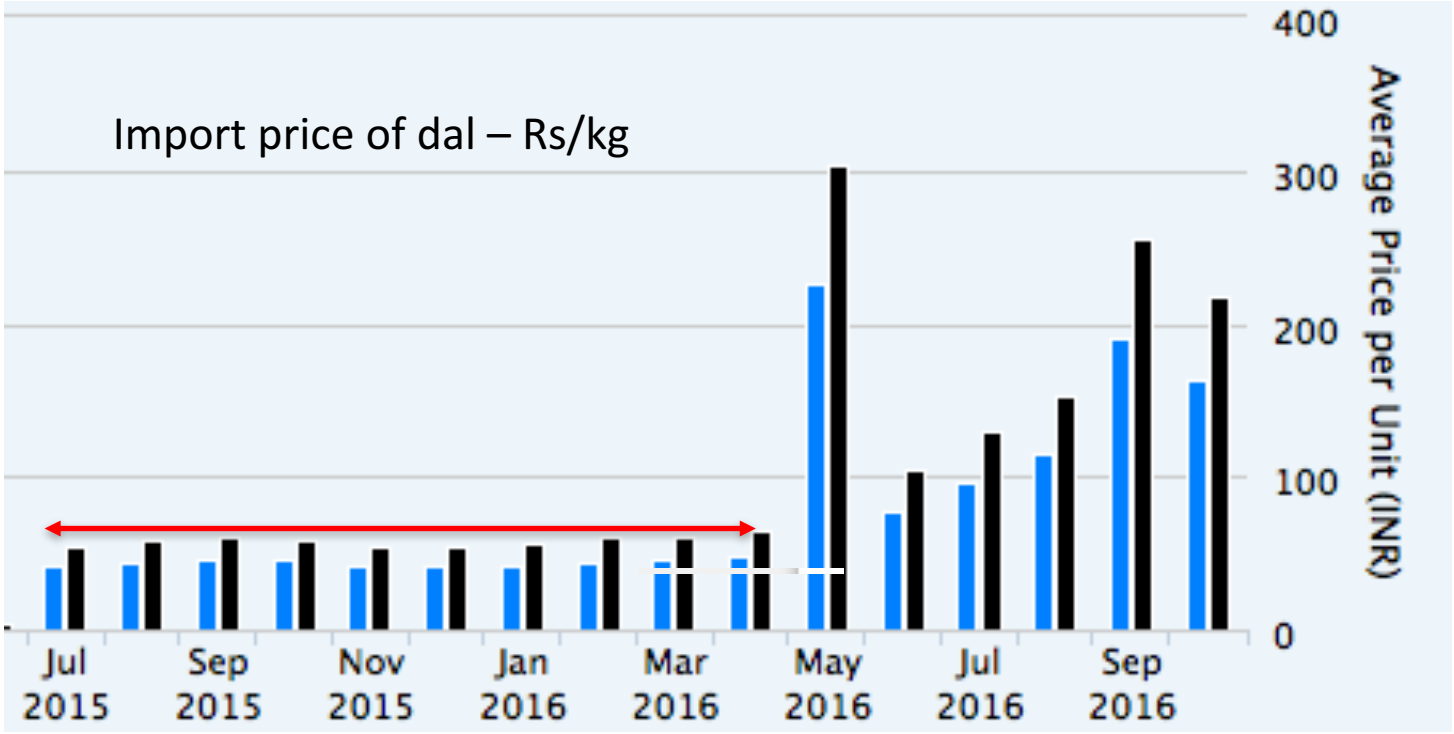

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Pulse crop prices jump in Canada, even as supply grows

