Process and Product Innovation

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Outline

I. Milk basics

II. Milk components and their value

III. Fractionation of milk protein

- Filtration and whey processing
- Filtration and milk protein fractionation

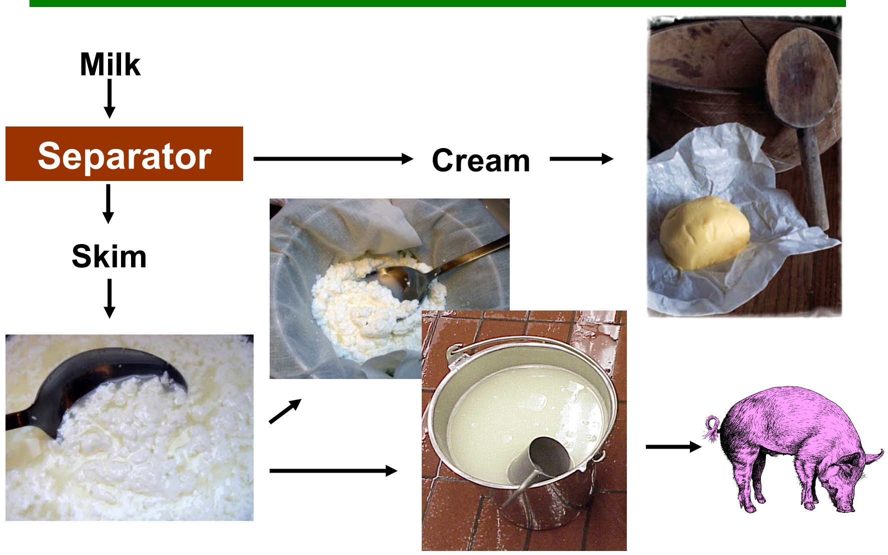
IV. The Future of Lactose

- Carbohydrate of choice?

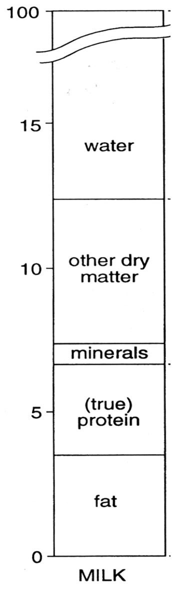
History of milk utilization

- Milk is perishable and farmers have the capacity to produce more milk than they can consume
- Choices are to increase population, throw milk away, or process milk into its components and develop new products

Milk fractionation



The components in milk



- Protein is considered to be the most valuable
- World demand for dairy protein is projected to exceeds the world supply

	Water	Lactose	Fat	Protein	Minerals
Whole Milk	87.6%	4.8%	3.7%	3.2%	.70%
Whole Milk (dry basis)	---	38.7%	29.8%	25.8%	5.6%
Skim Milk	90.9%	4.98%	.05%	3.32%	.73%
Skim Milk (dry basis)	---	54.8%	.55%	36.6%	8.0%

The value of milk protein

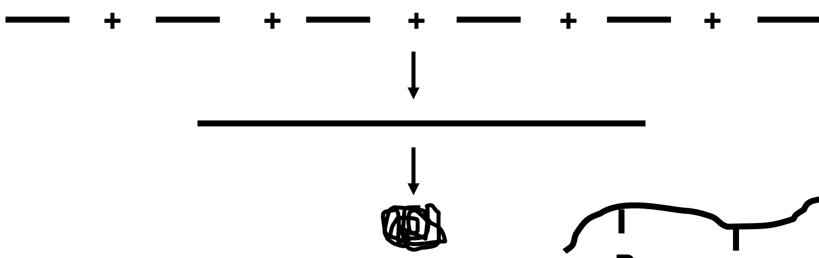
Nomenclature and relative amounts

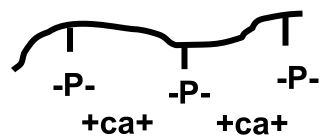
Fraction	% of protein
α_{s-1} - Casein	34-40
α_{s-2} - Casein	11-15
β - Casein	25-35
κ - Casein	8-15
β - Lactoglobulin	7-12
α - Lactalbumin	2-4
Blood serum albumin	.5-2
Lactotransferrin	trace
Immunoglobulins	trace

