



Increasing Plant-Based Products' Protein Quality through Ingredient Blending

Matthew G. Nosworthy, PhD

Food Science and Nutrition Research Scientist
Guelph Research and Development Centre
Agriculture and Agri-food Canada
Matthew.Nosworthy@Canada.ca

MARCH 24, 2021

2021 Premium Webinar:

Overcoming Technical Issues
when Formulating with Protein

A Global Food Forums, Inc. Event 



Agriculture and
Agri-Food Canada

Agriculture et
Agroalimentaire Canada

Canada

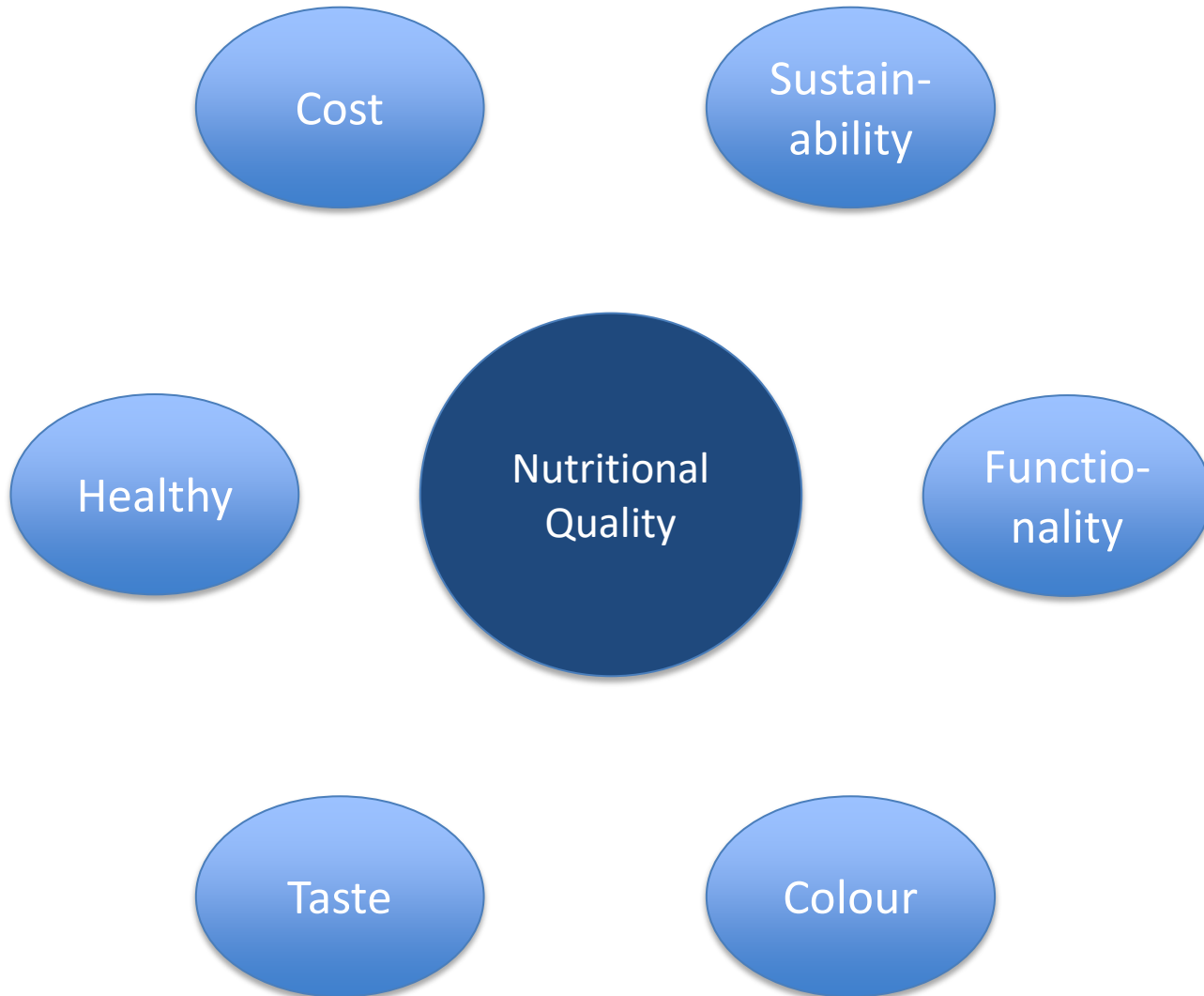
Outline

- Protein Quality
 - What is it?
 - Why is it important?
 - How is it determined?
- PDCAAS Protein Content Claims
- Plant Proteins
 - Benefits/Limitations
- Blending
 - Calculate theoretical PDCAAS values

Learning Objectives

- Understand how the Protein Digestibility Corrected Amino Acid Score (PDCAAS) is determined, and its relationship to content claims
- Know how PDCAAS differs between dietary proteins and how to predict the PDCAAS values of blends

Protein Quality



Protein Quality

- Value associated with a protein source reflecting its ability to meet human nutritional requirements
 - Amino acid composition
 - Protein digestibility
- Many different methods
 - Protein Efficiency Ratio (PER)
 - Protein Digestibility Corrected Amino Acid Score (PDCAAS)
 - Digestible Indispensable Amino Acid Score (DIAAS)

Protein Quality

- Why is it important?
- Individuals
 - Nutritional information about a protein
 - How 'Good' is it for humans?
 - Dietary planning/interventions
- Commercial/Industrial
 - Ingredient Selection
 - Package Labelling

Protein Quality Methods

Jurisdiction	Method	Acronym	Data Required
