Proteinkvalitet:
Fra teori til praksis i den grønne omstilling

Ernæringsfokuskonference 2024
Landbrug & Fødevarer

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PROTEIN KVALITET – AKTUELT I DEN GRØNNE OMSTILLING

Dietary protein requirements and recommendations for healthy older adults: a critical narrative review of the scientific evidence

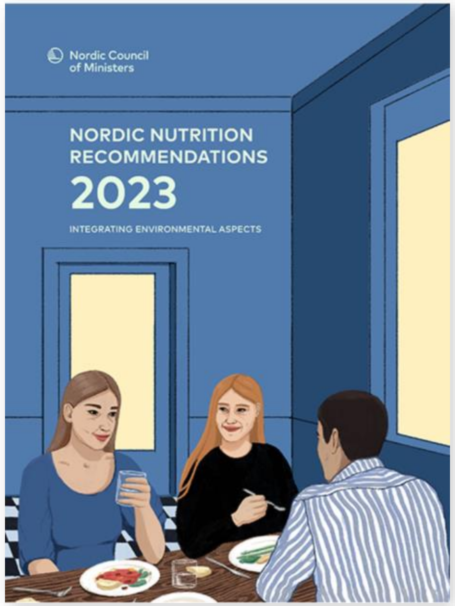
Proteinbehov og -anbefalinger igennem tiden

Table 1. Successive protein requirements and recommendations by international groups to ensure nitrogen balance in adults

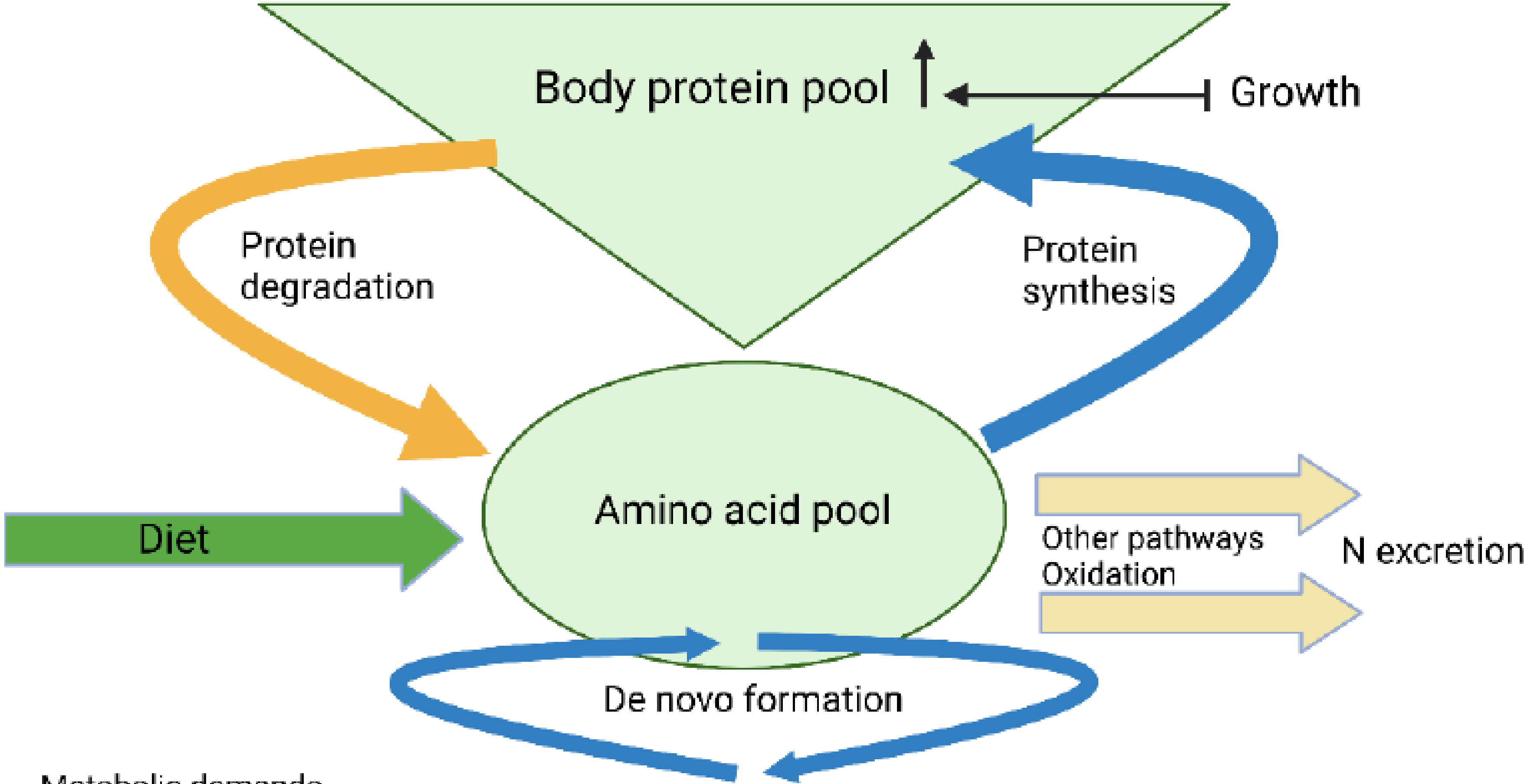
Report	Age	Methodological approach	Biological value of dietary protein (%)	Average protein requirements (g/kg/day)	Recommendation/ safe level of intake (g/kg/day)
League of Nations 1936[22]	Adults	–	–	–	1.0
FAO 1957[23]	Adults	N-balance	80	0.53	0.66
FAO/ WHO 1965[140]	Adults	Factorial	80	0.71	0.89
FAO/ WHO 1973[94]	Adults (20-39 yrs.)	Factorial	75	0.57	0.75
FAO/ WHO/ UNU 1985[95]	Adults	N-balance	100	**0.6**	0.75
FAO/ WHO/ UNU 2007[6]	Adults (≥ 18 yrs.)	Meta-analysis (N-balance studies)[7]	100	0.66	0.83

Adopted from NS Scrimshaw[141] and updated.

