Functionality and applications of milk proteins

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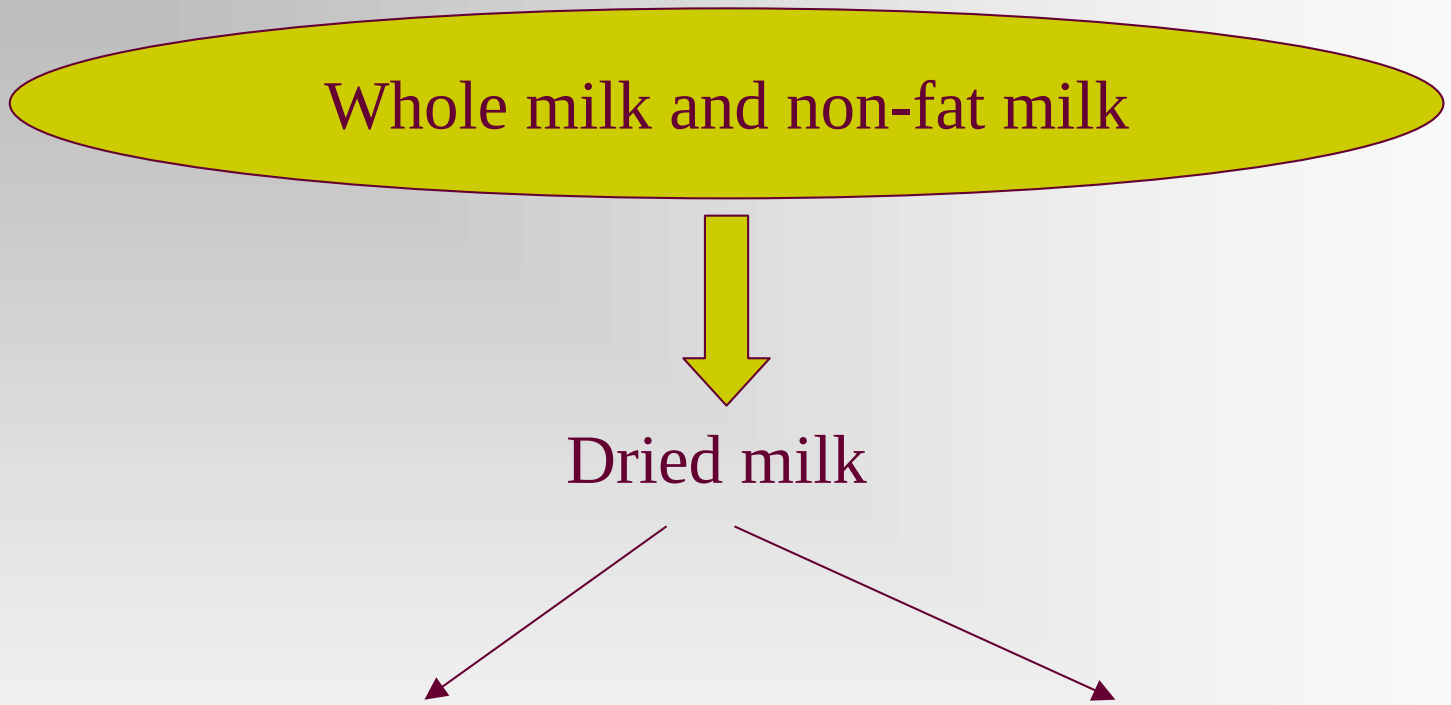
Outlines

- Background on types of milk powders and cost comparison
- Physical functional properties in general
- Functional properties specific to applications in UHT milk

