Legume-enriched Pasta
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**Legume-enriched Pasta**

### Structure/Nutrition: what is known on durum wheat pasta

**Durum wheat pasta: a low glycemic index (GI) food**

<table>
<thead>
<tr>
<th>Cereal</th>
<th>GI</th>
<th>Area A (tested food)</th>
<th>Area B (bread or glucose)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose</td>
<td>100</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>Water</td>
<td>53</td>
<td>53</td>
<td>53</td>
</tr>
</tbody>
</table>

**Main hypotheses:**
- Pasta compactness (Fardet et al., 1998; Granfeldt et al., 1991)
- Encapsulation of starch by proteins (Gallinaro et al., 1998; Fandri et al., 1998)
- Physical structure of starch (Granfeldt, 2000; Englyst et al., 1992; Holm et al., 1988)

### Impact of legume flour addition

- **100% Durum wheat pasta (control)**
  - GI: 53
  - Protein: 4.8
  - Starch: 76.1
  - Fibre: 5.6
  - Durum wheat: 11.6
  - Split pea: 1.6

- **35% legume fortified pasta:** 2.4
  - Protein: 5.1
  - Starch: 70.9
  - Fibre: 5.2

### Methodology

- **PASTA STRUCTURE**
  - Microscopic
  - Starch
  - Fibres
  - Proteins

- **GLYCEMIC INDEX**
  - in vitro starch digestibility
  - GI = Englyst et al., 1996
  - *P* < 0.05

- **PROTEIN HYDROLYSIS**
  - Germs: 35% split pea, 6% gluten
  - Protein: 37.6%, 52.4%

- **ALLERGENICITY**
  - Presence of IgE-reactive fragments in digestion juices: inhibition ELISA, sera from allergic patients to wheat or to pea

### Pasta structure and nutritional properties: impact of legume addition and changes in process

- **100% Durum wheat (control)**
- **35% Split pea (LT-dried)**

### Macroscopic structure of dry and cooked pasta

- **Porosity**
  - LT-dried: 5.4
  - 35% Split pea: No effect

- **Rheology (TAXT plus)**
  - 100% Durum wheat: 38 N.mm
  - 35% Split pea: 5.6 N/mm

- **Macroscopic structure of cooked pasta**
  - Starch
  - Fibres
  - Proteins
  - 35% Split pea: No major impact

### Impact of Legume consumption on starch and protein digestibilities

- **Glutens**: D-glutenins, L-glutens
- **Amylose Amylopectin**
- **S-S bonds**

### Interest of Mixing Durum Wheat and Legume in Pasta

- Inspired by the Mediterranean diet and its health benefits

- **Legume**: Protein, Rich in Lysine, Poor in sulphur Aa
- **Durum wheat**: Gluten (~13%), Starch (~75%)

### Durum wheat pasta structure

- Macromolecular structure
- Microscopic structure
- Supramolecular structure

### Durum wheat + water

- **Starch granules**: Amylose, Amylopectin
- **Gluten network**
- **S-S bonds**

### Methodology

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Supramolecular structure of cooked pasta

**SE-HPLC after protein extraction**

- Non covalent bonds
- Covalent (S-S)
- Covalent (other)
- Other covalent bonds

**Legume pasta**

- Non covalent bonds
- Covalent (S-S)
- Covalent (other)
- Other covalent bonds

Weaker protein network

In vitro starch digestibility of cooked pasta

**Rapidly available glucose: RAG value**

- Pasta samples
- % Available carbohydrates
- 100% Durum wheat: 12.5 ± 10.4
- 35% Split pea: 8.5 ± 2.4

No change in the in vitro starch digestibility (RAG)

In vitro Protein digestibility and allergenicity

- Degree of Protein hydrolysis (% DH)
- ELISA inhibition with allergic sera presence of IgE reactive fragments (IgE-RF)

Pasta fortification with 35% of legume flour on the RAG value

Impact of drying treatments

- Freeze-drying LT (55°C) CONTROL
- Freeze-drying VHT.LM (90°C)

Macroscopic structure of dry and cooked pasta

<table>
<thead>
<tr>
<th>Protein</th>
<th>Total porosity (%)</th>
<th>Freeze-drying LT</th>
<th>Freeze-drying VHT.LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freeze-drying LT</td>
<td>3.5</td>
<td>Freeze-drying VHT.LM</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Microscopic structure of cooked pasta

- Starch
- Proteins

Effect of drying

- No major impact

Supramolecular structure of cooked pasta

**SE-HPLC after protein extraction**

- Non covalent bonds
- S-S bonds
- Other covalent bonds

Freeze-drying: slightly LT dried pasta

VHT.LM: proteins linked by covalent bonds

In vitro starch digestibility of cooked pasta

**Rapidly available glucose: RAG value**

- Percent available carbohydrates
- Freeze-drying LT
- Freeze-drying VHT.LM

Higher porosity could increase accessibility to amylases

In vitro Protein digestibility of cooked pasta

<table>
<thead>
<tr>
<th>Degree of Protein hydrolysis (% DH)</th>
</tr>
</thead>
</table>

Freeze-drying

No significant difference

VHT.LM: DH in gastric conditions only – kinetical effect?

Stronger protein network at a supramolecular level

Freeze-drying: idem than LT dried pasta

VHT.LM:

Proteins linked by covalent bonds
In vitro allergenicity of digestion juices of cooked pasta

ELISA inhibition with allergic sera - presence of IgE-reactive fragments (IgE-RF)

<table>
<thead>
<tr>
<th>Protein fractions</th>
<th>Freeze-drying</th>
<th>VHT.LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>More fibres</td>
<td>Stronger protein network</td>
</tr>
<tr>
<td></td>
<td>No effect</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td>Same RAG value</td>
<td>Change DH and IgE-RF</td>
</tr>
</tbody>
</table>
| Gastric juices    | No significant difference | VHT.LM: Changes concerned wheat proteins (γ-gliadins, LTP…)
|                  | VHT.LM: Changes concerned wheat proteins (γ-gliadins, LTP…)

Conclusions (1)

COMPOSITION

MORE FIBRES

SAME RAG

FREEZE-DRIED:

Non-gelatinised starch at the core

VHT.LM:

Stronger protein network (Covalent links)

Gastric juices

0 20 40 60 80 100

% inhibition

Freeze-dried

LT PASTALEG PASTALEG PASTALEG

Pasta porosity: YES

Protein network thickness: No changes

Nature & quantity of interactions between proteins: YES

Structural elements involved in starch digestibility

Structural elements involved in protein digestibility and allergenicity:

Pasta porosity: NO

Protein network thickness: No changes

Nature & quantity of interactions between proteins: YES

A highly aggregated protein network would be more resistant to protein hydrolysis, which could delay hydrolysis of starch by amylases

Conclusions (3)

Hypothesis: A highly aggregated protein network would be more resistant to protein hydrolysis, which could delay hydrolysis of starch by amylases

Protein network thickness: No changes

Nature & quantity of interactions between proteins: YES

Structural elements involved in protein digestibility and allergenicity:

Pasta porosity: NO

Protein network thickness: No changes

Nature & quantity of interactions between proteins: YES

A highly aggregated protein network would be more resistant to protein hydrolysis, which could delay hydrolysis, change released fragments and impact their allergenicity response

Conclusions (2)

Hypothesis: A highly aggregated protein network would be more resistant to protein hydrolysis, which could delay hydrolysis of starch by amylases