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Dietary Protein Quality – Recent Advances

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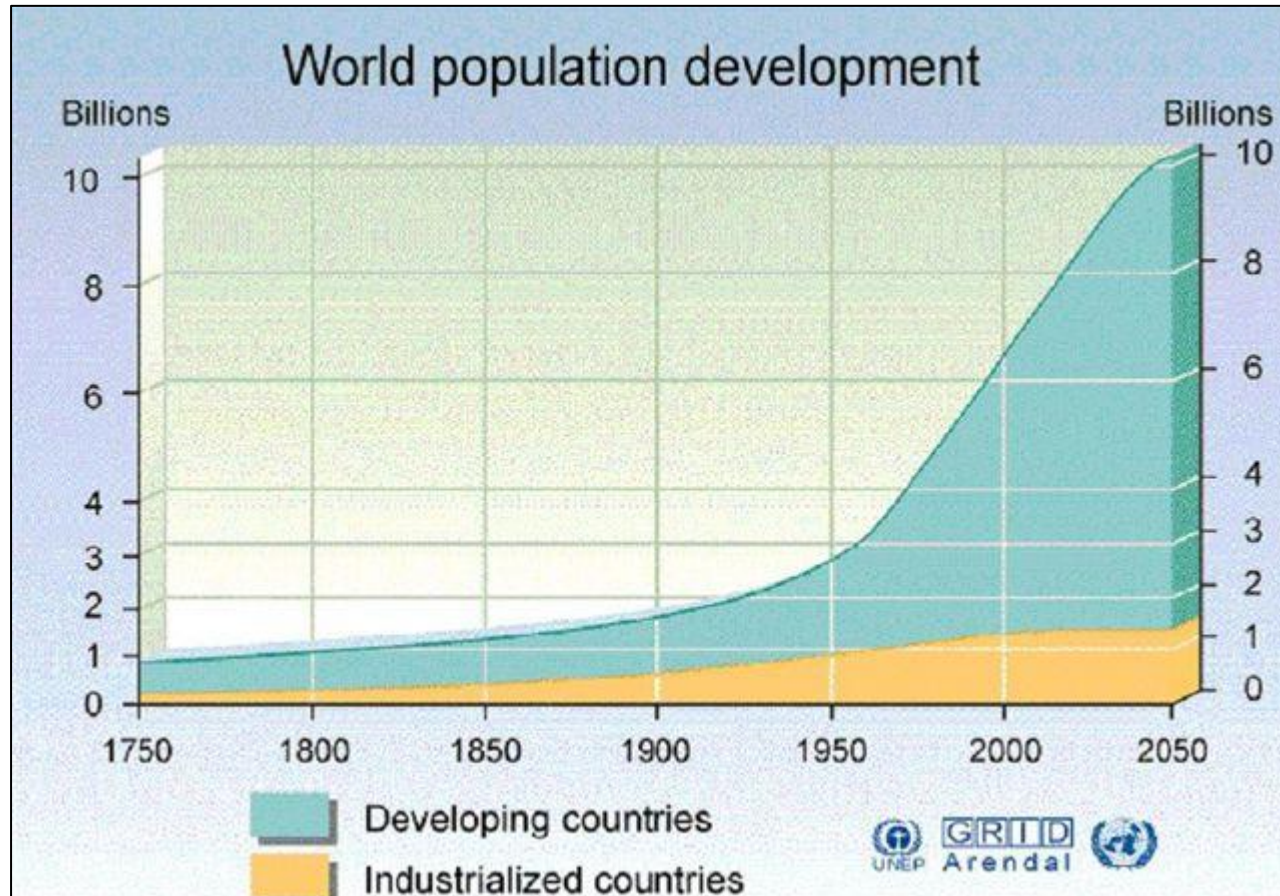
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**The world faces a major
challenge in food production and
environmental sustainability
over the next 30 years.**

“Forget the credit crunch and oil, the new global crisis is food”

Financial Times

Population Growth



-
- > It is estimated that the world needs to produce 70% more food by 2050.

AND not just more food but **nutritionally** better food.

