Nutritional & Health Benefits of Food Proteins

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Content

- Protein function in the body
- Protein quality
- Protein digestion and uptake
- Anti nutritional factors in plant derived proteins

Protein function in the body

- Structural Functions (collagen, keratin)
- Movement (muscle proteins)
- Enzymes (digestion, all kinds of reactions in the body)
- Hormones (insulin, glucagon)
- Immune function
- Fluid balance
- Acid base balance
- Transport (calcium, zinc, iron, Vitamin B6, oxygen)
- Energy source

- At least 10,000 different proteins make the body what it is !

How Much Protein Do You Need?

- Well, it depends on your sex, age, exercise and weight

- Infants require about 10 grams a day.
- Teenage boys need up to 52 grams a day.
- Teenage girls need 46 grams a day.
- Adult men need about 56 grams a day.
- Adult women need about 46 grams a day

Protein Quality

- **High-Quality Proteins**
  - Contains all the essential amino acids
  - Are very well digested in the stomach and small intestine
  - Are very well absorbed by the small intestine.

- **Complementary Proteins**
  - Combination of protein sources that compensate each other lack of an essential amino acid

Amino acids

- Nonessential amino acids, also called dispensable amino acids, are ones the body can create.

- **Essential amino acids**, also called indispensable amino acids, must be supplied by the foods people consume.
  - Essential amino acids include isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine.

- Conditionally essential amino acids refer to amino acids that are normally nonessential but essential under certain conditions (Arginine, glutamine, and cysteine)

Amino acid requirement pattern based on amino acid requirements of preschool-age child

- Source FAO

Amino acid	Requirement
	mg/g crude protein
Isoleucine	28
Leucine	66
Lysine	58
Total sulfur amino acids	25
Total aromatic amino acids	63
Threonine	34
Tryptophan	11
Valine	35
Total	320

Calculation of amino acid score

- The amino acid score is the lowest number for any of the essential amino acids in a protein.

$$\text{AAS (\%)} = \frac{\text{mg of limiting amino acid in 1 g of test protein}}{\text{mg of same amino acid in 1 g of reference protein}} \times 100\ \%$$

Example amino acid score (Rubisco)

Amino acids	Code	Content	FAO	AAS
Isoleucine	Ile (I)	3,8%	2.8%	137
Leucine	Leu (L)	8,6%	6.6%	130
Lysine	Lys (K)	5,1%	5.8%	87
Tryptophan	Trp (W)	2,0%	1.1%	186
Threonine	Thr (T)	6,9%	3.4%	202
Valine	Val (V)	6,9%	3.5%	196
Total sulphur		4,4%	2.5%	176
Total aromatic		9,2%	6.3%	147

AAS of Rubisco is 87 %

The 5 best scoring plant proteins on base of AAS

- Survey of more than 50 plant sources (data from FAO)
- Five sources shows an amino acid score above **100**

	Protein (g/100g)	Ile	Leu	Lys	Total sulfur	Thr	Trp	Val	Total aromatic
Soybean	38	165	120	112	**105**	115	118	139	130
Cowpea	23,4	152	118	131	**100**	118	110	144	137
Quinoa	12	186	**102**	107	112	121	109	131	110
Turnip seed	6,6	153	109	**108**	187	129	104	157	120
Sword bean	24,5	175	134	**116**	125	158	264	161	168

- The data regarding amino acid composition tend to differ a lot depending on the literature source