Farmers boost production to capitalize on drought in India

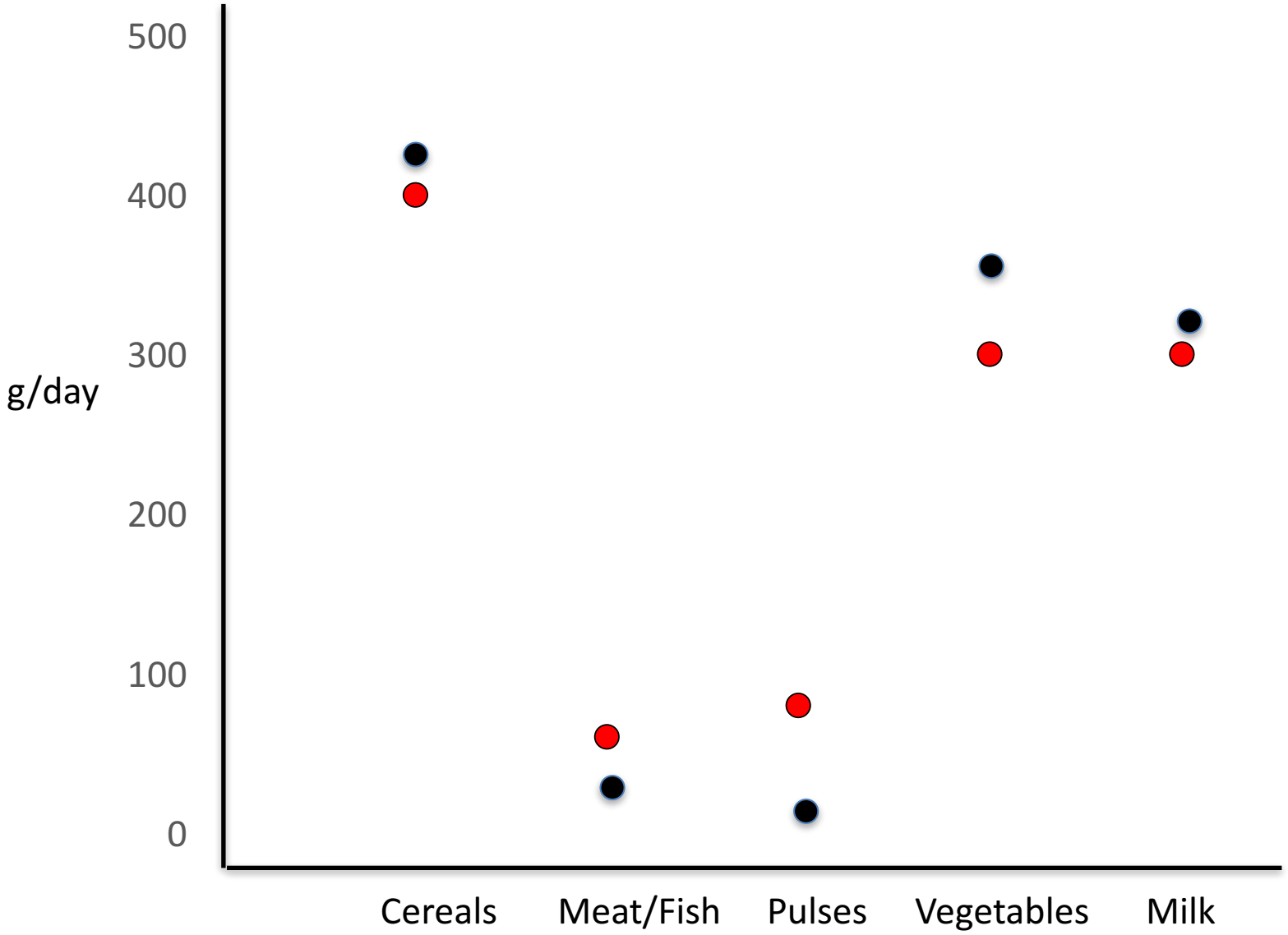
By Kyle Bakx, CBC News Posted: Feb 18, 2016 5:00 AM ET | Last Updated: Feb 18, 2016 5:00 AM ET

