Plant-based food ingredients

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Plants for food ingredients

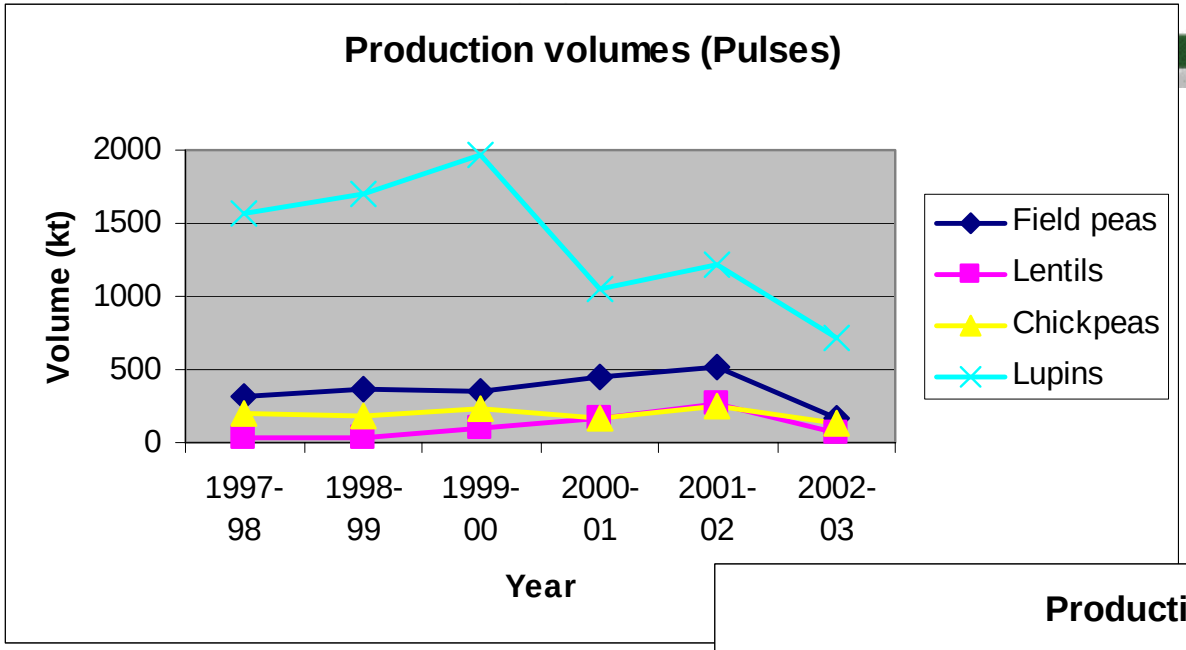
Starch storing seeds

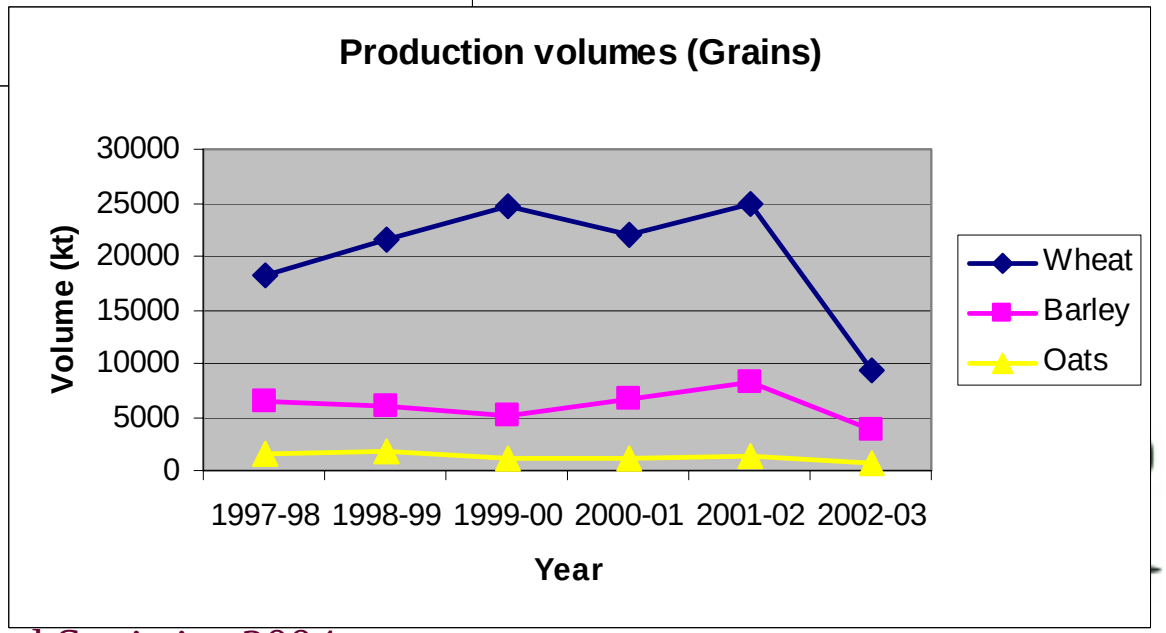
- Wheat
- Oats
- Barley
- Corn
- White Beans
- Field Peas

