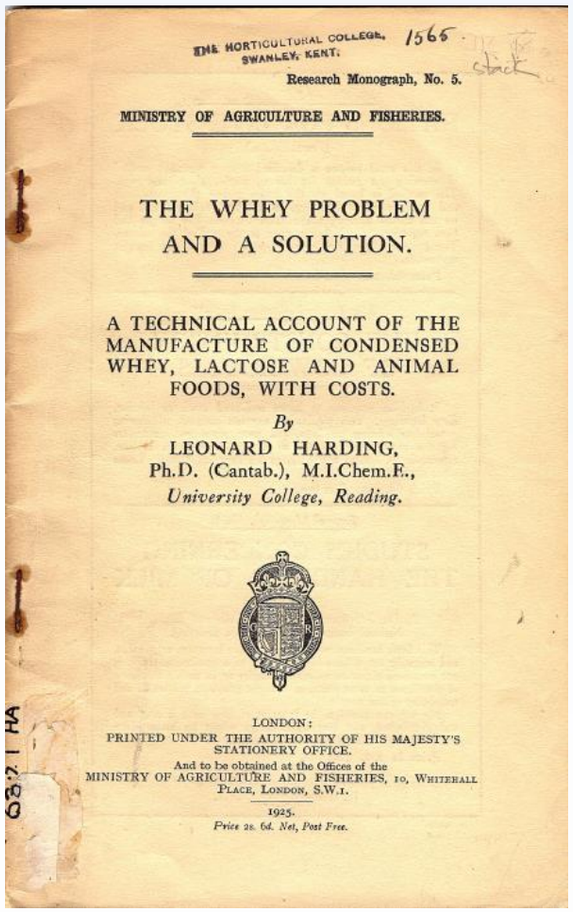
Lactose & GOS

Ken Burgess

Ken Burgess Associates

Lactose: History & perspectives



RHS HORTICULTURAL COLLEGE, SWANLEY, KENT. 1565

Research Monograph, No. 5.

MINISTRY OF AGRICULTURE AND FISHERIES.

THE WHEY PROBLEM AND A SOLUTION.

A TECHNICAL ACCOUNT OF THE MANUFACTURE OF CONDENSED WHEY, LACTOSE AND ANIMAL FOODS, WITH COSTS.

By
LEONARD HARDING,
Ph.D. (Cantab.), M.I.Chem.E.,
University College, Reading.

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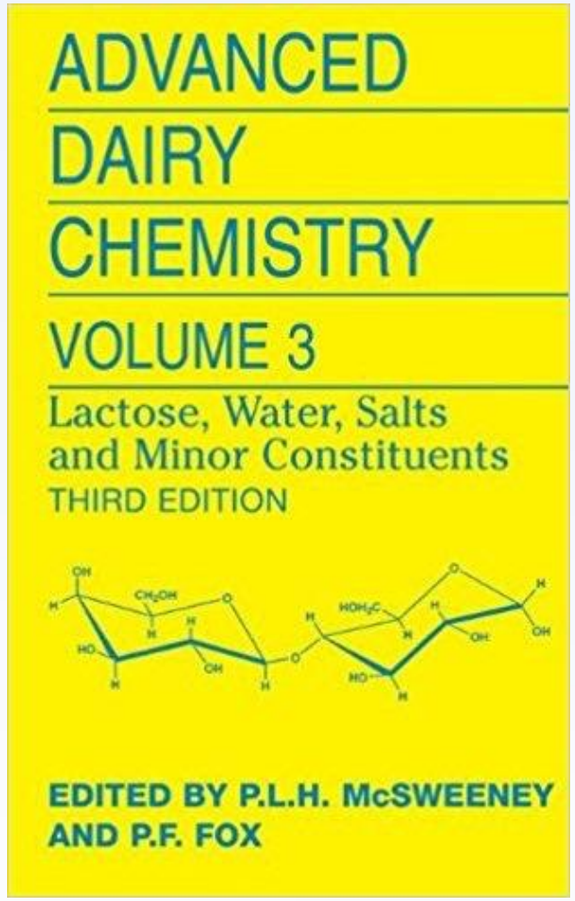


ADVANCED DAIRY CHEMISTRY

VOLUME 3

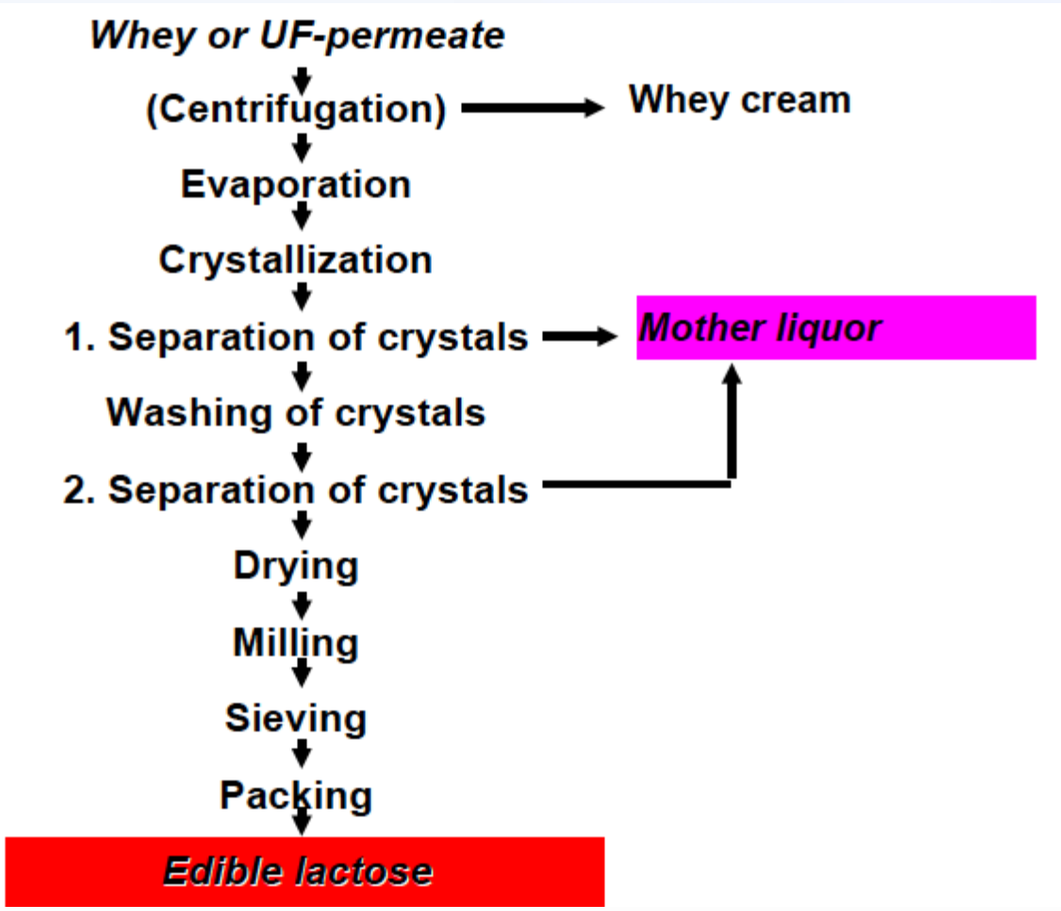
Lactose, Water, Salts and Minor Constituents