Milk-based products



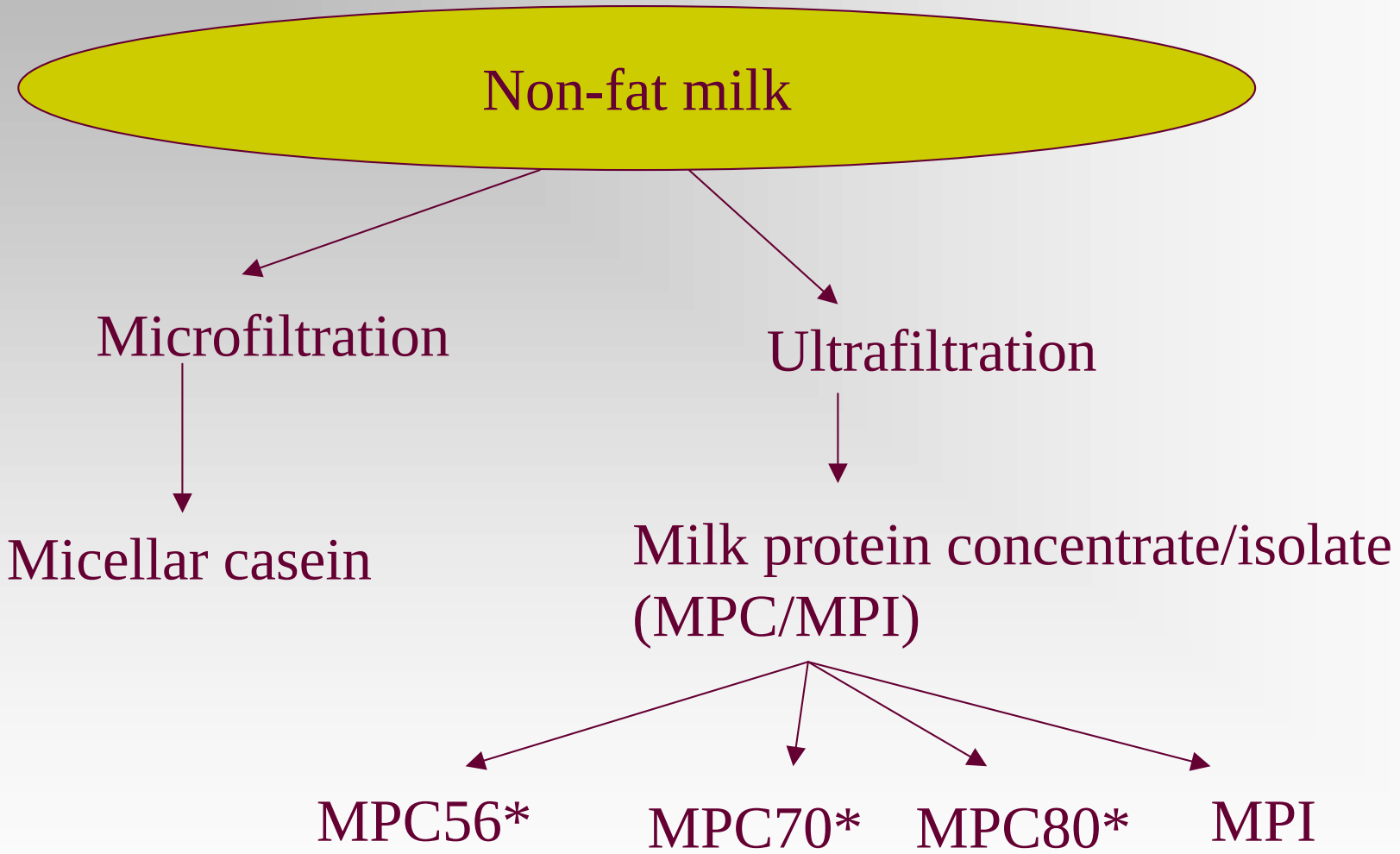
Heat classification

- Low heat
- Medium heat