Canada	Protein Efficiency Ratio	PER	Protein content, effect on weight gain
United States of America	Protein Digestibility Corrected Amino Acid Score	PDCAAS	Amino acid composition, protein digestibility
N/A	Digestible Indispensable Amino Acid Score	DIAAS	Amino acid composition, amino acid digestibility

Determination of PER, PDCAAS, DIAAS require the use of animals

Protein Digestibility-Corrected Amino Acid Score (PDCAAS)

- Proposed by FAO/WHO in 1991
 - Adopted by USA in 1993
- Amino Acid Score (AAS)
 - AA in food/AA in reference pattern
 - mg/g protein
 - Reference pattern of 2-5 yr old school children (1991)
- True Fecal Protein Digestibility (TFPD)
 - Fecal N output/Dietary N input
 - Corrected for endogenous losses

Reference Values (mg/g protein)	PDCAAS (1991)
THR	34
VAL	35
MET+CYS	25
ILE	28
LEU	66
PHE+TYR	63
HIS	19
LYS	58
TRP	11

Calculation of PDCAAS

- PDCAAS = AAS X TFPD%
 - Amino Acid Score (AAS)
 - True Protein Digestibility (TFPD%)
- AAS
$$\frac{\text{Amino Acid in Protein Source (mg/g protein)}}{\text{Amino Acid Requirement (mg/g protein)}}$$
 - Limiting amino acid has the lowest score = AAS
- TFPD%
 - TPD% = $((\text{Nitrogen Intake} - (\text{Fecal Nitrogen Loss} - \text{Metabolic Nitrogen Loss}))/\text{Nitrogen Intake}) \times 100$

Calculation of Protein Digestibility

Diet	Feed Consumed (5 days)	% N in diet	N consumed	Feces N	TPD%
Casein	66.37	1.64	1.09	0.08	95.12
Casein	62.14	1.64	1.02	0.07	96.00

Endogenous Nitrogen (5 Day Balance, grams) =	0.025
--	-------

TPD% = ((Nitrogen Intake – (Fecal Nitrogen Loss – Metabolic Nitrogen Loss))/Nitrogen Intake) x 100