THIRD EDITION

EDITED BY P.L.H. McSWEENEY AND P.F. FOX

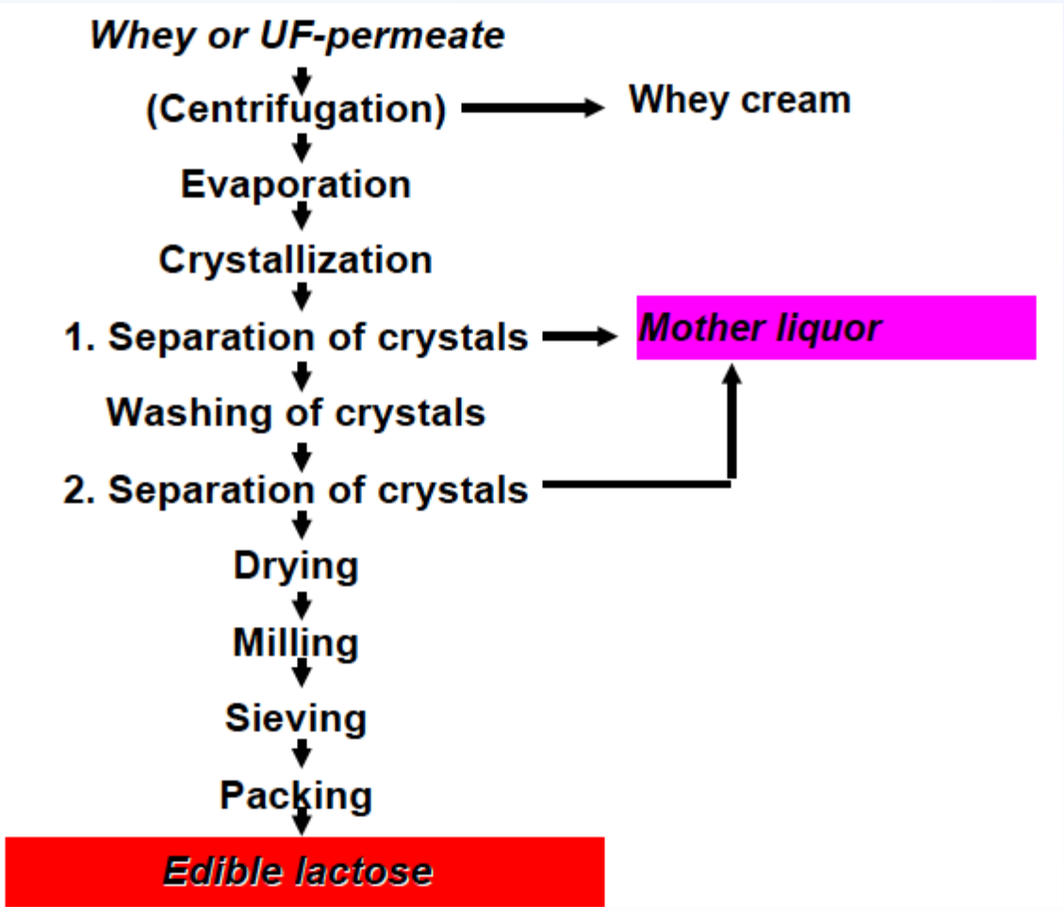
2010

Lactose manufacture



Arla, 80,000 tonnes pa lactose plant

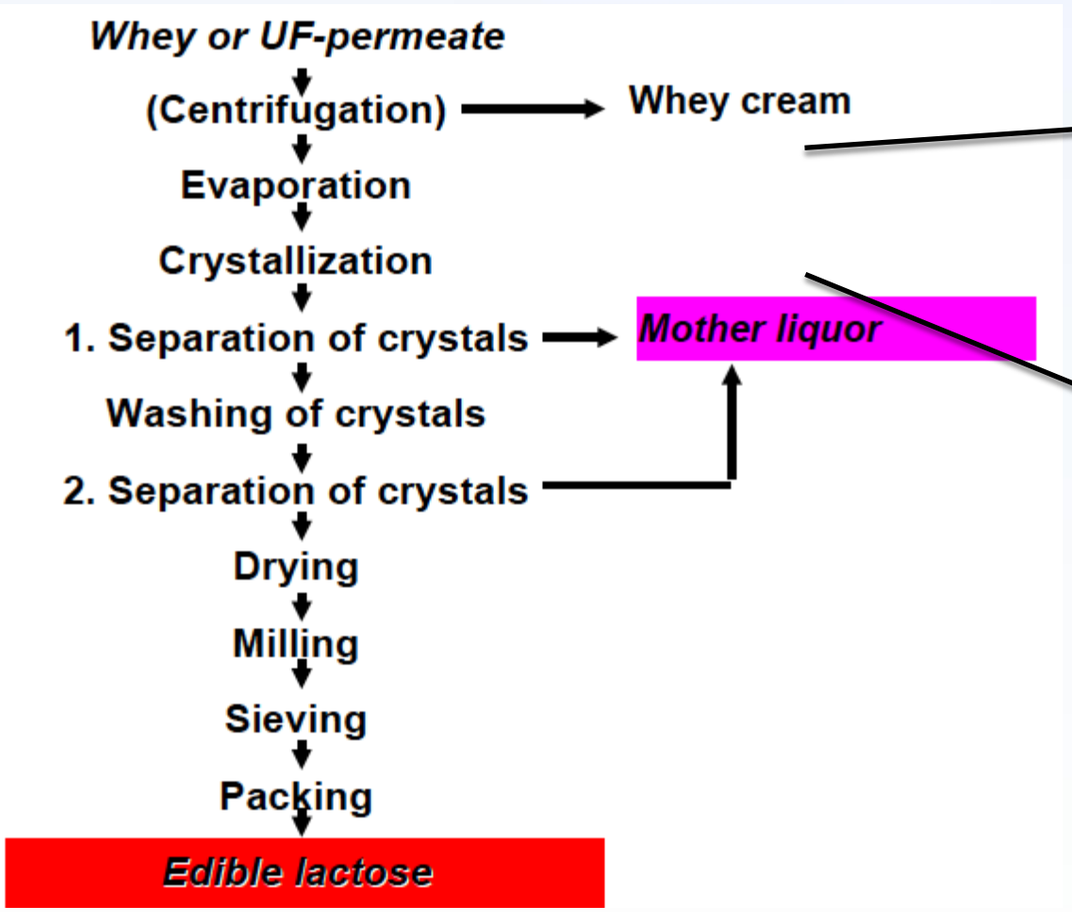
Lactose manufacture: Raw materials



Raw materials

% of TS	Whey	UF permeate
Lactose	72	83
Ash	8	9
Protein	12	3

Developments in lactose manufacture



Permeate softening (Ca reduction):

i) Precipitation

ii) Ion exchange

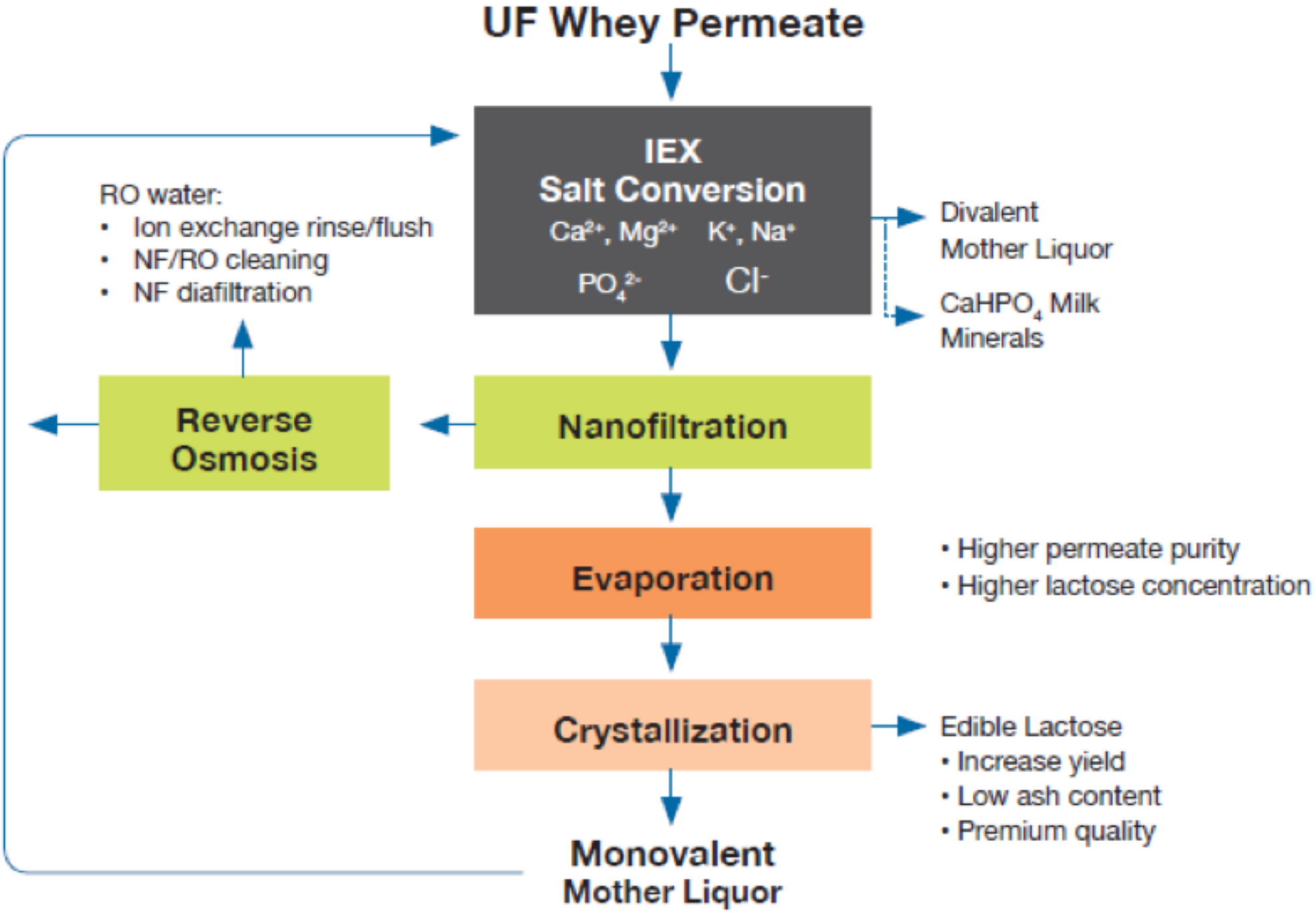
Yield* improvement:

i) Higher crystallisation yield

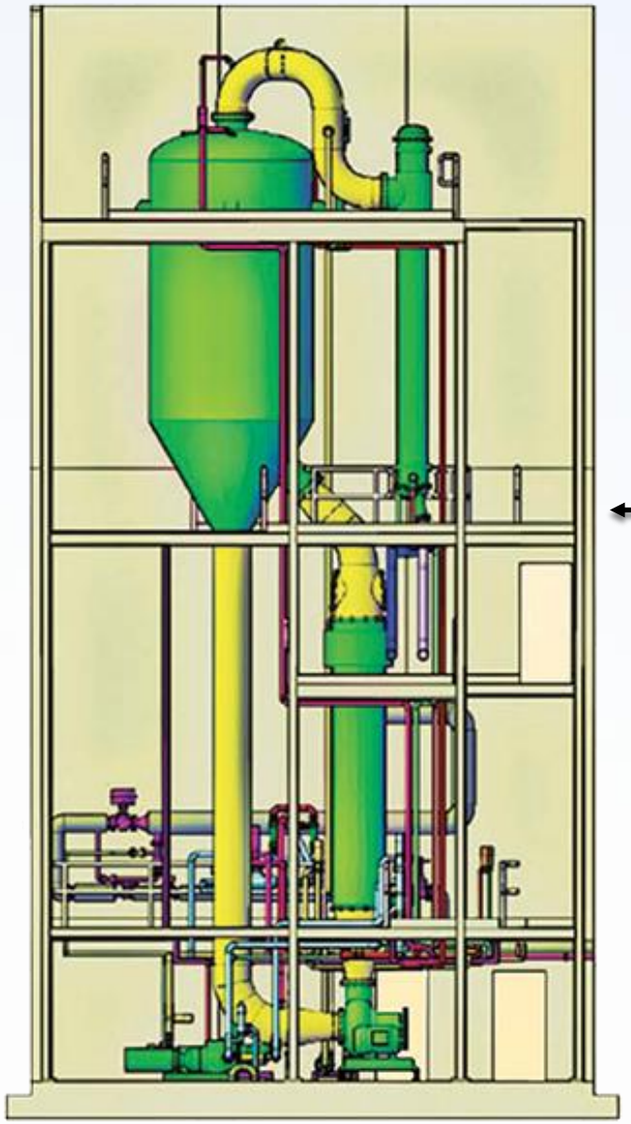
ii) Second crop of lactose

* often with related purity improvement

Permeate softening: Novasep



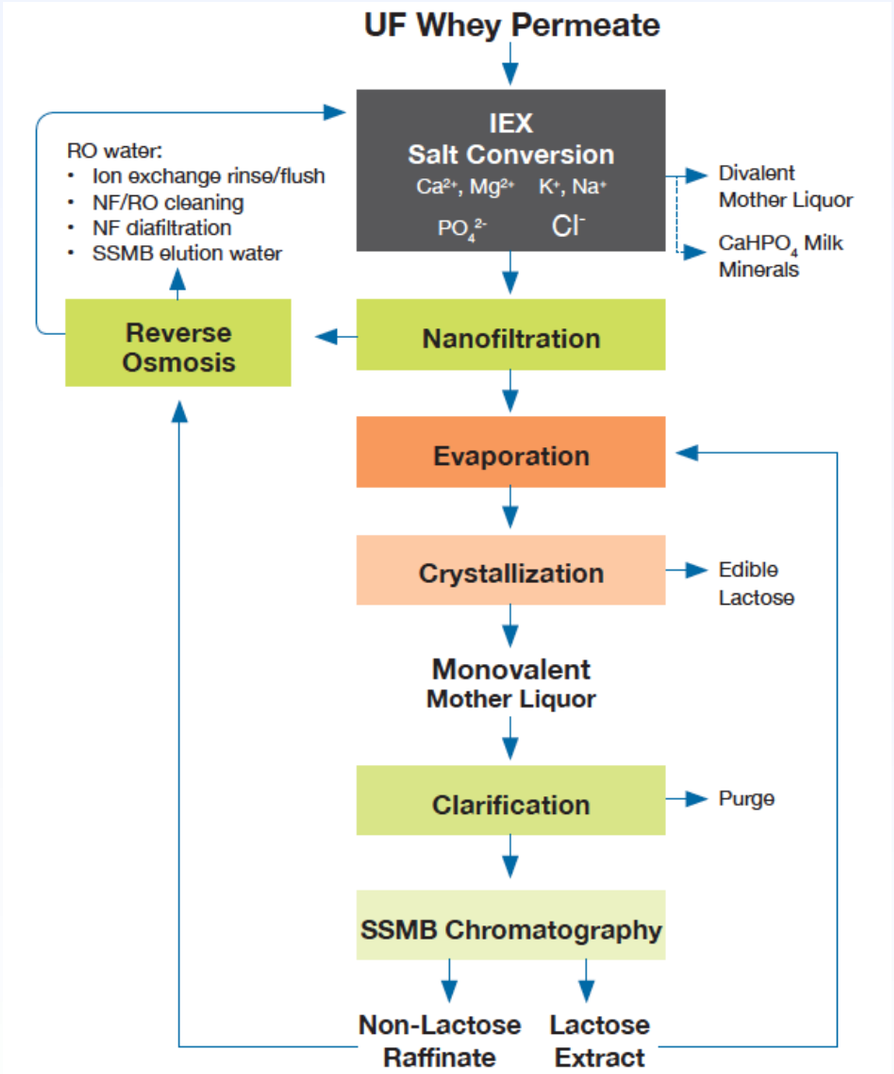
Lactose manufacture: Yield improvement



Yield improvement:

i) **Higher crystallisation yield**

ii) **Second crop of lactose**



Crystallac process

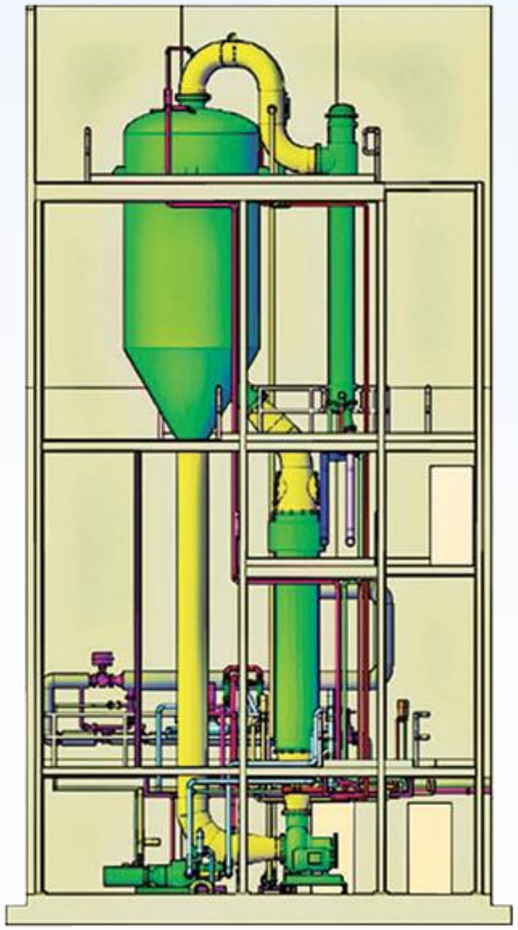
(Relco)