Nishimura et al (2023). Nutr. Res. Rev. doi:10.1017/S0954422421000329



Omsætning af proteiner og aminosyrer i kroppen



Metabolic demands
Growth + maintenance

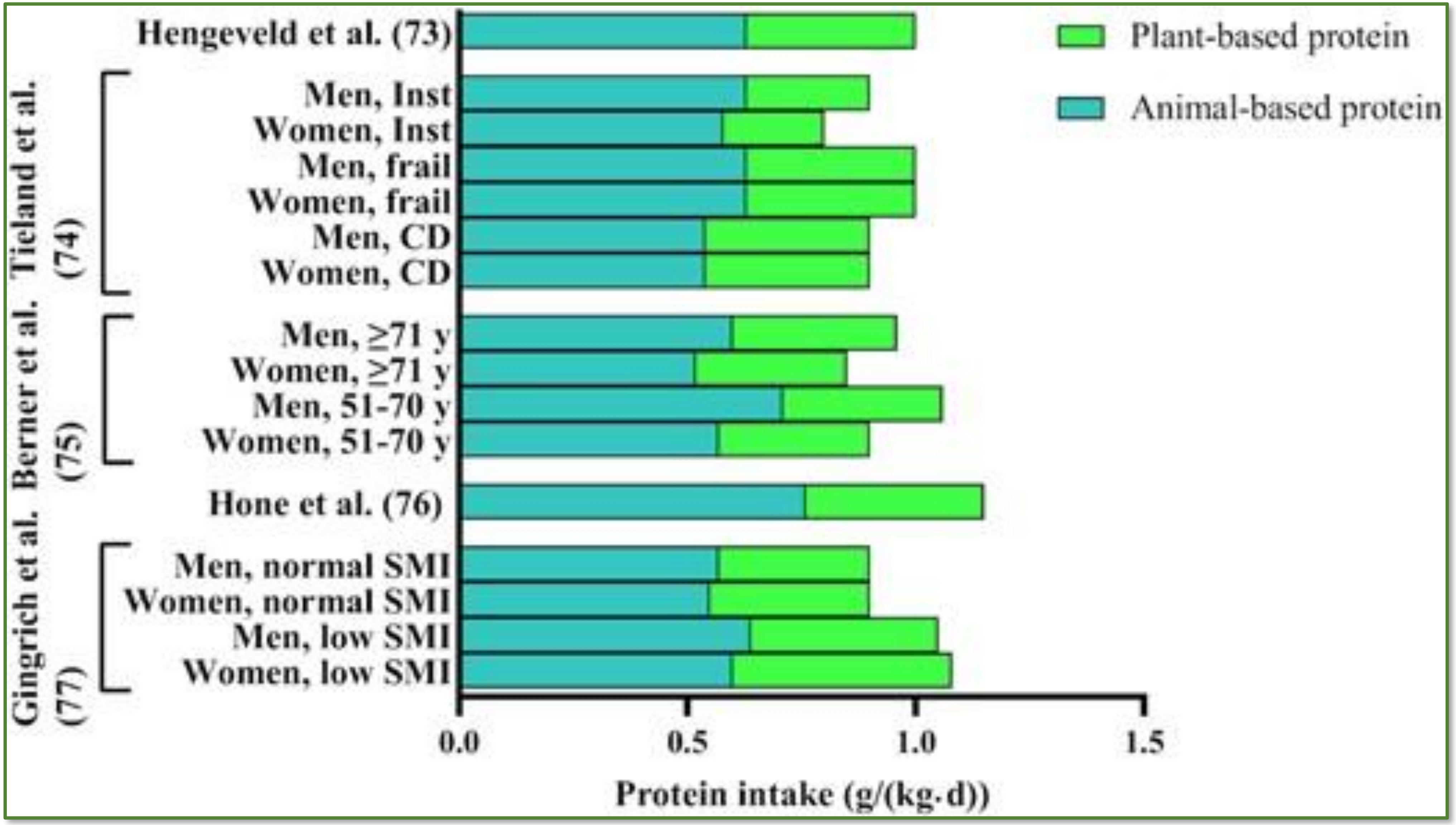
Dietary requirement
Metabolic demand/efficiency of utilisation

Maintenance
Nitrogen balance and obligatory losses

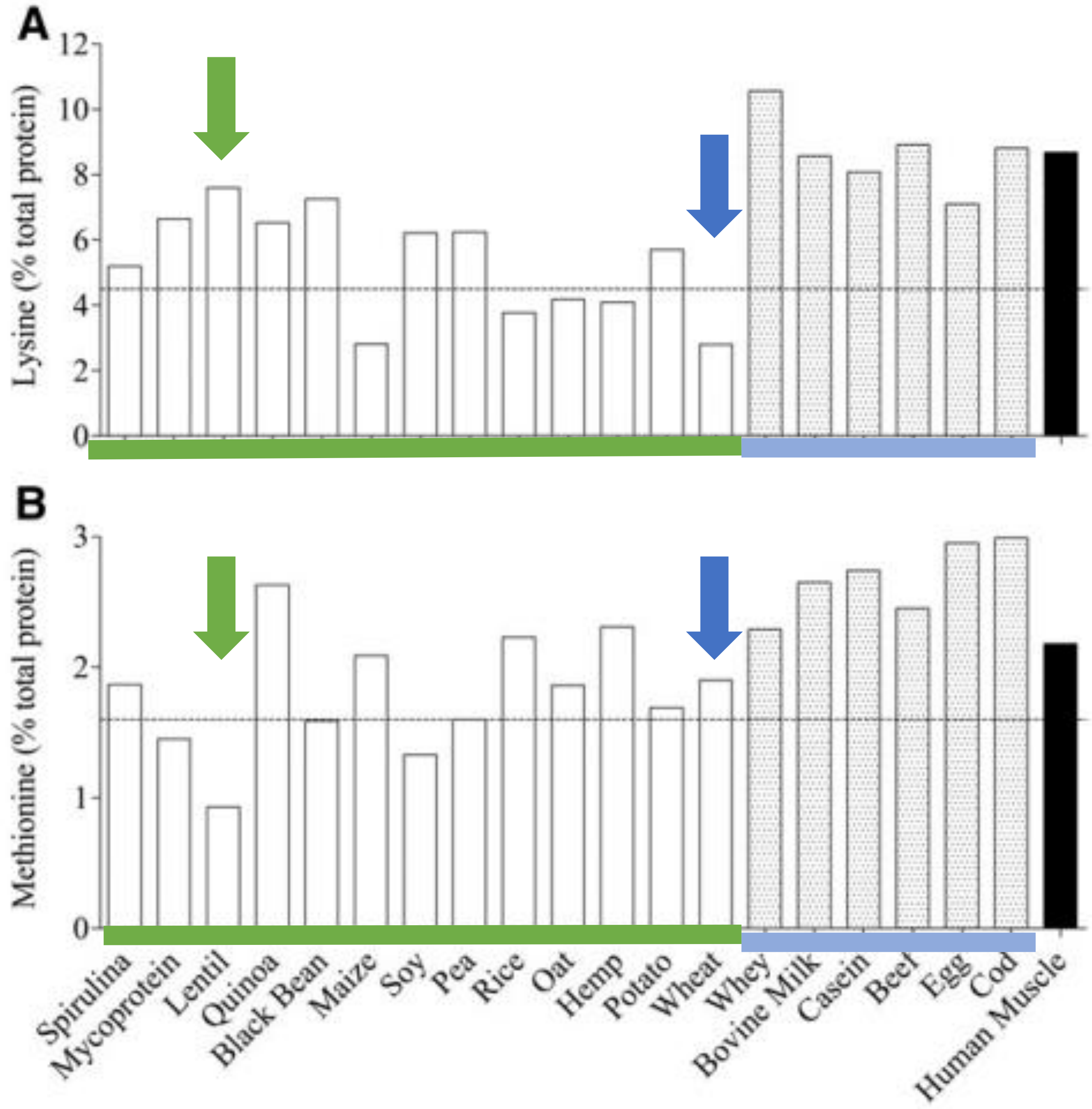
Målgrupper, hvor proteinkvaliteten i kosten kræver særlig opmærksomhed

- Ældre
- Syge
- Småtspisende
- Børn
- Gravide og ammende
- Veganere

Protein Quantity and Quality



Domic et al. (2022). doi: https://doi.org/10.1093/advances/nmac009.



Lysine (A) and methionine (B) concentrations of various protein sources: Plant-based and Animal-based.