The value of milk protein

Amino acids

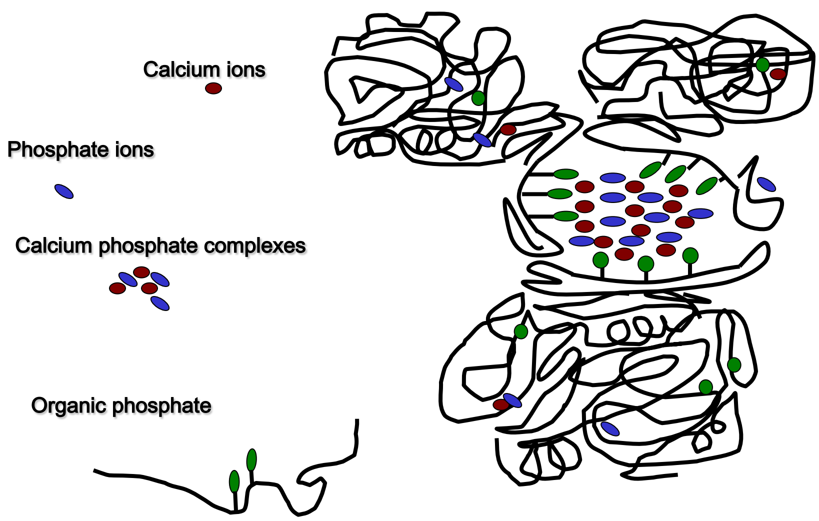
- 20 possible amino acids – Connected via peptide bond to form protein



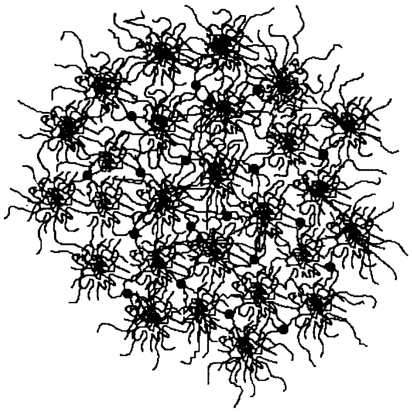


- Casein is a phospho protein (phosphorus is linked to a serine amino acid)

Calcium, phosphate and casein



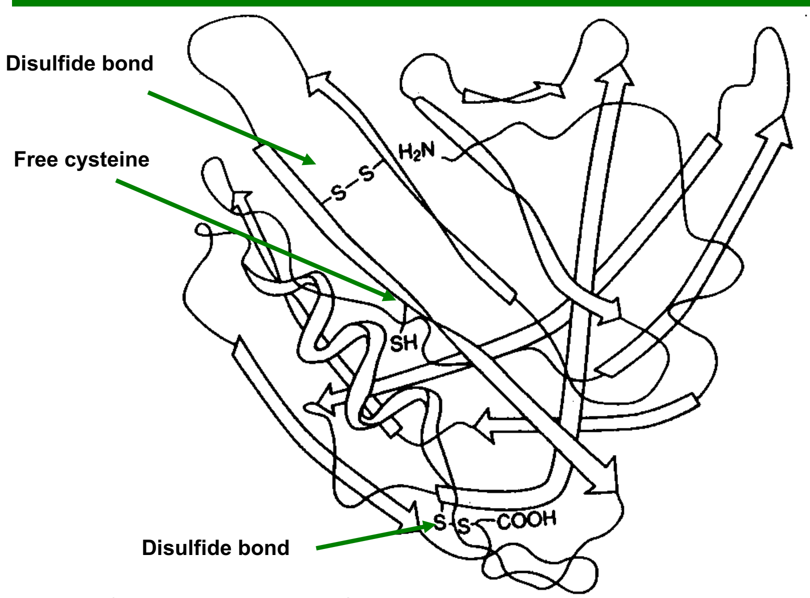
Casein micelle structure – proposed model



- 10,000 polypeptide chains of the four caseins
- micro-granules of calcium phosphate
- glyco-macro peptide portion on k-casein is concentrated on the surface
- rennet coagulation - remove hairs

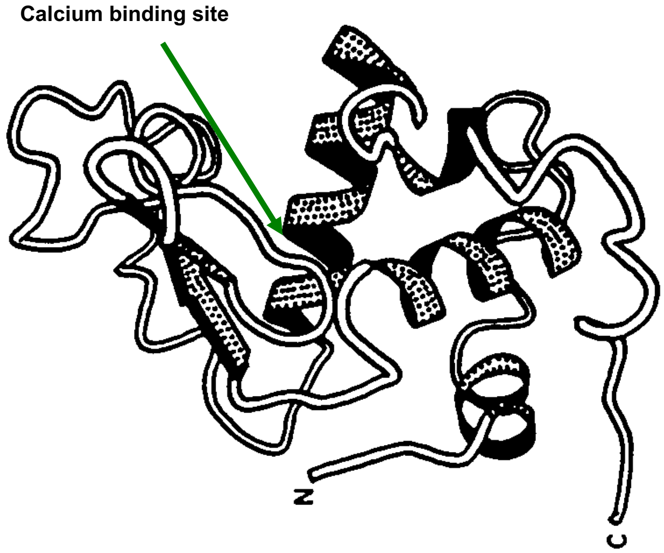
Adapted from Adv. Prot. Chem – 1992, Holt 43:63-151