SMB Chromatography

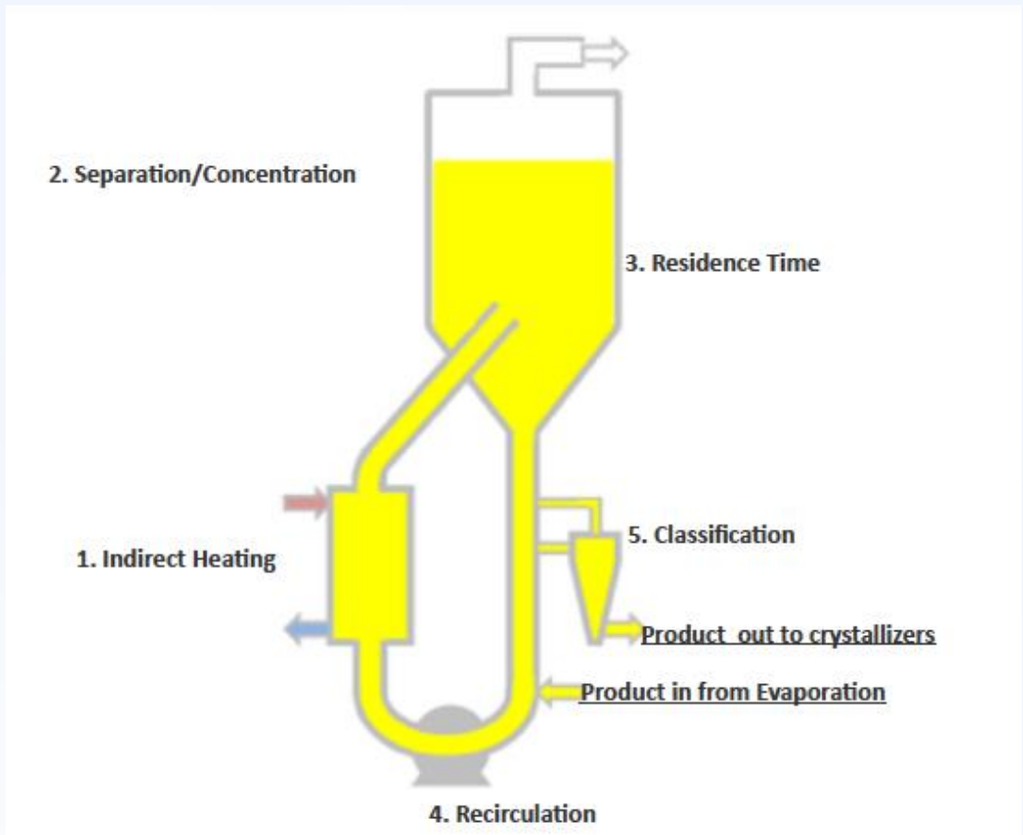
(Novasep)