Human muscle is provided as the reference standard according to WHO/FAO/UNU

The dashed lines represent recommendations for a minimal intake by WHO/FAO/UNU

Vliet et al (2015). The skeletal muscle anabolic response to plant-versus animal-based protein consumption. JN 145:1981-91

Proteinkvalitet

Definition: et udtryk for, hvor godt en proteinkilde opfylder kroppens behov for essentielle aminosyrer i forhold til behov

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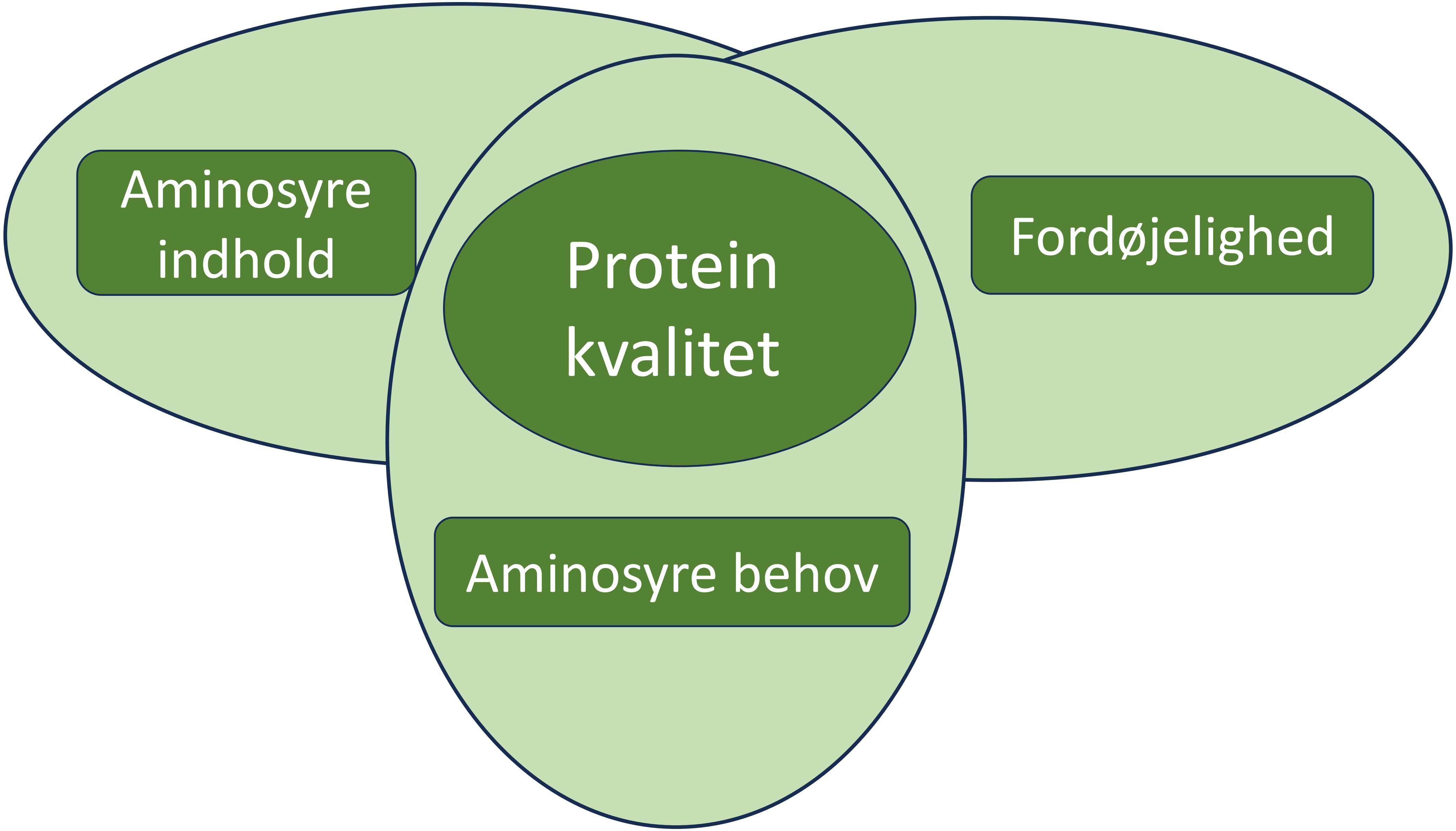
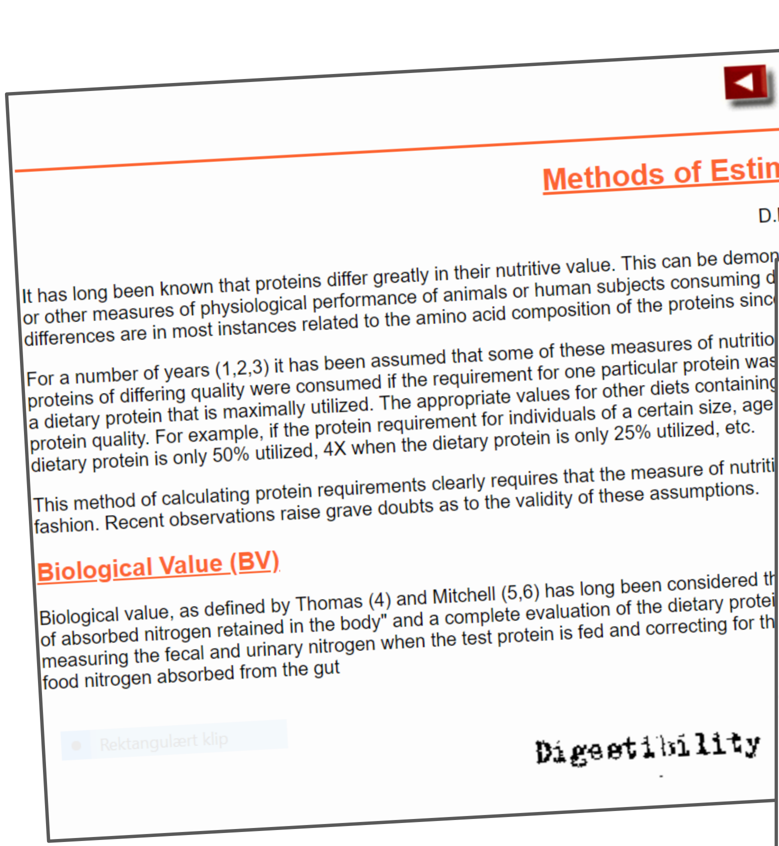
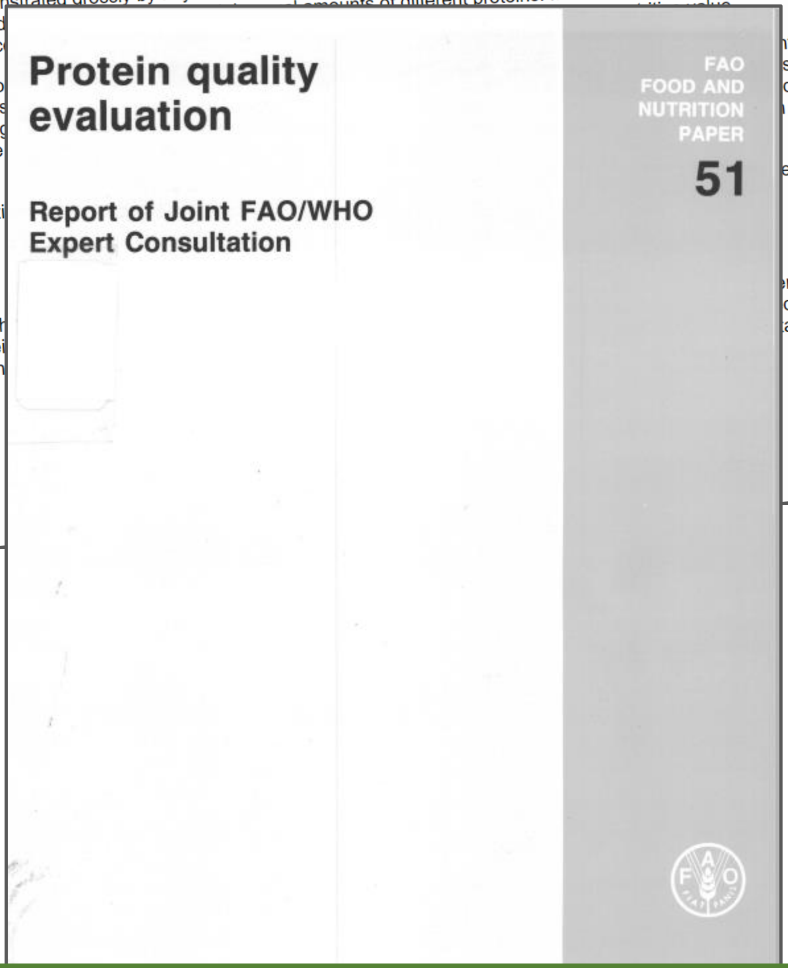
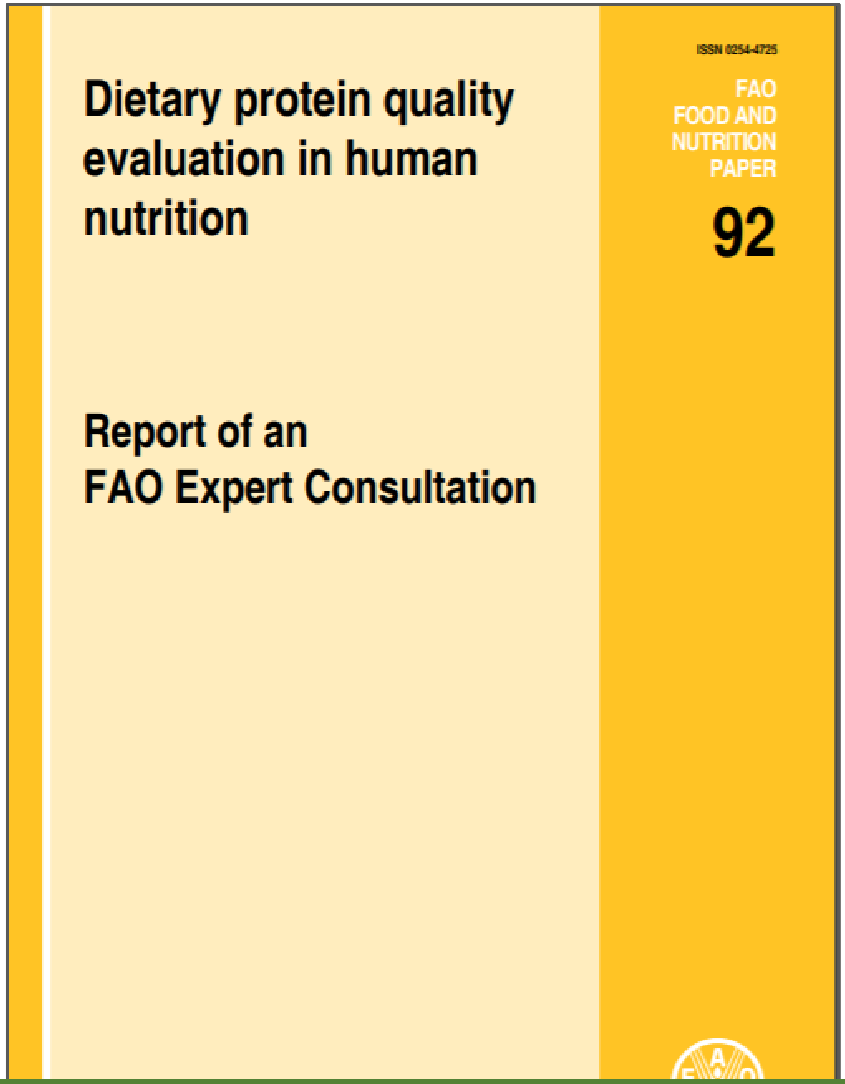