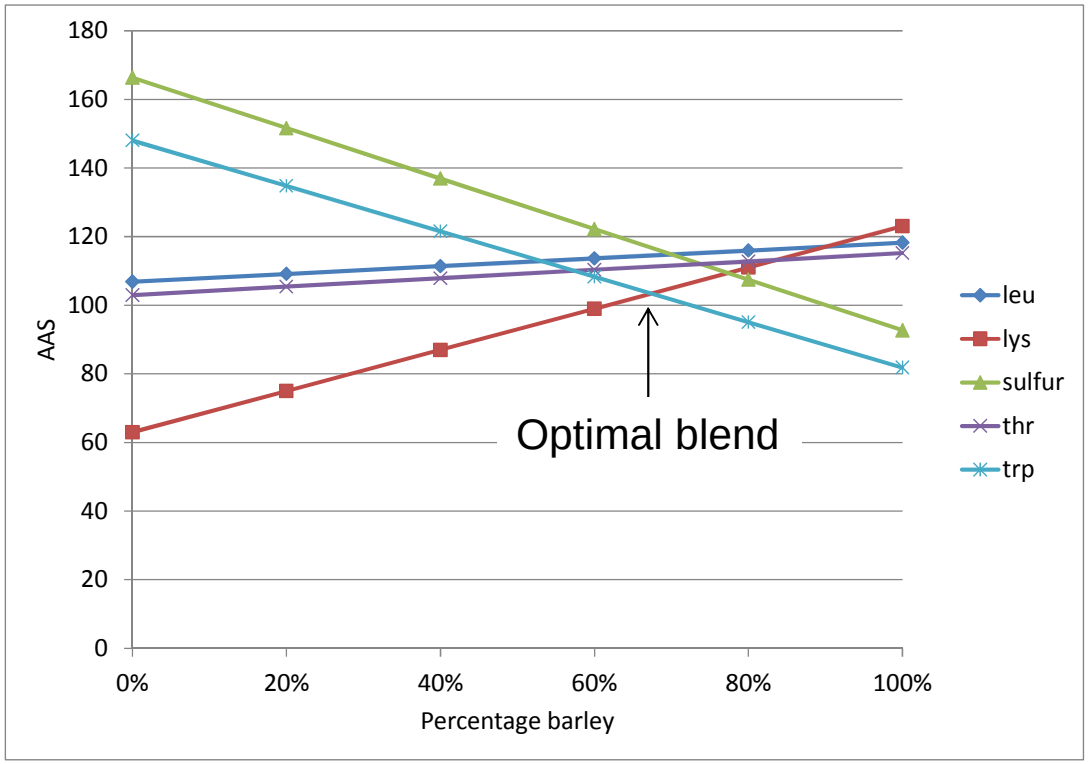
Mixing protein sources to improve the AAS

- By mixing different protein sources the most limiting amino acid can be partially compensated

Amino acid	Apple	Brazil nut	Apple/Brazil nut (1/1)
Isoleucine	151	106	128
Leucine	114	111	112
Lysine	123	51	87
Total sulfur a.a.	102	335	218
Threonine	130	81	106
Tryptophan	101	183	142
Valine	137	130	134
Total aromatic a.a.	77	111	94

Optimisation of ratio for maximum AAS

- Chickpea and barley protein



Calculation of PDCAAS

- **Protein Digestibility Corrected Amino Acid Score**
- PDCAAS = AAS × fecal true digestibility (%)
- Fecal true digestibility is the amount of nutrients absorbed from the small intestine
- **Example Rubisco**
  - AAS = 87
  - True digestibility is 99%
  - PDCAAS = 87 × 99% = 86

Fecal true digestibility, amino acid score and PDCAAS for some selected proteins.

Protein	Digestibility (%)	AAS %	PDCAAS (%)
Egg	98	121	118
Cow's milk	95	127	121
Beef	98	94	92
Soy	95	96	91
Wheat	91	47	42

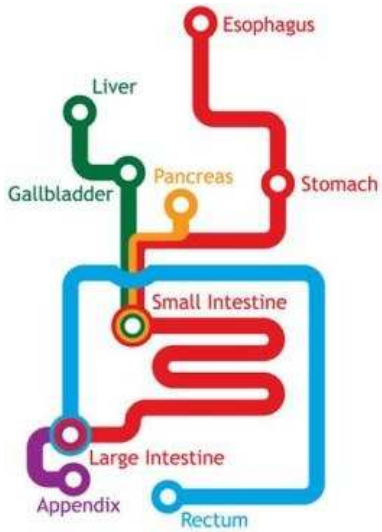
In case PDCAAS is more than 100, the score is set to 100

PDCAAS of several plant derived proteins

Protein source	AAS	True digestibility (%)	PDCAAS
Amaranth	92	90	83
Buckwheat	70	80	56
Millet	60	79	48
Rice	65	91	59
Chick-pea	82	88	72
Cowpea	100	79	79
Pea	87	88	77
Soybean	105	94	96
Sword bean	116	50	58
Velvet bean	89	68	61
Canola	95	87	83

