Harnessing Emerging Technologies in Nutrition and Biomedical Science for Public Health Improvement

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Professor, Dept. of Biochemistry, National University of Singapore
The Father of Human Nutrition: Dutch Scientist Christiaan Eijkman

1870s
- Batavia
- Conducted research using chickens in search of the cause of beriberi
- Surmised that the cause was depriving the body of a dietary component found in unpolished rice that was lacking in polished rice (anti-beriberi factor)

1897
- Discovered Thiamin, Vitamin B1
Beginnings of food technology?

Fig. 2.1. The title page from the first edition of Appert’s book.
Pellagra
Deaths from Pellagra in USA 1938-1954

DEATHS FROM PELLAGRA IN THE UNITED STATES
(1938 TO 1954)

- Bread enrichment began in 1938 and continued voluntarily through 1942
- Use of synthetic vitamins established (1939)
- Cereal enrichment legally accepted (1941)
- Mandatory state enrichment began (1942)
- Mandatory federal enrichment began (1943)
- Mandatory federal enrichment repealed (1946)
- By 1948, 22 states required enrichment

Source: National Center for Health Statistics
Prepared by Don Miller, FDA

CHANGING TOMORROW'S HEALTH, TODAY
Flour fortification

• Worldwide
  – Flour (except wholemeal) is fortified with; calcium, iron, thiamin and niacin.

• USA
  – In the USA the flour is also fortified with folic acid.
Nutrition moved from Therapeutic to Preventive Health
300,000 known plant species

100,000 used by humankind

30000 Edible

3 provide 60% calories (rice, wheat, maize)

30 provide 90% of plant calories

7000 used as food at local level

120 Important at national scale
Cereals & Tubers of Global Importance Today

- Wheat
- Rice
- Corn
- Potato
- Cassava
- Sweet Potato
Public Health Concerns

Diabetes
Obesity
Cardiovascular diseases
Hypertension
Cancer
Cognitive decline (Healthy ageing)

FOODS, a major contributor to NCDs

PROTEIN
CARB
FAT

CHANGING TOMORROW'S HEALTH, TODAY

Singapore Institute for Clinical Sciences
Technology is advancing Exponentially

Source: Vivek Wadwa
Food Structure Engineering for Nutrition and Health Scientific Workshop

6th September 2017
8.30am – 3.15pm
Biopolis, Singapore

“The integration of food engineering with nutrition is the disruptive science we have been waiting for. Join us on the 6th of Sept.”
Jeya Henry, Director of CNRC
“FOOD ENGINEERING may be defined as the use of processing, novel ingredients and physicochemical manipulation in order to enhance the sensory and health attributes of native foods”
Food Funct., 2015, 6, 663-678
How food structure can influence nutrition

1. Sensory and Cognitive Influences
   - Cognitive Influences on energy intake
   - Food choice and energy selection
   - Sensory perception
   - Mastication / Oral processing
   - Texture cues to change eating rate

2. Metabolic Impact of food intake
   - Glycaemia / Glucose metabolism
   - Lipid metabolism
   - Brown Adipose Tissue activation
   - Cardio-metabolic risk factors

3. Impact of food on Body Composition and Metabolic Health
   - Partitioning of energy metabolism
   - Changes in BC after weight loss
   - Impact of weight change on metabolism
   - Insulin sensitivity after weight loss
Can bread processing conditions alter glycaemic response?

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\textsuperscript{b}Food Science and Technology Programme, Department of Chemistry, National University of Singapore, S14 Level 5, Science Drive 2, Singapore 117543, Singapore
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\textbf{Fig. 2.} Blood glucose responses to 50 g equivalent portions of bread in healthy subjects (n = 13).
Role of food structure influencing glycemic response

• Two foods with almost identical composition, i.e. protein, fat, carbohydrate, may have vastly different GI value
  – e.g. ice cream - GI value = 50
  milkshake - GI value = 75

• Why?
Structure of ice cream

(1) air cells; (2) fat globules; (3) ice crystals; (4) lactose/sucrose
Microstructures for healthy foods

- Modifying manufacturing processes
- Extruded Low Fat Ice cream
- Low Fat Mayonnaise and Spread
- Reduces energy density of food
- More satiety with low volume of food

Palzer, 2009, Trends in Food Science and Technology
Manipulation of Lipid Food Structure: Oleogel Formation

Ethylcellulose

Oil

Oleogel

Food & Function, 3(3), 327-337.

ILSI SEA Region Symposium: Transformation Technologies and Translational Research 23 April 2018 Singapore

CHANGING TOMORROW'S HEALTH, TODAY
Influence of Oleogel on Glycaemia and Lipidemia Response

The transformation of liquid oil to a gel using ethyl cellulose has an effect on the elevation of Triglycerides when oils are consumed in the liquid form.
CHANGING TOMORROW’S HEALTH, TODAY
Water, salts, bile

Enzymes, bile

Glucose, amino acids, fatty acids and other micro-nutrients

Duodenum

Terminal ileum

Macro-nutrients

Cell wall

Particle breakdown
Hydrolysis of macro-nutrient
Absorption of micro-nutrients
Swelling and solubilisation of fibre

Figure concept adapted from Gidley, *Current Opinions in Colloid and Interface Science*, 18, 371-378 (2013)

Rheological effects

Fermentation in large intestine

(Dikeman & Fahey, 2006; Jenkins et al., 2002; Makelainen et al., 2006; Marciani et al., 2001; Fanahi, Ezatagha, Temelli, Vasanthan & Vuksan, 2007; Queenan, Stewart, Smith, Thomas, Fulcher & Slavin, 2007; Würsch & Pi-Sunyer, 1997).