PDCAAS Example

	g/100g (As-Is)	mg/g Protein	Reference Pattern (mg/g protein)	Amino Acid Score
THR	2.77	31.9	34	0.94
VAL	5.41	62.3	35	1.78
MET + CYS	2.84	32.6	25	1.3
ILE	3.46	39.7	28	1.42
LEU	8.4	96.6	66	1.46
PHE+TYR	8.74	100.5	63	1.6
HIS	2.46	28.3	19	1.49
LYS	6.58	75.6	58	1.3
TRP	0.91	10.5	11	0.96

Protein: Casein. TPD – 95.1%.
PDCAAS = 95.1% X 0.94 = 89.1

Challenges with PDCAAS

- Requires truncation ($\text{PDCAAS} \leq 1$)
 - Doesn't give credit to high quality proteins
 - Inaccurate indication of blend quality
- Fecal digestibility
 - Confounding influence of colonic microflora can lead to overestimation of protein digestibility
- Focus on nitrogen digestibility rather than amino acids
 - Overall nitrogen digestibility \neq individual amino acid digestibility
- Use of rodents
 - Different amino acid requirements than humans

PDCAAS Content Claim

- PDCAAS > 0.20 considered a “significant source of protein” for all non-infant foods (US FDA; CFR Title 21)
- Foods with PDCAAS-corrected protein values =
 - 5-10 grams per Reference Amount Customarily Consumed (RACC) = **Good Source of Protein**
 - 10 grams or $>$ = **Excellent Source of Protein**

Content Claims

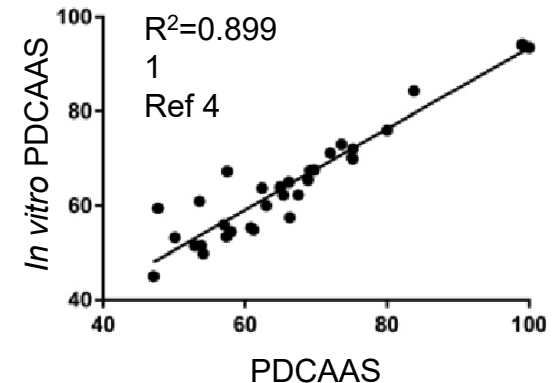
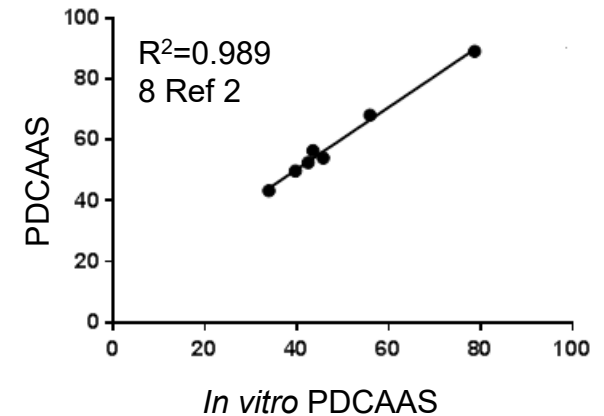
Protein Source	PDCAAS	Corrected Protein Content in RACC (g)	Permitted Protein Claim
Almonds	39	2.5	No claim
Sunflower Seeds	66	4.1	No claim
Peanut Butter	45	3.2	No claim
Navy beans	47	5.7	Good Source
Whole Green Lentils	43	5.8	Good Source
Split Red Lentils	54	5.6	Good Source
Split Yellow Peas	64	5.7	Good Source
Chickpeas	74	5.9	Good Source
Tofu	56	8.22	Good Source

PDCAAS: Good source = 5-9.9g protein/RACC

DIAAS: Good source = 5-9.9g protein/RACC if DIAAS >75

In vivo vs *in vitro* analysis

- Desire to reduce animal experimentation
 - Protein alone requires animal experimentation
 - PDCAAS - rats
 - DIAAS- Humans or ileal-cannulated pigs
- Increasing evidence supporting *in vitro* protein quality (PDCAAS)
 - $R^2 = 0.9784^1, 0.9898^2, 0.9442^3, 0.8991^4$