Protein digestion

- The human body needs to fully digest proteins to the level of amino acids for uptake by the small intestine and for reuse in protein synthesis.
- Therefore the uptake of amino acids is strongly correlated to the ease at which proteins are digested

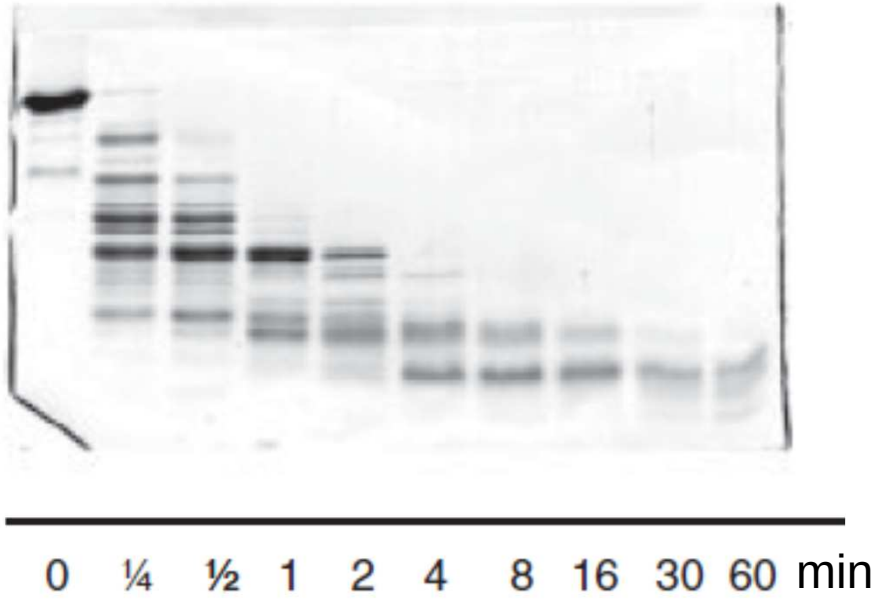


Proteases in the digestive system

- Stomach: pepsin
- Pancreas:
  - Trypsin
  - Chymotrypsin
  - Elastase
  - Carboxy-peptidase A
  - Carboxypeptidase B
  - Kallikreins
  - Small intestine: brush border enzymes