Oil storing seeds

- Soybeans
- Canola
- Flax seed
- Mustard

Production volume comparison





Source: Australian Food Statistics 2004

Current status of Australian grains and pulses

- Currently more than 80% are exported in one form or other
- Export forms
  - Whole seeds, container packed
  - Flour – bagged and exported
- Uses of ingredients
  - Whole seeds – for human consumption in South and SE Asia and Middle East, small markets in Europe
  - Flour – for snack foods in Asia, Australia
  - Some pulses for animal feed in combination with cereals and coarse grains

Approximate gross composition

	Lentils	Field peas	Chickpea	Soy	Wheat	Barley
Moisture (%)	10-12	8-11	9-12	8-10	10-12	10-12
Protein (%)	22-31	21-32	25-28	35-40	8-14	8-15
Carbohydrate (%)	62-68	60-65		28-35	60-70	70-75
Fat (%)	1-2	1-2	4-5	16-20	2-3	2-3
Ash (%)	2-3	2-3	2-3		2-3	2-3

Food ingredients

Physical functional ingredients →

- Provide structure, texture and mouth feel and can affect flavour
  - Protein
  - Starch
  - etc

Physiological functional ingredients →

- Provide health benefits (can affect structure, texture and moth feel)
  - Protein/peptides
  - Lipids
  - Resistant starch
  - Fibre
  - Minerals, vitamins, anti-oxidants etc

Physical functional properties

Functional property	Mode of action	Food system
Water binding	H bonding, entrapping of water	Meat sausages, cakes, breads
Solubility	Ingredient solvation	Beverages
Heat stability	Low levels of secondary or tertiary structures	Heat sterilised nutritional drinks
Gelation	Ingredient matrix formation & setting	Meats, curds, baked goods, pasta products
Viscosity	Ingredient swelling, increased hydrodynamic volume	Soups, gravies, salad dressings
Whipping & foaming	Surface activity at the air/water interface	Cakes, whipped toppings, ice cream
Emulsification	Surface activity at the oil/water interface	Sausages, salad dressings, coffee whitener, soups, cakes infant and adult nutritional

Physiological functional properties

- Anti-microbial
  - Antibacterial– including control of gut microflora
  - Anti-viral
  - Binding of E coli and cholera enterotoxins
- Anti-cancer
- Immunomodulation
- Anti-oxidative
- Opioid effects
- Retard osteoporosis
- Cardiovascular functions
  - Anti-inflammatory
  - Anti-hypertensive
  - Anti-thrombic
  - Cholesterol reduction

Starch

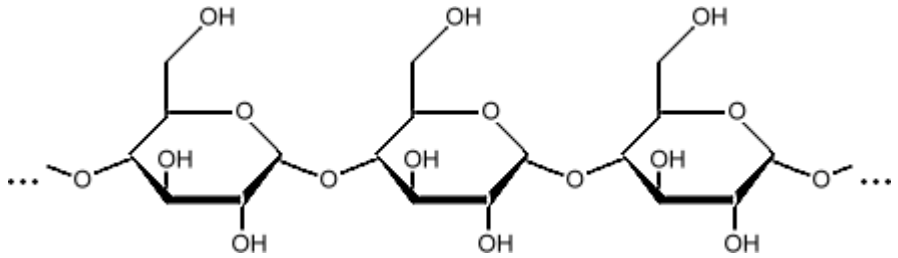
- Starch is a polysaccharide, a chain of many glucose molecules. It is the main carbohydrate store in roots and seeds.
- Starch is made up of two types of glucose chains - a simple chain called amylose, and the a complex branched form called amylopectin
- In the starch grains in a plant, amylopectin makes up the bulk of the material, between 50 to 80 percent by weight, made up of several million amylopectin molecules per starch grain. The rest is a much larger number of the smaller amylose chains, made up of 500 to 20,000 glucose units in each chain. Amylopectin molecules are made of several million glucose units.

Major sources of starch

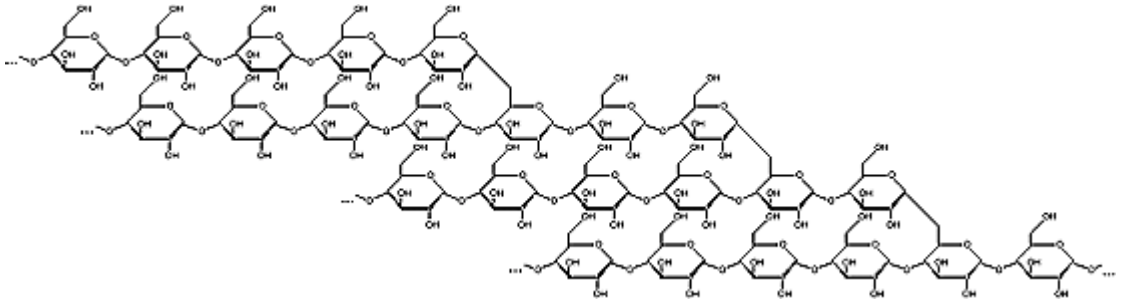
- Wheat
- Corn
- Tapioca
- Potato
- Rice

