Challenges and Opportunities for Innovative Protein Foods: Focus on Nutritional Quality

James D. House
Department of Food & Human Nutritional Sciences
University of Manitoba
Winnipeg, MB, Canada
Outline

• Factors impacting protein utilization
• Importance of measuring protein quality
  • Current and proposed methods
• Advantages and disadvantages of current and proposed methods
• New options to position quality proteins in the human food marketplace using *in vitro* approaches
• Summary comments
Factors Impacting Protein Utilization

Global Protein Ingredients Market Estimates and Forecast, 2014-2025

Global Plant Protein Ingredients Market, Compound Annual Growth Rate, 2016-2025 (USD Millions)

Source: Protein Industries Canada; Unleashing the potential of Canadian crops. Accessed: www.proteinindustriescanada.ca
Factors Impacting Protein Utilization

- Culture
- Cost
- Healthfulness
- Sustainability
- Convenience
- Sensory Attributes
- Innovation
- Food
- Safety
- Ethics
Incorporating Proteins Into Foods

- Measures of Protein Functionality
  - Critical for Sensory Qualities and Consumer Acceptability
  - What about Protein Quality?

<table>
<thead>
<tr>
<th>Protein Attribute</th>
<th>Example Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Holding Capacity</td>
<td>Baked Goods</td>
</tr>
<tr>
<td>Oil Holding Capacity</td>
<td>Baked Goods</td>
</tr>
<tr>
<td>Emulsification</td>
<td>Salad Dressings</td>
</tr>
<tr>
<td>Foaming</td>
<td>Egg Substitutes</td>
</tr>
<tr>
<td>Gelation</td>
<td>Sauces</td>
</tr>
<tr>
<td>Fibration</td>
<td>Meat Analogues</td>
</tr>
<tr>
<td>Solubility</td>
<td>Beverages</td>
</tr>
<tr>
<td>Extrudability</td>
<td>Snack Foods</td>
</tr>
</tbody>
</table>
Defining Protein Quality

Amino Acid Composition

How well does the amino acid pattern match human amino acid needs?

Digestibility/Availability

To what extent are the amino acids digested, absorbed and ultimately made available for metabolic demands?
Protein Quality: Important for Communicating Food Protein Messages

- Nutrition Facts Panel
  - Crude Protein Content
  - % Daily Value (in US)

- Claims
  - Origin Claims
  - Composition Claims
  - Symbols
  - Nutrient Content Claims
    - Source → Excellent Source
    - Comparative Claims

**Nutrition Facts**

<table>
<thead>
<tr>
<th>Valeur nutritive</th>
<th>Valeur nutritive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per 1 bowl (300 g) / Pour 1 bol (300 g)</td>
<td>Amount / % valeur quotidienne</td>
</tr>
<tr>
<td>Calories / Calories</td>
<td>440 / 29 %</td>
</tr>
<tr>
<td>Fat / Lipides</td>
<td>19 g / 29 %</td>
</tr>
<tr>
<td>Saturated / Saturés</td>
<td>4 g / 21 %</td>
</tr>
<tr>
<td>+ Trans / Trans</td>
<td>0.2 g / 21 %</td>
</tr>
<tr>
<td>Cholesterol / Cholestérol</td>
<td>35 mg / 18 %</td>
</tr>
<tr>
<td>Sodium / Sodium</td>
<td>860 mg / 38 %</td>
</tr>
<tr>
<td>Carbohydrate / Glucides</td>
<td>53 g / 18 %</td>
</tr>
<tr>
<td>Fibre / Fibres</td>
<td>4 g / 2 %</td>
</tr>
<tr>
<td>Sugars / Sucres</td>
<td>6 g / 2 %</td>
</tr>
<tr>
<td>Protein / Protéines</td>
<td>15 g / 25 %</td>
</tr>
<tr>
<td>Vitamin A / Vitamine A</td>
<td>15 %</td>
</tr>
<tr>
<td>Vitamin C / Vitamine C</td>
<td>4 %</td>
</tr>
<tr>
<td>Calcium / Calcium</td>
<td>20 %</td>
</tr>
<tr>
<td>Iron / Fer</td>
<td>20 %</td>
</tr>
</tbody>
</table>