Many complicating factors

- Fragmented landholding, low mechanization
- Pulses are grown with 'residual' water- *Not* rain or irrigation fed
- *No* fertilizer; *No* seed distribution; *No* agricultural extension services

- MSP – difficult to understand; skewed towards cereals
  - MSP for Cereal:Pulses = 1:3 BUT Production = 6:1
  - Should be crop neutral
- WTO - '*de minimis*' clause; '*Amber Box*' subsidies - 10%
  - Limiting clause; India uses its subsidized grain for the PDS, not export
  - India cannot 'bring' pulses into this fold- since pulses are not in the PDS

Food need vs availability vs consumption



Data: The NSSO survey

- The Household Consumer Expenditure Surveys of National Sample Survey Office (NSSO) are the primary source of data on various indicators of living standards of different segments of the population at National and State levels in India.
- This is a household survey, using a 30 day recall (7 day is also available recently)
- The raw data is from the latest round of the survey (68^{th}), carried out during July 2011 to June 2012, the ninth quinquennial survey in the series.
- Based on consumer expenditure
  - quantities of various items of consumption using an exhaustive list of food items consumed by the household during the recall period.
  - Quantities of food consumed by different households converted to nutritive values
  - Household demographics used to estimate per capita/consumer nutrient intake.
- All the analyses were conducted using R.

Data: The NSSO survey
Geographical coverage and sample size

- The survey covered the whole of the Indian Union except interior villages of Nagaland situated beyond five kilometers of the bus route and villages in Andaman and Nicobar Islands which remain inaccessible throughout the year.
- No sample was surveyed in the districts of Leh (Ladakh), Kargil and Poonch of Jammu & Kashmir.

- Each district from the state and union territory is taken as the primary stratum which is divided into rural and urban sector.
  - If the number of households of a district is large, it is sub-divided into two or more sub-strata of nearly equal households by grouping together contiguous groups of villages having similar socio-economic characteristics.
  - Villages within each sub-stratum for both the sectors are taken as the first-stage units.

- From each sample village and urban block, two samples of 8 households available for survey were selected as second-stage units.
- The sample size consisted of 59,695 rural and 41,967 urban households.

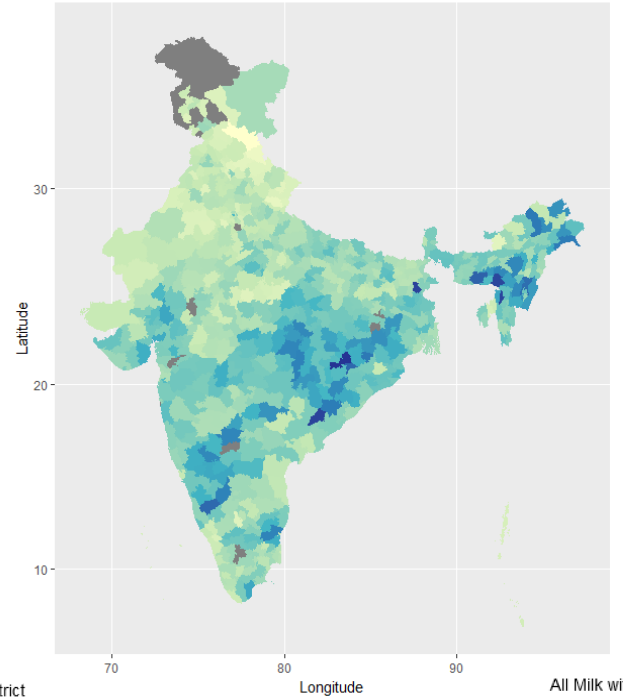
Data: The NSSO survey
Reporting and data weighting

- To derive individual level intakes from household level intakes, consumer units were used as a proxy for body weights of individuals within the household, since body weight was not available in this survey
- Only the number, sex, and age of members within the household were provided.
- Children aged <6 months are usually exclusively breastfed, but could not be distinguished from >6-month-old children, as the age was reported in completed years; therefore, children <1 year were not included in age-specific analyses.
- The data were weighted appropriate for the survey design and sampling plan to allow the estimation of the intake of nutrient by an individual belonging to a population category (Adult men, Adult women, Girls 16-17y, Boys 16-17y etc).

