Metabolic quality of starchy foods

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Overview

- Background

- Methodology:
  Determination starch characteristics and choice of metabolic parameters

- Results study:
  Glucose influx rate and gastrointestinal hormones
Metabolic quality of starchy foods

- Starch main daily energy source

- Recommendations for healthy food pattern:
  - decrease saturated fat
  - decrease simple sugar
  - increase cereal fiber

→ increased starchy food consumption

Metabolic quality of starchy foods?
Different types of starch

1. rapidly digestible starch
2. slowly digestible starch
3. resistant starch

small intestine

large intestine
Metabolic quality of starchy foods

food properties ➔ metabolism/physiology ➔ health/disease

- Saturated fat
- Blood cholesterol
- Glucose/insulin response,
- Gastrointestinal hormones,
- Slowly digestible starch,
- Adipokines,
- Resistant starch,
- Fermentation products,
- Cereal fiber,
- Inflammation markers,
- ... choice raw material,
- method of processing
- Cardiovascular disease
- Obesity,
- Type 2 diabetes,
- ...
Metabolic quality of starchy foods

How to determine food properties?

Starch characteristics
How to determine starch characteristics?

Glycemic response

Change glucose concentration in blood

1 h 2 h 3 h 4 h after meal

Glycemic index

high

low
Debate Glycemic Index

- definition (glycemic load)
- high variability

Glycemic response is dependent on
  - characteristics starch
  - other meal components
  - gastric emptying rate
  - hormonal response
  - endogenous glucose production
  - glucose disposal
  - previous meal
The glycemic response is the net result of different postmeal processes.

- Glucose from food (exogenous)
- Glucose from liver (endogenous)
- Disposal glucose in tissue

Glycemic index: limited information about starch characteristics
How to determine starch characteristics?

Glucose

- Total glucose
- Exogenous glucose

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>0</th>
<th>60</th>
<th>120</th>
<th>180</th>
<th>240</th>
<th>300</th>
<th>360</th>
</tr>
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<tbody>
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<td>mmol/l</td>
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Determining starch characteristics

in vivo

Dual isotope technique:

Consumption of $^{13}$C-enriched starch products and

infusion of $^2$H-glucose
Dual isotope technique

Total blood glucose

endogenous (liver)  exogenous (food)  glucose disposal

i.v. infusion
$^2\text{H} -$ glucose

+ $^{13}\text{C} -$ enriched carbohydrate

Total rate of appearance of glucose

Rate of appearance of exogenous glucose

“Glucose influx”
$^{13}$C- enriched plants

C$_4$ plants:
- $\uparrow ^{13}$C/$^{12}$C ratio
- corn, millet, teff, sugarcane

C$_3$ plant:
- wheat, potato, rice, bean

Availability of $^{13}$C-labelled starch

Obtained by culture under $^{13}$CO$_2$ atmosphere

- $^{13}$C-enriched wheat
- $^{13}$C-enriched barley
- $^{13}$C-enriched potato
**Study design**

**dual isotope technique**

**Priming D-[6,6-2H₂]glucose**

**Ingestion ¹³C-carbohydrates**

**Time (min):**

-120 0 120 360

**Blood samples:**

- every 30 min
- every 15 min
- every 30 min

**Continuous D-[6,6-2H₂]glucose (3.5 mg/min)**
Metabolic quality of starchy foods

What are relevant metabolic factors to investigate?
Hormonal regulation of carbohydrate metabolism

Gastrointestinal hormones:
- Ghrelin
- GIP
- GLP-1
- PYY
- etc.

Adipokines:
- Adiponectin
- Leptin
- Resistin
- TNF-α
- etc.

Adapted from Rosen ED et al, Nature 2006
Gastrointestinal hormones

GIP (Glucose-dependent insulino-tropic peptide)
- stimulates glucose-induced insulin release
- stimulates glucose and fat uptake in fat cells
- stimulates fat storage in fat cells
- ....

GLP-1 (Glucagon-like peptide 1)
- stimulates glucose-induced insulin release
- decreases appetite and food intake
- slows gastric emptying rate
- ....
To assess the effect of glucose and 2 starchy foods - rapidly and slowly digestible starch - on the secretion of GIP and GLP-1
Study design (1)

- cross-over study

- 7 healthy male volunteers
  (age 23.4 ± 1.0 yr, BMI 21.6 ± 1.1)

- fasted overnight (> 22:00 hrs, day before experiment)
test meals:
- glucose in 250 ml water
- corn pasta
  (89 % rapidly available glucose, 7 % slowly available glucose)*
- raw corn starch in 250 ml water
  (28 % rapidly available glucose, 45 % slowly available glucose)*

aimed doses: equivalent of 50 g glucose
naturally labeled with $^{13}$C: corn derived

*Englyst Carbohydrates – Research and Services, Southampton, UK
Results (mean±SEM)

Glucose influx
- glucose
- raw starch (slow)
- pasta (rapid)

GIP
- glucose
- raw starch
- pasta

Insulin

GLP-1
Results: correlation GIP and glucose influx rate (mean)

within-subject relationship:

GIP – gluc influx: \( r = 0.84 \)
Insulin – gluc influx: \( r = 0.77 \)
GLP-1 – gluc influx: \( r = 0.38 \)

\( p < 0.01 \)
Ingestion of slowly digestible carbohydrates results in late GLP-1 response.

.... influence on glucose response of subsequent meal?
Secretion of GIP is strongly correlated to the rate of influx of exogenous glucose.

- **Type starch**: rapidly digestible starch
- **Hormonal response**: insulin ↑
- **Glucose uptake in**:
  - fat cells ↑
  - muscle ↑
  - liver ↑
Summary results and discussion (2)

- Secretion of GIP is strongly correlated to the rate of influx of exogenous glucose.

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<th>Hormonal response</th>
<th>Glucose/fat uptake in</th>
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<tbody>
<tr>
<td>rapidly digestible starch</td>
<td>insulin $\uparrow$</td>
<td>fat cells $\uparrow$</td>
</tr>
<tr>
<td></td>
<td>GIP $\uparrow$</td>
<td>muscle $\uparrow$</td>
</tr>
<tr>
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<td>liver $\uparrow$</td>
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Conclusions

- The glycemic index gives limited information about starch characteristics.
- The glycemic response is only one aspect of the physiological/metabolic response.
- More information is needed about the metabolic quality of starchy foods.
- Different rate of glucose influx results in different gastrointestinal hormone response.
- GIP could be involved in effects of rapidly digestible carbohydrates on fat accumulation.
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