- High heat

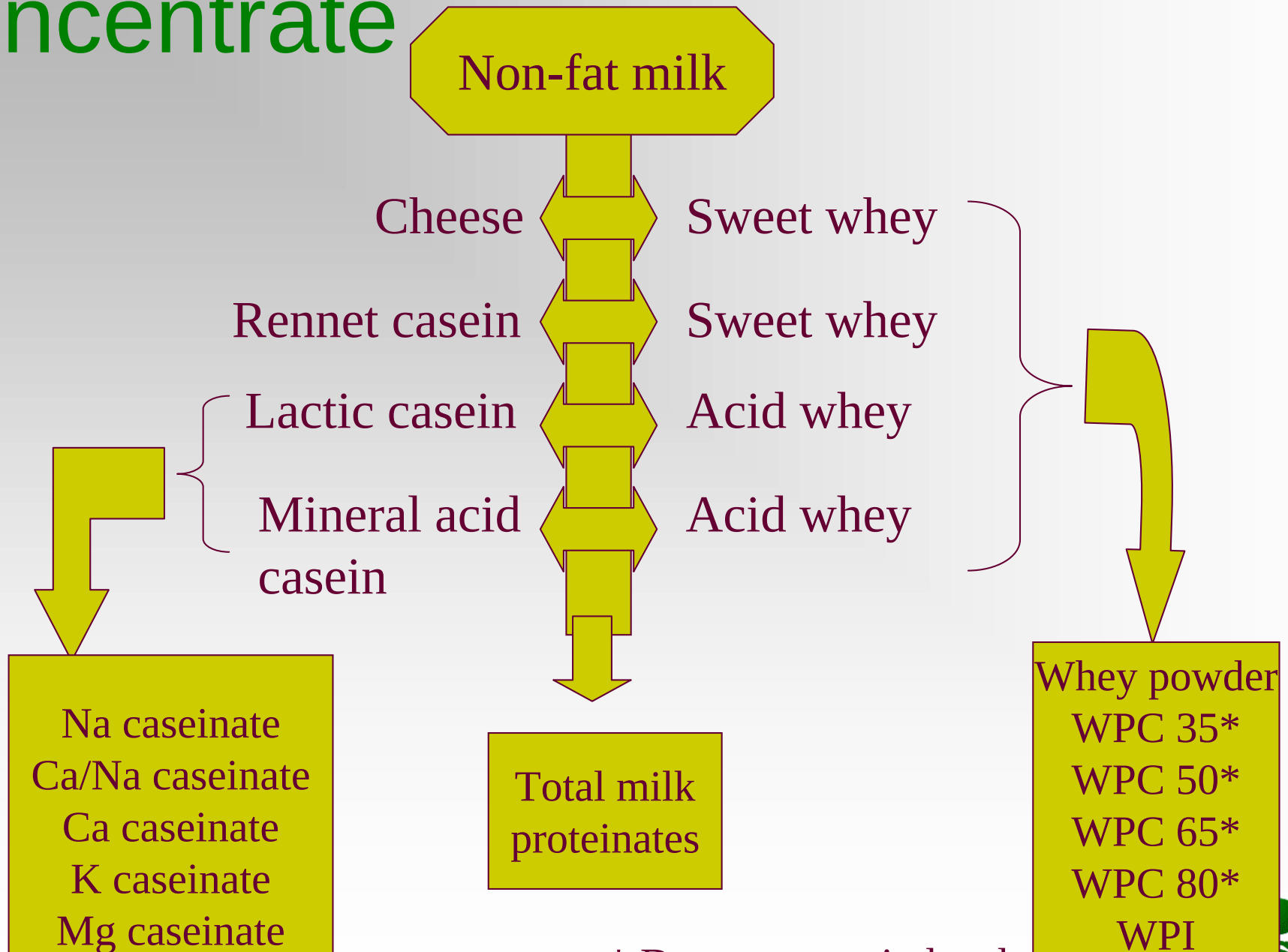
Fat levels

- Non-fat
- Partial fat
- Full fat
