Dempster-Shafer Theory Evaluation of Optimal Protein Intake

for Moderately Active Healthy Adults >60 Years

1. Brief Theoretical Explanation

Dempster-Shafer (DS) theory (also called belief function theory) is a mathematical framework for reasoning under uncertainty that generalizes classical probability. Unlike standard probability, DS allows explicit representation of **ignorance** and **conflict** and provides **imprecise probabilities** (intervals) rather than single numbers.

Key concepts:

- **Frame of discernment Ω**: the set of mutually exclusive hypotheses (here: three protein intake ranges).
- **Basic belief assignment (mass function) m(·)**: distributes a total mass of 1 over subsets of Ω (focal elements).
  m(S) = degree of belief exactly committed to S (and nothing smaller).
- **Belief function Bel(S)**: lower bound of probability that the truth lies in S
  Bel(S) = Σ m(T) over all T ⊆ S, T ≠ ∅
- **Plausibility function Pl(S)**: upper bound of probability that the truth lies in S
  Pl(S) = Σ m(T) over all T such that T ∩ S ≠ ∅
- Result: for any proposition S, the **imprecise probability** is the interval [Bel(S), Pl(S)]

2. Premises and Frame of Discernment

We evaluate three competing scenarios for the **optimal daily protein intake** (g/kg body weight) for **moderately active, healthy adults >60 years**:

Label	Scenario	Protein range (g/kg/d)
A	Low-to-moderate	0.8 – 1.0
B	Moderate-to-high	1.0 – 1.6
C	Very high	> 1.6

Frame of discernment: Ω = {A, B, C}

3. Basic Belief Assignment (Masses)

Masses were assigned based on a synthesis of current scientific literature, expert consensus, and practical considerations:

Focal element	Mass m(·)	Rationale
{A}	0.10	Some older guidelines and a few experts still defend ~0.8 g/kg/d
{B}	0.45	Strongest consensus in recent reviews and expert panels (e.g., PROT-AGE, Stokes 2019, Hector & Phillips 2018)
{C}	0.05	Only supported for intense training or severe sarcopenia; weak evidence for average case
{A,B}	0.35	Very strong evidence that optimal is ≤1.6 g/kg/d and >0.8 g/kg/d
{A,C}	0.00	No credible evidence supports both extremes
{B,C}	0.05	Some experts argue higher end (1.2–1.6+) may be beneficial even without intense training
{A,B,C}	0.00	No residual total ignorance
Total	**1.00**	

4. Calculations: Belief and Plausibility

Formulas used:

$Bel(S) = \Sigma\ m(T)$ for all $T \subseteq S, T \neq \varnothing$

$Pl(S) = \Sigma\ m(T)$ for all T such that $T \cap S \neq \varnothing$

Proposition S	Belief Bel(S)	Plausibility Pl(S)	Imprecise probability interval [Bel, Pl]
{A}	0.10	0.45	[0.10 – 0.45]
{B}	0.45	0.85	[0.45 – 0.85]
{C}	0.05	0.10	[0.05 – 0.10]
{A,B}	0.90	0.95	[0.90 – 0.95]
{B,C}	0.55	0.90	[0.55 – 0.90]
{A,C}	0.15	0.55	[0.15 – 0.55]
{A,B,C}	1.00	1.00	[1.00 – 1.00]

5. Results Summary (Technical)

Key question	Interval [Bel, Pl]	Interpretation
Is 0.8–1.0 g/kg/d optimal? (A)	[0.10 – 0.45]	Low belief, moderate plausibility
Is 1.0–1.6 g/kg/d optimal? (B)	[0.45 – 0.85]	Highest belief and plausibility among single scenarios
Is >1.6 g/kg/d optimal? (C)	[0.05 – 0.10]	Very weak support
Optimal is ≤1.6 g/kg/d (A or B)	[0.90 – 0.95]	Overwhelming evidence against very high intakes
Optimal is ≥1.0 g/kg/d (B or C)	[0.55 – 0.90]	Strong evidence that RDA is too low for most

6. Simplified Results for Mathematically Lay People

Think of the results as **confidence ranges** instead of exact numbers.

- The **classic RDA (0.8 g/kg/d)** has only **10–45% support**. It is possible but not strongly believed.
- The **range 1.0–1.6 g/kg/d** has **45–85% support**. This is the **most credible and widely accepted** target.
- The **very high range (>1.6 g/kg/d)** has only **5–10% support**. It is **highly unlikely** to be necessary for the average moderately active adult >60.
- There is **90–95% confidence** that the optimal intake is **at most 1.6 g/kg/d**.
- There is **55–90% confidence** that it is **at least 1.0 g/kg/d** (i.e., the old RDA is probably too low).

Practical recommendation:
For most moderately active healthy adults over 60, aim for **1.0 to 1.6 grams of protein per kilogram of body weight per day**. This range is strongly supported by current evidence and expert consensus. Intakes above 1.6 g/kg/d are **not necessary** for the average person in this group.

This DS model shows that the evidence is **clear enough** to give a confident practical recommendation, while still acknowledging some remaining uncertainty.