RAW MATERIAL IN EXTRUSION
Raw material for Extrusion

**BIOPOLYMER Base**
generates the matrix for the *Starch* and *Protein* extrudates: of the cereals (wheat, corn, oat, rice, barley, etc.), tubers (potatoes, yuca) or oilseeds (after oil extraction: soy).

**INGREDIENTS**
These influence both the cooking level, the blending properties and the product quality:
- Modified starches
- Sugar
- Fibers, bran
- Milk proteins
- Lipids, emulsifiers
- Minerals
- Flavors
Production of grains in the world

Wheat: 28%
Corn: 36%
Rice: 19%
Soy: 11%
Barley: 6%

2,500 Million Tons (cereals + oilseeds), 2015
World production (2011) = 2,287 MT (470 MT of rice)

- **EUROPE**
  - 1st wheat world producer (137 Mt)
- **RUSSIA**
  - 1st barley world producer
- **CHINA**
  - 2nd wheat world producer (118 Mt)
  - 2nd corn world producer (183 Mt)

- **UNITED STATES**
  - 1st corn and soy bean world producer (314 Mt + 87 Mt)
## Composition of grains

<table>
<thead>
<tr>
<th>NUTRIENTS</th>
<th>MOISTURE (%)</th>
<th>PROTEIN (%)</th>
<th>TOTAL LIPIDS (%)</th>
<th>CARBOHYDRATES (%)</th>
<th>ASH (%)</th>
<th>TOTAL DIETARY FIBERS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHEAT</td>
<td>10.27</td>
<td>13.70</td>
<td>1.87</td>
<td>72.57</td>
<td>1.60</td>
<td>12.2</td>
</tr>
<tr>
<td>RICE</td>
<td>11.97</td>
<td>7.23</td>
<td>2.78</td>
<td>76.48</td>
<td>1.54</td>
<td>4.6</td>
</tr>
<tr>
<td>CORN</td>
<td>10.91</td>
<td>6.93</td>
<td>3.86</td>
<td>76.85</td>
<td>1.45</td>
<td>13.4</td>
</tr>
<tr>
<td>OAT</td>
<td>8.22</td>
<td>16.89</td>
<td>6.90</td>
<td>66.27</td>
<td>1.72</td>
<td>10.6</td>
</tr>
</tbody>
</table>
AMYLOSE is a linear chain of \( \alpha \) D-Glucose, which gives it a low molecular weight.

AMYLOPECTIN is a high-weight branched molecule with double helical chains.
**COMPOSITION OF STARCH**

**AMYLOPECTIN**
- Increases the snack’s expansion ability → Crunchy
- Increases the fragility of flakes

**AMYLOSE**
- Breaks down with more difficulty than amylopectin
- Increases the crunchiness and resistance of the final product
- Reduces radial expansion (SEI) and increases longitudinal expansion (LEI)
- Increases the bulk density of the extrudate

<table>
<thead>
<tr>
<th>BIOPOLYMER BASE</th>
<th>SEI</th>
<th>LEI</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMYLOPECTIN</td>
<td>70%</td>
<td></td>
</tr>
<tr>
<td>AMYLOSE</td>
<td>30%</td>
<td></td>
</tr>
</tbody>
</table>
STARCH MATRIX: Corn (White or yellow)

Composition
- Endosperm: 80%
- Pericarp: 5 – 6%
- Germ: 10 – 14%

2 types of endosperm

Starch granules of various sizes
STARCH MATRIX: Corn (White or yellow)

- **Specifications of corn for extrusion:**
  
  - **Protein:** 8 – 10%
  - **Starch:** > 75% max
  - **Fat:** 1.5% max
  - **Moisture:** 10-13%

  Usually degermed corn flour or degermed corn meal

- **Particles sizes of “ideal” corn meal for extrusion:**

<table>
<thead>
<tr>
<th>MICRONS</th>
<th>% RETAINED</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>&gt; 1%</td>
</tr>
<tr>
<td>710</td>
<td>10 – 30%</td>
</tr>
<tr>
<td>550</td>
<td>&gt; 55%</td>
</tr>
<tr>
<td>355</td>
<td>&gt; 10%</td>
</tr>
<tr>
<td>250</td>
<td>&lt; 3%</td>
</tr>
<tr>
<td>Less than 250</td>
<td>&lt; 2%</td>
</tr>
</tbody>
</table>

- **Behaviour in extrusion:**
  
  - Good expansion
  - Medium to high cooking temperature required
STARCH MATRIX: Wheat (Soft, durum)

Composition:
- Endosperm: 83%
- Bran: 14%
- Germ: 3%

Quite long starch granules

Importance of gluten
STARCH MATRIX : Wheat (Soft, durum)