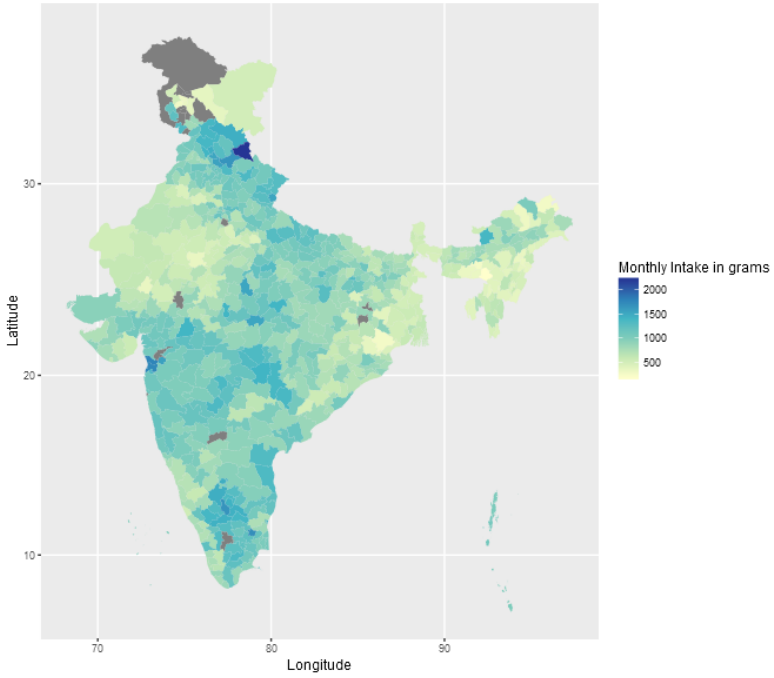
Identifying risk of a deficient intake

- EAR cutpoint method
- EAR was considered for each consumer unit
- Increased (lysine, limiting AA) by ~20% to account for parasites and EED

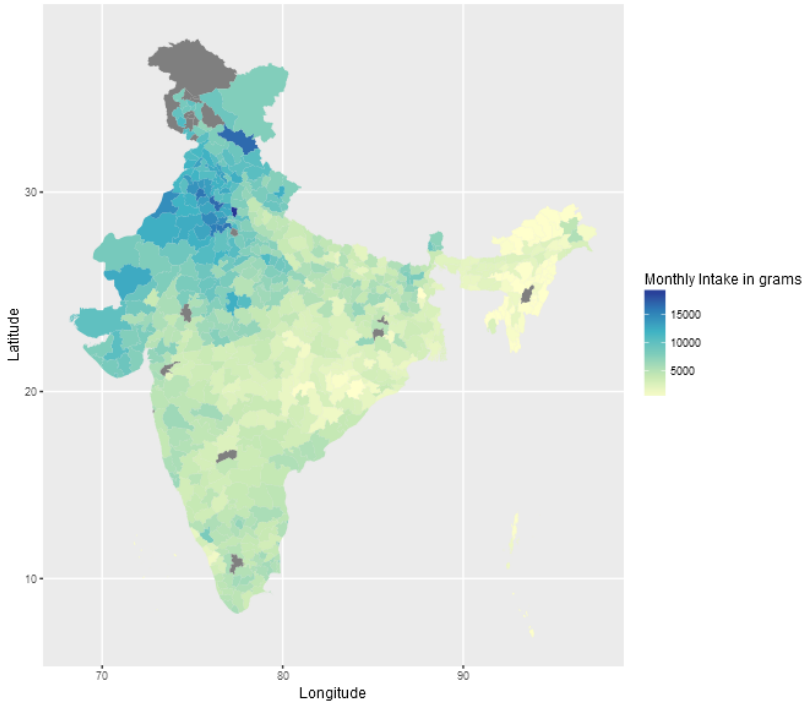
Risk of deficiency of quality protein- by District