- > Burgeoning middle class will demand more animal proteins (milk, meat, eggs, fish)

Already:

“World-wide 842 million people are undernourished. Protein/Energy Malnutrition is by far the most lethal form of malnutrition – Children are its most visible victims”

WHO (2001)



“Protein / Energy
malnutrition affects
every fourth child
world-wide”

WHO/NHD (2000)

At the same time:

There is an
“obesity
epidemic”
world-wide.



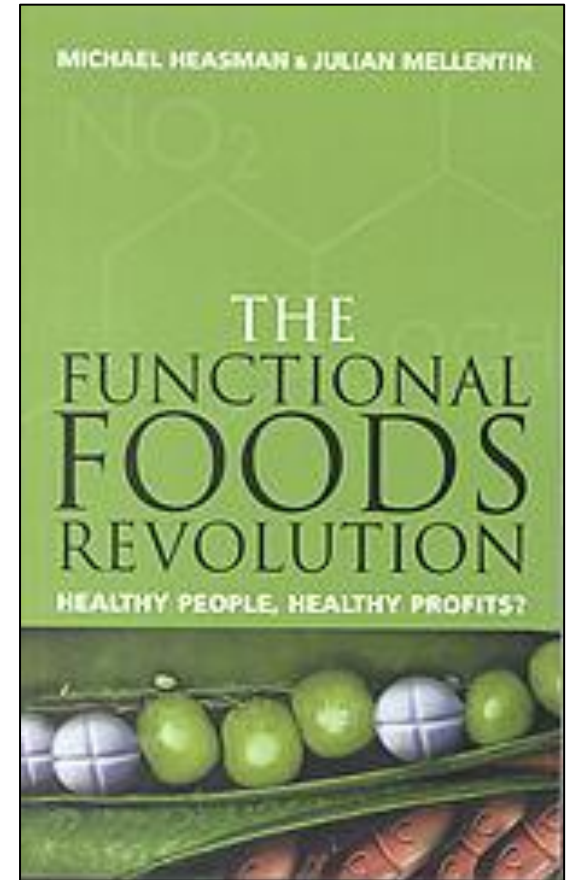
The Metabolic Syndrome is seen increasingly in both developed and developing countries

- > Obesity
- > High blood pressure
- > Type II diabetes
- > Cardio-vascular disease

These are largely **preventable** conditions (diet/lifestyle)

High-protein foods are “in-vogue”:

- > Awareness of role of protein in satiety and body muscle metabolism.
- > Estimates of protein requirement being revised upwards
- > Emphasis towards food/health/wellness (especially high protein foods)
- > High-protein “weight loss” foods and diets.



**This all means an increasing
global demand for food protein.**

With Increased Demand for Protein:

**Dietary Protein Quality will become
of fundamental importance**

Not all proteins are equal nutritionally

- > Milk
- > Soya
- > Fish
- > Meat
- > Egg
- > Bean
- > Peas
- > Cereal
- > Pulses etc



In particular vegetable-based proteins are of lower quality than dairy/meat/fish based proteins

- > fibre
- > anti-nutritional factors
- > different structures

This is **not** properly captured in the traditional way of describing the Protein Quality of food: “**Protein Digestibility Corrected Amino Acid Score**”, PDCAAS.

How is PDCAAS calculated?

1. Amino acid composition of protein is determined.
2. Amino acid composition is corrected for single value of Protein digestibility (rat faecal).
3. Digested amino acids are compared with required amino acid values for human.
4. Lowest ratio is the score.
5. If score is greater than 1.0 it is truncated to 1.0

PDCAAS is inadequate for several reasons:

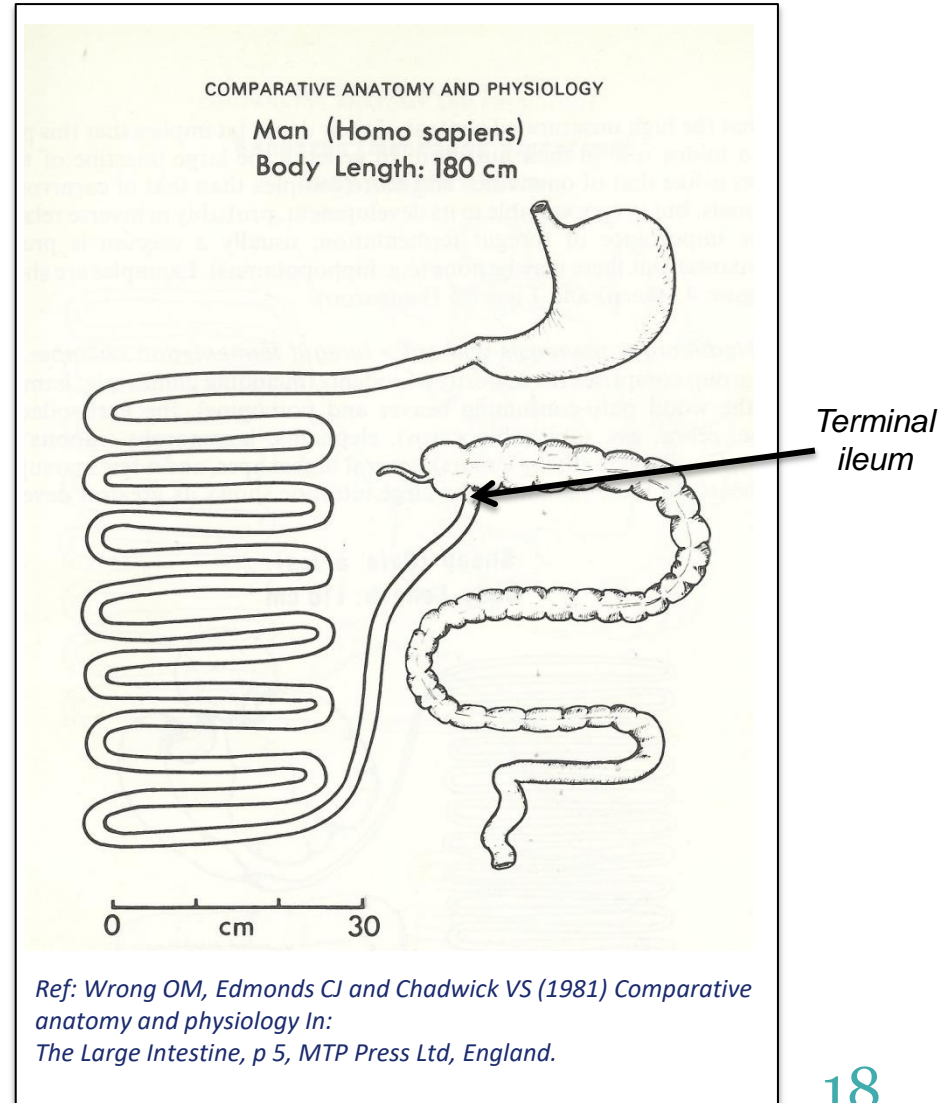
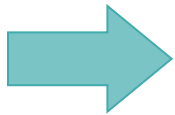
- > Truncation of scores greater than 1.0 to 1.0 (loses much information).
- > Protein digestibility rather than individual amino acid digestibilities.
- > Use of conventional lysine (For many processed foods conventionally determined lysine, often first-limiting amino acid, is in error).
- > Use of Faecal Digestibility (rat assay)
- > Inadequate representation of endogenous/metabolic protein.

Amino acid digestibility needs to be determined at the end of the small intestine (ileum): True ileal AA digestibility.

