Alternative proteins in Food

PHIL JOHNSON
FDST, UNL
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Overview

• Protein diversity in the diet
• Exposure to proteins from the diet
• Considerations for alternative proteins
Prediction: The biochemistry of proteins will matter more to us in the future
Protein diversity in the diet
Food Proteomes

**Single-source** food typically contains

- 10’s to 1000’s of protein sequences
- With 10-20 proteoforms for each sequence
- Protein sequences are typically **unique** to both species and protein
- **Amounts** of each protein vary of many orders of magnitude
The ‘generalist’ human

• Homo sapiens is likely the most generalist of consumers
• Over 80,000 edible plant species
• Many animal species with broad taxonomic representation
• Foraging: Eat what we can that is safe and nutritious
Cranial development is extremely **energetically expensive**.

Speculation that consumption of various insects allowed **rapid cranial volume expansion** 0.5-2MYa.

*Figure 2. The growth rate of hominid cranial capacity began to rapidly increase starting around two million years ago. Figure adapted from Le Journal du Net (2010).*
Decreasing variety

• Nowadays, we consume approx. 200 plant species and 10 animal species
• 75% of Humanities’ food is generated from only **12 plants** and **5 animal species** (*United Nations, “Our Biodiversity, Our Food, Our Health”, 22 May 2019*).
• Pre-packaged foods mostly consist of the same **4-5 food species** combined in different ways.
Consequences of shrinking diet diversity

Problematic for both the conservation of biodiversity and for human health.

• Directly linked to malnutrition and diseases such as diabetes, obesity, high blood pressure, atherosclerosis, and cardiovascular disease.

• In 100 years, more than 90 per cent of crop varieties have disappeared from farmers’ fields.

• Local, indigenous, traditional knowledge of food production have been lost.
Other potential consequences

• **Food security** – fewer crops/animals = greater likelihood of failure

• Essential **dietary components** (amino acids)

• **Immune system** maturation (including inadvertent exposure to parasites and pathogens)

• Unknown ? Bioactives
Exposure to proteins from the diet
‘Xenoproteome’ exposure

- Through skin, lung, intestinal epithelia (from oral mucosa down)
- Through direct interaction with the microflora of our gut
Can proteome diversity even matter beyond the GI tract?

"Protein digestion is the process of cleavage of protein into absorbable smaller fragments constituted by amino acids, dipeptides, and tripeptides. Amino acid absorption is the process of amino acid, dipeptide, and tripeptide uptake from the gastrointestinal lumen”

Amino acid composition, digestibility the traditional variables in food science
Ingested protein enters the human bloodstream

Presence of mostly intact proteins in blood after ingestion:

- Peanut (Ara h 2, Ara h 6)
- Milk (β-lactoglobulin, caseins)
- MS-based analysis of human breast milk suggested that protein adsorption was more prevalent and broad than previously suspected (36 nonhuman proteins and 1577 human proteins) (Zhu et al, 2019)
- Some conditions indicate intact proteins (e.g. allergy)
The human sera proteome contains significant numbers of dietary proteins

Amino acid composition
- Digestibility

Amino acid composition
- Primary Sequence
- Secondary Structure
- Tertiary Structure
- Quaternary Structure

Biological Activity
New class of potential bioactives

Presence and implications of dietary proteins in the human body

• How much protein?

• What factors determine protein uptake? What are the mechanism(s)?

• Are the proteins active?

• Are some beneficial?

• Are some harmful?
‘Alternative’ proteins
Replacing diversity loss

• We can consider the current trend of diversifying food sources, particularly proteins, as ‘reintroducing old friends’

• We are reintroducing **taxonomic diversity** into our diets:
  • New **organism**
  • New **tissues**

• In addition to new sources of proteins, we are starting to use **properties of individual proteins**.
- **Novel organism**: The organism from which the novel food is derived has no clear history of documented consumption in the region of interest.

- **Novel tissue**: The tissue from which the food is derived has no clear history of documented consumption in the region of interest.

- **Cell culture**: Foods produced by culturing cells of organisms. The source of the cells may be novel or existing foods. Example: lab-grown meat.

- **Novel processing**: Food processing techniques differ to those used previously. Example: pea protein isolates.

- **Novel consumption**: The expected or intended consumption of the food differs to previous. Example: pea protein isolates.
‘Novel protein’ work in FDST

• Allergenicity risk assessment is required as part of GRAS

• Potential allergenicity is not trivial to estimate

• Generally examine sequence of major proteins in the food to look at similarity to known, existing allergens (e.g. via AllergenOnline.org)

• Perform lab-based tests as indicated
Safety evaluation often already involves examination of individual protein sequence

• **Whole genome sequencing** allows to compare all possible proteins in the novel food to existing allergens.

• Resultant ORFs are **compared to allergen database** (e.g. Allergen Online) to assess similarity.

• Regulators do not currently *require* the submission of such data, but there are indications that it is *favored*. 
Tropomyosin

- Major muscle protein
- Highly conserved
- Known to be allergens in shellfish
- Insect tropomyosins are substantially similar to those in shellfish
- Similarity includes regions of the protein to which human IgE is thought to bind (epitopes)
Specific selection of proteins

Small, but increasing number of the use of specific proteins in foods

- **Taste** (e.g. heme-containing, sugar mimics)
- **Physicochemical** properties (ice-structuring proteins in ice cream, silk for packaging)
- **Mimicry** of animal foods with non-animal sources (BLG, caseins in ‘milk’).
- Proteins are usually produced by **recombinant expression**
Freeze/thaw quality (ISP)

Structural mimics of sugar

Silkworm silk as a packaging material
Summary

• The presence of **food-derived proteins in our blood** indicates a possible new direction for food / health research.

• This, together with technologies to produce individual protein ingredients for food, will drive interest in **bioactive effects of specific proteins, including from new, alternative sources.**