- Free-fat levels

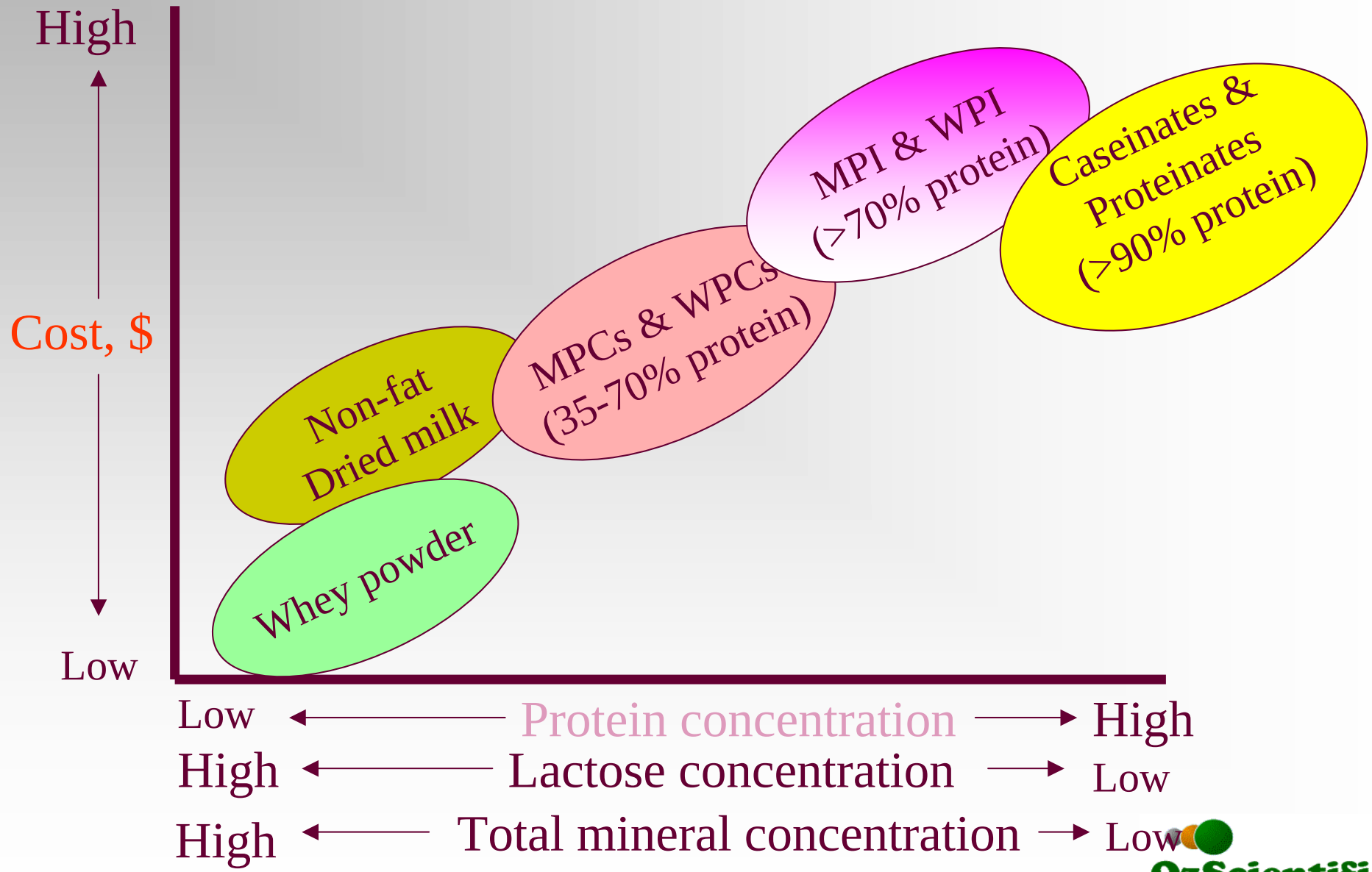
Milk protein concentrates