**High in Protein**

**Excellent Source of Protein**
What Evidence is Needed to Support Content Claims?

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Basis for Protein Content Claims</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>Protein Quality &amp; Quantity</td>
<td>Protein Rating System based on the Protein Efficiency Ratio (PER)</td>
</tr>
<tr>
<td>USA</td>
<td>Protein Quality &amp; Quantity</td>
<td>Protein Digestibility-Corrected Amino Acid Score (PDCAAS)</td>
</tr>
<tr>
<td>EU</td>
<td>Protein Quantity</td>
<td>Expression of protein content relative to energy content</td>
</tr>
</tbody>
</table>

**Proposed Method**: Digestible Indispensable Amino Acid Score (DIAAS)
The Protein Rating Approach

- Based on Protein Efficiency Ratio
  - Rat bioassay
  - Weight gain/Protein intake over 28 days
- Adjustments relative to reference protein (Casein)
  - Adj. PER of Casein = 2.5
- Protein Rating = PER x Protein

Contained in Reasonable Daily Intake
- 20 ->39.9 = Source of Protein
- 40 and above = Excellent Source of Protein

Eggs
Protein Rating = 100 g x 12.63% x 3.1
= 39.2 (Good Source)
The Protein Rating Approach

Advantages

• Simple
• Provides a summative biological response to protein intake

Disadvantages

• Rodent bioassay → not reflective of human amino acid needs
• Ethical constraints
• Limited data available
  • 47 entries in the CFIA PER table
  • 247,326 foods in USDA Food Composition Databases
• Non-additive
  • Limits predictions for new food products
The PDCAAS Approach

Product of:

- 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

![PDCAAS Values of Common Foods Chart]
Protein Content Claims

- **PDCAAS x Protein content of “RACC”**
  - Representative amount customarily consumed

- **Compare to Daily Value (50 g)**
  - 5 – 9.9 g = Good Source
  - 10 g or greater = Excellent Source

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**Example:**

- **Eggs**
  - 50 g x 12.63% x 1.0 = 6.32 *(Good Source)*
# The PDCAAS Approach

## Advantages

- Simple
- Robust AA datasets
- Additive
  - Permits calculations of PDCAAS values of mixtures

## Disadvantages

- Rodent bioassay → not reflective of human amino acid needs
- Fecal protein digestibility
  - Impact of gut microbiota
- Ethical constraints
- Truncation of values > 1.00
In Canada:

- CFIA will permit PER values to be calculated from PDCAAS.

Calc. PER = $rac{\text{PDCAAS (Test)}}{\text{PDCAAS (Casein) \times 2.5}}$

Various Pulses/Cereals & Processing Methods
The DIAAS Approach

Proposed Approach
• AA treated as individual nutrients
• Uses ileal digestibility values
• Scores >1.00 are not truncated
• Reference amino acid pattern updated

Advantages
• Should be more reflective of the ability of a food to provide available protein

Disadvantages
• Multiple analyses required for one DIAAS value
  • Expense
  • Analytical Errors
    • Minimum of 10 separate analyses for 1 number!
• Bioassay
  • Ethical constraints
## PDCAAS vs. DIAAS