1) Plank, D. Medallion Labs; 2) Nosworthy & House (2017) Cereal Chem., 94, 1-8;
3) Tavano et al. (2016) FRI, 89, 756-763; 4) Nosworthy et al. Unpublished

PER Update

- Change to regulations in 2020
- Accepting conversion from PDCAAS to PER
 - $\text{PDCAAS} \times 2.5 = \text{PER}$

Established PERs are listed in the table [protein efficiency ratios](#). For those not already established, it is the manufacturer's responsibility to determine the PER. The official method for determining the protein rating is [Method FO-1, October 15, 1981 - PDF \(213 kb\)](#). However, Health Canada also [permits](#) the use of the protein digestibility - corrected amino acid score (PDCAAS) method to calculate an estimated PER.

The PER may be estimated from the PDCAAS using the following formula:

PDCAAS for food x 2.5 = estimated PER for food

The PER of 2 or more sources cannot be added to calculate the total PER of a food with multiple sources of protein.

Plant Protein Limitations

- Allergenicity
 - Pea Protein
- Committed supply chain
 - Rice, pumpkin seed, microalgae
- Composition
 - Low protein content (cereals)
 - Anti-nutritional factors (pulses)
 - Amino acid composition & protein digestibility

Plant Protein Limitations

- Amino Acid Composition
 - Lysine: Cereals
 - Leucine: Ancient grains
 - Methionine, Cysteine, Tryptophan: Pulses
- Protein Digestibility
 - Anti-nutritional factors
 - Protease inhibitors
 - Tannins
 - Phenolics
 - Phytate

Blending

- Combining two, or more, protein sources to balance desired characteristics
- How can you determine optimal blends?
 - PDCAAS is mathematically friendly
 - Can use known values to extrapolate blends
 - NB: PER can not be used in the same way

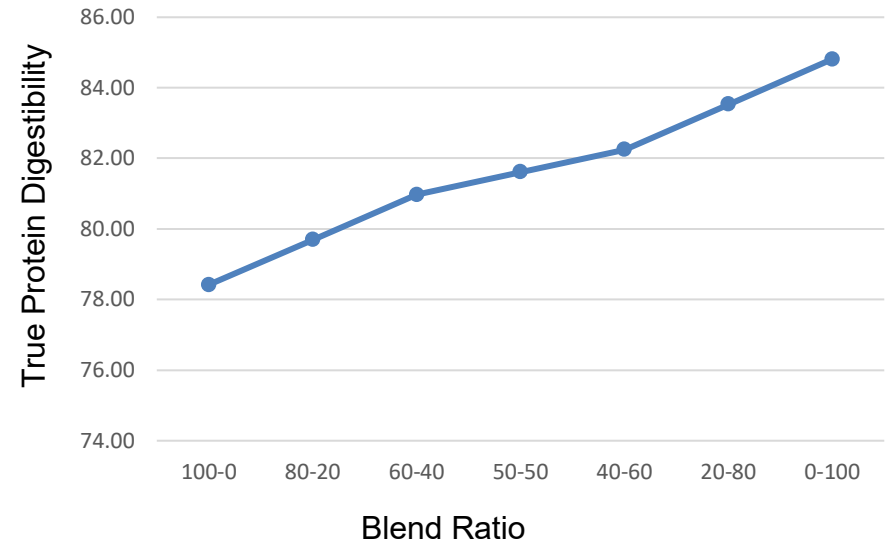
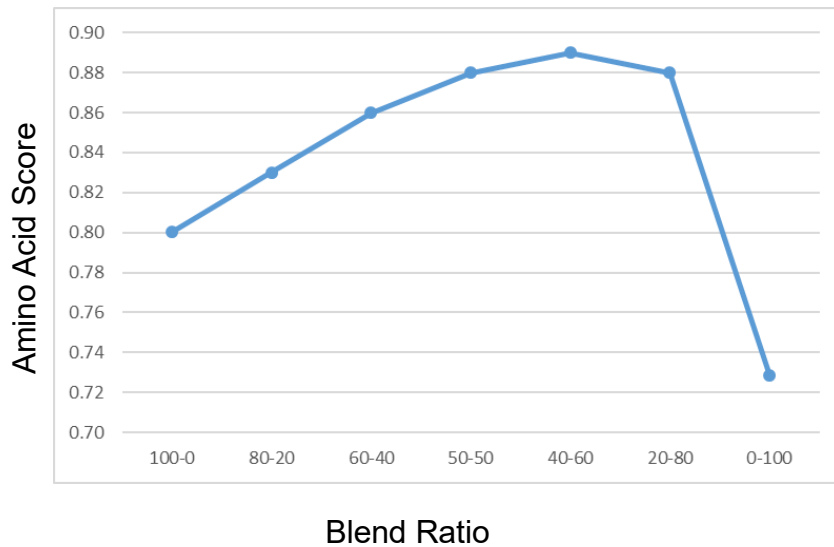
Blending