Whey protein - B-lactoglobulin



Adapted from Food Prot. Applic. – Cayot and Lorient 225-256

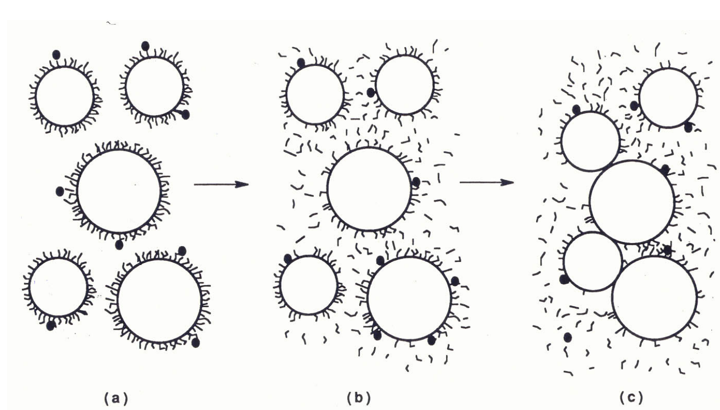
Whey proteins – α-lactalbumin



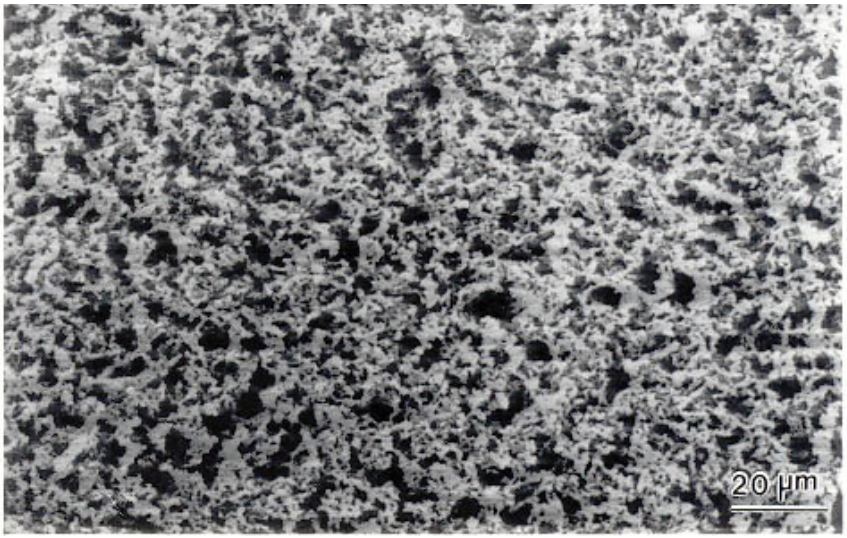
Adapted from Crit. Rev. Food Sci. – 1996, Wong et al. 807-844

Cheese manufacture

Casein separation process with an enzyme



Cheese Structure – at set



Adapted from Kiely et al 1992

- The protein matrix contains embedded fat and moisture
- Protein matrix is cross-linked by calcium and phosphate

Cutting and removal of whey:

10 lbs milk

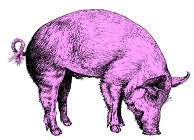
↓ **1 lb cheese**

↓ **9 lb whey**

Fractionation of milk protein

Whey utilization

1970



Today

Whey protein fractions

Whey protein nomenclature and relative amounts

- Raw whey only contains about .8% protein
- Most abundant protein is β-lactoglobulin

Fraction	% of protein in whey
β - Lactoglobulin	50
α - Lactalbumin	25
Glyco-macro-peptide (GMP)	16
Blood serum albumin	5
lactoperoxidase	trace
Lactotransferrin	trace
Immunoglobulins	trace

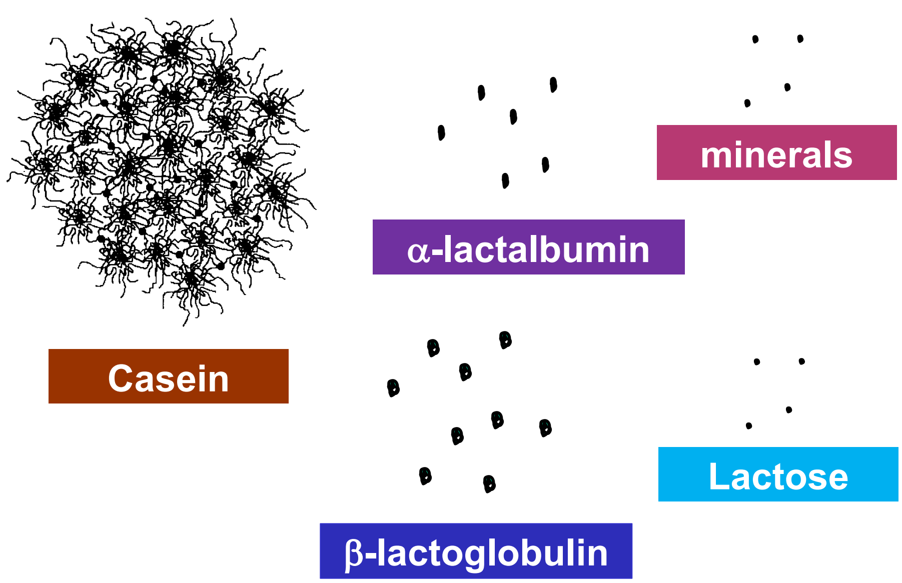
What caused the change in whey utilization?