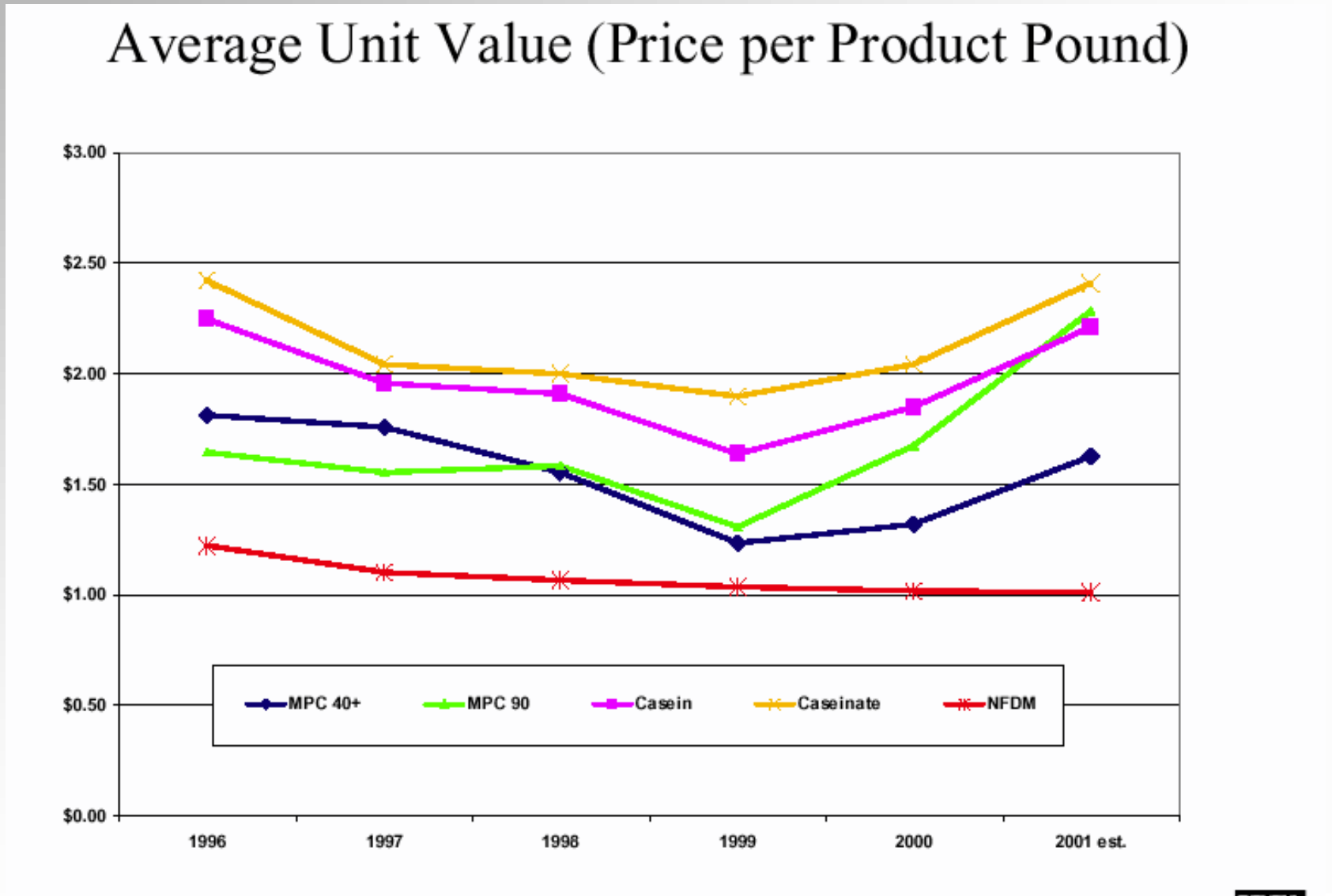
Caseinate and whey protein concentrate



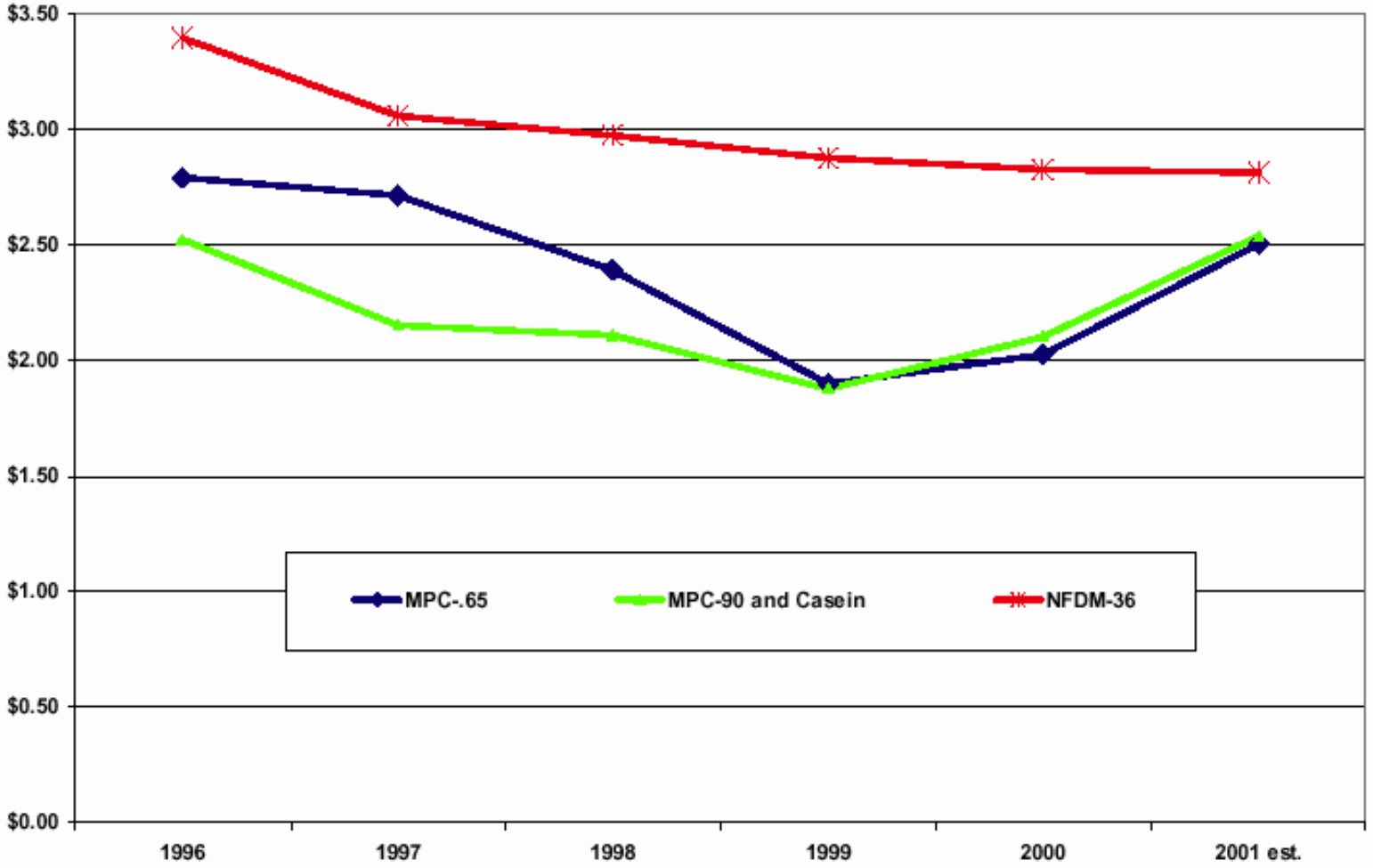
Comparison of dairy ingredients



US market data



Price per Pound of Milk Protein (3 categories)