- Variations in
  - Amount of starch
  - Molecular structure
  - Ratio of amylose and amylopectin
  - Granule size, structure and shape
  - Amount of lyso-phospholipids

Amylose and amylopectin



Amylose



Amylopectin

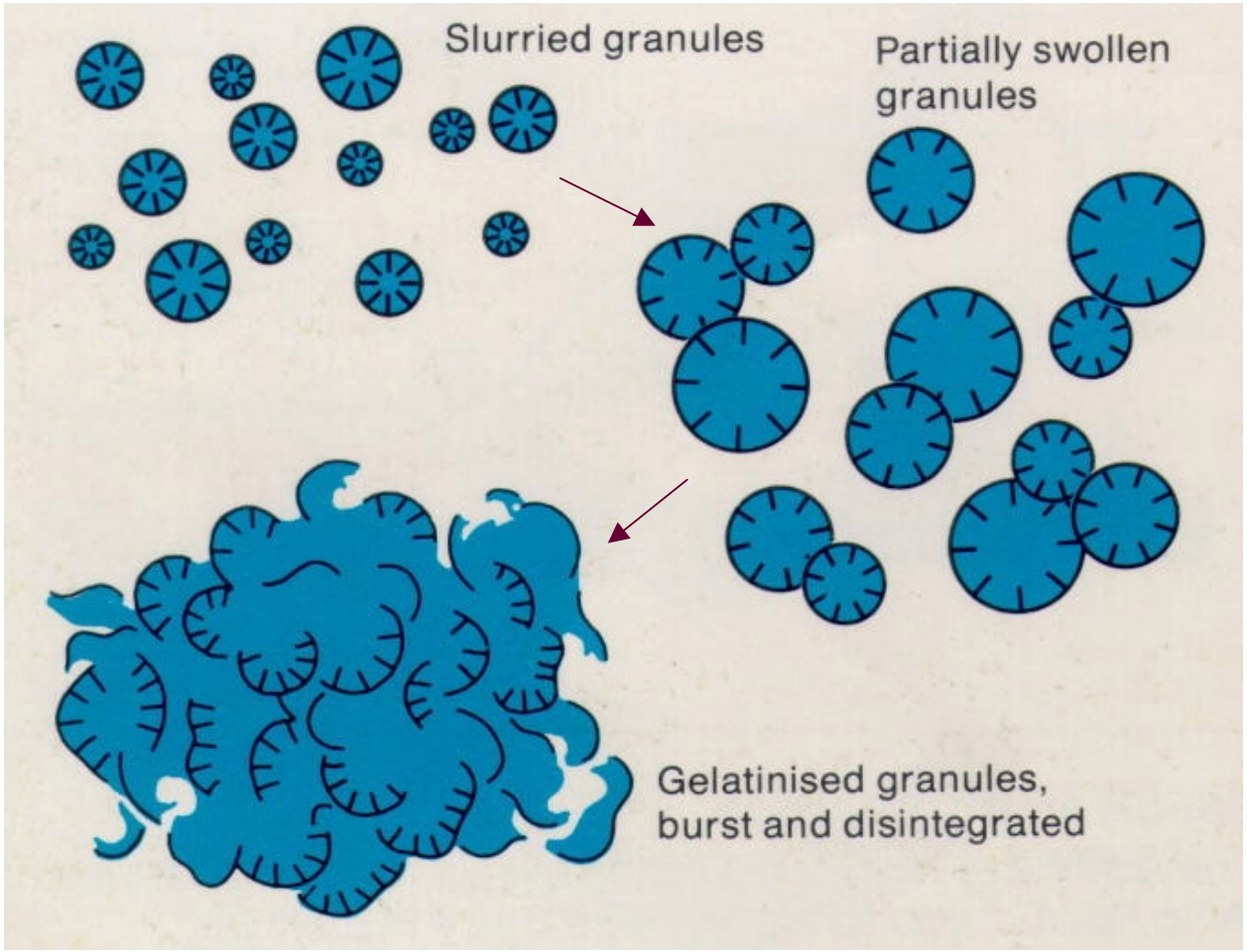
Starch gelatinisation

- Gelatinisation
  - Sum of changes that occur during first stage of heating
- Without gelatinisation starch has little functionality
  - Not soluble in cold water
  - Settles
  - No adhesive power
  - No binding capacity

Starch gelatinisation

- Heating causes the following:
  - Water absorption
  - Rupturing of the amyloplast
  - Starch network formed
  - Hydrated network with water pockets
  - Gelatinisation!