Courtesy of Centre for Nutrition and Food Sciences
Starch granules from different sources

- Potato starch
- Wheat starch
- Rice starch
- Corn starch
Specially designed food structures

- Resistant or slowly digestible starches to replace low molecular weight or rapidly digestible carbohydrates
- Hardly digestible lipids - Sn-2 monoglycerides
- Enhances satiety
Physicochemical and physiological processes that may occur during lipid digestion and absorption of emulsified lipids in the human GI tract

*Advances in Colloid and Interface Science*, 159 (2), 2010, pg 213-228
Fish oil

Omega 6 fatty acids

- C18:2n-6 Linoleic acid
- C20:4n-6 Arachidonic acid
- C22:5n-6 Docosapentanoic acid

Omega 3 fatty acids

- Plant derived
  - C18:3n-3 α linolenic acid
- Marine derived
  - C20:5n-3 Eicosapentanoic acid (EPA)
  - C22:6n-3 Docosahexanoic acid
Omega 3 and Omega 6: Striking a balance

**Overconsumption**

- Omega 6 > Omega 3 consumption may lead to an overproduction of inflammation producing prostaglandins (PGE2s) and a lack of anti-inflammatory prostaglandins (PGE1s and PGE2s) \( \rightarrow \) variety of health problems

**Undesirable properties**

Negative effect on head cause by Linoleic acid.

Increase risk of age related macular degeneration – disease of eye that lead to progressive loss of vision and eventually blindness

**Interactions**

- Nutrient essential for use of Omega 6 fatty acid in the body: magnesium, selenium, zinc, Vit A, carotene, Vita B3, B6, C and E
Micro-encapsulation to enhance the use of fish oils
Encapsulation for delivery of bioactive compounds
Filled hydrogel beads containing encapsulated lipid droplets can be formed by injecting droplet-alginate solutions into a solution of calcium.
Different kinds of structured emulsion-based delivery systems that can be used to control lipid digestion and release.

*Advances in Colloid and Interface Science, 159 (2), 2010, pg 213-228*
Alternative Protein
Leaf Protein Concentrate
Amino acid of leaf protein concentrate

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<tr>
<th>Amino Acid</th>
<th>Telfaira occidentalis</th>
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<td>Lysine</td>
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<tr>
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<tr>
<td>Phenylalasine</td>
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MEALWORMS - A COMBINATION OF THE BEST

- Protein content of beef
- More vitamin B12 than eggs
- Essential aminoacid profile of tofu
- More fibre than broccoli

- Potential therapeutic compounds for Alzheimer’s disease
- Vitamin B5 for your skin
- Choline for your liver
- Phosphorus for your teeth and bones

CHANGING TOMORROW’S HEALTH, TODAY
## Amino acid profile of Earthworms

<table>
<thead>
<tr>
<th>Amino Acid*</th>
<th>Earthworm L. rubellus</th>
<th>Earthworm meal L. rubellus</th>
<th>Earthworm meal P. excavatus</th>
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* Dry matter basis (%); 1) Tram et al., 2005
# Amino acid profile of Grasshopper

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*Food and Nutrition Sciences, 3(02), p.164.*

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**ILSI SEA Region Symposium: Transformation Technologies and Translational Research 23 April 2018 Singapore**

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**CHANGING TOMORROW’S HEALTH, TODAY**

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**Singapore Institute for Clinical Sciences**
Prediction of Nutrition Status and food Selection

1. Vitamin Status
2. Mineral Status
3. Lipid Triglycerides
Prediction of Nutrition Status

1. Vitamin Status
2. Mineral Status
3. Lipid Triglycerides
Moving forward - understanding food structure will enable us to develop foods to prevent chronic and improve health and wellbeing.

The structure of foods and interactions:
- Natives food structures
- Natural polymers (proteins and carbohydrates)
- Polymers assemblies

UNDERSTANDING ...

- Food structure
- Food intake
- Prevention of chronic disease
- Health & well-being

Microstructure to design foods with unique nutritional advantages:
- Slowly digestible carbohydrates
- Lipid structuring (control lipidemia)
- Texture and taste enhancement for appetite control
- Encapsulation & target delivery (enhance bioavailability)

Food to improve quality and health:
- Product development
- Process engineering & optimization
- Clinical validation
- Consumer validation

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Conclusion

• The food and nutrition landscape will dramatically change in the next few years
• Health and well being will be main driver of food innovation
• An understanding of how the structure of food can be manipulated will revolutionize both food technology and human nutrition
• Rapid measurement of nutrient status in combination with nutrient selection will enable consumers to eat an optimal diet
• Evidence based science will provide new insights into how phytochemicals present in plants may become the “new medicine” in the combat against diabetes, heart disease, cancer and decline in cognition.
• The 21st century will witness the greatest revolution in food science and nutrition