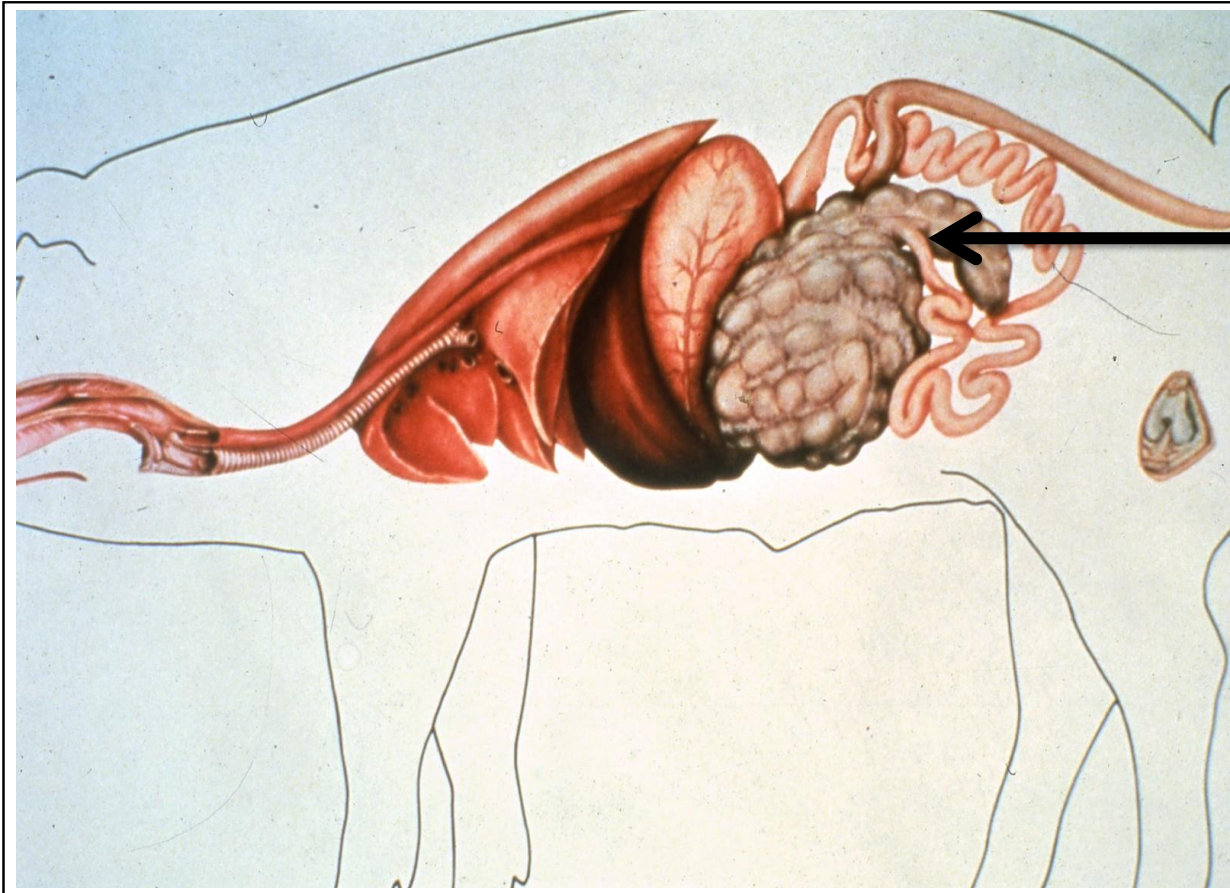
In humans:

- > Digesta can be collected using ileostomates
- > Digesta can be collected using a naso-ileal tube
- > Both methods have drawbacks and are not routine

Need for an animal model.