- **Specifications of wheat for extrusion:**
  - Protein: 10 – 14%
  - Moisture: 10 – 14%
  - Ash: 0.6 – 0.75%

- **Behaviour in extrusion:**
  - Good expansion
  - White to pale colours
  - Medium to low cooking temperature required
STARCH MATRIX : Rice and oat

Rice (Long/medium/short grain)
- The smallest grain size
- Mild flavour
- Good expansion
- White colour
- Requires the highest temperature for cooking

Oat
- Small-size granules
- Low expansion due to fibers and fat contents
- Strong flavour and light-brown colour
- Relatively low gelatinisation temperature but high mechanical energy
STARCH MATRIX: Barley and Potatoes

Barley

- Medium to large-size granules
- Normal expansion
- Light to golden brown colour
- Low cooking temperature required
- Barley/wheat mixtures give a sweet and pleasant flavour

Potatoes

- Very large starch granules
- Exhibits very high viscosity when cooked
- The starch in the potatoes expands the most
- Excellent binder
- Golden to light brown colour
- Low cooking temperature required
STARCH MATRIX: Yucca, Starches

Tapioca, Yuca
- Medium-size starch granules
- Exhibits high viscosity
- Excellent binder
- Mild flavour and white colour
- Requires moderate cooking temperatures

Starch (Native or Pregelatinised)
- Binder during extrusion
- Exhibits better expansion level
Influence of added starches on SEI and LEI corn meal matrix

<table>
<thead>
<tr>
<th>ADDED STARCHES</th>
<th>SEI</th>
<th>LEI</th>
</tr>
</thead>
<tbody>
<tr>
<td>RICE</td>
<td>0%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18%</td>
</tr>
<tr>
<td>WHEAT</td>
<td>0%</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32%</td>
</tr>
<tr>
<td>YUCA</td>
<td>0%</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12%</td>
</tr>
<tr>
<td>SOY</td>
<td>0%</td>
<td>5.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Whole-grain Cereals:

- Wheat, rice, corn, oat, barley, sorghum, millet, etc.
- Reduces expansion due to their high fiber and fat contents.
- May exhibit rancidity and develop bitter taste.

<table>
<thead>
<tr>
<th>NUTRIENTS</th>
<th>WATER (G)</th>
<th>PROTEIN (G)</th>
<th>TOTAL LIPIDS (G)</th>
<th>CARBOHYDRATES (G)</th>
<th>ASH (G)</th>
<th>TOTAL DIETARY fiber (G)</th>
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“USDA National Nutrient Database” for reference of standards
**PROTEIN MATRIX**

- Sources: Soy, wheat, dairy protein, pulses

- Generates an elastic dough, indigestible for babies, and some are known as allergen

- With starch- or expanded cereal-based products, the high protein level:
  - Reduces expansion
  - Crunchier product
  - Firmer product

- With non-expanded cereals, the high protein level: increases firmness

- The use of a high percentage of soy or pea protein and wheat gluten and a high quantity of water may texturize: TVP or HMEC
Example of corn snack with and without soy protein:

- 100% corn flour
- 85% corn flour, 15% soy flour

Examples of Soy Crisps:
Example of fibrated or texturized soy protein:

- HMEC
- HMEC
- TVP
HMEC: FIBRATION MECHANISMS

Native State → Extrusion Cooking (Shear-Heat) → Unfolded State → Die Fibration/Lamination → Crossliking State
MINOR INGREDIENTS : main characteristics

- The ingredients in extrusion cooking consist of components of low or intermediate molecular weight: represent the smallest part of the formula
- The purpose of adding varied ingredients to the formulas is to improve the quality profile of finished products:

  **Flavour and taste:** sugar, minerals, aromas, etc.
  **Expansion and texture:** modified starches, emulsifiers, fibers, etc.
  **Nutritional value:** bran, milk proteins, etc.
MINOR INGREDIENTS

**Bicarbonate:**
- Common in “ready-to-eat” cereals
- Helps in the process by stabilising the pH → improves the formation of colour and flavour
- Sodium bicarbonate reduces radial expansion

**Calcium carbonate:**
- Reduces expansion
- Thinner and more regular structure

**Calcium diphosphate:**
- Thinner structure

**Emulsifiers: dimodan, diglycerides:**
- Improve the characteristics of the product (binding with the starch molecules to affect gelatinisation and reduce the viscosity of the melt)
MINOR INGREDIENTS

Fibers
- Indigestible fraction of food (cellulose, hemicellulose, gums and lignins): soluble and insoluble fibers; fibers in oat, pea, fruit, high-fiber wheat flour
- Oat and rice fiber: low expansion
- Wheat fibers create a smooth surface, small bubbles of regular size.