Functional properties of milk powder

Nutritional Properties

- source of nutrients, biological value

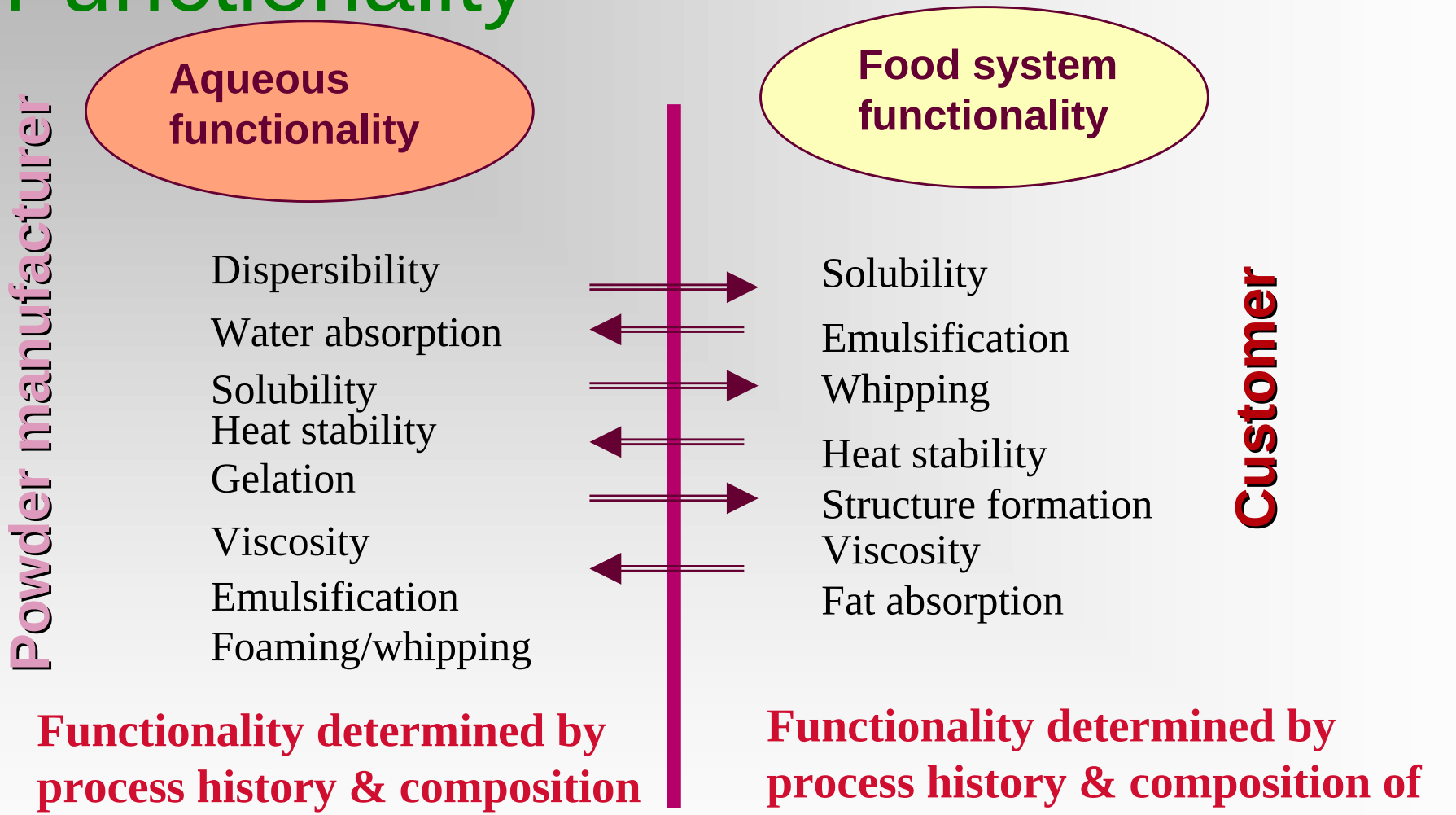
Physically Functional Properties

- impart desirable physical and sensory properties

Physiologically Functional Properties

- bio-modulating response

“Aqueous” & “Food System” Functionality



Functional properties - some comments

- No single product provides all functional properties at optimum levels
- Aqueous or manufacturing functionality can direct us to its application functionality but not necessarily guarantee satisfactory usage
- Manufacturing functionality is a grading tool for powder products; depends on the processing history, composition, aggregation state and conformation of protein and other molecules in water
- Application functionality is related to complex interactions in food products. Expensive to evaluate all powders in applications, therefore routine testing comprises of aqueous testing

FUNCTIONAL PROPERTIES

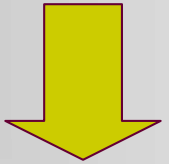
Functional property	Mode of action	Food system
Water binding	H bonding, entrapping of water	Meat sausages, cakes, breads
Solubility	Protein solvation	Beverages
Heat stability	Low levels of secondary or tertiary structures of caseins	Heat sterilised nutritional drinks
Gelation	Protein matrix formation & setting	Meats, curds, baked goods, pasta products
Viscosity	Protein and carbohydrate swelling, increased hydrodynamic volume	Soups, gravies, salad dressing
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 formulae

Factors affecting functional properties

- Milk composition
- pH and ionic composition
- Temperature
- Preheat treatment of milk
- Other ingredients

Milk protein is the key to the functionality

Milk protein functionality



Modulated by other components

Inherent milk functionality

Processing & drying conditions

Final milk powder functionality

PHYSICO-CHEMICAL PROPERTIES OF MILK PROTEINS

CASEIN

- Strong hydrophobic regions
- Low cysteine
- High ester phosphates
- Little or no secondary structure
- Unstable in acidic conditions
- Micelles in native form
- Random coil in dissociated form

WHEY PROTEIN

- Balance in hydrophobic and hydrophilic residues
- Contains cysteine and cystine
- Globular, much helical
- No ester phosphate
- Easily heat denatured
- Stable in mild acidic condition
- Present as soluble aggregates (<10 nm)

Functionality of milk powders for applications in UHT milks

- Dispersibility
- Water binding/hydration
- Solubility
- Heat stability
- Emulsification