Aminosyre indhold
Protein kvalitet
Fordøjelighed
Aminosyre behov

Proteinkvalitet – metoder til måling/beregning

- **Aminosyre score**: baseret på aminosyreindhold sammenlignet med et 'ideelt' protein
- **PDCAAS**: aminosyreindhold med korrektion for protein fordøjelighed og udtrykt i forhold til behov
- **DIAAS:** aminosyreindhold med korrektion for fordøjelighed i tyndtarmen af hver enkelt aminosyre og udtrykt I forhold til behov







1971: PER: Protein efficiency ratio

1991: PDCAAS: Protein digestibility corrected amino acid score in relation to Human Requirements

2013: DIAAS: Digestible Indispensable Amino Acid Score in relation to a Reference Protein

Protein kvalitet udtrykt som **PDCAAS**

	P:E ratio	Lysine (mg/g protein)	Threonine (mg/g protein)	SAAs (mg/g protein)	Tryptophan (mg/g protein)	Score	Limiting amino acid	Digestibility	PDCAAS	Adjusted P:E ratios
Requirement pattern		48	25	23	6.6					
Beef	0.66	91	47	40	13	100		100	100	0.660
Egg	0.34	70	47	57	17	100		100	100	0.340
Cow's milk	0.19	78	44	33	14	100		100	100	0.194
Breast milk	0.060	69	44	33	17	100		100	100	0.060
Soya	0.388	65	38	25	13	100		90	90	0.349
Wheat	0.160	26	29	45	12	54	Lysine	95	51	0.082
Maize	0.130	29	36	29	5	60	Lysine	82	50	0.064
Improved maize	0.135	40	44	48	7	83	Lysine	80	67	0.090
Potatoes	0.100	54	38	29	14	100		82	82	0.082
Rice	0.072	36	37	40	11	75	Lysine	82	62	0.044
Yam	0.061	42	34	28	13	88	Lysine	80	70	0.043
Cassava	0.034	32	21	29	14	67	Lysine	80	53	0.018

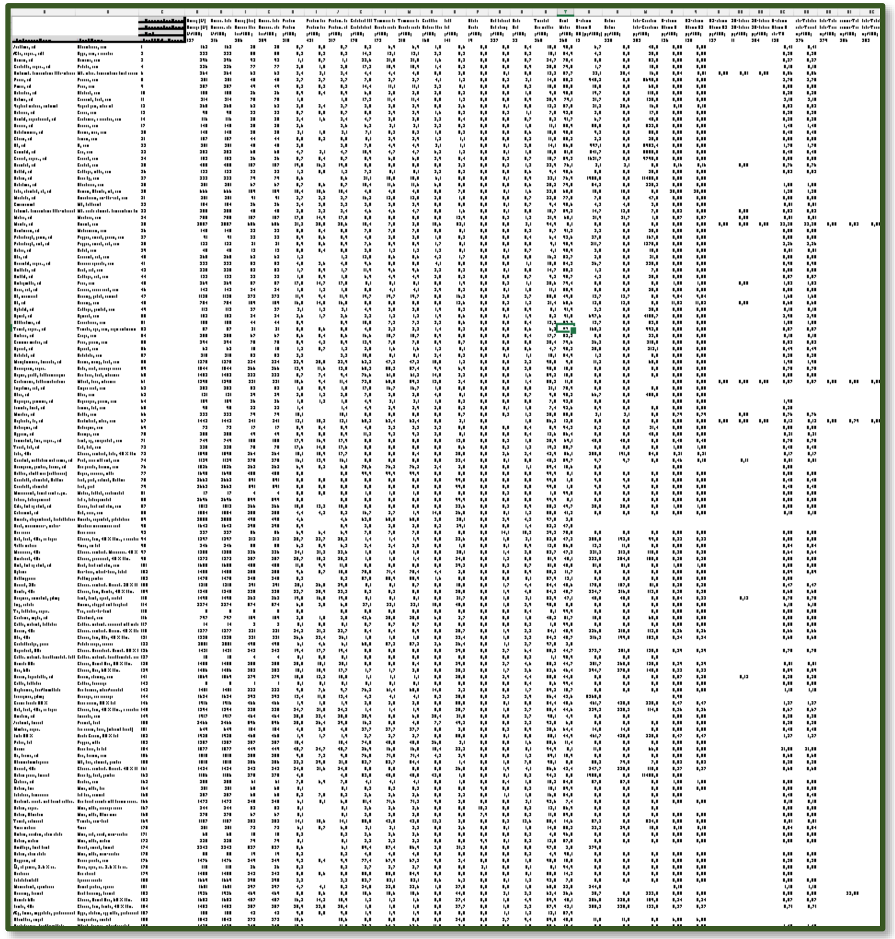
Animal foods generally perform well on both counts. Lysine is the limiting amino acid for cereal proteins, yam, and cassava. Maize also contains less than the reference tryptophan level, but at 83% of reference compared with lysine at 60%.