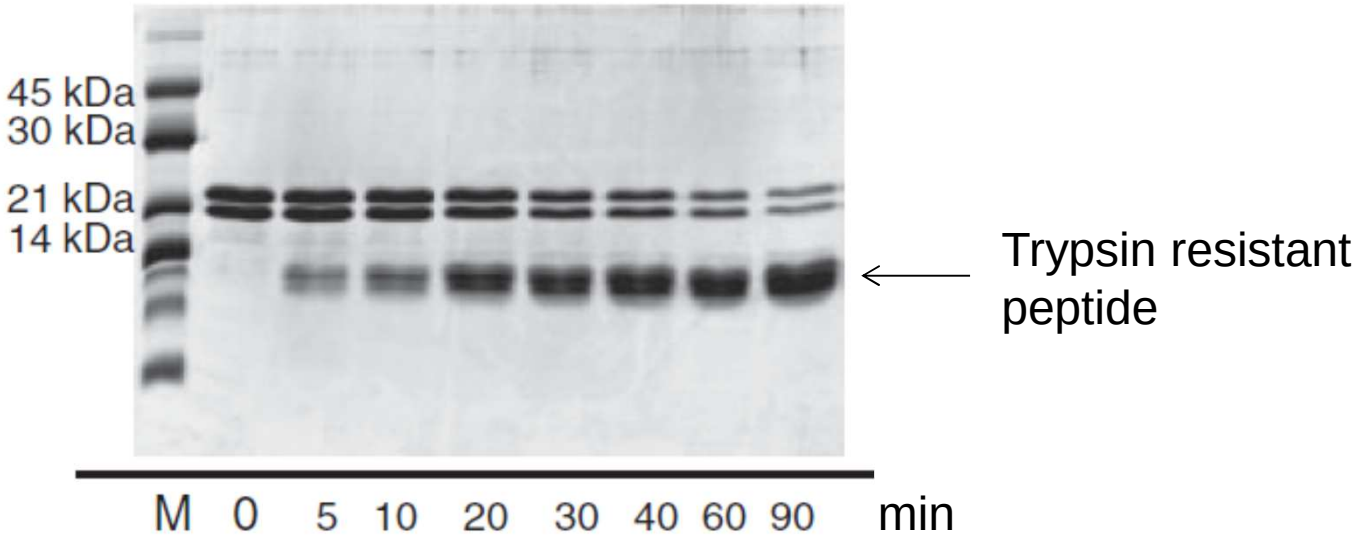
Digestion in the stomach

- Example of a peanut protein (Ara h1) hydrolysis by pepsin

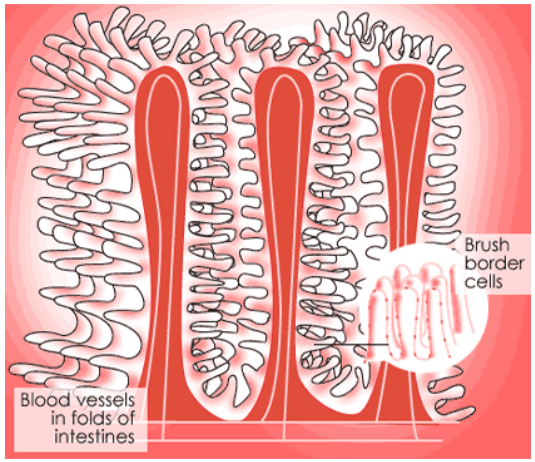


Digestion in the small intestine

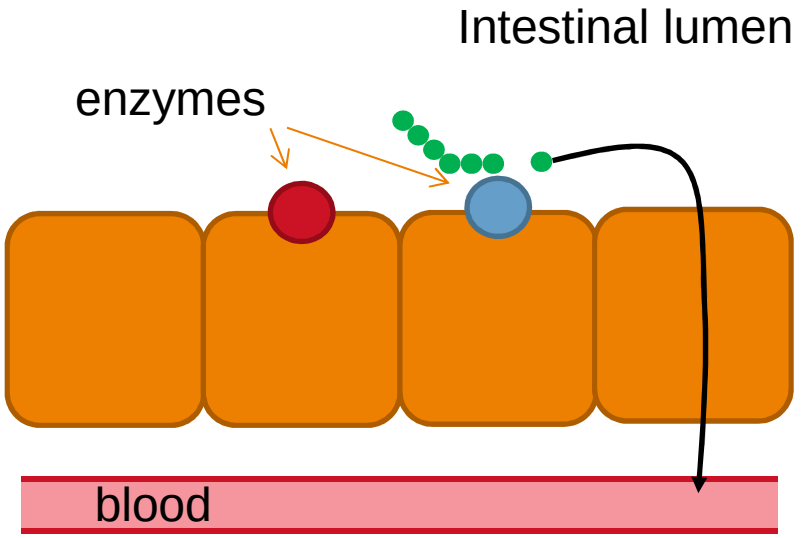
- Example of a peanut protein (Ara H2) hydrolysis by trypsin



Brush border enzymes



Brush border



Function brush border peptidases
further hydrolysis of luminal peptides, converting them to free amino acids and very small peptides.

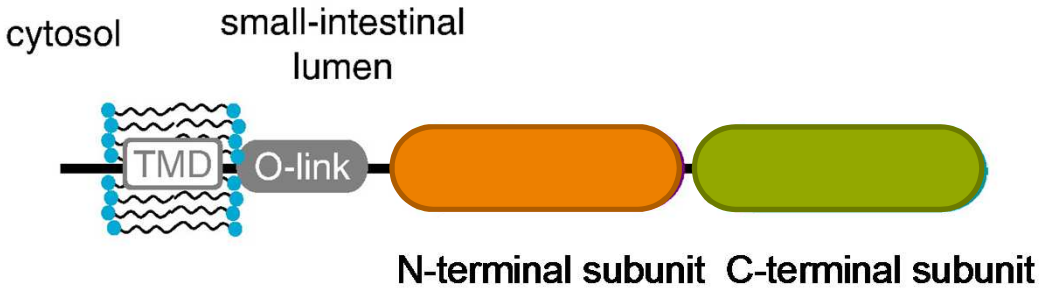
There is virtually no absorption of peptides longer than four amino acids