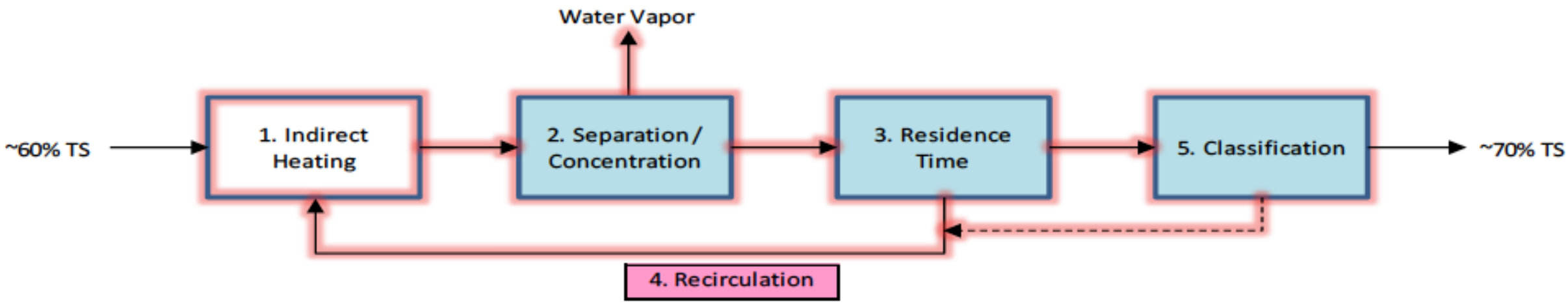
Ken Burgess Associates

Lactose yield improvement: Crystallac

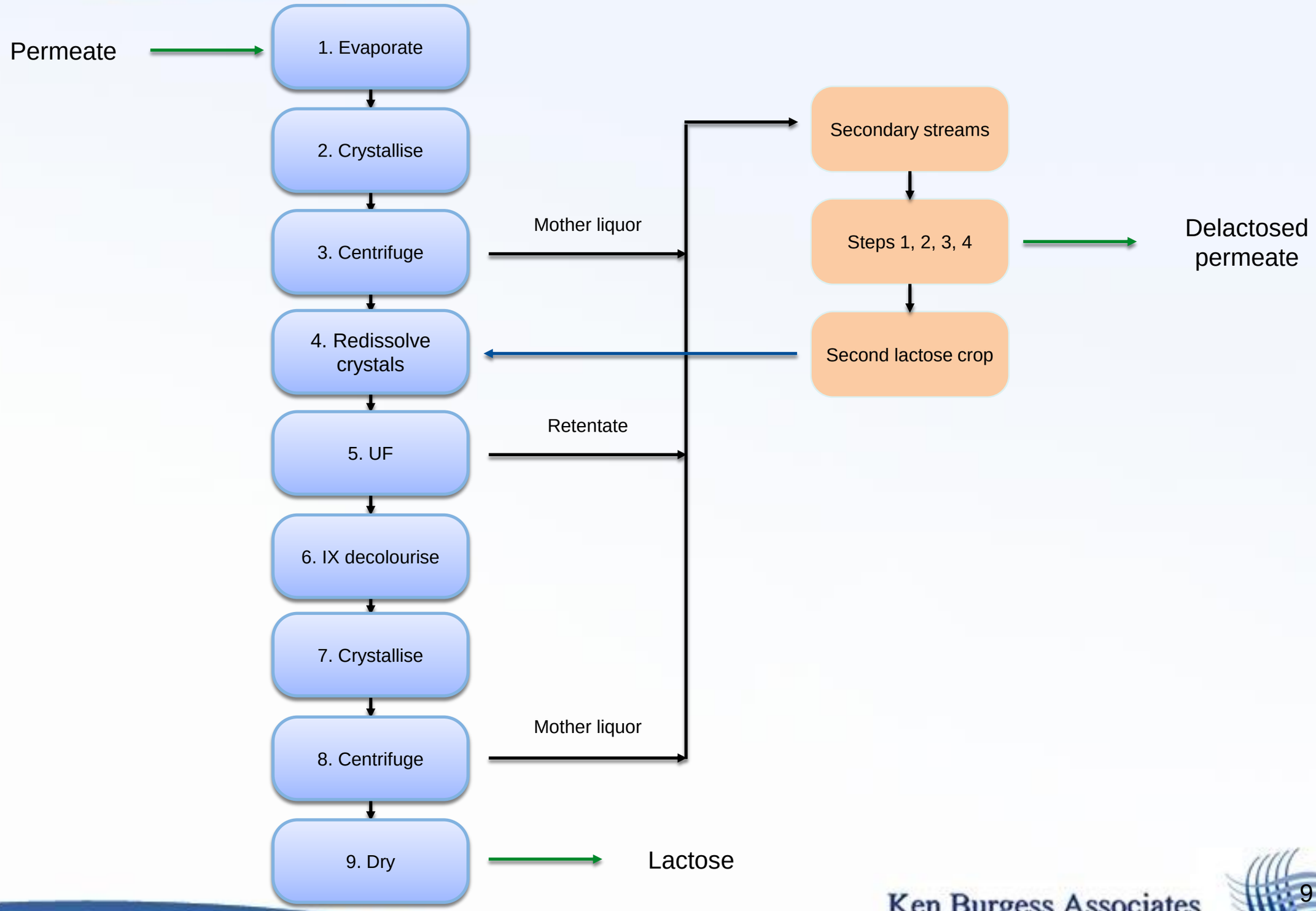


Lactose crystallising evaporator





Lactose yield improvement: Second crop



Anon, 2017

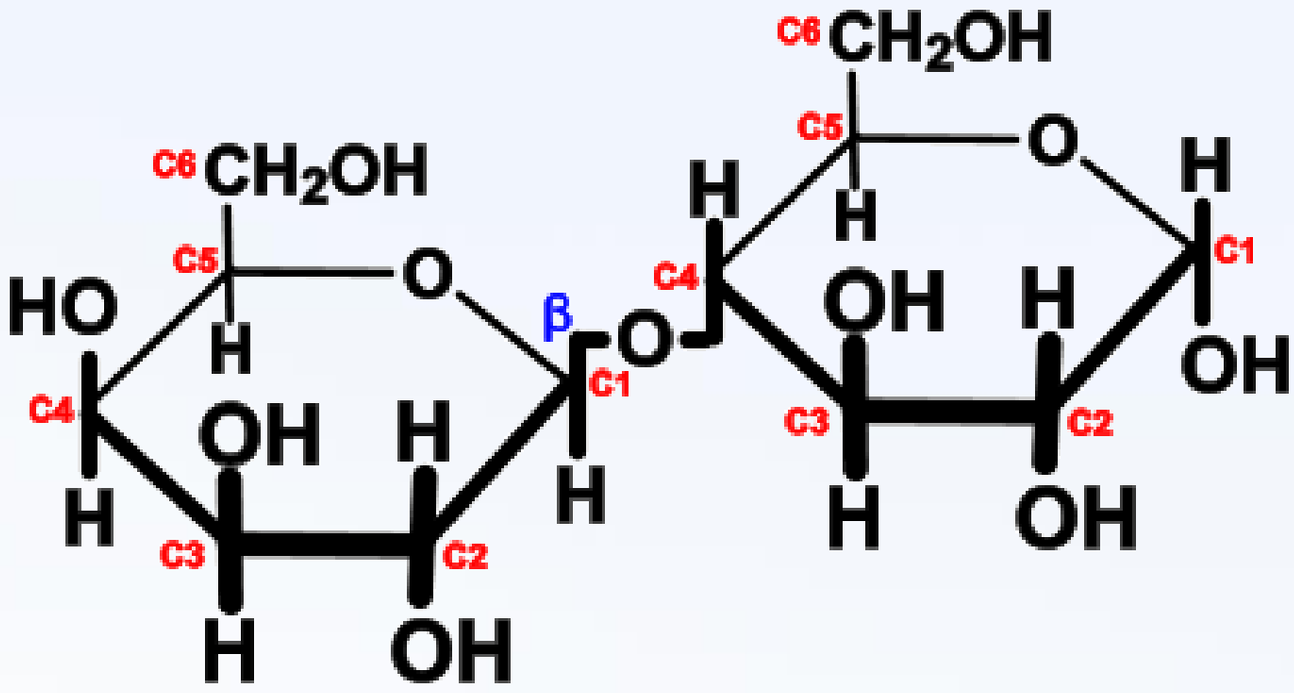
Lactose production

Lactose production (Source: Giract, 2014)	
Year	Global production
2012	1,136 kt
2017 (f)	1,421 kt
CAGR (12-17)	5%

Lactose demand spikes	
Year	Demand driver
1940’s	Penicillin fermentation
1999	Milk powder standardisation (Codex)
2000’s	Infant Formula

Lactose

Galactose joined to glucose with a β 1-4 linkage



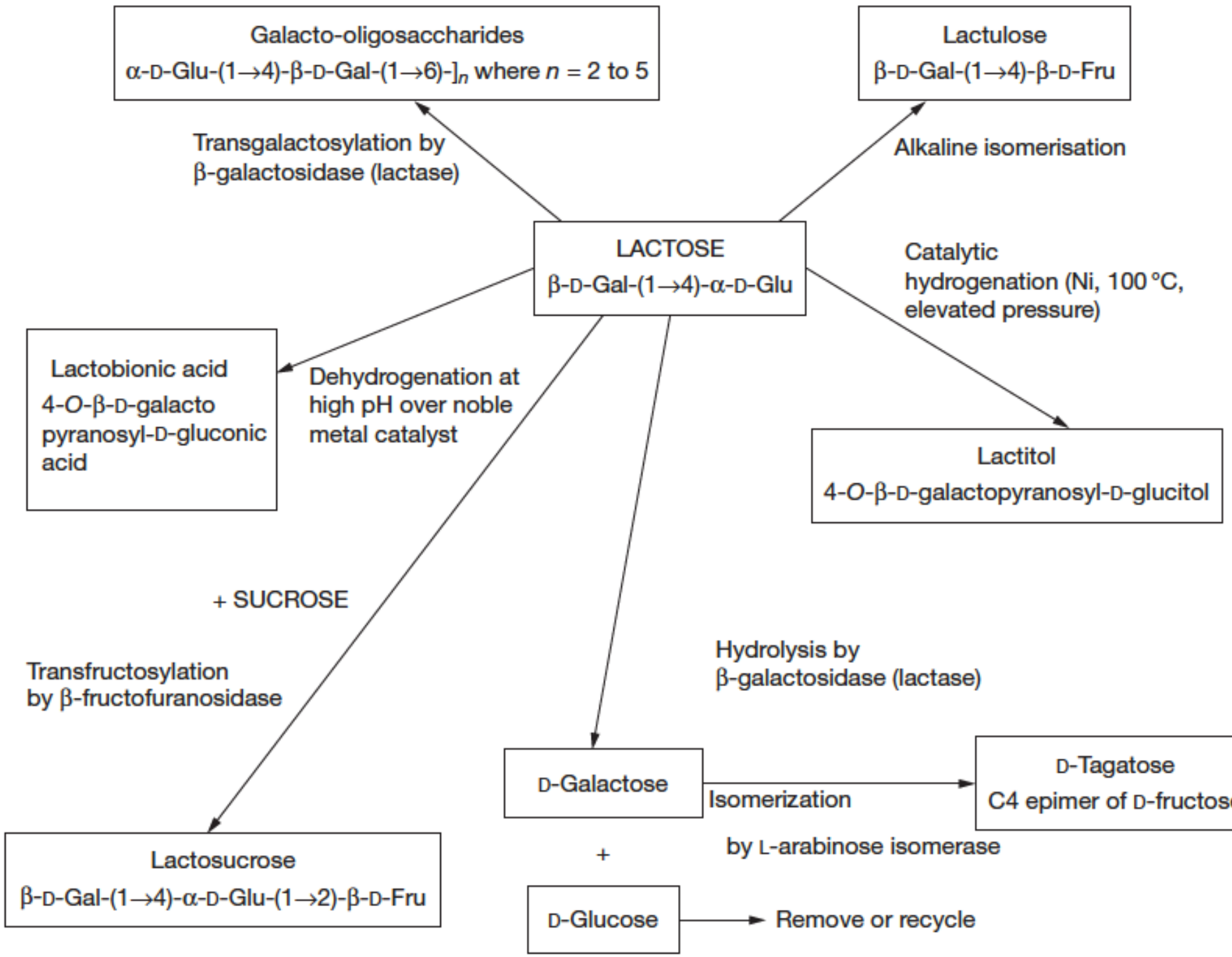
Two places in the lactose molecule are reactive and can be specifically modified:

- the carbonyl group and,
- the link between the glucose and galactose moieties.

Lactose conversions:

- biological,
- biochemical,
- chemical

Lactose derivatives



Shendurse & Khedkar, 2016

Oligosaccharides in human milk

- **General**
  - Abundant in human milk (8-15 g/L)
  - >200 different oligosaccharides have been identified in human milk
  - Trace levels in bovine milk/whey
- **Functions**
  - Neural development
  - Prebiotics
  - Protect against enteric infection

Component	Unit	Bovine	Human
Carbohydrate	g/L	48	70
Lactose	g/L	48	60
Oligosaccharides	**g/L**	Trace	**8-15**

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REVIEW

Milk oligosaccharides: A review

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McSweeney, 2013

Galacto-oligosaccharide (GOS) production

Estimated annual production of Galacto-Oligosaccharides		
Year	Estimated production, tpa	Reference
1995	15,000	Sako et al (1999)
2004	12-14,000	Playne & Crittenden (2009)
2007	25,000	Paterson & Kellam (2009)
2009	21,000	Playne & Crittenden (2009)
2010[a]	33-44,000	Paterson & Kellam (2009)
2013	94,100	Grand View Research (2015)
2020[a]	175,700	Grand View Research (2015)