Proteinkvalitet udtrykt som **DIAAS**

Protein source	DIAAS	Limiting amino acid
Cereals		
Corn	38	Lysine
Rice	52	Lysine
Wheat	39	Lysine
Oat	44	Lysine
Barley	50	Lysine
Legumes		
Soy	92	Methionine + Cysteine
Fava bean	67	Methionine + Cysteine
Lupin	68	Methionine + Cysteine
Pea	66	Methionine + Cysteine
Chickpeas	69	Methionine + Cysteine
Lentils	75	Methionine + Cysteine
Kidney beans	61	Methionine + Cysteine
Root vegetables		
Potato	85	Histidine
Animal proteins		
Gelatin	2	Tryptophan
Whey	85	Histidine
Casein	117	None
Milk	108	None
Egg	101	None
Pork	117	None
Chicken	108	None
Beef	112	None

McClements & Grossmann. Next-Generation Plant-based Foods (2022). Ch 5

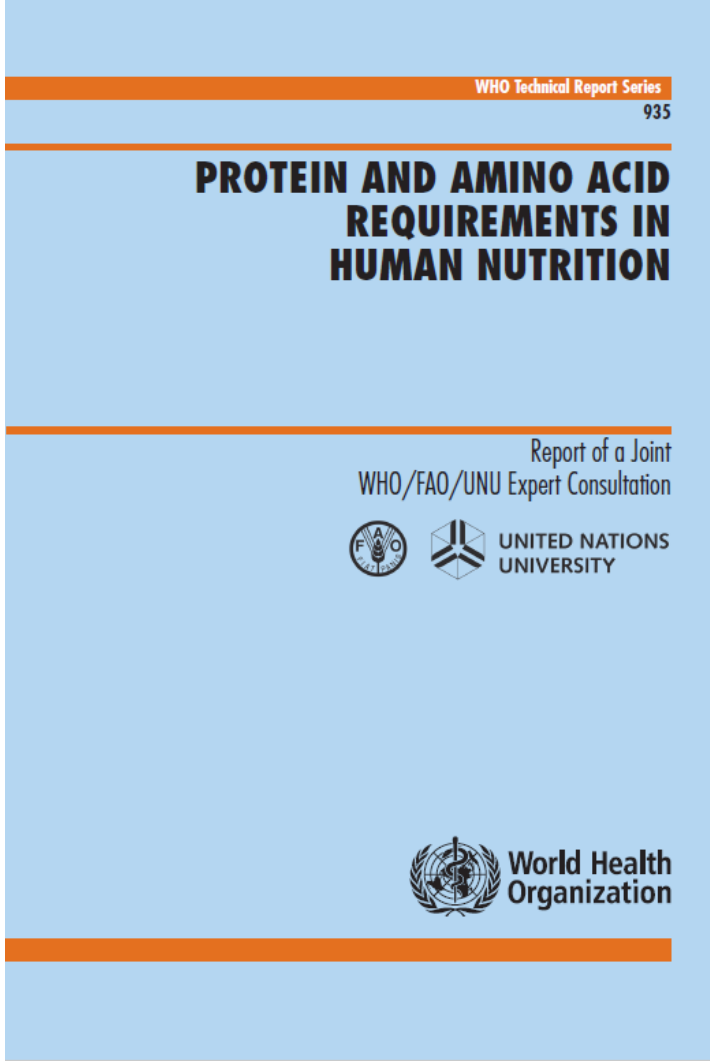
Proteinkvalitet – beregning i praksis



Fordøjeligheds -faktorer

Digestibility factors

NEVO product group	NEVO product group description	Overview of digestibility factors in literature per food group	Final digestibility factor
1	Potatoes and tubers	- Potatoes: 0.55 (1) - Sweet potatoes:0.5 (1) Potatoes are more often consumed than sweet potatoes, therefore 0.55.	0.55
2	Alcoholic beverages	Plant-based products	0.65
3	Bread	0.9 (1)	0.9
4	Miscellaneous foods (plant-based foods such as seaweed, cacao powder, yeast, etc.)	Seaweed: 0.43 (2) Yeast: 0.82 (3) Cacao powder: 0.36 (4) Almonds (for almond paste): 0.88 (4)	0.65
5	Eggs	0.97 (5, 6)	0.97
6	Fruits	- Kiwi: 0.6 (1) - Fruit 0.76 (7)	0.76
7	Pastry and biscuits	- Biscuits: 0.9 (1) - Wheat flour biscuit: 0.9 (1)	0.9
8	Cereals and cereal products	- Barley: 0.78 (1) - Breakfast cereal (1): Flaked corn 0.67 (1) Rolled oat 0.9 (1) Wheat bran 0.73 (1) - Corn/corn flour: 0.82 (1) - Oats: 0.74 (1, 4, 8) - Rice: 0.9 (but cooked 0.7) (1), 0.88 (5) - Whole wheat 0.45 (7) - Wheat: 0.93 (1), 0.86 (5) - Wheat flour: 0.9 (1)	0.7
9	Vegetables	0.65 (5)	0.65
10	Savoury bread spreads	- Peanut butter 0.95 (6) - Sandwichspread (vegetable spread): 0.65 (5) Sandwichspread is only a small part of the products in this group	0.9
11	Savoury sauces		Animal-based: 0.9 Plant-based: 0.65
12	Savoury snacks	- Potato crisps: 0.47 (1) - Potato fries: 0.50 (1)	Animal-based: 0.9 Plant-based: 0.65
13	Cheese	0.95 (5, 6)	0.95
14	Herbs and spices	Plant-based products	0.65
15	Milk and milk products	Milk: 0.95 (1, 5)	0.95



The Journal of Nutrition 153 (2023) 2137–2146

THE JOURNAL OF NUTRITION

journal homepage: https://jn.nutrition.org/

Perspectives

Perspective: Developing a Nutrient-Based Framework for Protein Quality

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[1] *Nutrient Institute LLC, Reno, NV, United States;* [2] *WISEcode, Reno, NV, United States;* [3] *Department of Food Science and Human Nutrition, University of Illinois at Urbana-Champaign, Urbana, IL*

ABSTRACT

The future of precision nutrition requires treating amino acids as essential nutrients. Currently, recognition of essential amino acid requirements is embedded within a generalized measure of protein quality known as the PDCAAS (Protein Digestibility-Corrected Amino Acid Score). Calculating the PDCAAS includes the FAO/WHO/UNU amino acid score, which is based on the limiting amino acid in a food, that is, the single amino acid with the lowest concentration compared to the reference standard. That "limiting" amino acid score is then multiplied by a bioavailability factor to obtain the PDCAAS, which ranks proteins from 0.0 (poor quality) to 1.0 (high quality). However, the PDCAAS has multiple limitations: it only allows for direct protein quality comparison between 2 proteins, and it is not scalable, transparent, or additive. We therefore propose that shifting the protein quality evaluation paradigm from the current generalized perspective to a precision nutrition focus treating amino acids as unique, metabolically active nutrients will be valuable for multiple areas of science and public health. We report the development and validation of the Essential Amino Acid 9 (EAA-9) score, an innovative, nutrient-based protein quality scoring framework. EAA-9 scores can be used to ensure that dietary recommendations for each essential amino acid are met. The EAA-9 scoring framework also offers the advantages of being additive and, perhaps most importantly, allows for personalization of essential amino acid needs based on age or metabolic conditions. Comparisons of the EAA-9 score with PDCAAS demonstrated the validity of the EAA-9 framework, and practical applications demonstrated that the EAA-9 framework is a powerful tool for precision nutrition applications.