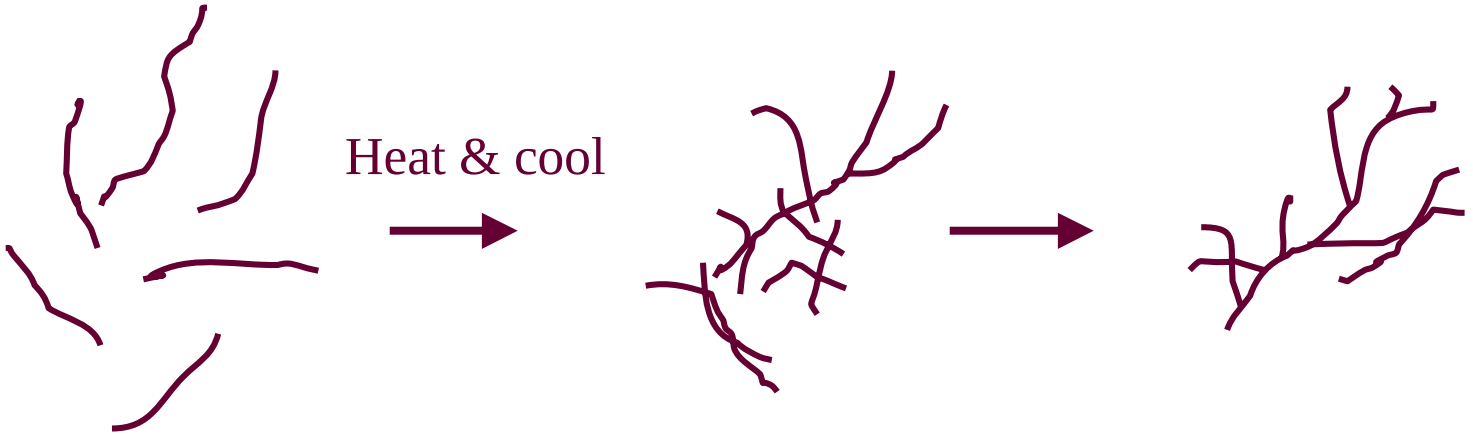
Starch gelatinisation



Starch retrogradation

- The process in which starch molecules, particularly the amylose fraction, re-associate in an ordered structure after disruption by gelatinisation; ultimately a crystalline order appears
- Realignment of the amylose and amylopectin and swollen starch granule to form a pocket.

Steps in retrogradation



A. Solution

B. Gelation after cooling

C. Retrograded

Uses of starch

- Starch is a major source of energy in plants and food products
- Several uses as physical functional ingredient
  - Thickener gel in gravies, sauces, and puddings. It absorbs water, and becomes a gel when cooked. As the starch swells up with water, the amylose leaches out, and the amylopectin forms the gel. Some starches have higher amylopectin content, and make better gels than those containing lots of amylose.
  - Viscosity enhancer- it is the amylose that has the main function. The long water-soluble chains increase the viscosity, and that viscosity doesn't change much with temperature.

Uses of starch

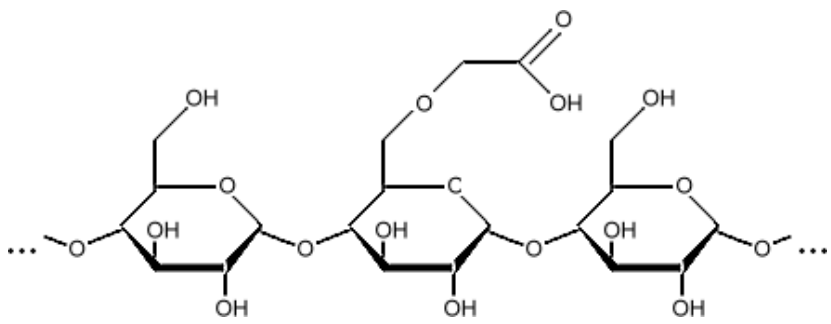
- Encapsulant for fats, oils and flavours
  - Amylose chains tend to curl up into helices (spirals) with the hydrophobic parts inside. This allows them to trap oils and fats inside the helix, as well as aroma molecules.
- Fat substitute
  - Due moisture absorption and structure build up
- Source of fibre and nutrition for gut health
  - "resistant starch", It is also a source of nutrition for intestinal flora, which make important vitamins (and intestinal gas).
- Fillers and structural elements
  - Fillers in processed meats (lunch meats, hot dogs, sausages, etc.),
  - Extruded cereals and snacks to hold the shape of the material.

Modified starch

- Starches can be modified in several ways to change their function as additives in products.
  - They can be cross-linked, where the chains get stuck together into a mesh.
  - They can be heated to break the long chains down into simpler molecules like dextrin, polydextrin, and malto-dextrin. These are simply short starches.
  - Starches can have a hydrogen replaced by something else, such as a carboxymethyl group, making carboxymethyl starch.

