Research targeting food reformulation in the regulation of hunger and satiety

Julian Mercer

Rowett Institute of Nutrition and Health

UNIVERSITY OF ABERDEEN
Obesity

Obesity prevalence in Scotland (2008):

- 24.9% males
- 26.5% females

Global obesity:

- 300 million adults

Source: WHO Global Database on Body Mass Index

Source: The Scottish Health Survey 2008
Obesity-related health consequences

Coronary artery disease and stroke:
- Left ventricular hypertrophy
- Cardiac failure
- Ischaemic stroke

Cancers

Metabolic syndrome

Type-2 diabetes

Hypertension

Reproductive dysfunction:
- Infertility in women
- Impotency/infertility in men

Osteoarthritis

Liver and gallbladder disease:
- Non-alcoholic fatty liver disease
- Non-alcoholic steatohepatitis
- Dyslipidaemia

Respiratory complications:
- Obstructive sleep apnoea
- Daytime somnolence
- Pulmonary hypertension

After: Kopelman, Obesity Reviews 2007
Obesity treatments

- **Surgery**
  
  Types of Weight Loss Surgery

  Gastric banding and gastroplasty ("stomach stapling") are restrictive procedures that decrease the stomach size from about six cups to one. Malabsorptive procedures, which block food absorption, include gastric bypass. "Roux-en-Y” gastric bypass combines both approaches and is the most common weight loss surgery in the U.S. It reduces the size of the stomach and prevents the absorption of calories in the small intestine.

- **Drugs**

- **Diet-based – caloric restriction, diet composition, reformulation**
Can we rely on population level behaviour change?

Or do we need a variety of approaches for different consumer groups?
**How to deliver change? – e.g. green/ethical customer categories**

<table>
<thead>
<tr>
<th>‘green crusaders’</th>
<th>..will choose anyway</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘if it’s easy!’</td>
<td>..provide clear choice</td>
</tr>
<tr>
<td>‘what’s the point?’</td>
<td>..education; choice; reformulation</td>
</tr>
<tr>
<td>‘not interested’</td>
<td>..reformulation – ‘health by stealth’</td>
</tr>
</tbody>
</table>

**DIETARY CHANGE**
Satiety cascade as a target for reformulation

- processes that start, sustain and terminate a meal
- processes that suppress further consumption
- strategies for limiting over-consumption of calories or sustaining appropriate levels of intake
Exploiting satiation and satiety

Finlayson & Blundell 2012
Food characteristics and the satiety cascade

**Meal Quality**
- Consumer appeal
- Flavour
- Texture
- Nutrient composition

**Meal Quantity**
- Oral metering
- Osmotic load
- Gastric stretch
- Gastric emptying

**Nutrient status**
- Microbiota
- Gut biomarkers
- Nutrient absorption
- Substrate oxidation

**Cognitive Sensory**

**Pre-Absorptive**

**Post-Absorptive**

Pre-prandial motivation

Termination of meal early

Inhibition of food intake late

Onset of next meal

SATIATION

SATIETY

SATIATION

Finlayson & Blundell, 2012
What role for hedonics and reward?

In addition to physiological regulation, food consumption is subject to psychological control involving reward pathways.

Figure 2. The mesolimbic reward system: a target for natural and artificial rewards.
3 projects from KBBE:

**NeuroFAST** - food intake, addiction and stress

**Full4Health** - food-gut-brain, hunger and satiety, lifespan

**SATIN** - satiety, food structure and processing
What does reformulation for satiety/satiation mean?

- Re-balancing macronutrients in the diet
- Protein is the most satiating macronutrient
- Selecting advantageous ingredients/matrices from within macronutrient categories

Fat (9 kcal/g)

Protein (4 kcal/g)

CHO (4 kcal/g)
Research towards palatable foods that match the nutritional and energetic needs of the consumer

- Evidence base: bioactive components, mode of action, target - e.g. satiety for weight control, metabolic health
- Markers of biological effect and health benefit
- Population subgroup-specific solutions
- Linking the food industry and public health policy
Gut-brain hunger and satiety mechanisms – food largely overlooked
Food – a key component of the food-gut-brain cycle

Potential to manipulate gut-brain interactions with drugs, but also through reformulation of food: e.g. reduced energy density at the same palatability, nutrient release of gut satiety peptides, mimic effect of bariatric surgery, exploiting brain mechanisms of food reward, and addressing food addiction.
• gut hormones and food reward
• addiction-like behaviour – higher brain centres
NeuroFAST view of ‘food addiction’:

- Not substance based
- No specific neural mechanism – rare mutations leading to phenotype
- Overlap with reward systems is insufficient to define food addiction
- Weak association with obesity – higher prevalence in specific groups within obesity range e.g. binge eating disorder
- Behaviour based - wide range of mechanisms

**Diagnostic and Statistical Manual of Mental Disorders:**

DSM IV – ‘substance related disorders’

DSM V – ‘substance use and addictive disorders’
Covert manipulation of dietary macronutrient composition – food intake and preference

• covert manipulation of fat content - higher fat content increases energy intake

• subjects have preference for foods higher in dietary fat even when caloric content is masked

• brain pathways detect dietary macronutrients and affect eating behaviour before the meal is completed

• replacement of sucrose with sweetener (energy dilution with erythritol) does not affect hunger or satiety, and at fixed energy intake may have beneficial effects on gut hormone release

Implications for beneficial food reformulation

University of Cambridge

NIZO The Food Researchers

NeuroFAST
Understanding food-gut-brain mechanisms across the lifespan in the regulation of hunger and satiety for health

FEB 2011-JAN 2016

Co-ordinator: Julian Mercer

www.full4health.eu
Full4Health objectives – ‘food-gut-brain’