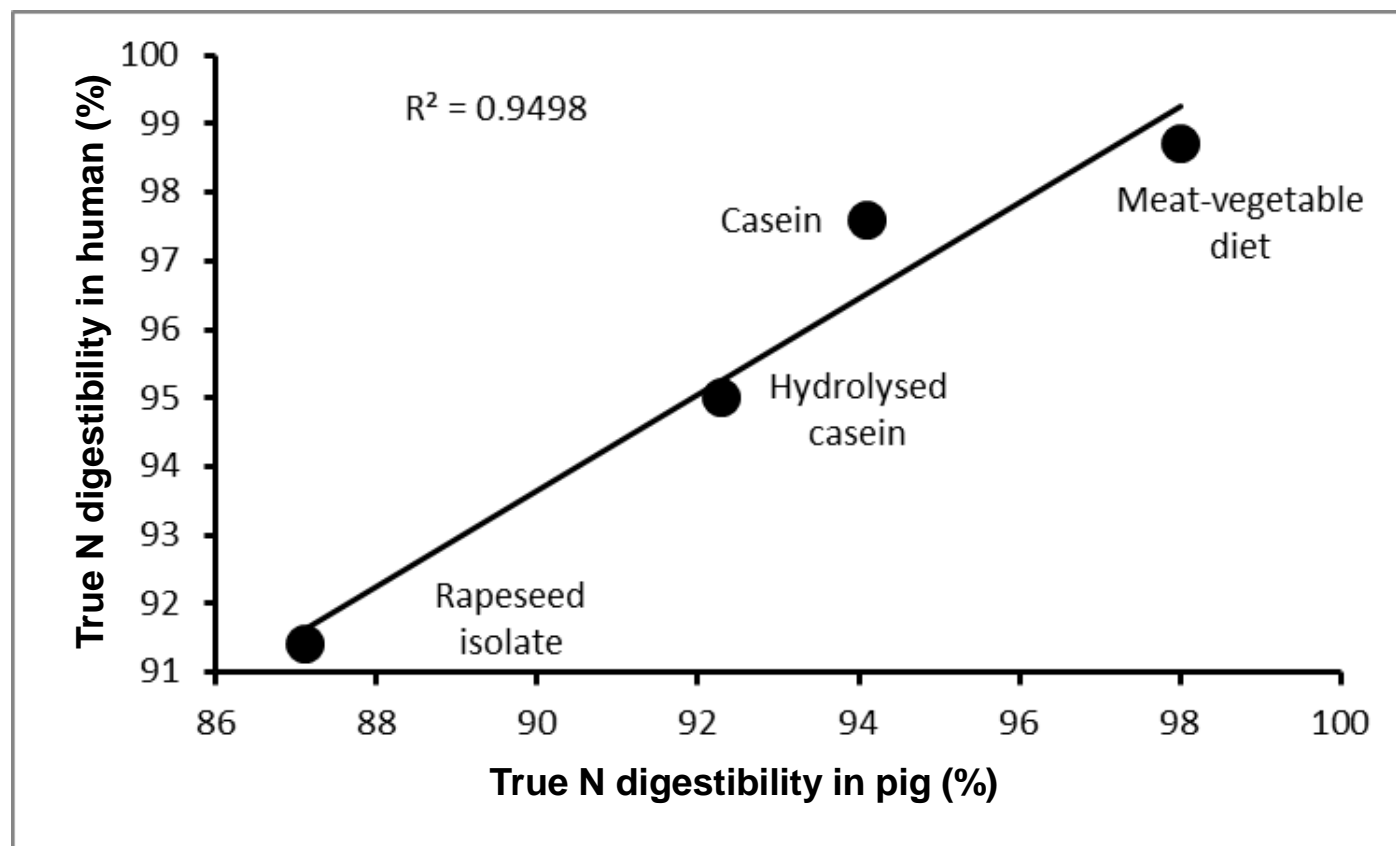


Growing pig (a meal-eating omnivore) is preferred model:



*Need to
collect ileal
digesta*

True ileal AA digestibility in the adult human and growing pig



(Moughan, unpublished)

20

The three-week-old piglet is a good model for protein digestion in the 3-month-old baby



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Milk-fed piglet as model for human baby

Simopoulos AP (ed): Nutritional Triggers for Health and in Disease.
World Rev Nutr Diet. Basel, Karger, 1992, vol 67, pp 40–113

The Piglet as a Model Animal for Studying Aspects of Digestion and Absorption in Milk-Fed Human Infants

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Classic citation paper

Underlying deficiencies of PDCAAS

Ileal vs Faecal Digestibility

Mean ileal (ileostomates) and faecal digestibility coefficients in adult human subjects.

	Ileal	Faecal	Difference
Glycine	0.72	0.87***	0.15
Serine	0.87	0.92***	0.05
Methionine	0.93	0.83***	0.10
Tryptophan	0.77	0.83**	0.06

Adult humans receiving a meat/cereal/dairy - based diet;

Rowan, A.M., Moughan, P.J. Wilson, M.N., Maher, K. and Tasman-Jones, C. (1994). *Br. J. Nutr.* **71**: 29-42

CP Digestibility vs AA Digestibility

True ileal digestibility coefficients

	<u>Soya isolate¹</u> True digestibility	<u>Human milk²</u> True digestibility
Methionine	99	100
Threonine	90	86
Histidine	96	95
Cysteine	90	-
Crude Protein	95	88

¹Rutherford, S.M. and Moughan, P.J. (1998) Laboratory rat assay; *J. Dairy Sci.* **81**: 909-917.