Modified starch – Carboxymethyl starch

- Improved functionality
- Increased hydrophilicity
- Less prone to damage by heat and bacteria
- Improved cross-linking



Carboxymethyl starch (starch ether)

Proteins

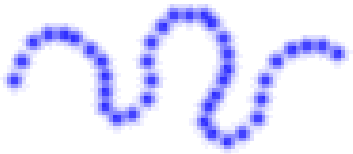
- Proteins are polymers of amino acids
- Proteins are needed to build and repair body tissue and for the metabolic functions of our body
- The shape and thus the function of a protein is determined by the sequence of its amino acids
- The conformation of a protein molecule in the native state is determined by the level of structure present

Levels of protein structure

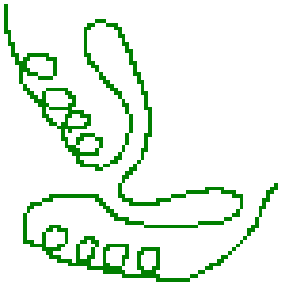
- Primary structure
  - the linear arrangement of amino acids in a protein and the location of covalent linkages such as disulfide bonds between amino acids.
- Secondary structure
  - areas of folding or coiling within a protein; examples include alpha helices and pleated sheets, which are stabilized by hydrogen bonding.
- Tertiary structure
  - the final three-dimensional structure of a protein, which results from a large number of non-covalent interactions between amino acids.
- Quaternary structure
  - non-covalent interactions that bind multiple polypeptides into a single, larger protein.

Protein structure

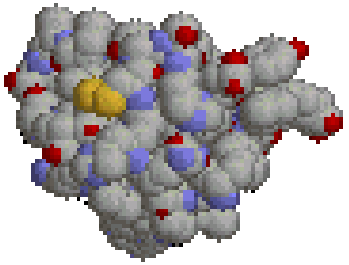
Primary structure



Secondary structure



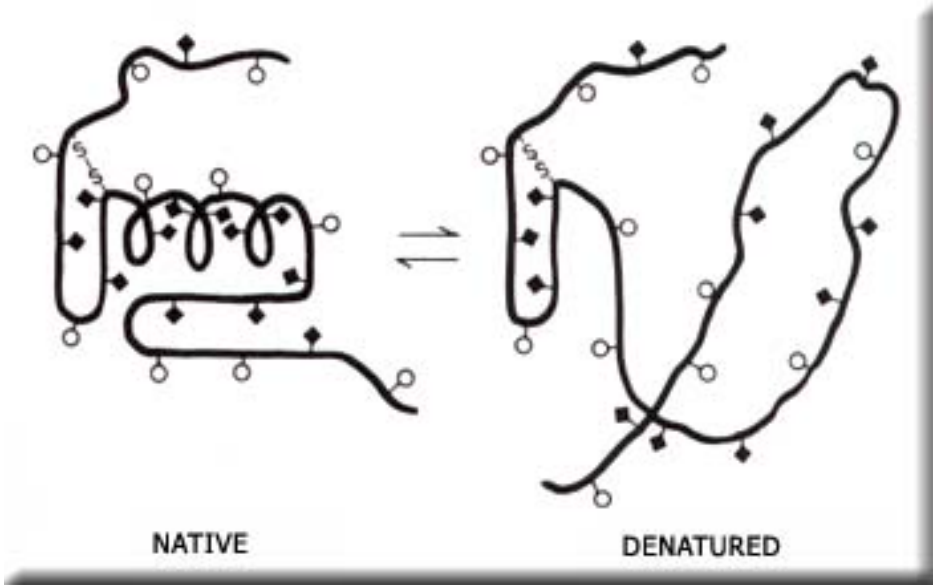
Tertiary structure



http://arbl.cvmbs.colostate.edu/hbooks/genetics/biotech/basics/prostruct.html

Protein denaturation

- Protein denaturation is commonly defined as any non-covalent change in the structure of a protein. This change may alter the secondary, tertiary or quaternary structure of the molecules



Fractionation and isolation of ingredients

- To purify components
- To isolate specific components for physical and/or physiological functionality
- To develop new food products
- To add value to plant foods

Wheat-based ingredients

- Wheat flour
- Protein isolates
- Gluten powder
- Gliadin powder
- Glutenin powder
- Wheat fibre
- Wheat germ
- Starch
- Textured wheat protein

Pulse/legume ingredients

- Processed into three main components
  1. Dietary Fiber - white and hence used extensively in white breads etc
  2. Protein Isolate - high acceptance in Europe as peas are non-GMO
  3. Starch - for a variety of food and non-food uses

The Oilseeds

- Soybeans
- Canola (Rapeseed)
- Flax seed
- Mustard seed

- All store oil as energy source (not starch)
- These oils play a key role in CVD (both positive and negatives roles)

The oilseeds

	Oil(%)	Protein(%)
• Soybeans	20	40
• Canola	40	30
• Flax	44	24
• Mustard	30	30

- Values are approximate, they are influenced by specific plant variety, growing season and fertilizer use, etc
- Only soybeans are processed for protein

Oilseed processing

HOT PROCESSING

- Crush and squeeze the oil out of the seeds
- First oil released from broken cells flows out of the remaining biomass (cell walls, hull and protein)
- This oil is green/brown/black in colour (it contains many impurities) - called virgin oil
- Then use hot hexane to wash the remaining oil out of the biomass --> more crude oil + meal (the meal will have about 1% oil in it)
- Combine all oil fractions to refine/purify
- Overall about 14 processing steps
- The use of hexane is questioned as some studies have shown it to be cancer inducing

Oilseed processing

- **COLD PROCESSING**
  - **Uses high pressure machines (called presses) to physically squeeze oil out of the broken seeds**
  - **This crude oil is then purified**
  - **Uses no hot hexane**
  - **Final meal has about 3-7% oil**
  - **Overall process is not as efficient at recovering oil, therefore cold pressed oils are more expensive**