Filtration technology

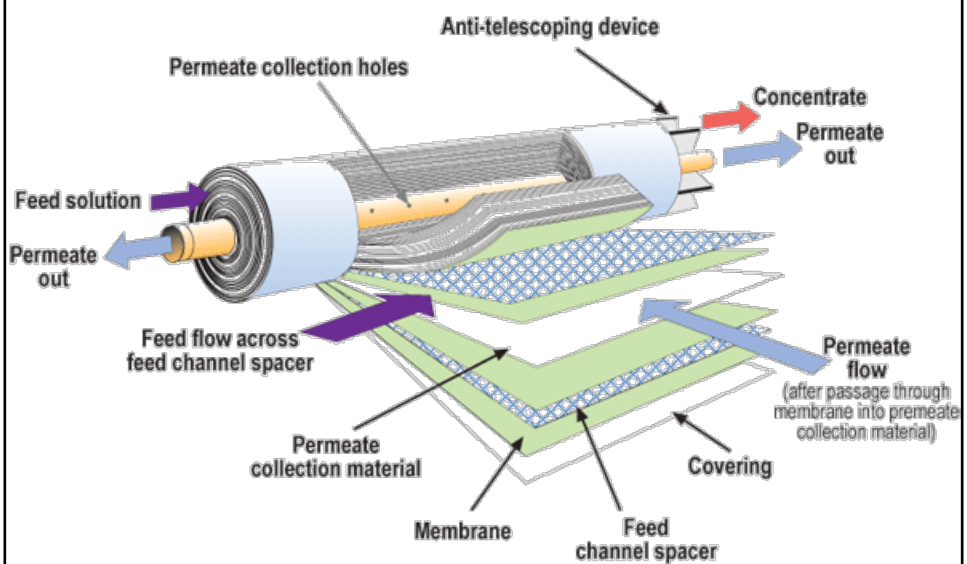
- Semi-permeable membrane is used to separate the protein in whey from the other components

	Water	Lactose	Fat	Protein	Minerals
Whey	93.1%	5.14%	.36%	.85%	.77%
Dried whey	3.19%	74.5%	1.07%	12.93%	8.35%
Whey protein concentrate	2.70%	51.9%	2.90%	35.0%	6.90%
Whey protein isolate	4.80%	.20%	.40%	93.0%	2.0%