Keywords: amino acids, protein quality, DIAAS, lysine, leucine, PDCAAS, dietary recommendations, precision nutrition

Introduction

Amino acids are unique nutrients with individual dietary requirements and distinct, noninterchangeable metabolic functions [1]. Just as vitamins A, B_6, C, and D have distinct functions and metabolic requirements despite being grouped as vitamins, amino acids are equally distinct despite being grouped as protein. Nevertheless, an understanding of amino acids as unique nutrients has not yet been clearly incorporated into nutrition recommendations or protein quality scores.

Most consumer-facing dietary guidelines still treat amino acids as interchangeable equivalents by generically representing them as "protein." This generalization is built into nutrition recommendations such as the Dietary Guidelines for Americans (DGA) and the Nutrition Facts Panel, which both use protein as a surrogate for amino acid requirements [2,3]. The DGA and Nutrition Facts Panel are informed by DRI reports, which specify the amounts of the 9 essential amino acids (EAAs) that must be consumed in the diet. However, DRI data is not intended for consumers and is not built in an easily accessible, user-friendly format for professionals' use [4].

Currently, there is no available dietary guideline framework that evaluates food or meal protein quality based on the distinct metabolic roles and requirements of EAAs or that allows professionals or consumers to customize a diet based on specific individual requirements for one or more EAAs.

Understanding amino acids as individual nutrients requires understanding their unique metabolic roles beyond the fundamental role for protein synthesis (Table 1) [5–12]. For example, leucine (Leu) is a dietary signal that activates the mTOR

Abbreviations: AAS, amino acid score; DGA, Dietary Guidelines for Americans; DIAAS, Digestible Indispensable Amino Acid Score; EAA, essential amino acid; EAA-9, Essential Amino Acid 9; PDCAAS, Protein Digestibility-Corrected Amino Acid Score; SR Legacy, USDA National Nutrient Database for Standard Reference Legacy Release.

* Corresponding author. *E-mail address:* shavawn@nutrientinstitute.org (S.M. Forester).

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EAA-9 score

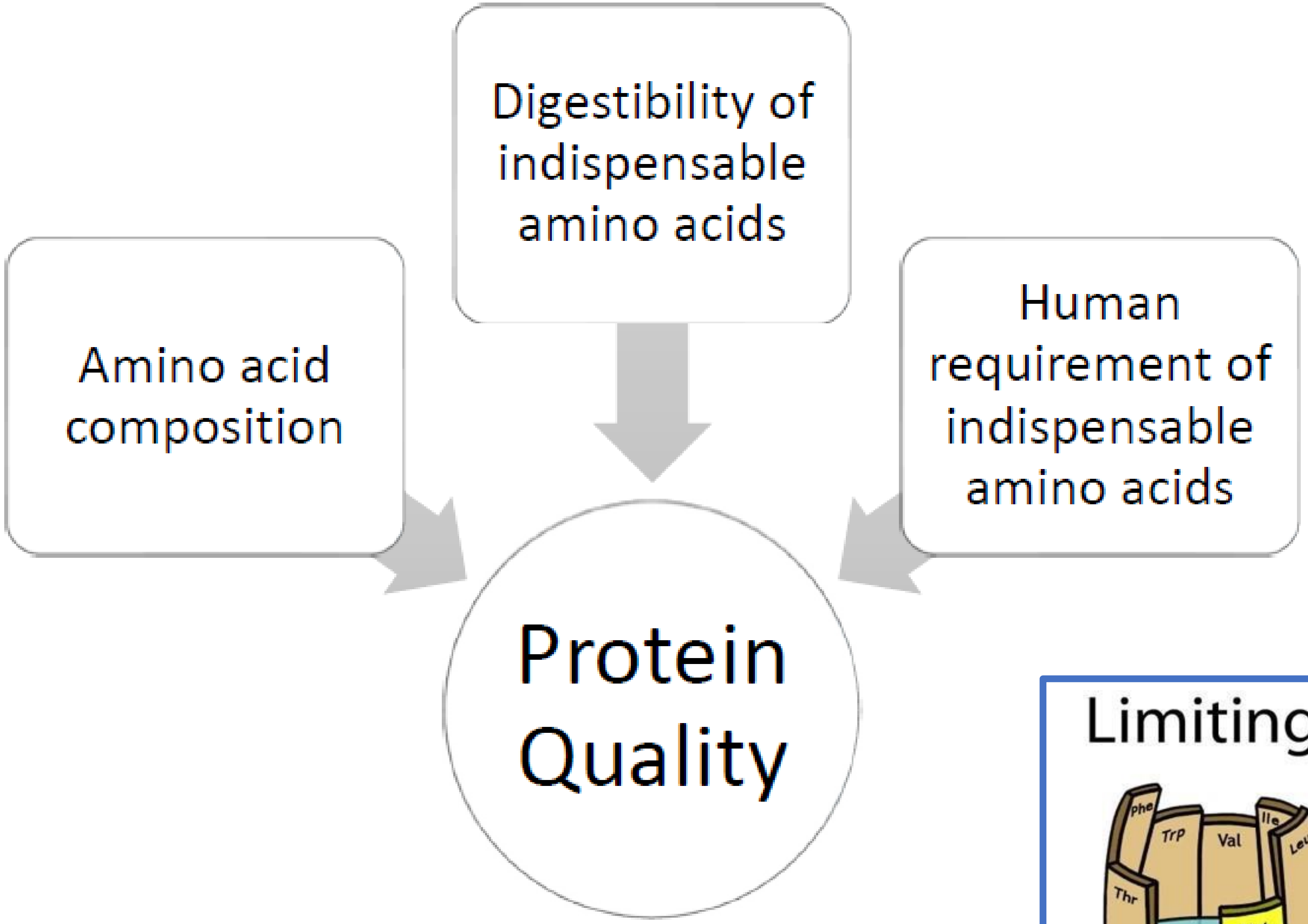
Et værktøj til at:

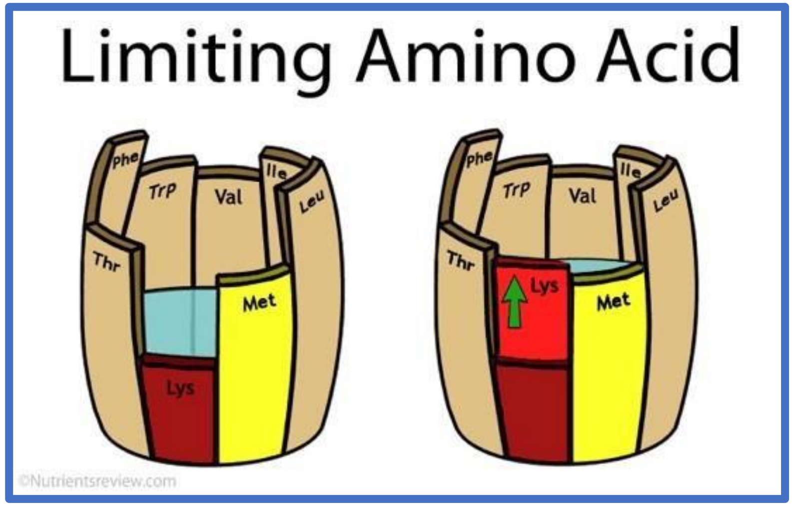
- beregne og sammenligne proteinkvalitet på tværs af ingredienser, fødevarer og måltider
- Beregne proteinkvalitet for en enkelte (personificeret)

Fordele fremhævet af forfattere:

- Additiv
- EAA-9 score repræsenterer % EAA-krav opfyldt
- Kan bruges på individ niveau