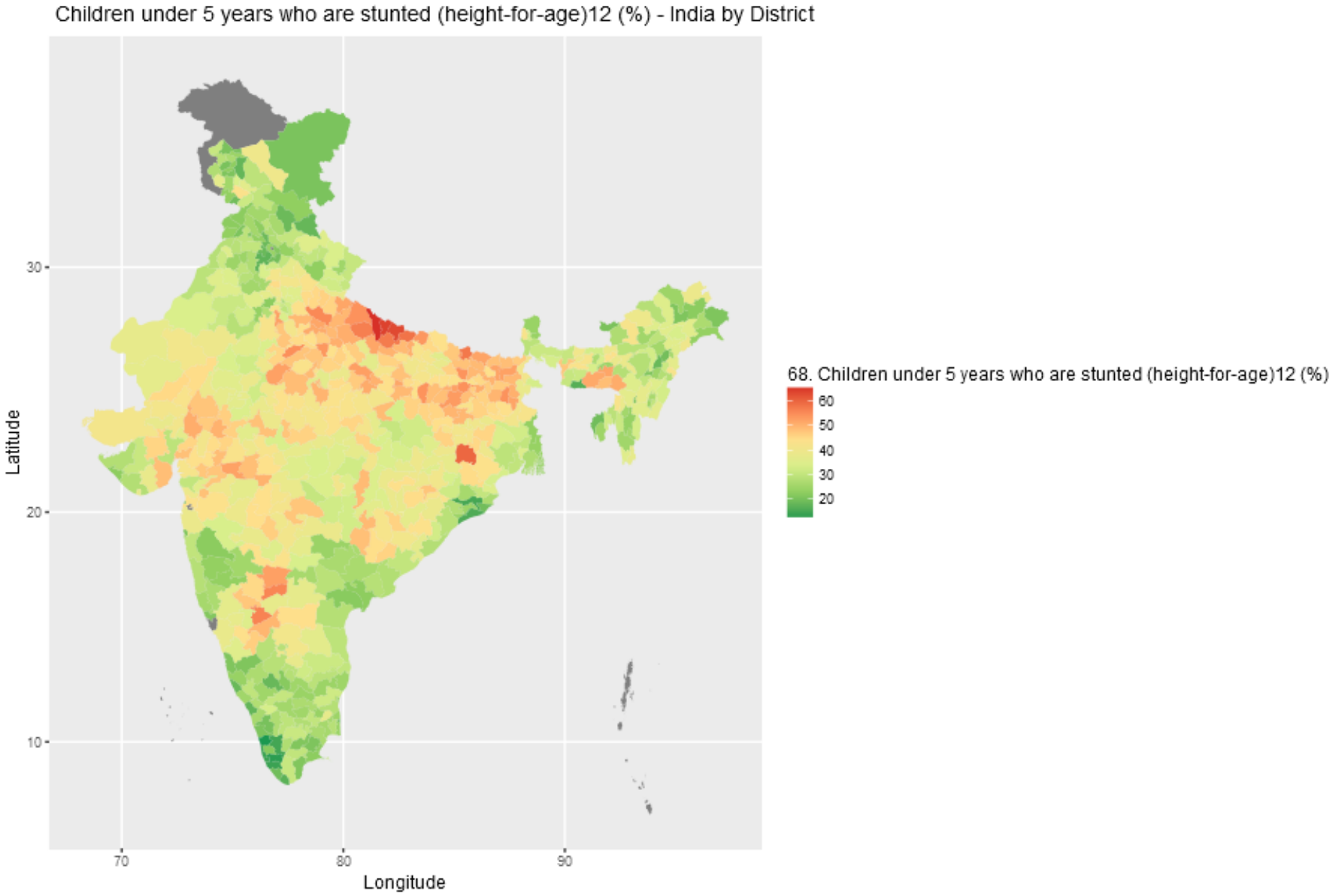


All Pulses Monthly Intake in grams per consumer unit- India by District