- understanding the **mechanisms of hunger and satiety** to prevent chronic disease – human interventions, pre-clinical and in vitro studies

- researching **gut-brain interactions** in response to food across the lifespan

- the role of **dietary components** in the control of food intake and satiety

- a **food solution** to both caloric over-consumption and malnutrition in the elderly, and in clinical situations
Protein-induced satiety for weight loss

A protein enriched diet allows eating to appetite but at a lower caloric intake
- weight loss
- no hunger pangs

Extension of diet manipulation studies to:
- vegetable vs meat protein
- sustainable protein sources

More Hungry

Less Hungry

Breakfast
Lunch
Dinner
High protein-low GI diet for **weight maintenance**

EU FP6 Diogenes - the “world’s largest diet study” recommends a diet that is:

- high in proteins (lean meat, low-fat dairy products and beans)
- low in refined starch calories e.g. white bread and white rice

Diet can be eaten until full without counting calories and without gaining weight

From: Larsen et al 2010 NEJM 363:2102-13
Hypothesis: small changes in protein in the diet may have major effects on carbohydrate and fat intake, and therefore on energy intake.

Is there an effect of both high and low protein (dairy or soy) in the diet?

Simpson et al. 2005

- 12-day cross-over study
- Diets: P/CHO+F (energy %); Low protein: (5/95), Normal protein: (15/85), High protein: (30/70)
- P completely exchanged by CHO
High protein vs. normal protein – increase in P to CHO+F
• Lower total energy intake, predominantly from meals - satiation effect

Low protein vs. normal protein – decrease in P to CHO+F
• No effect on energy intake

Implications for everyday diets:
• Energy intake can be reduced by increasing protein intake, reducing fat and CHO intake
• No evidence for protein leverage effects from diets containing a lower ratio of protein to CHO+fat – the high carbohydrate content of the low-protein diet did not cause overeating
• A relatively low protein diet with a high fat content could still cause overeating - risk of overeating may be due to a high-fat diet (with lower protein and CHO intakes)

Interactions with food across the life span

Young vs Elderly

Effect of dietary macronutrients on short-term appetite - 4 test-meals - normal/enriched protein meal (15% or 30% energy, as low calorie or maintenance energy requirements) - Fig. 4

Psychological and behavioural factors influencing appetite

Brain (fMRI) activation

Biomarkers of appetite (gut hormones)

Ages 8-10y, 13-17y, 25-45y, 65-75y; male/female; lean/overweight; contrasting food cultures

Plus: Short-term appetite control in undernourished elderly
Rationale: Increasing secretion due to local nutrient delivery could enhance insulin secretion and decrease food intake.

- GLP-1
- PYY
- Oxyntomodulin
- GLP-2

Effect of encapsulated nutrients on gut peptide secretion – proof-of-concept in human subjects

- dose dependence of effect on gut hormones, hunger/food intake in lean/obese
- delivery of nutrient to different regions of the GI tract
- effect on glucose tolerance in lean and obese, and type 2 diabetic subjects
SATIN - Satiety Control Through Food Structures Made by Novel Processing: *Generating Novel Food Structures to Aid Consumer Weight Management*

Coordinator: Prof Jason C. G. Halford
Despite advances in the
i) measurement of appetite expression and the biomarkers underpinning the processes of satiation and satiety,
ii) understanding of the impact of nutrient composition
iii) knowledge of the physical characteristics of food on eating behaviour

...few satiety-enhancing products have successfully remained in the European market, due to the failure to produce effective and appealing products.
Aims and Objectives

Develop novel food products through processing innovation to help regulate food intake through enhanced satiety allowing achievement of a balanced diet.

- accelerating satiation during a meal, enhancing satiety and/or reducing appetite
- validate these products in human trials by examining key biomarkers, nutrient availability and behaviour

1. **Screen novel food structures** to isolate and refine products with satiating potential.

2. **Develop novel food processing technologies** to produce a range of novel satiety enhancing ingredients.

3. **Produce finished food products** that pass through safety analysis, early sensory evaluation and consumer testing.

4. **Demonstrate the effects of prototype products** on biomarkers of satiety and intestinal fate/nutrient bioavailability.

5. **Demonstrate the effects of final food products** on within-meal satiation, post-meal satiety and/or reduced appetite using biomarkers of satiety.

6. **Demonstrate the enduring effects of individual food products** on satiety and their potential to induce weight loss.

7. **Demonstrate the long-term consumer and health benefits** of adhering to a diet containing satiety-enhancing products.
The purpose of generating satiety-enhancing processed food products is to help consumers achieve a balanced diet resulting in long-term beneficial effects in body weight and health. Large-scale clinical trials are required to demonstrate that changes in food structure can modify the mechanisms involved in the regulation of total energy intake, beneficially affecting energy balance and body weight regulation.

The proof of concept study will be conducted in line with EFSA’s Scientific Opinion on the scientific requirements for health claims related to appetite ratings and weight management.

DELIVERABLE: The ability to maintain a reduced body weight (after 24 weeks) through sustained effects on satiety and satiation will be the primary outcome. Developing a “basket” of novel products that can make a different when incorporated into European diets. Do satiety enhancing foods make a difference for the consumer?
Food and Health Innovation Service

€5m, 5-year project funded by Scottish Enterprise to help Scottish food and drink companies tap into the growing market for food and health related products - ingredients/components and final products. Product reformulation – removal of fat, sugar, salt etc, functional foods.
NeuroFAST – Dickson; www.neurofast.eu

Full4Health – Mercer; www.full4health.eu

SATIN – Halford; www.satin-satiety.eu