Brush border peptidases

Enzyme	Molecular mass	Carbohydrate content
Aminopeptidase A	170 (*2)	+
Aminopeptidase N	162 (*2)	+
Aminopeptidase W	130	+
Carboxypeptidase P	130	+
Dipeptidyl aminopept. IV	136 (*2)	+
Pteroyl polyglutamate hydrolase	91	
Enteropeptidase	300	+
Endopeptidase 24.11	96 (*2)	+
Endopeptidase 2	100(*2)	+
Γ-Glutamyl transferase	62 + 21	+
Peptidyl dipeptidase	180	

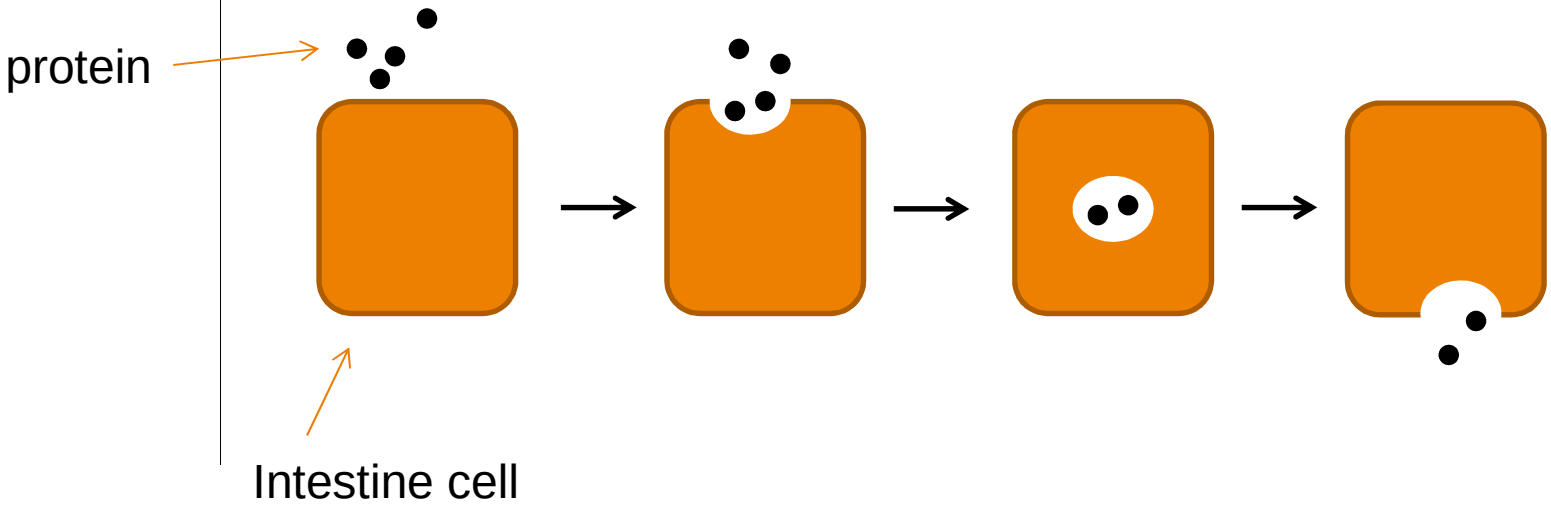
Common feature in 5 brush border peptidases

- Half of all the brush border peptidases are covalently linked dimers



Alternatives in uptake of proteins by the small intestine

- Sometimes whole protein or large protein fragments are found in the bloodstream. How is this possible as only amino acids seem to be taken up by the intestine ?
- Answer: several mechanisms are found that are used to take up larger protein molecules



Other factors that determine protein digestion

- Digestibility of protein in traditional diets from developing countries such as India, Guatemala, and Brazil is considerably lower compared to that of protein in typical North American diets (54-78 versus 88-94%).