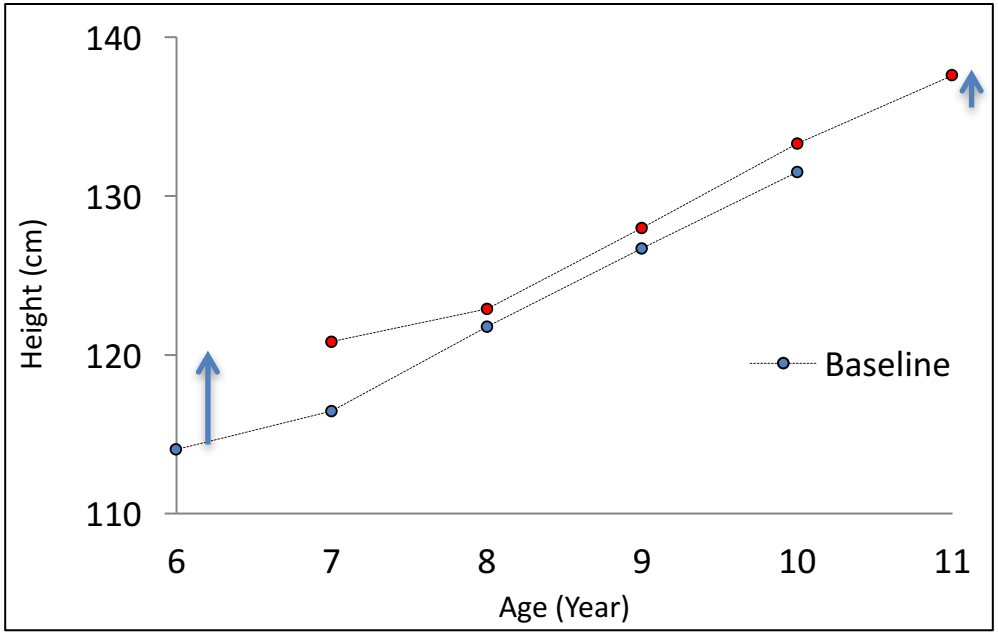
All Milk without Baby Food Monthly Intake in grams per consumer unit- India by District