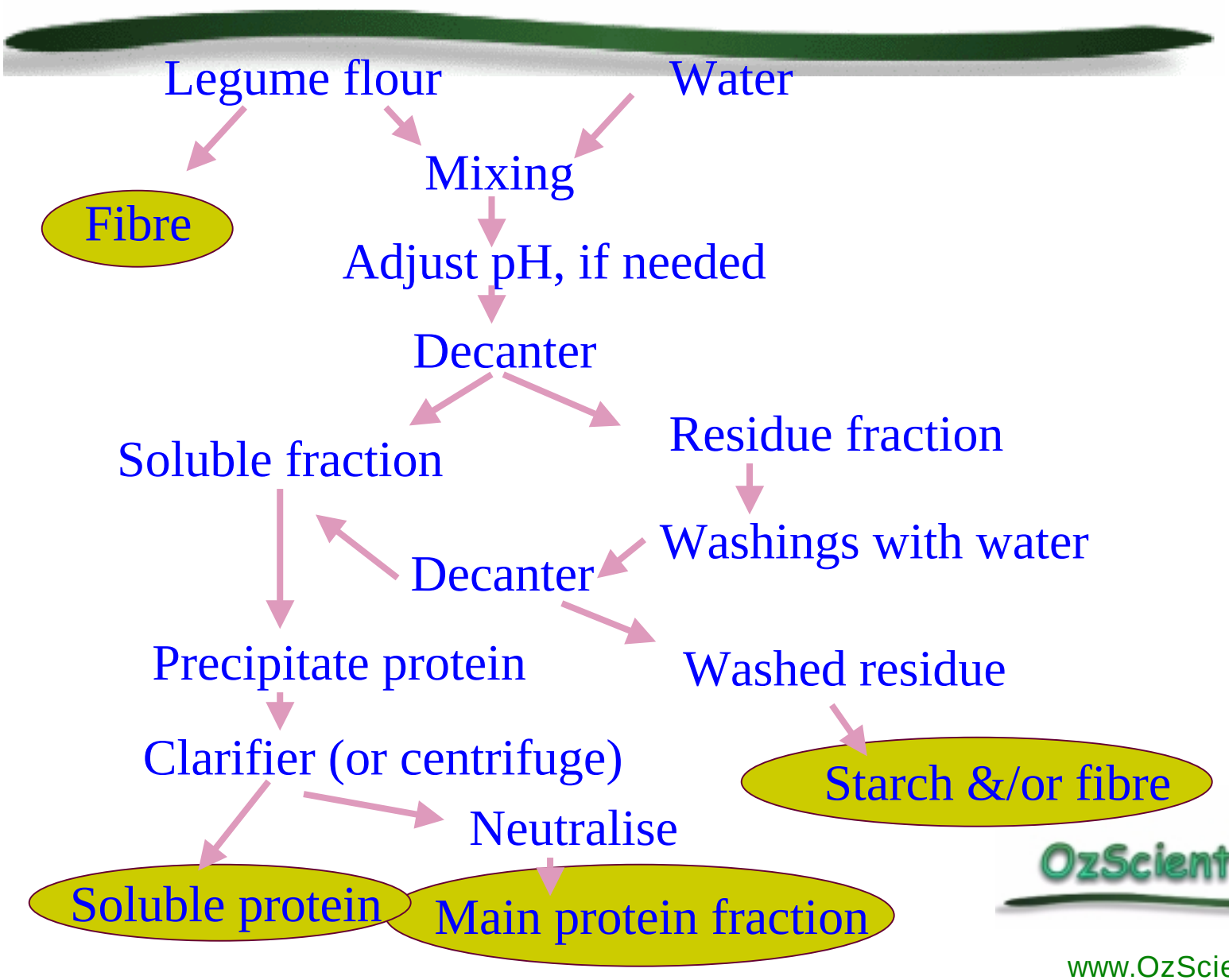
Soy protein ingredients

- Soy Flour
  - ground de-fatted flakes minimum protein content 44%
- Soy Protein Concentrate (>65% protein)
  - made by washing away non-proteinaceous materials from the soy flour
  - may use water, alcohol, acid
  - but acid washes away isoflavones