Forester SM (2023). J.Nutrition doi:10.1016/j.tjnut.2023.06.004


Digestibility of indispensable amino acids
Amino acid composition
Human requirement of indispensable amino acids
Protein Quality


Limiting Amino Acid
Phe
Trp
Val
Ile
Leu
Thr
Met
Lys
©Nutrientsreview.com

MPQS Måltids Proteinkvalitets Score

- Behov for essentielle aminosyrer **per måltid**:
  - Total protein: 0.3 g/kg BW
  - Multiply by FAO/WHO behov
  - Justering for fordøjelighed
  - Laveste procent relativt til behov = **MPQS**

MPQS: 61
Limiting: Methionine

125 kidney beans
150 bulgur
30 cherry tomatoes
20 olive oil
30 tofu
90 spinach

Opskrifter fra BBH: *Meal Protein Quality Score*

ONLY ENTER VALUES IN THE BLUE BOX

WAGENINGEN UNIVERSITY & RESEARCH   UNIVERSITY OF COPENHAGEN

Torsdag menu 1 fisk med rejer

Dato 09-02-2024

Portions	20													
Grams	**Ingredient**	**digestibility**	**isoleucine**	**leucine**	**lysine**	**methionine**	**cysteine**	**met + cys**	**phenylalanine**	**tyrosine**	**phe+tyr**	**threonine**	**tryptohan**	**valine**	**histidine**
301	Asparagus white boiled	0,65	0	0	0	0	0	0	0	0	0	0	0	0	0
167	Beans broad boiled	0,65	209	303	331	80	23	103	149	114	263	226	60	269	103
42	Celery boiled	0,65	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Cornstarch	0,7	0	0	0	0	0	0	0	0	0	0	0	0	0
50	Cream 25% fat	0,95	83	137	128	36	11	47	72	60	132	60	19	99	41
79	Drink soya natural	0,94	126	217	178	35	37	72	138	87	225	108	36	134	70
43	Flour wheat white	0,7	140	286	94	64	90	154	204	118	322	112	49	170	89
145	Peas chick boiled	0,75	370	619	566	106	119	225	477	238	715	317	66	370	225
152	Egg whole chicken av boiled	0,97	1075	1656	1429	640	377	1017	1017	813	1830	871	256	1364	465
143	Tahoe soya curd	0,94	708	1213	996	198	208	406	772	490	1261	602	200	748	394
25	Chervil fresh	0	0	0	0	0	0	0	0	0	0	0	0	0	0
755	Tomatoes classic round raw	0,65	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Linseeds	0,75	21	29	20	9	8	17	23	12	34	18	7	25	11
44	Flour rye	0,7	122	212	132	52	48	100	148	80	228	116	39	180	80
13	Sunflower seeds	0,75	67	102	62	38	28	66	76	41	117	59	26	80	42
1	Yeast fresh	0,65	4	6	6	1	0	1	3	3	6	4	1	5	2
82	Flour rye	0,7	227	395	247	97	90	187	276	148	425	217	72	336	148
14	Flour wheat white	0,7	45	93	31	21	29	50	66	38	105	37	16	55	29
14	Syrup maple	0,8	0	0	0	0	0	0	0	0	0	0	0	0	0
58	Peas chick boiled	0,75	149	250	229	43	48	91	193	96	289	128	27	149	91
16	Flour rye	0,7	44	77	48	19	18	36	54	29	83	42	14	66	29
246	Peas frozen boiled	0,65	460	691	644	106	33	138	398	276	675	415	83	584	200
86	Peas chick boiled	0,75	220	368	336	63	71	133	284	141	425	188	39	220	133
47	Pumpkin seeds	0,75	380	733	400	215	114	329	533	350	883	306	179	503	240
451	Potatoes wo skin boiled av	0,55	177	259	276	66	40	106	191	92	283	160	73	283	85
188	Radish raw	0,65	0	0	0	0	0	0	0	0	0	0	0	0	0
39	Tempeh fermented soya beans prepared wo fat	0,94	203	348	286	57	60	116	221	140	362	173	57	214	113
20	Buckwheat groats	0,7	46	83	73	21	12	33	52	27	79	44	21	69	29
1000	Prawns cooked	0,9	7334	10857	11954	3991	930	4920	6006	5325	11331	5325	1553	7334	2882
0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total meal (mg)		12209	18931	18466	5956	2392	8348	11352	8719	20071	9527	2893	13256	5498
	total meal (mg/person)		610	947	923	298	120	417	568	436	1004	476	145	663	275
	percentage of requirement		93	73	94	85	91				121	95	110	78	84

Meal Protein Quality Score

73

Limiting EAA:

Leucine

Opskrifter fra BBH: *Meal Protein Quality Score*

ONLY ENTER VALUES IN THE BLUE BOX

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Torsdag menu 1 fisk – **rejer udskiftet med tun**

Dato 09-02-2024

Portions	20														
Grams	**Ingredient**	**digestibility**	**isoleucine**	**leucine**	**lysine**	**methionine**	**cysteine**	**met + cys**	**phenylalanine**	**tyrosine**	**phe+tyr**	**threonine**	**tryptohan**	**valine**	**histidine**
301	Asparagus white boiled	0,65	0	0	0	0	0	0	0	0	0	0	0	0	0
167	Beans broad boiled	0,65	209	303	331	80	23	103	149	114	263	226	60	269	103
42	Celery boiled	0,65	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Cornstarch	0,7	0	0	0	0	0	0	0	0	0	0	0	0	0
50	Cream 25% fat	0,95	83	137	128	36	11	47	72	60	132	60	19	99	41
79	Drink soya natural	0,94	126	217	178	35	37	72	138	87	225	108	36	134	70
43	Flour wheat white	0,7	140	286	94	64	90	154	204	118	322	112	49	170	89
145	Peas chick boiled	0,75	370	619	566	106	119	225	477	238	715	317	66	370	225
152	Egg whole chicken av boiled	0,97	1075	1656	1429	640	377	1017	1017	813	1830	871	256	1364	465
143	Tahoe soya curd	0,94	708	1213	996	198	208	406	772	490	1261	602	200	748	394
25	Chervil fresh	0	0	0	0	0	0	0	0	0	0	0	0	0	0
755	Tomatoes classic round raw	0,65	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Linseeds	0,75	21	29	20	9	8	17	23	12	34	18	7	25	11
44	Flour rye	0,7	122	212	132	52	48	100	148	80	228	116	39	180	80
13	Sunflower seeds	0,75	67	102	62	38	28	66	76	41	117	59	26	80	42
1	Yeast fresh	0,65	4	6	6	1	0	1	3	3	6	4	1	5	2
82	Flour rye	0,7	227	395	247	97	90	187	276	148	425	217	72	336	148
14	Flour wheat white	0,7	45	93	31	21	29	50	66	38	105	37	16	55	29
14	Syrup maple	0,8	0	0	0	0	0	0	0	0	0	0	0	0	0
58	Peas chick boiled	0,75	149	250	229	43	48	91	193	96	289	128	27	149	91
16	Flour rye	0,7	44	77	48	19	18	36	54	29	83	42	14	66	29
246	Peas frozen boiled	0,65	460	691	644	106	33	138	398	276	675	415	83	584	200
86	Peas chick boiled	0,75	220	368	336	63	71	133	284	141	425	188	39	220	133
47	Pumpkin seeds	0,75	380	733	400	215	114	329	533	350	883	306	179	503	240
451	Potatoes wo skin boiled av	0,55	177	259	276	66	40	106	191	92	283	160	73	283	85
188	Radish raw	0,65	0	0	0	0	0	0	0	0	0	0	0	0	0
39	Tempeh fermented soya beans prepared wo fat	0,94	203	348	286	57	60	116	221	140	362	173	57	214	113
20	Buckwheat groats	0,7	46	83	73	21	12	33	52	27	79	44	21	69	29
1000	Tuna prepared wo fat	0,9	14219	20298	24613	7766	1853	9620	10787	9492	20279	11669	3020	15984	13336
0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
	total meal (mg)		19094	28373	31125	9732	3315	13047	16132	12886	29019	15871	4359	21906	15952
	total meal (mg/person)		955	1419	1556	487	166	652	807	644	1451	794	218	1095	798
	percentage of requirement		145	110	158	139	126				174	158	166	128	243

Meal Protein Quality Score

110

Limiting EAA:

Current Developments in Nutrition 8 (2024) 104439

Current Developments in Nutrition CDN

journal homepage: https://cdn.nutrition.org/

Original Research

Meal Protein Quality Score: A Novel Tool to Evaluate Protein Quantity and Quality of Meals

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ABSTRACT

Background: The recent shift toward increased plant-based protein consumption has necessitated the development of new tools to evaluate the quality and quantity of protein in meals, especially given the changing dietary guidelines and the adoption of plant-centric menus in healthcare and other settings.