Blend of Extruded Buckwheat Flour and Extruded Pinto Bean Flour

BWF- PBF	THR	VAL	M+C	ILE	LEU	P+T	HIS	LYS	TRP	AAS	TPD	PDCAAS
100-0	0.97	1.13	1.50	0.96	0.80	1.35	1.37	0.86	1.16	0.80	78.42	62.74
80-20	0.99	1.13	1.34	0.99	0.83	1.32	1.42	0.89	1.10	0.83	79.69	66.15
60-40	1.01	1.13	1.19	1.02	0.86	1.30	1.46	0.92	1.05	0.86	80.97	69.63
50-50	1.02	1.14	1.11	1.04	0.88	1.28	1.49	0.93	1.02	0.88	81.61	71.82
40-60	1.03	1.14	1.04	1.06	0.89	1.27	1.51	0.95	0.99	0.89	82.25	73.20
20-80	1.06	1.14	0.88	1.09	0.92	1.24	1.56	0.98	0.94	0.88	83.52	73.50
0-100	1.08	1.14	0.73	1.12	0.96	1.22	1.60	1.01	0.88	0.73	84.80	61.76

Theoretical AAS/TPD

Extruded Buckwheat Flour and Extruded Pinto Bean Flour Blends



But how accurate is the prediction?