[a] Forecasted value

Vera & Illanes, 2016

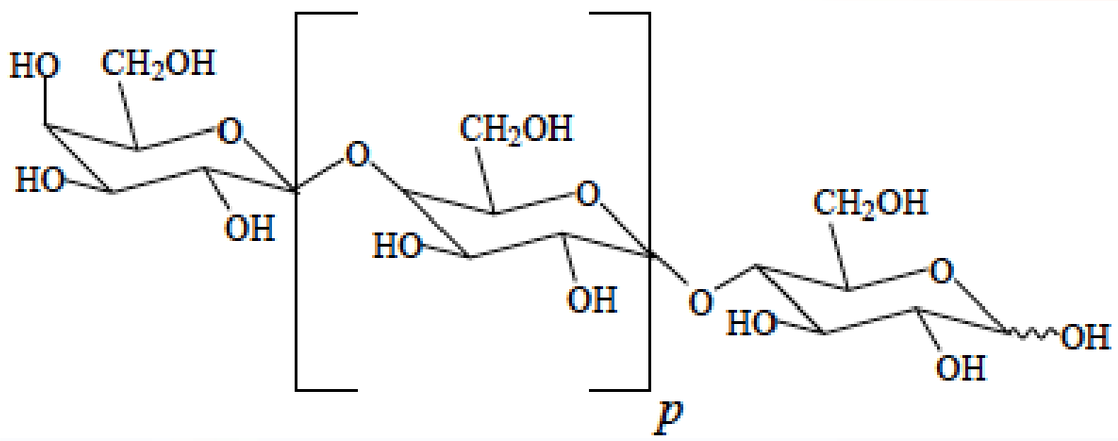
Galacto-oligosaccharides (GOS)

- Galacto-oligosaccharides (GOS) are derived from lactose by the **transgalactosylation reaction** catalyzed by β-galactosidases.
- GOS are **galactose-rich oligosaccharides** consisting of 2-10 monosaccharides joined by different glycosidic linkages, often contain one glucose molecule

Galactose — Glucose

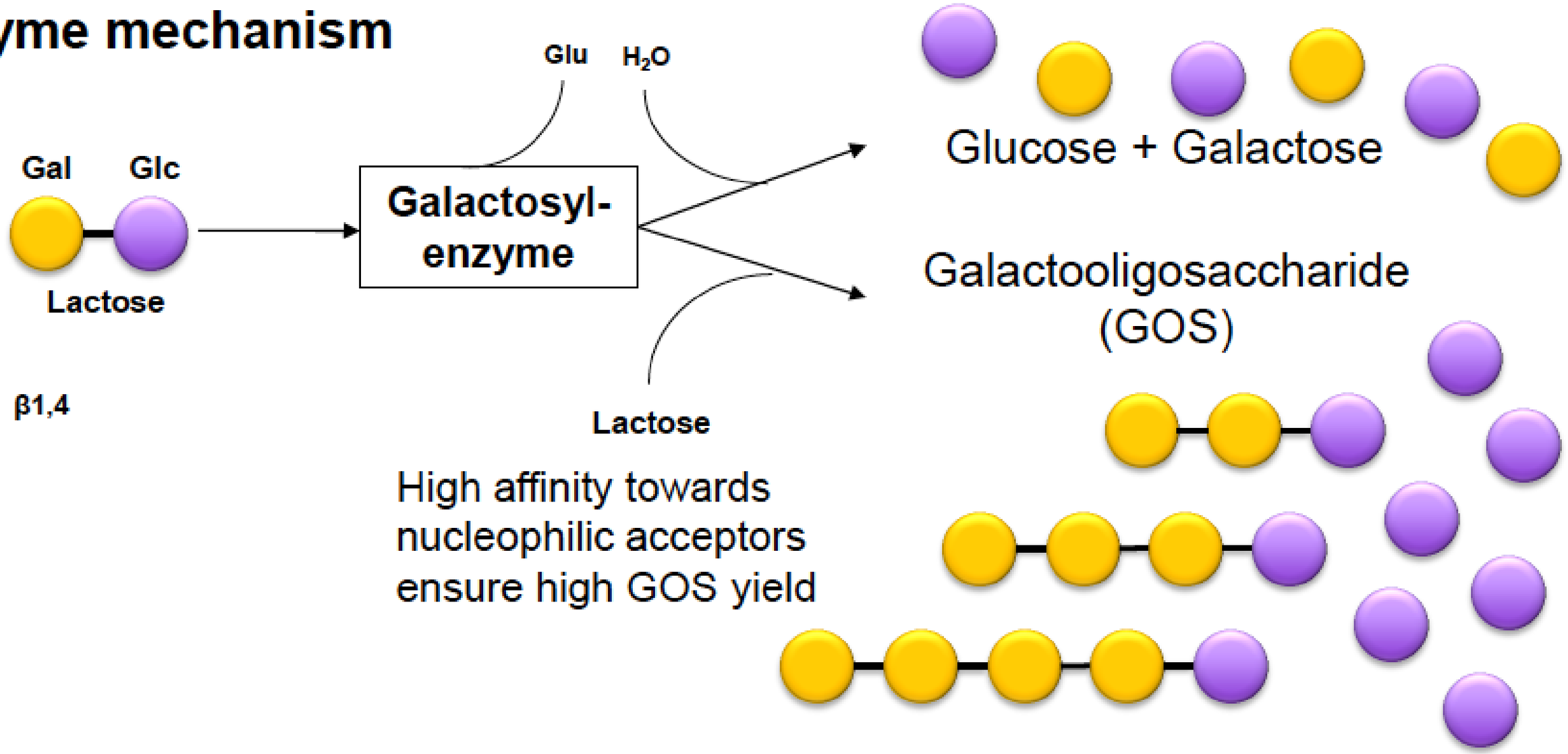
Galactose — Galactose — Glucose

Galactose — Galactose — Galactose — Glucose



GOS production: β-galactosidase reactions

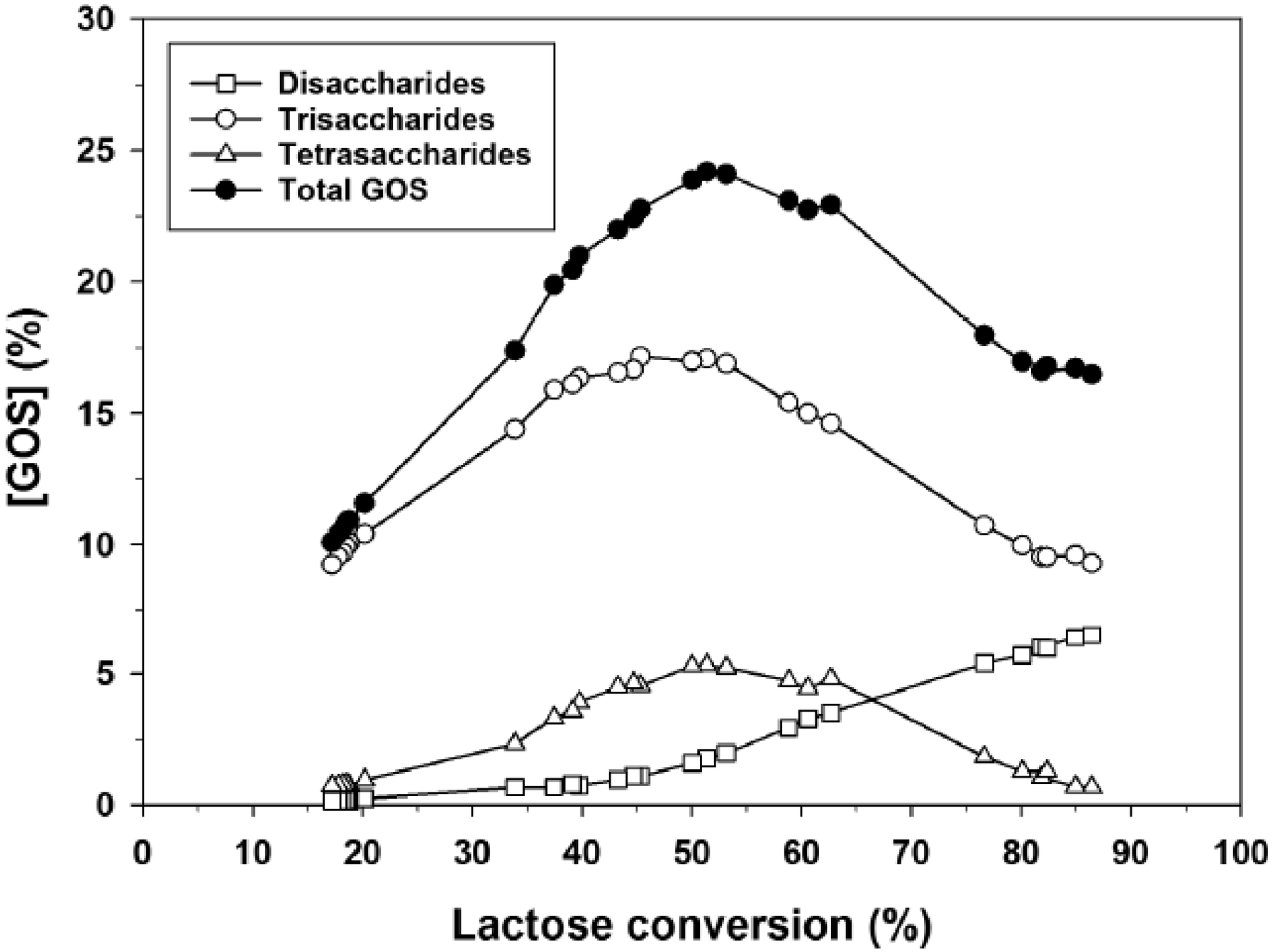
Enzyme mechanism



High affinity towards nucleophilic acceptors ensure high GOS yield

Cilliers, 2015

GOS production: reaction progress



Rodriguez-Colinas et al, 2016

Commercial GOS Products

GOS content of some commercial GOS products		
GOS product	% GOS of TS	
	Liquid	Powder
Oligomate 55N	55	
Oligomate 55NP		55
Vivinal GOS Syrup	59	
Vivinal GOS Powder		69
Bioligo GL 5700	57	
Cup-oligo H-70	70	
Cup-oligo P		70
Bimuno	52	
Bimuno		52
King Prebiotics GOS-570-S	57	