Objectives: To develop and test the feasibility of the meal protein quality score (MPQS), a novel metric that assesses the protein quality and quantity in meals based on essential amino acid (EAA) content, digestibility, and requirements, with a focus on optimizing protein intake for vulnerable populations, particularly older adults.

Methods: The MPQS integrates digestibility-adjusted EAA intake with total protein consumed in a meal, which, together with the EAA requirements, provides a score from 0 to 100 to reflect EAA coverage adequacy. The score was tested for feasibility by applying it to recipe data from real-life hospital meals and to dietary data from the [New Dietary Strategies Addressing the Specific Needs of Elderly Population for Healthy Aging in Europe] NU-AGE trial, involving detailed 7-d food records from 252 nonvegan participants analyzed over multiple meal moments.

Results: The analyses revealed that the higher the content of plant protein in a meal, the lower the meal protein quality. Also, breakfast meals scored lowest on protein quality, mainly due to low contents of protein overall, and of lysine and methionine. The MPQS effectively highlighted the difference in protein quality between plant-based and animal-based meals, and across different meal types.

Conclusions: The MPQS appears to be a practical tool that facilitates the assessment of meal-based protein quality. The MPQS can be used to guide dietary transitions toward plant-rich diets, ensuring that such shifts do not compromise protein adequacy for at-risk populations. The score allows for guidance in meal planning, leading to improvements in plant-rich meal formulation to meet both individual and public health nutritional needs.

Keywords: protein quality, meal protein quality score, plant-based proteins, plant-based diets, veganism.

Introduction

The shift in dietary protein intake toward more plant-based proteins instead of animal-based proteins is gaining traction among consumers, employees, hospital patients, and dietary guidelines [1]. Although the beneficial effects of this transition on cardiometabolic outcomes and environmental sustainability are much welcome, it does pose a health risk to some groups of consumers [2]. These are, in general, consumers with increased protein requirements, lower food intakes, at risk of malnutrition, or at risk of sarcopenia, such as older adults and patients [3]. For these consumers, the lower anabolic properties of plant-based proteins, due to their reduced protein concentrations and quality, could increase risks of sarcopenia and osteoporosis [4].

Protein quality is a product of the digestibility, the essential amino acid (EAA) contents of a protein source, and the amino

Abbreviations: DIAAS, digestible indispensable amino acid score; EAA, essential amino acid; EAA-9, essential amino acid 9 score; MPQS, meal protein quality score; PDCAAS, protein digestibility-corrected amino acid score.

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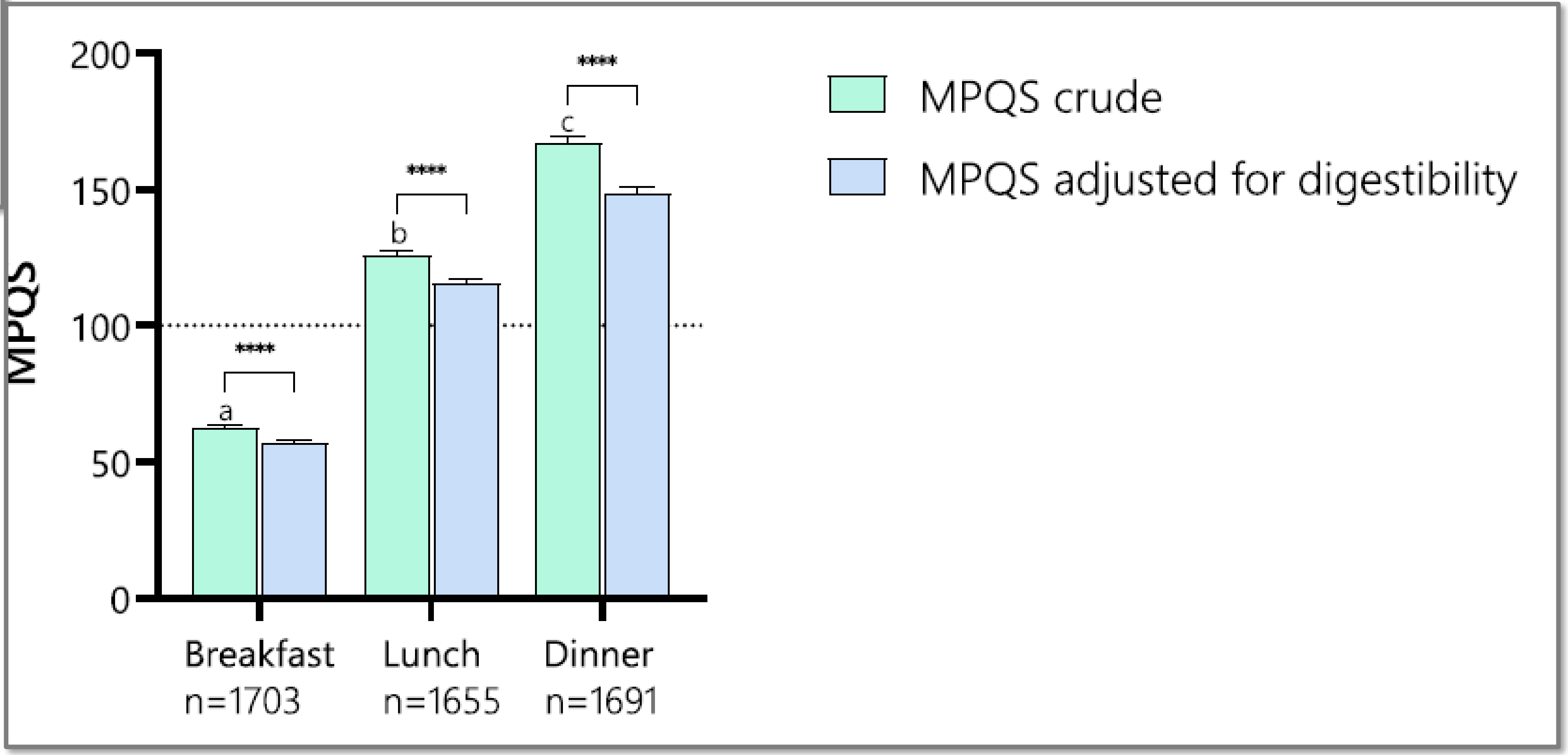

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Take-home messages

- ✓Proteinkvalitet er blevet et vigtigt emne i forhold til den grønne omstilling – især ift ældre, børn og veganere
- ✓Flere metoder, som PDCAAS og DIAAS, bruges til at beregne proteinkvalitet, men der er ingen enighed om den bedste metode
- ✓Nye værktøjer som EEA-9 og MPQS er udviklet til specifikke formål for at vurdere proteinkvalitet til specifikke formål