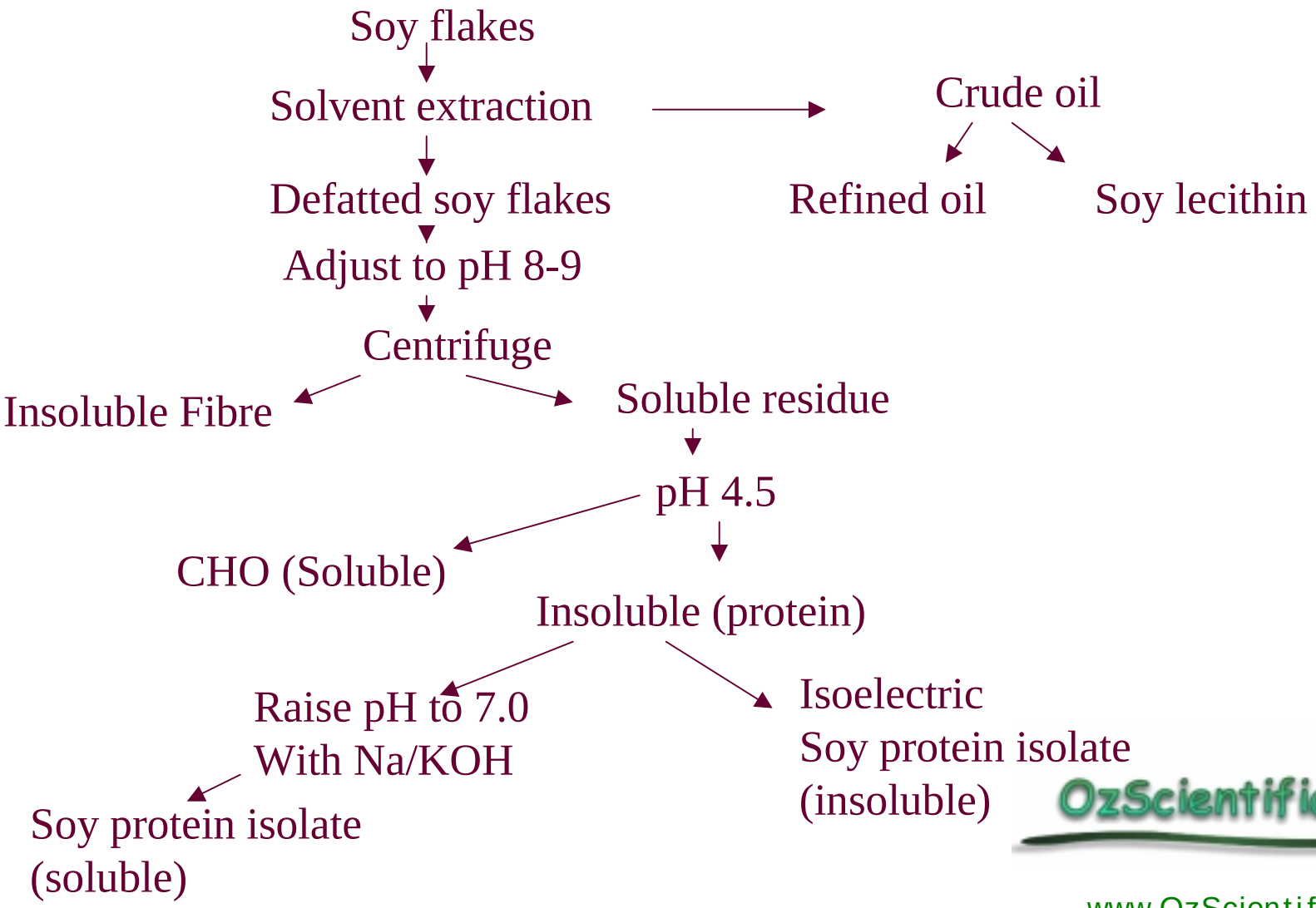
Soy protein ingredients

- **Soy Protein Isolate (90% minimum)**
  - uses alkali (NaOH) to solubilize the protein in a meal or flour or concentrate
  - centrifuge out insoluble material (cell walls etc)
  - precipitate the remaining soluble protein with acid
  - spray dry the wet precipitate --> protein powder
- **Textured Soy Protein**
  - heated and pressure extruded flour or concentrate to form small chunks of material (about 5mm in size)
  - these make up about 40% of a soyburger
  - may have taste and flatulence problems