Hydrocolloids
- Examples: gum arabic, xanthan gum, guar, alginates, carrageenans, ...
- Improve texture properties (smoothness, firmness...)
- Maintain moisture

Lecithin:
- Functional ingredient for emulsification
- Reduces expansion and provides a finer texture

Salt:
- Crunchier texture
- < 1.5% - increases expansion
- > 1.5% - 4.5% - reduces the average size of the cell & increases the cell’s density
MINOR INGREDIENTS

Powdered cocoa
- > 3-4% → reduces expansion
- Firmer, crunchier texture in milk

Powdered milk
- Gives colour (Maillard reaction)

Honey
- Excellent increase of the Maillard reaction (light darkening)
- Up to 12% can be added (sweet and savoury formulas)

Maltodextrin
- 1% up to 10%, reduces viscosity → increases output
- More constant expansion and crunchier texture

Malt
- Gives colour and flavour
- Malt extract: reduces expansion
- Malt syrup: can create a bitter flavour in the final product if used in excess
MINOR INGREDIENTS

Sugar
- Sweetener
- Texture development: increases the crunchy sensation
- Hydrophilic effect (stabilisation of water activity, increases the gelatinisation temperature of starch)
- Darkening agent – complex with protein

Lipids and oil
- Lubricant: protect starch-based products from division → less cooking and gelatinisation
- Reduce the pressure of the die/box
- < 5% oil = increases expansion (increases cell size)
- > 5% oil = reduces expansion
- Smoother surface

Vitamins
- Many are stable, except for Vitamin A, K3 and C.
Influence of ingredients on expansion - Corn base

- NaCl & NaHCO₃
- Emulsifiers
- Fatty acids
- Sucrose
- Lipids

Corn meal base
EFFECTS OF PARTICLE SIZE

Identical operating parameters

350 rpm – 16% moisture

Corn meal – 500 µm
Corn flour – 100 µm

Corn meal – 500 µm
Corn flour – 100 µm

Smaller cellular structure

LEI
SEI
Density

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The bigger the particle size, the longer the hydration time.

Homogeneity of the mixture and controlled particle size
Normally between 500 µm for meal and 100 µm for flour.
# Basic recipes for DX Snacks

## Corn curls:

<table>
<thead>
<tr>
<th>RAW MATERIALS</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn meal</td>
<td>98-100</td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>0-1</td>
</tr>
<tr>
<td>Salt</td>
<td>0-1</td>
</tr>
</tbody>
</table>

## Corn/Potato Chipstick:

<table>
<thead>
<tr>
<th>RAW MATERIALS</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn meal</td>
<td>68-100</td>
</tr>
<tr>
<td>Potato Flour</td>
<td>0-30</td>
</tr>
<tr>
<td>Salt</td>
<td>0-1</td>
</tr>
</tbody>
</table>

## Multi-grain Snack:

<table>
<thead>
<tr>
<th>RAW MATERIALS</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Flour</td>
<td>50-60</td>
</tr>
<tr>
<td>Wheat Flour</td>
<td>20-30</td>
</tr>
<tr>
<td>Rice Flour</td>
<td>10-20</td>
</tr>
<tr>
<td>Salt</td>
<td>0-1</td>
</tr>
</tbody>
</table>
## Basic recipes for DX Snacks – breakfast cereals

### Chocolate balls

<table>
<thead>
<tr>
<th>RAW MATERIALS</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat Flour</td>
<td>79.7</td>
</tr>
<tr>
<td>Sugar</td>
<td>9</td>
</tr>
<tr>
<td>Cocoa powder</td>
<td>5</td>
</tr>
<tr>
<td>Malt powder</td>
<td>5</td>
</tr>
<tr>
<td>Salt</td>
<td>0.8</td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>0.5</td>
</tr>
</tbody>
</table>

### Rings

<table>
<thead>
<tr>
<th>RAW MATERIALS</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Flour</td>
<td>31.45</td>
</tr>
<tr>
<td>Wheat Flour</td>
<td>30</td>
</tr>
<tr>
<td>Rice Flour</td>
<td>30</td>
</tr>
<tr>
<td>Sugar</td>
<td>8</td>
</tr>
<tr>
<td>Salt</td>
<td>0.55</td>
</tr>
</tbody>
</table>

### Expanded rice

<table>
<thead>
<tr>
<th>RAW MATERIALS</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Flour</td>
<td>85</td>
</tr>
<tr>
<td>Sugar</td>
<td>5</td>
</tr>
<tr>
<td>Malt syrup</td>
<td>10</td>
</tr>
</tbody>
</table>
Thank you for your attention

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