- Reason:
  - The presence of less digestible protein fractions
  - high levels of insoluble fibre
  - high concentrations of anti-nutritional factors in the diets of developing countries (less refinery)

Examples of alteration of protein digestion

- Thermal processing
  - Can have a positive effect on digestion in case
    - globular proteins unfold
    - protease inhibitors are destroyed
  - Can have a negative effect on digestion when site reactions occur
    - Maillard reactions
    - protein crosslinking
- Chemical modification of proteins
- Enzymatic modification of proteins
  - Hydrolysis → positive effect
  - Crosslinking → negative effect

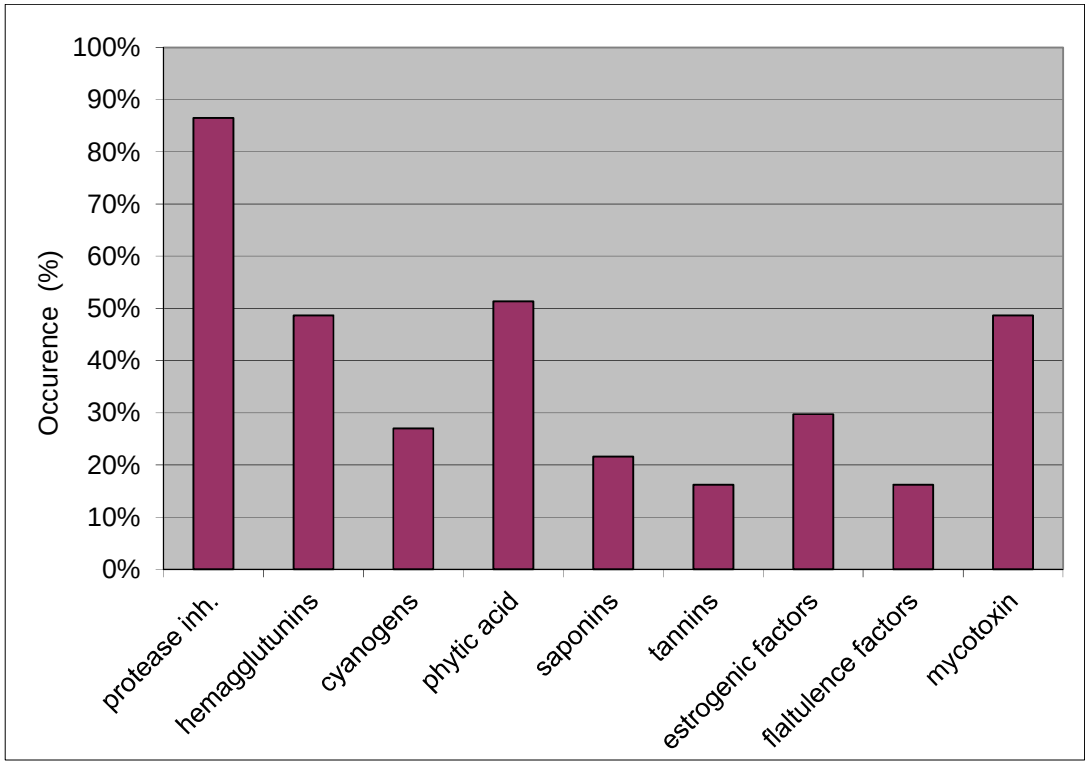
Anti nutritional factors in plant derived proteins

- Anti nutritional factors may occur naturally, such as protease inhibitors, glucosinolates, hemagglutinins, phytates, tannins, gossypol, etc. Around 25 natural antinutritional factors are known

- Anti nutritional factors may also be formed during heat/alkaline processing of protein products, yielding: Maillard compounds, oxidized forms of sulfur amino acids, D-amino acids, and lysinoalanine (LAL, an unnatural amino acid derivative).

Anti nutritional factors in plant derived proteins

- Occurrence of ANF's in 37 plant sources (tubers, legumes, cereals)



Conclusions

- Without proteins there is no life (on earth)
- Proteins are an essential part in our daily diet
- The quality of proteins is determined by:
  - Amino acid composition
  - Digestibility (natural factors but also processing)
  - Presence of anti nutritional factors (natural factors but also processing)