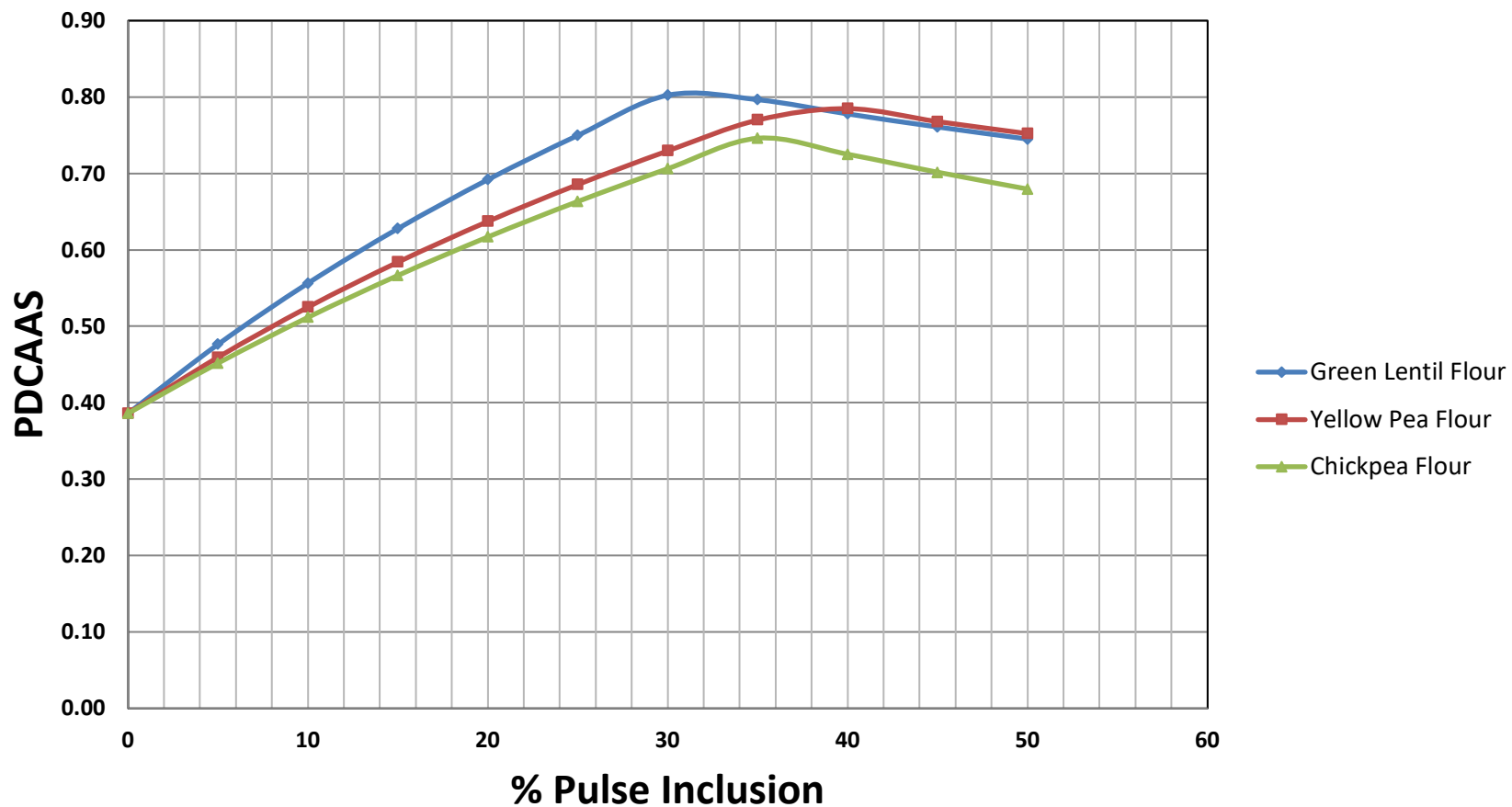
Theoretical vs Actual 50:50 Blend

	THR	VAL	M+C	ILE	LEU	P+T	HIS	LYS	TRP	AAS	TPD	PDCAAS
Theory	1.02	1.14	1.11	1.04	0.88	1.28	1.49	0.93	1.02	0.88	81.61	71.82
Actual	1.08	1.14	1.00	1.11	0.93	1.09	1.55	0.95	1.13	0.93	81.75	76.26

How accurate is the prediction?

Pretty good.

The Impact of Adding Pulse Flour to Wheat Flour on PDCAAS Values



House, J.D. Unpublished data

Take Home Message(s)

- Protein quality assessment is complex
 - PDCAAS: protein digestibility (animal trial), amino acid composition
- Different protein sources have their own unique challenges
 - Protein content/composition, anti-nutritional factors
- Blends can be designed theoretically to maximize quality

Learning Objectives

- Understand how the Protein Digestibility Corrected Amino Acid Score (PDCAAS) is determined, and its relationship to content claims
- Know how PDCAAS differs between dietary proteins and how to predict the PDCAAS values of blends



Guelph, Ontario, Canada

Acknowledgements

- Dr. James House, Protein Quality research group, University of Manitoba
- Pulse Science Cluster, Growing Forward 2 (Agriculture and Agri-Food Canada)
- Global Institute for Food Security

Questions? Matthew.Nosworthy@Canada.ca



AAFC Guelph Research and Development Centre