GOS process steps

i) Raw materials (lactose, enzyme/s)

ii) Lactose dissolving

iii) Enzyme conversion

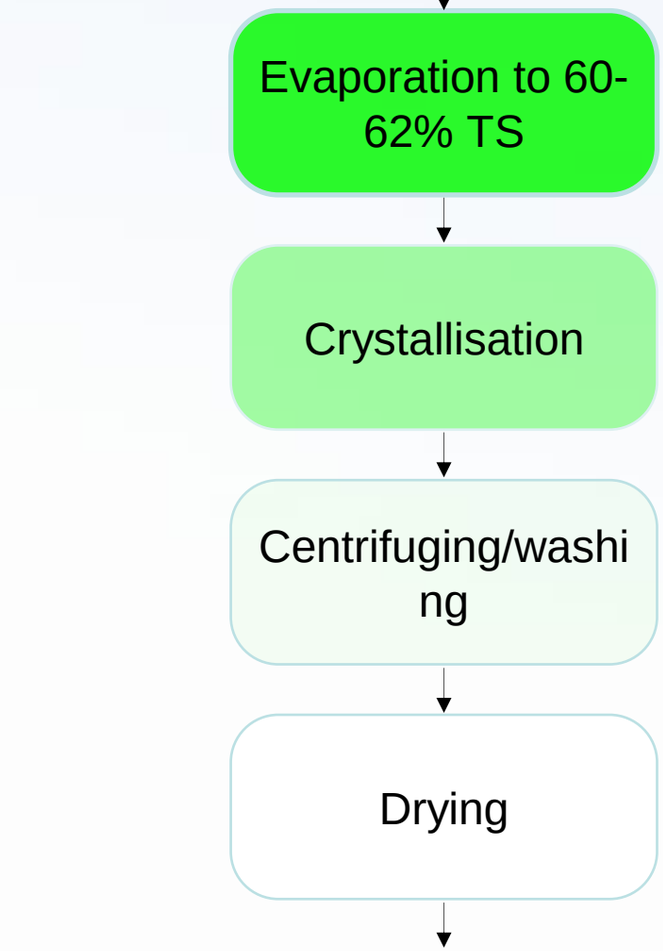
iv) Impurity removal

v) Fractionation

vi) Evaporation

Raw Material: Edible lactose

Whey permeate; 82-84% lactose



Edible lactose; 99% lactose

Test	Specification
Lactose	min 99.0% in DM
Ash	max 0.3 %
Protein	max 0.3 %
pH	4.5 - 7.0
Colour	White/yellowish

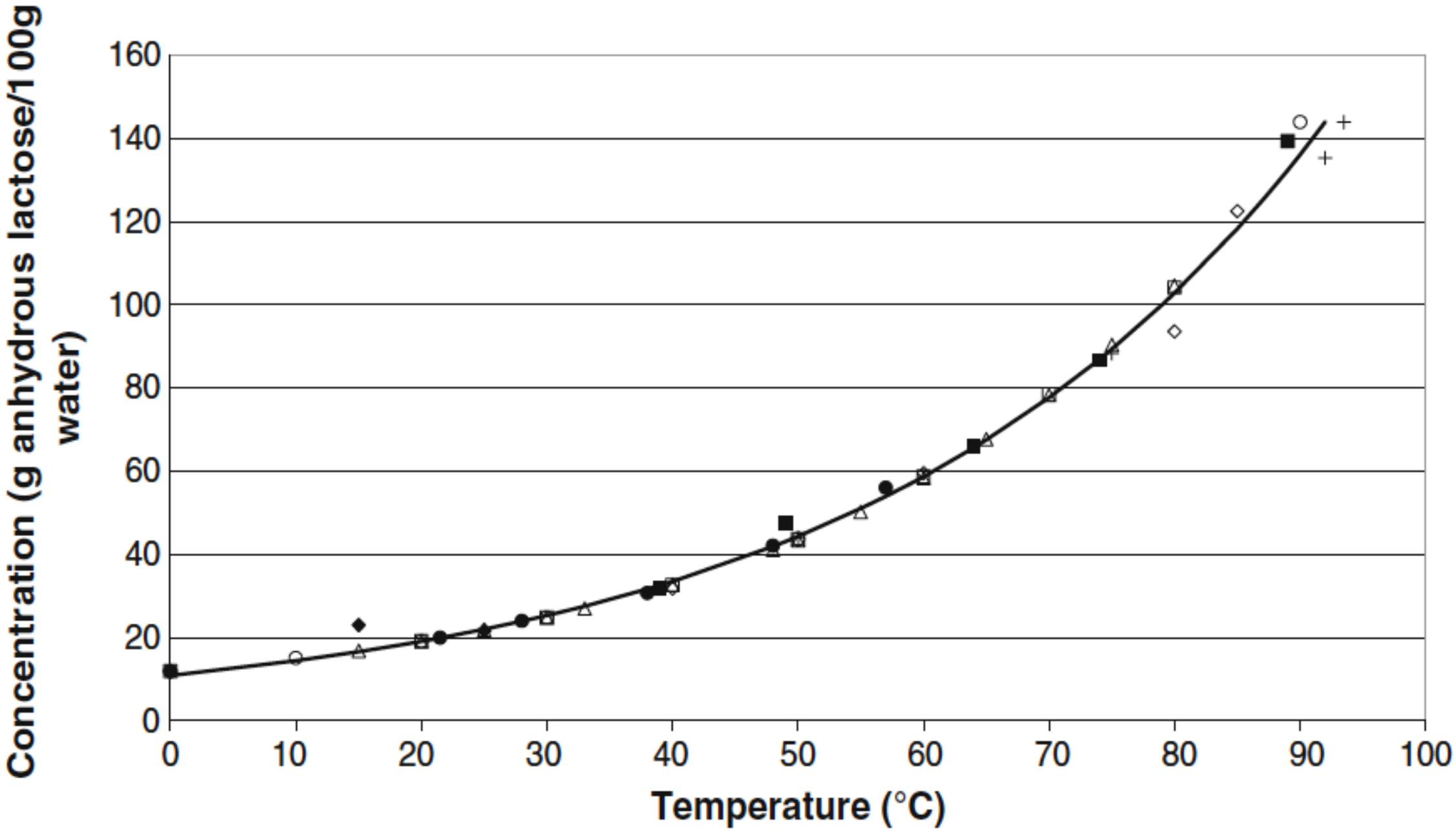
Raw Material: β-galactosidase enzyme

Enzyme selection important for:

- overall GOS yield
- mix of oligosaccharides
- type of β-glycosidic bonds
- level of chemical impurities

Enzyme sources, examples	
Organism	**Strain**
Bacteria	***Bacillus circulans*** ***Bifidobacterium bifidum***
Yeasts	***Kluyveromyces lactis*** ***Sporobolomyces singularis***
Moulds	***Aspergillus niger*** ***Aspergillus oryzae***

Lactose solubility with temperature



Paterson, 2009

Lactose dissolving

Process step	Inputs	Typical operating range
Lactose dissolving	Water, steam Lactose	90-95 C 55+% TS
pH adjustment	Citric acid/Na_2CO_3	pH 4-7

Lactose dissolving/pH adjustment

Enzyme reactions

Process step	Inputs	Typical operating range
Cooling	Water jacket	50-60 C
Enzyme reaction	Enzyme addition	approx 2-5 hours (to end point)
Enzyme inactivation	Steam &/or Citric acid/Na_2CO_3	95 C and/or pH adjustment