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>PDCAAS 1991*</th>
<th>PDCAAS 2013¥</th>
<th>DIAAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WPI</td>
<td>99&lt;sup&gt;a&lt;/sup&gt; (AAA)</td>
<td>97&lt;sup&gt;b&lt;/sup&gt; (His)</td>
<td>100&lt;sup&gt;a&lt;/sup&gt; (His)</td>
</tr>
<tr>
<td>WPC</td>
<td>100&lt;sup&gt;b&lt;/sup&gt; (AAA)</td>
<td>107&lt;sup&gt;a&lt;/sup&gt; (His)</td>
<td>107&lt;sup&gt;a&lt;/sup&gt; (His)</td>
</tr>
<tr>
<td>MPC</td>
<td>100&lt;sup&gt;c&lt;/sup&gt; (Thr)</td>
<td>121&lt;sup&gt;b&lt;/sup&gt; (SAA)</td>
<td>120&lt;sup&gt;b&lt;/sup&gt; (SAA)</td>
</tr>
<tr>
<td>SMP</td>
<td>100&lt;sup&gt;d&lt;/sup&gt; (SAA)</td>
<td>112&lt;sup&gt;b&lt;/sup&gt; (SAA)</td>
<td>105&lt;sup&gt;c&lt;/sup&gt; (SAA)</td>
</tr>
<tr>
<td>PPC</td>
<td>75&lt;sup&gt;a&lt;/sup&gt; (Trp)</td>
<td>71&lt;sup&gt;b&lt;/sup&gt; (SAA)</td>
<td>62&lt;sup&gt;c&lt;/sup&gt; (SAA)</td>
</tr>
<tr>
<td>SPI</td>
<td>93&lt;sup&gt;a&lt;/sup&gt; (SAA)</td>
<td>86&lt;sup&gt;b&lt;/sup&gt; (SAA)</td>
<td>84&lt;sup&gt;c&lt;/sup&gt; (SAA)</td>
</tr>
<tr>
<td>Soya flour</td>
<td>98&lt;sup&gt;a&lt;/sup&gt; (Lys)</td>
<td>93&lt;sup&gt;b&lt;/sup&gt; (SAA)</td>
<td>89&lt;sup&gt;c&lt;/sup&gt; (SAA)</td>
</tr>
<tr>
<td>Wheat</td>
<td>50&lt;sup&gt;a&lt;/sup&gt; (Lys)</td>
<td>51&lt;sup&gt;a&lt;/sup&gt; (Lys)</td>
<td>45&lt;sup&gt;b&lt;/sup&gt; (Lys)</td>
</tr>
</tbody>
</table>

WPI = whey protein isolate  
WPC = whey protein concentrate  
MPC = milk protein concentrate  
SMP = skim milk powder  
PPC = pea protein concentrate  
SPI = soy protein isolate

FAO Committee Recommended that no protein with DIAAS < 75 should qualify for source claims

* Mathai et al., 2017

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Bridge2Food - 12th Plant Protein Ingredients Summit 2019

Mathai et al., 2017
Achieving Higher Protein Quality

The Impact of Adding Lentil Flour to Cereals on DIAAS Values

DIAAS Value vs. % Lentil Flour for various cereals:
- Wheat
- Oats
- Corn
- Brown Rice
Key Issues Moving Forward

• How do we manage variability in protein quality?
  • Need to understand the sources of variability

• Do we need to use animal testing to substantiate protein content claims?
  • In vitro methods?
  • Focus on protein content only?
## Factors Influencing Plant Protein Quality

<table>
<thead>
<tr>
<th>Factor</th>
<th>Amino Acids</th>
<th>Digestibility / Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Genetics</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Environmental Factors</td>
<td>✔</td>
<td>?</td>
</tr>
<tr>
<td>Management Factors</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Thermal Processing</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Particle Size</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Blending</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Concentration/Isolation</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Fermentation</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Germination/Sprouting</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Hydrolysis</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
in vitro PDCAAS

Do we need to have a bioassay to measure protein quality? No!

A. Franczyk et al., 2018

Ph Drop Method
\[ y = 0.8992x + 3.7391 \]
\[ R^2 = 0.8321 \]

Two Step Digestion Method
\[ y = 1.0069x - 0.0716 \]
\[ R^2 = 0.8627 \]
Advantages

• Removes ethical concerns of animal testing
• Simple and readily implemented
• Robust AA datasets
• Additive
  • Permits calculations of PDCAAS or DIAAS values of mixtures
• Maintains process for regulatory oversight of novel proteins

Disadvantages

• Requires additional validation against *in vivo* measures
• Need for standardized approaches and inter-laboratory validation studies
• As with all measures of quality, need to determine if it “matters” for human health
  • Particularly for foods not designed as sole-source foods (e.g. infant formulas)
What is a "Good Protein"?

Considerations for Protein Food
Innovation Ideas
What is a "Good Protein"?

- Cost
- Supply
- Functionality
- Sensory Attributes
- Nutritional Attributes
- Societal Expectations
Thank You!

- The Protein Quality team at University of Manitoba
- Our collaborators
- Our funding partners and sponsors
- Bridge2Food and Protein Industries Canada