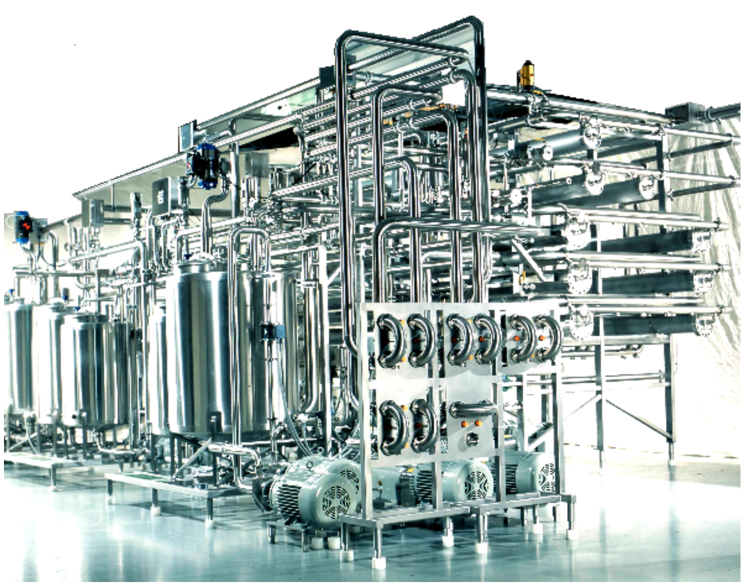
Relative size of major milk components

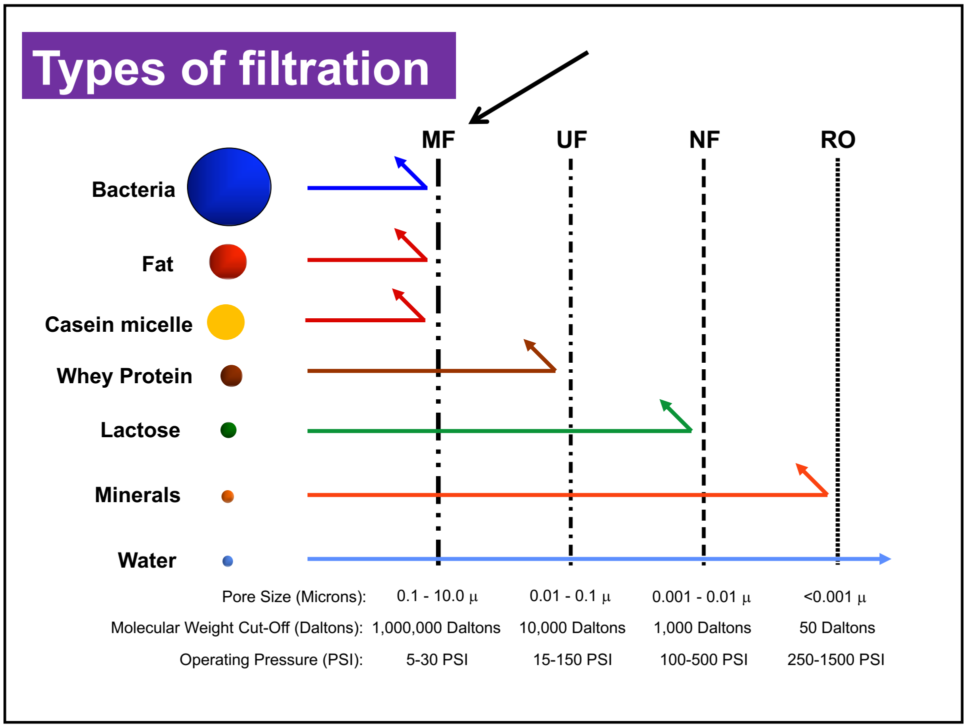


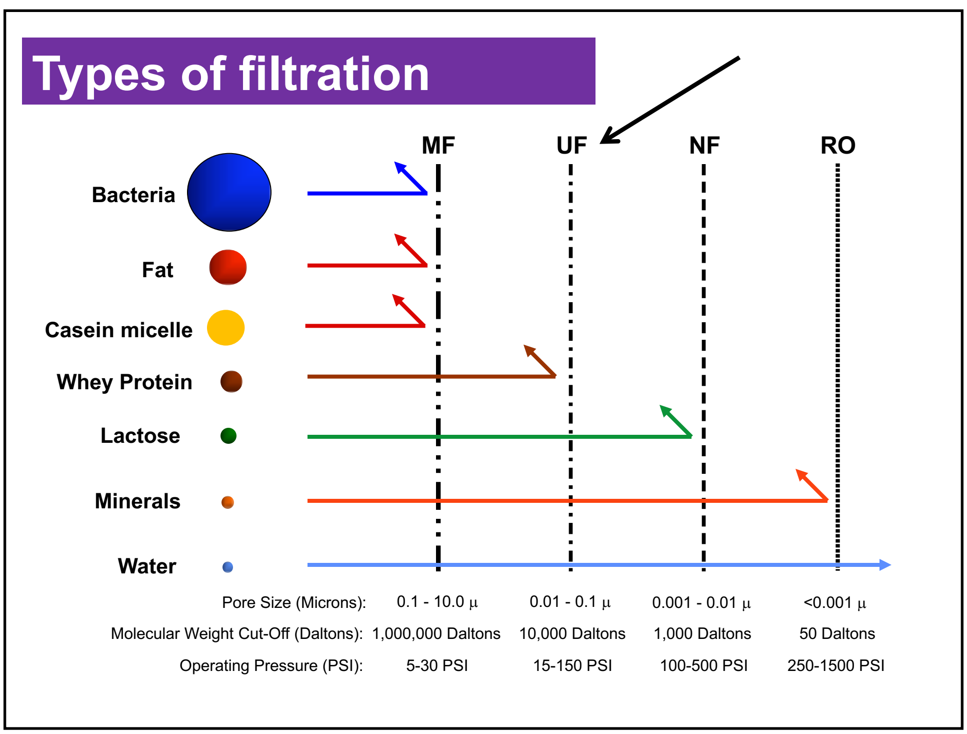
Spiral wound membranes



Complete filtration system




Types of filtration
MF
UF
NF
RO
Bacteria
Fat
Casein micelle