Reaction tanks

Purification of crude GOS

Impurities
Riboflavin
Proteins/proteose peptone
Maillard compounds
Minerals

Technologies
Membrane filtration (UF)
Activated carbon
Ion exchange

Activated carbon treatment

Process step	Inputs	Typical operating range
Decolourisation	Activated carbon	90-95 C 15-30 min
Protein precipitation	Citric acid	pH 4.5
Filtration	Filter aid	To clarity

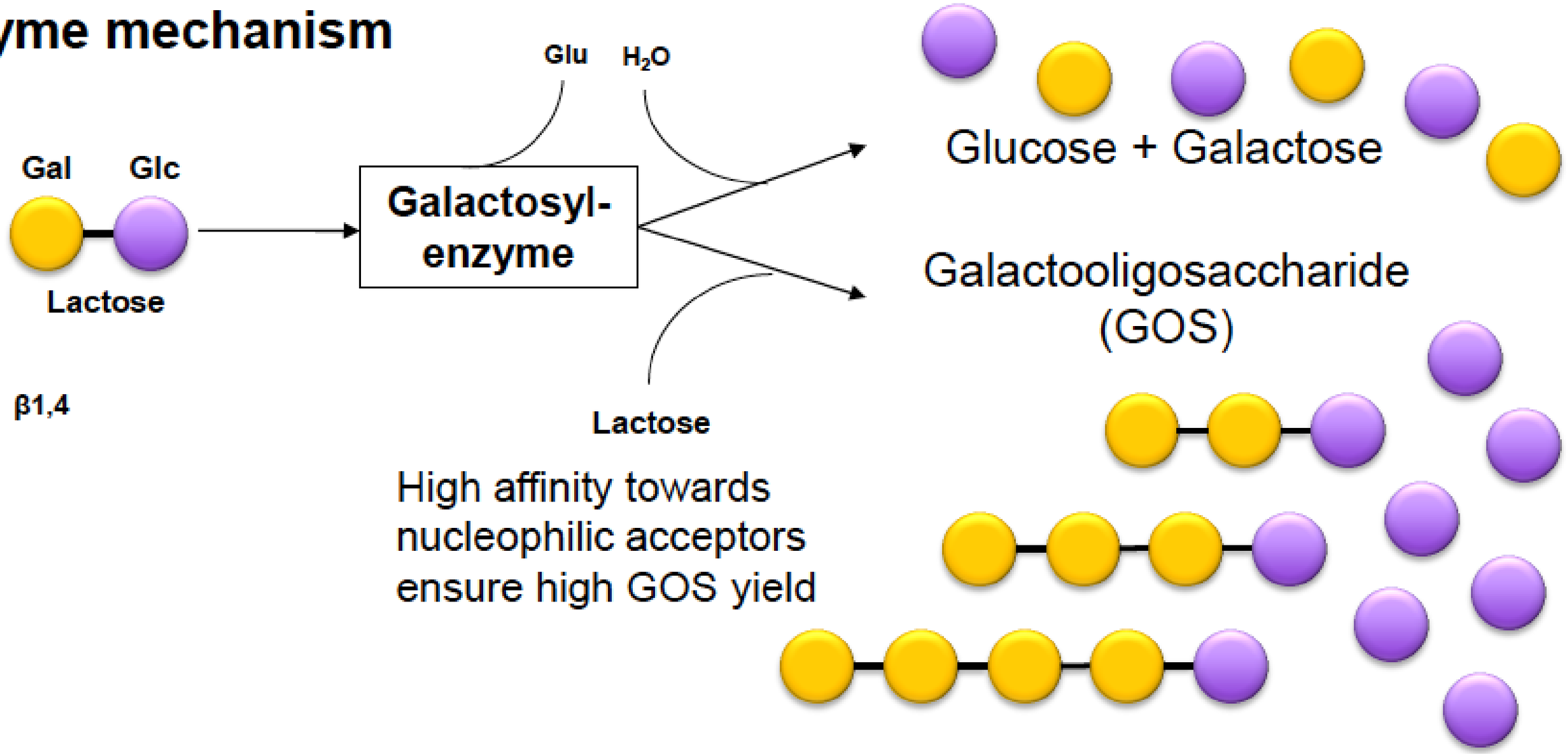
Carbon mixing tank

Colour range

Filtration

GOS production: β-galactosidase reactions

Enzyme mechanism



High affinity towards nucleophilic acceptors ensure high GOS yield

Cilliers, 2015

Fractionation of GOS

Nanofiltration

Separation of GOS from residual lactose & glucose

Simulated moving bed chromatography

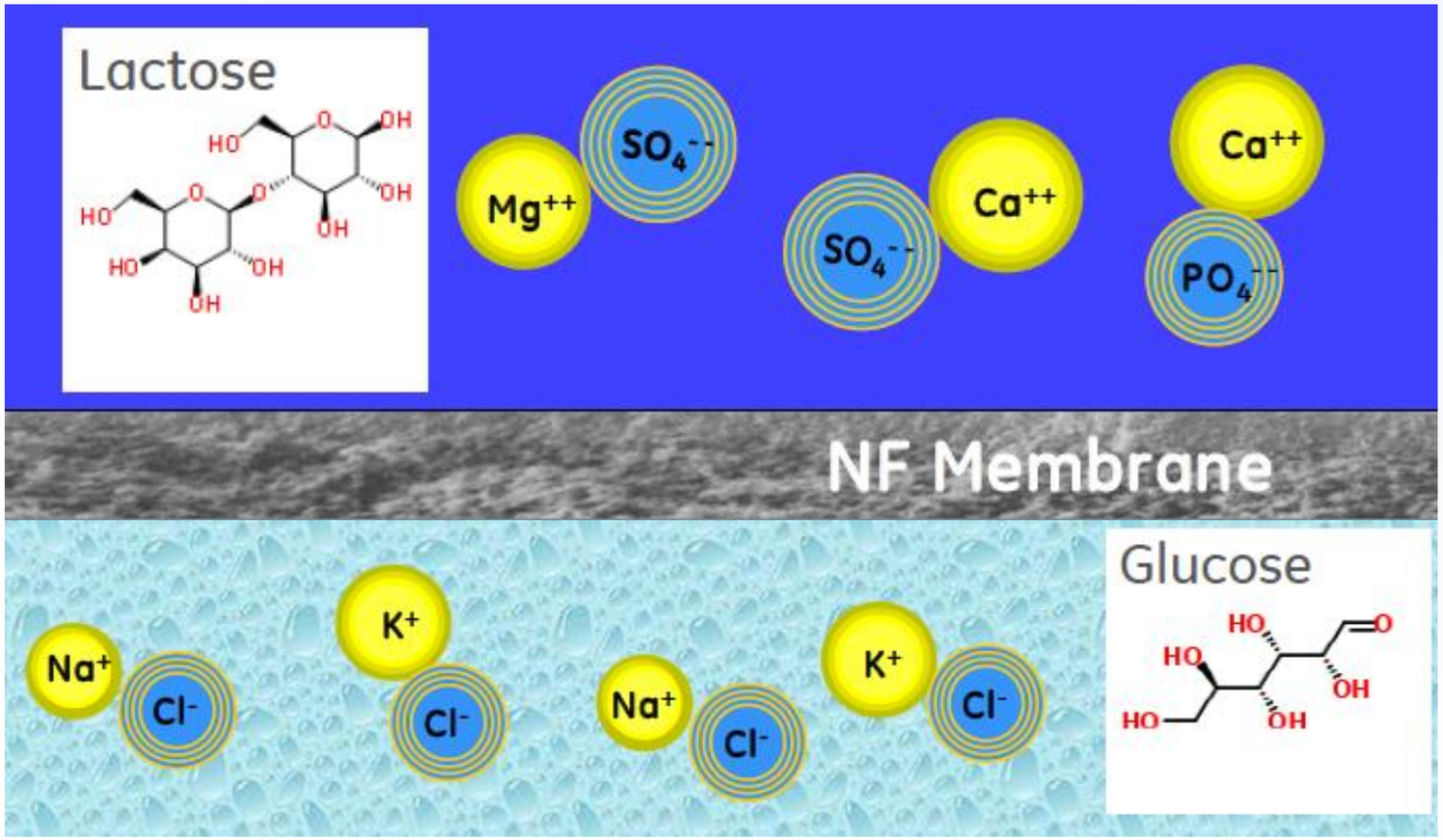
Yeast fermentation

Ken Burgess Associates

Nanofiltration

Membrane separation of saccharides:

- **Nanofiltration**
- **Diafiltration**



GOS: Galacto-oligosaccharide Syrup

GOS Syrup	75% solids	50+% GOS	pH 3.2

Evaporation to 75% TS

Thank You