² Darragh, A.J. and Moughan, P.J. (1998) Piglet Model; *Br. J. Nutr.* **80**: 25-34

25

Processed Foods — Conventional AA Digestibility Is Inaccurate: (lysine as example)

- > Conventional determination of lysine and lysine digestibility are inaccurate for processed foods.
- > Damaged lysine molecules revert to lysine with conventional procedures.
- > Need for a new approach.
- > Reaction of food and digesta with o-methylisourea allows accurate determination of absorbed actual lysine.

Differences can be great

Digestible reactive¹ (available) lysine versus digestible total lysine (conventional) (gKg⁻¹)

	Lysine		Difference %
	Conventional	Available	
Shredded Wheat	1.8	1.6	11
Dried corn	2.6	1.9	27
Unleavened bread ²	6.5	4.9	25
Puffed Rice	1.1	0.6	45
Rolled Oats	3.7	2.8	24
Wheat Bran	1.1	0.7	36
Corn	0.4	0.2	50
Evaporated milk	23.4	20.5	12

¹Based on o-methylisourea assay; ²P Pellett, N Scrimshaw and P Moughan (unpublished data).

But generally not in dairy:

Ileal digestible total (conventional) and “available” lysine contents (g/kg air-dry) for 12 dairy protein sources

	Lysine	
	Conventional	Available ^a
Whole milk protein	26.2	24.0
Infant formula A	8.3	8.6
Infant formula B	9.1	9.2
Infant formula C	11.1	11.7
Whey protein concentrate	79.9	77.5
UHT milk	31.7	31.4
Evaporated milk	23.4	20.5
Weight-gain formula	24.4	24.1
Sports formula	20.4	19.1
Elderly formula	11.7	11.8
Hydrolysed lactose milk powder	27.2	25.1
High-protein supplement	14.3	14.3

^aBioavailable lysine; minimal difference between total lysine and reactive lysine denotes minimal Maillard damage. Adapted from Rutherfurd & Moughan (2005), with permission of the publisher.

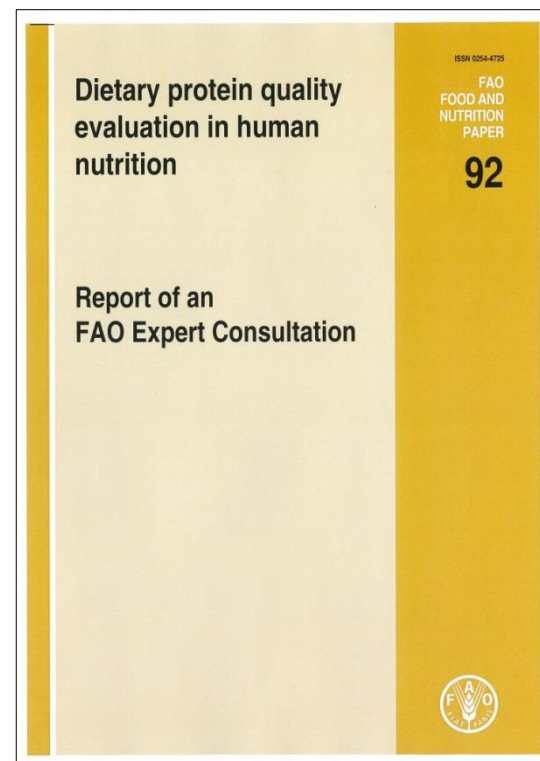
Truncation of scores undervalues good proteins

	Score			
	Milk Protein Concentrate	Whey Protein Isolate	Whey Protein Concentrate	Red meat
Non-truncated	1.31	1.25	1.10	1.10
Truncated	1.0	1.0	1.0	1.0

Where is thinking heading? (FAO, 2013)

1. Emphasis on individual digestible amino acid contents rather than a single score (ie treat each amino acid as an individual unit). **This maximises the information on the nutritional (protein) value of food.**

- > Amino acid digestibility is determined at the end of the small intestine (True ileal digestibility).
- > For processed foods 'reactive lysine' is determined in diet and ileal digesta rather than 'total lysine' to give lysine availability measures.