Whey Protein
Lactose
Minerals
Water
Pore Size (Microns): 0.1 - 10.0 µ 0.01 - 0.1 µ 0.001 - 0.01 µ <0.001 µ
Molecular Weight Cut-Off (Daltons): 1,000,000 Daltons 10,000 Daltons 1,000 Daltons 50 Daltons
Operating Pressure (PSI): 5-30 PSI 15-150 PSI 100-500 PSI 250-1500 PSI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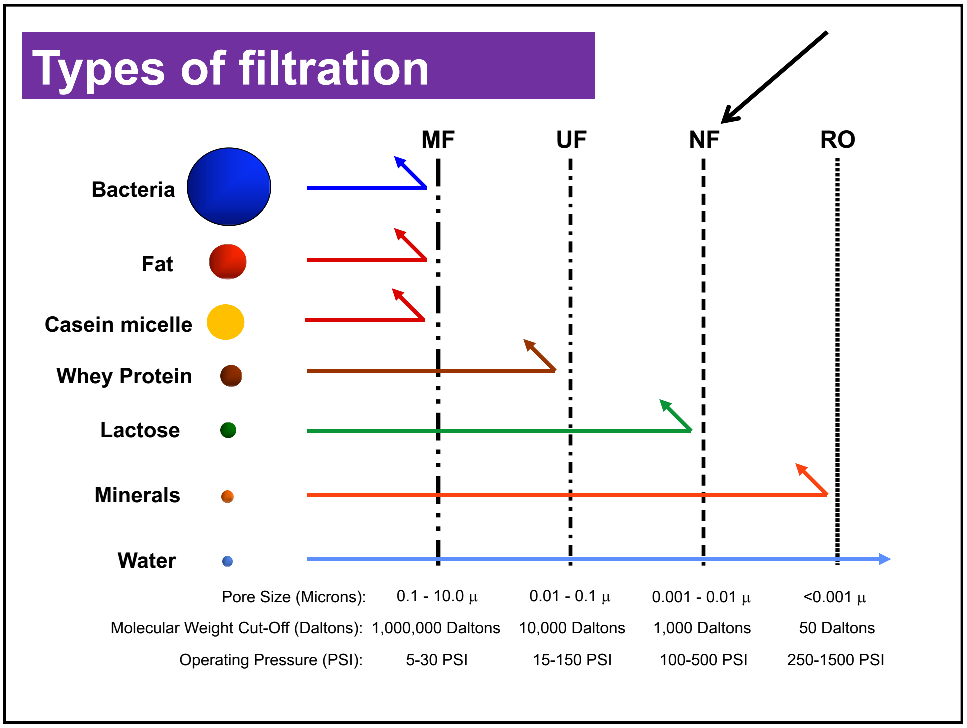
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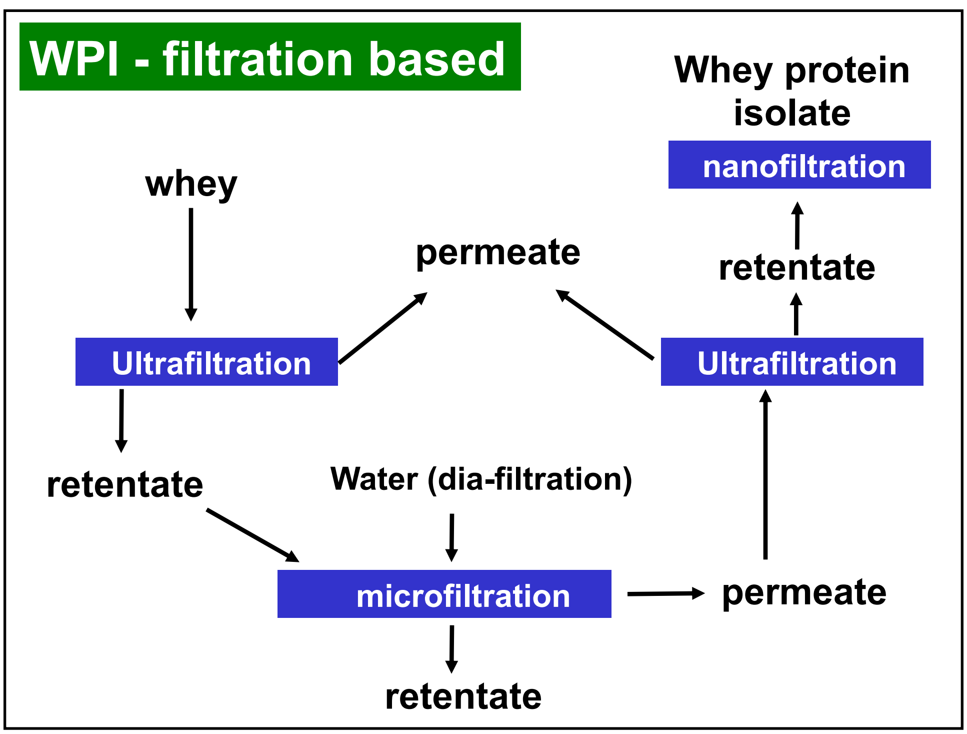
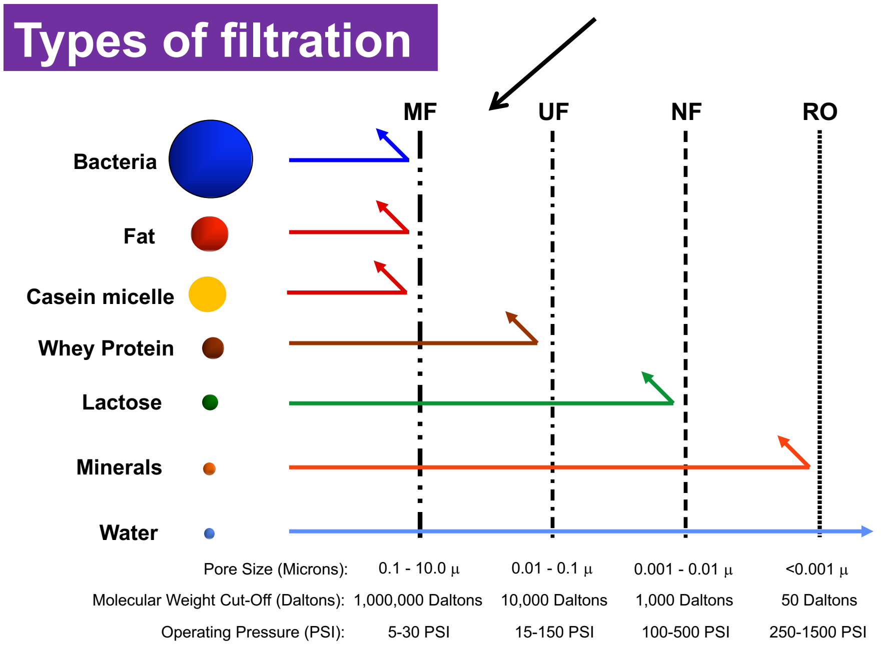
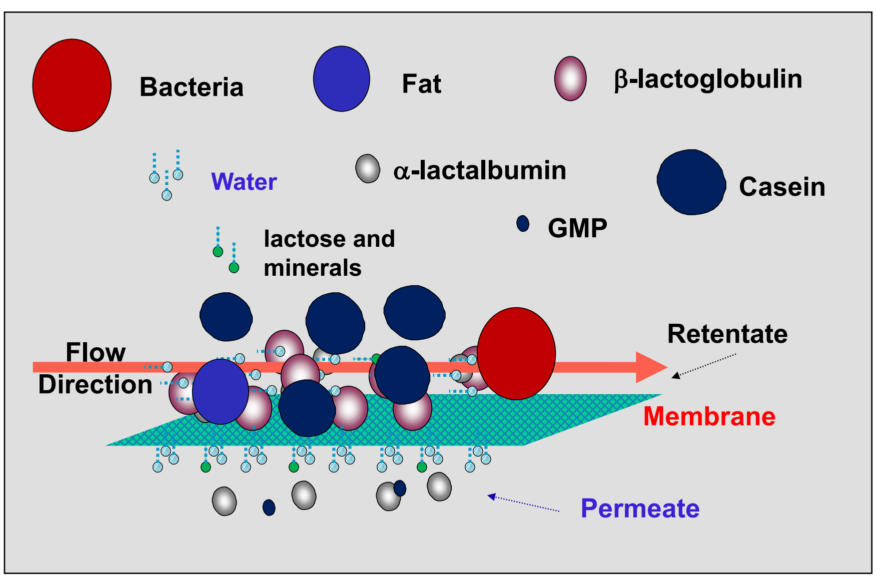