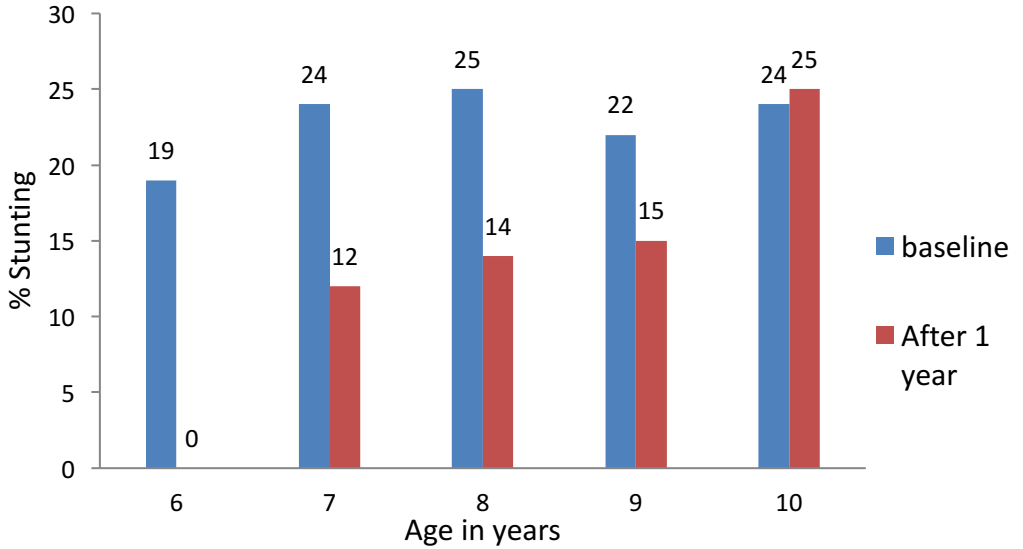



Children under 5 years who are stunted (height-for-age)12 (%) - India by District
Latitude
30
20
10
70
80
90
Longitude
68. Children under 5 years who are stunted (height-for-age)12 (%)
60
50
40
30
20

Re-analysis of a 1 year intervention with quality protein in Indian children. Muthayya et al, Am J Clin Nutr 2009

- A 1 year intervention in school children – 2 high protein snacks/day
- PE ratio 13%
- Reanalysis of all children (n=600)
- No control group





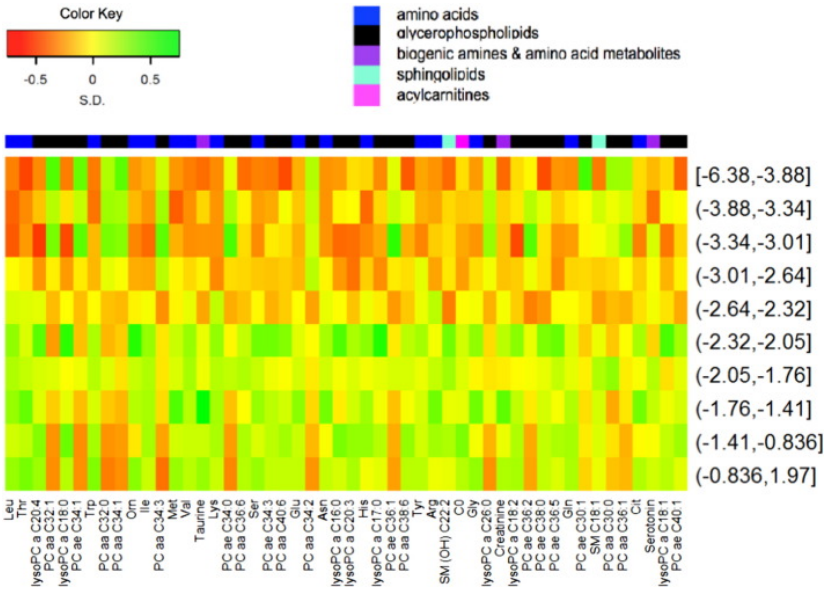
EBioMedicine. 2016 Apr; 6: 246–252.
Published online 2016 Feb 19. doi: 10.1016/j.ebiom.2016.02.030
PMCID: PMC4856740

Child Stunting is Associated with Low Circulating Essential Amino Acids

Richard D. Semba,[a,*] Michelle Shardell,[b] Fayrouz A. Sakr Ashour,[c] Ruin Moaddel,[b] Indi Trehan,[d,e] Kenneth M. Maleta,[e] M. Isabel Ordiz,[d] Klaus Kraemer,[f,g] Mohammed A. Khadeer,[b] Luigi Ferrucci,[b] and Mark J. Manary[d,e]

Children with stunting had lower serum concentrations of

- All essential amino acids
- Conditionally essential amino acids
- 6 different sphingolipids.



Many key questions for current policy priorities

- What is the optimal protein (and other nutrient) requirement in under-nourished populations in challenging environments?
- How do we provide enough high quality food and protein in India?
- Does one size fit all?
- What production systems allow for maximum productivity in a context of increasing water scarcity, climate change and need for ecologically-sensitivity?