Dispersibility

- Ability of powder particles to disperse throughout without clumping or floating
- Useful property in initiating the hydration and solubilizing of powder particle
- Measured by empirical methods

Water binding/hydration

- **Depends on number and availability of water binding sites, e.g. polar amino acids, carboxyl, hydroxyl or thiol side chains**
- **Caseins**
  - **Good water absorption in native state**
  - **Precipitation causes reduction in water absorption**
- **Whey proteins**
  - **Poor water absorption in native state**
  - **Heat-induced unfolding improves water absorption**

Water binding/hydration

- **Techniques for measurement- academic interest**
  - **Thermodynamic properties, e.g. sorption isotherms for measuring entahlpy, entropy, aW, freezing and boiling points**
  - **Kinetic properties: mobility of water by NMR, light scattering, intrinsic viscosity**
  - **Nature & strength of H bond: spectroscopic techniques- IR, Raman**
  - **Position & orientation of water molecules: light and X-ray scattering**

- **Techniques for measurement- routine techniques**
  - **Water absorption: baumann apparatus, viscometry, farinograph, rehydration tests, sorption isotherms**
  - **Water retention: centrifugation test, DSC, filtration methods**

SOLUBILITY

- **Pre-requisite for most other functional properties**
- **Determined by the balance of repulsive and attractive forces**
- **Measured by low speed centrifugation**
- **casein - soluble > pH 5.5**
- **Whey proteins - soluble throughout the pH range**
- **Heating WPs near pI causes insolubility**

Solubility – milk powder

- Reconstitute milk powders by mixing with water at high speed at 20-25°C
  - 10 g powder in 100 mL water
  - Mixing at 3550 rpm
- Centrifuge (50 mL) at a designated speed
- Dilute with water and re-centrifuge
- Read the sediment volume and reporting sediment volume (sedimentation index) as mL

Ref: AS 1629-1974, Standards Association of Australia

Heat Stability

Heat Stability: The ability of a liquid product to withstand heat processing

⇓

- Successful application of ingredients require that they are compatible with heat processing operations
- Heat treatment modifies functionality of milk proteins

HEAT STABILITY

- Depends on the amount of secondary structure in the polypeptide chain - caseins have minimum secondary structure, hence are very heat stable.
- Heat stability is important in UHT and retorted formulations

Heat Stability Tests

Subjective evaluation:

Time taken for a 20% MSNF solution to thicken

Objective evaluation:

Viscosity of 18% MSNF:8% fat concentrate sterilised at 120 °C for 13 min

Product related specifications ⇒ Ensures against product failure

Heat stability - recombined milk

- Reconstitute milk powder
- Recombine with milk fat and homogenise
- Add phosphates
- Measure pH
- Transfer to stainless steel tubes
- Immerse in boiling water bath for 5 min
- Heat at 120°C (using oil bath) for 13 min
- Cool to 25°C in the water bath
- Measure viscosity using Brookfield viscometer
- Present data as viscosity versus pH

Ref: Kieseker & Aitken, 1988, Australian Journal of Dairy Technology, May 1988

Emulsifying properties

Emulsifying properties are dependent on the ability of surfactant (protein) to:

- Lower surface tension
- Stabilize the emulsion

Factors affecting emulsification of milk

- milk composition
- pH and mineral balance
- fat
- temperature
- others (e.g. low molecular weight surfactants)

EMULSIFYING PROPERTIES

EMULSIFYING CAPACITY

EMULSION ACTIVITY INDEX

RATE OF EMULSION BREAKDOWN

DISTRIBUTION OF OIL DROPLETS

FAT OR WATER IN UPPER OR LOWER LAYERS

Emulsification – protein powder

- Prepare 0.5% protein dispersion by mixing protein powder in water for 30 min
- Adjust pH 7.0
- Mix for further 30 min
- Weigh 100 g protein dispersion into a 600 mL tall beaker
- Place the beaker in a water bath at 20°C, attach conductivity probe
- Add oil at a rate of 1 mL/s while mixing the protein dispersion (note the timing of the oil addition)
- Monitor resistance reading on the multimeter – resistance will decrease gradually and then suddenly move to the end of the scale
- Stop oil addition and timer, turn off blender
- Calculate emulsifying capacity as
  - Oil (g)/g protein