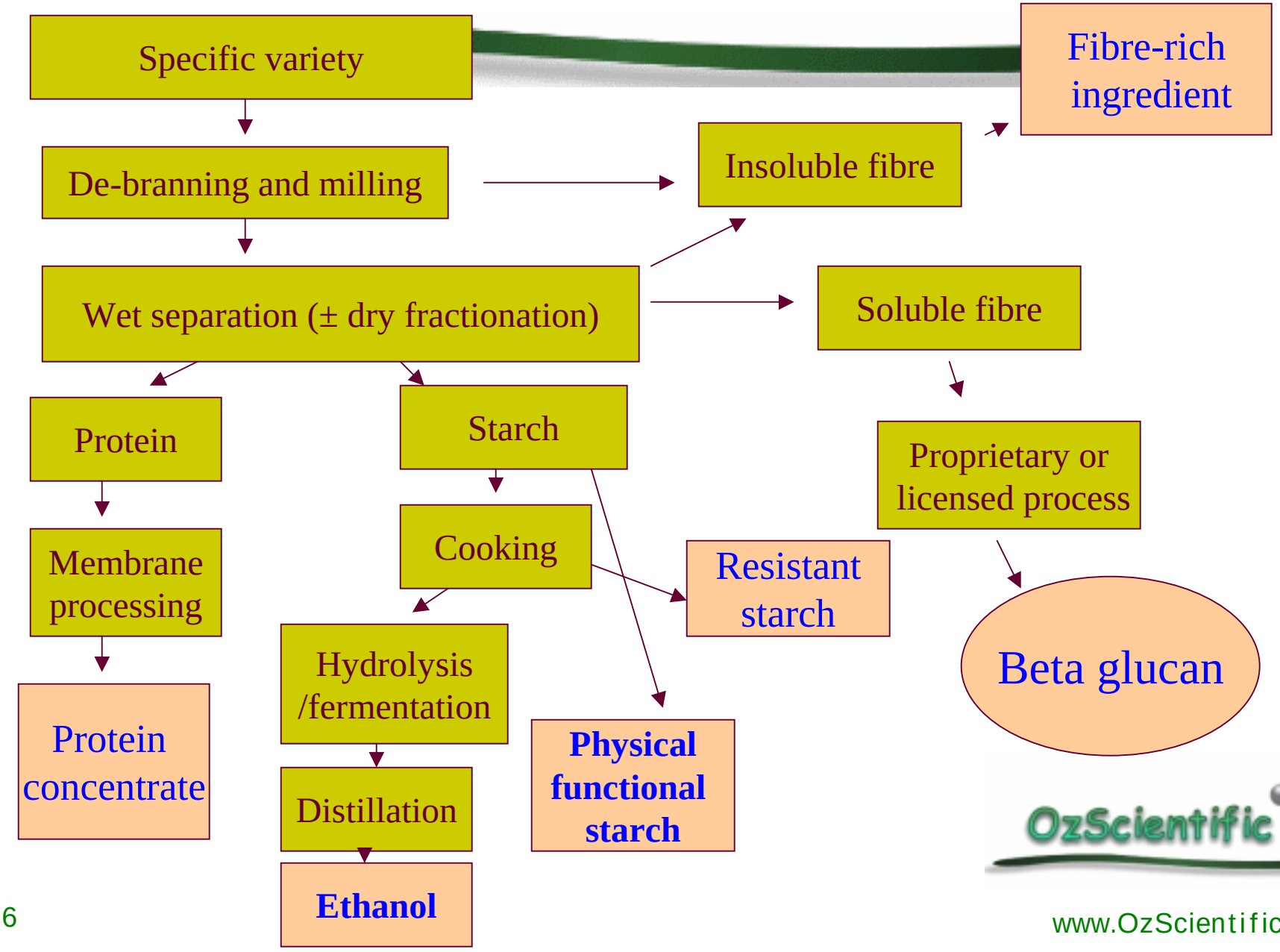
Fractionation of main legume/pulse ingredients



Method for soy ingredients



Ingredients from barley and oat



Physiological functional ingredients

- Health and nutraceutical benefits
  - Proteins/peptides
  - Dietary fibre
  - Phenolics
  - Phytosterol
  - Trypsin inhibitors

Dietary fibre

Dietary fibre is not broken down by digestive enzymes, limited breakdown only by gut microbes.

- holds and binds much water

- **Health benefits of dietary fibre**
  - **fecal bulking and gut regularity**
  - **more rapid movement of material through gut**
  - **cholesterol reduction in blood**
  - **prevention of colon cancer**
  - **prevention of breast cancer**

Insoluble versus soluble fibre from plant foods

	Insoluble dietary fibre	Soluble dietary fibre
Consequence of chewing muscle	●●●	○
Reduction of the energy density	●●●	●●●
Reduction of the hunger feeling	●●	●●●
Lowering of the blood sugar levels	●●	●●
Lower of the blood cholesterol levels	○	●●●
Binding of toxic materials	●	●●
Promotion of intestinal digestion	●●●	●
Effects on the digestion time	●●●	○
Fermentation in the colon	○	●●●

●●● Marked effect ●● Significant effect ● Good effect ○ No effect

Phytic acid: (PA, $InsP_6$)

- Widely distributed in plants - about 5% of the wheat bran
- Made up of inositol (an alcohol sugar) and six phosphate groups
- Binds Ca, Mg, Mn etc and decreases the availability of these nutrients in a diet
- Originally recognized as an anti-nutritional factor
- Recent research has opened some new possibilities
    - PA gives a protective effect for several cancers (colon, breast and maybe prostate)

- **Phytosterols**
  - have cholesterol lowering properties
  - now being introduced in some margarines
  - e.g. sitosterol is main one (about 12 known to exist in various plants)
- **Trypsin Inhibitor**
  - inhibits the gut enzyme trypsin (hence heat in processing)
  - has some potential anti-cancer activity

Phenolics

- Flavonoids - Anthocyanins (red, blue, violet pigments) (6467 types)
- Isoflavones (Genistein, etc)
- Flavonols (Quercetin, rutin, etc)
- Lignans (100s of these)
- Saponins
- Tannins
- Quinones
- Coumarins

Isoflavones

- About 12 known
- 3 in soy, main ones are genistein, daidzin and glycitin
- they can slow calcium loss from bones
- they can act as phytoestrogens
- they can inhibit growth of cancer cells

SAPONINS

- Polyphenolic compounds
- Steroid and terpene-like compounds with attached sugars (pentose, glucose etc)
- Reduce platelet formation, reduce cholesterol, stimulate the immune system and suppress growth of cancer tumors