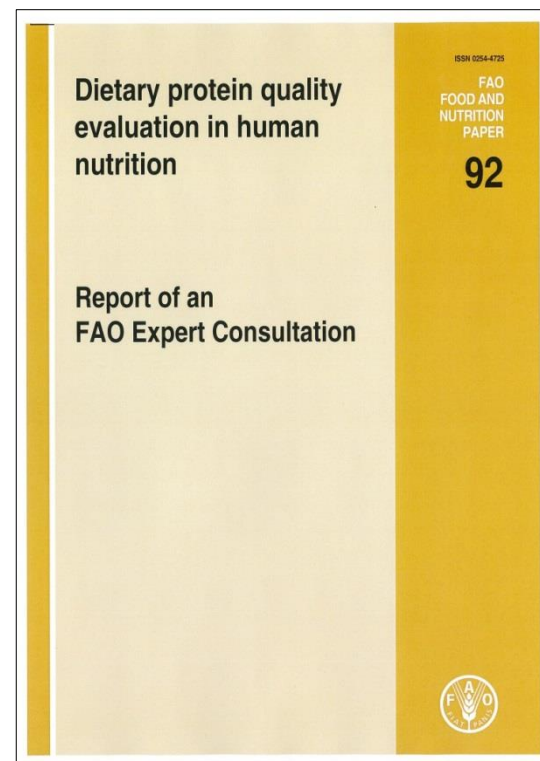


Where is thinking heading? (FAO, 2013)

2. When a single score of Protein Quality is needed **DIAAS** replaces PDCAAS.

New score (Digestible Indispensable Amino Acid Score, DIAAS) replaces PDCAAS:

- i. True (corrected for endogenous losses) Ileal digestibility of each amino acid
- ii. Available versus conventional digestible lysine
- iii. Disbanding Truncation of Scores
- iv. Pig as preferred animal model for determining digestibility
- v. Updated reference (AA requirement) patterns



DIAAS is a considerable step forward in the description of Dietary Protein Quality

DIAAS and PDCAAS values¹ are different. PDCAAS often overestimates particularly for lower quality proteins

	Milk Protein Concentrate	Whey Protein Isolate	Soya Protein Isolate	Pea Protein	Cooked Beans	Cooked Rolled Oats	Wheat Bran	Roasted Peanuts	Rice Protein	Cooked Peas
PDCAAS	1.00	1.00	1.00	0.89	0.65	0.67	0.53	0.51	0.42	0.60
DIAAS	1.18	1.10	0.97	0.82	0.58	0.54	0.41	0.43	0.37	0.58

¹(Rutherford and Moughan, unpublished data).

Such differences have meaningful impacts in describing protein supply and the value of specific proteins.

Example based on Indian foods^{1,2,3}

	True Ileal Digestible Lysine intake (g/d)	Adequacy (%)
Mung bean dal and wheat roti	1.76	0.83
Lentil dal and wheat roti	1.83	0.87
Mung bean dal and cooked rice	1.91	0.90
Mung bean dal and maize roti	1.34	0.63
Chickpea curry and maize roti	1.28	0.60
Rajmah and maize roti	1.22	0.58
Rajmah and naan	1.33	0.63

Rutherford, Bains and Moughan (2012). British Journal of Nutrition: 108.

¹Intakes based on amounts required to meet energy intakes. 70 kg adult.

²Each meal is 20% legumes 80% cereal, based on upper estimates of legume and cereal supply.

³Adequacy = $\frac{\text{Intake}}{\text{Requirement}} \times \frac{100}{1}$

Re-cap

- > Protein will be central to world food and nutrition security.
- > Protein Quality Evaluation is of fundamental importance.
- > A new emphasis on the availability of each AA as a single nutrient.
- > DIAAS incorporates recent scientific advances. Is an improvement over the old Scoring method (PDCAAS).
- > Robust information on true ileal AA digestibility of foods and DIAAS values is greatly needed.
- > DIAAS represents an opportunity for the marketing of dairy foods.

Conclusion

These are important steps in the fight against malnutrition, both under- and over-feeding and in ensuring sustainable food and protein nutrition.

Thank you



38