WPI - filtration based
Whey protein isolate
nanofiltration
whey
permeate
retentate
Ultrafiltration
Ultrafiltration
retentate
Water (dia-filtration)
microfiltration
permeate
retentate

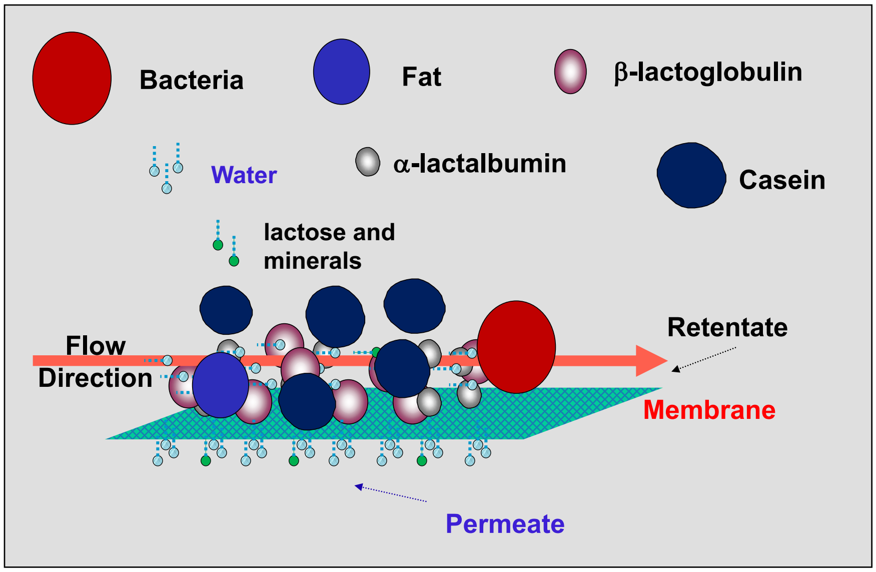
Types of filtration



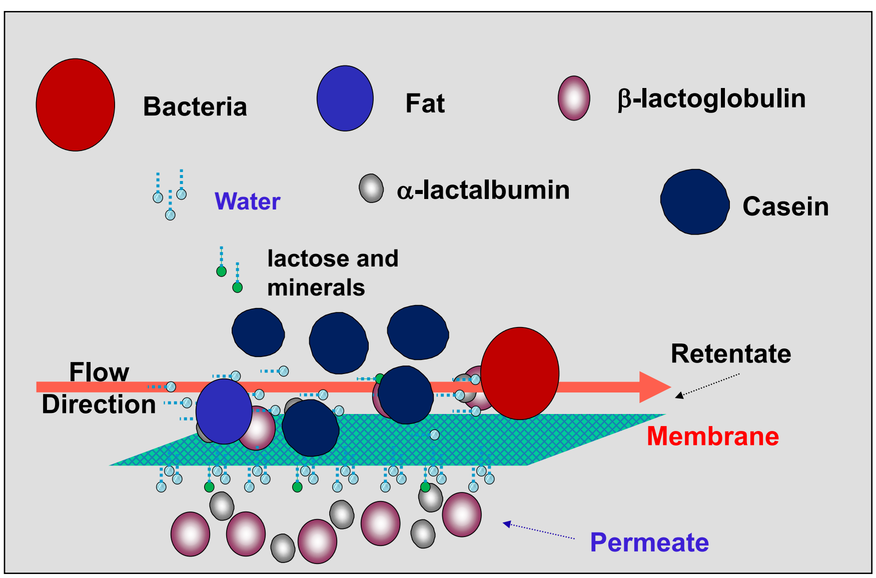
Milk/whey wide pore ultrafiltration



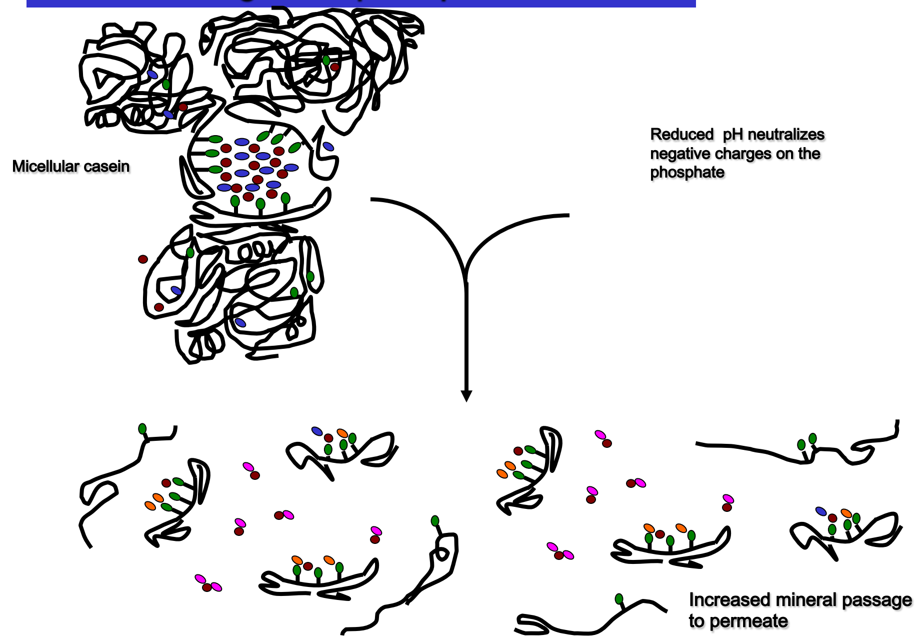
Milk ultrafiltration



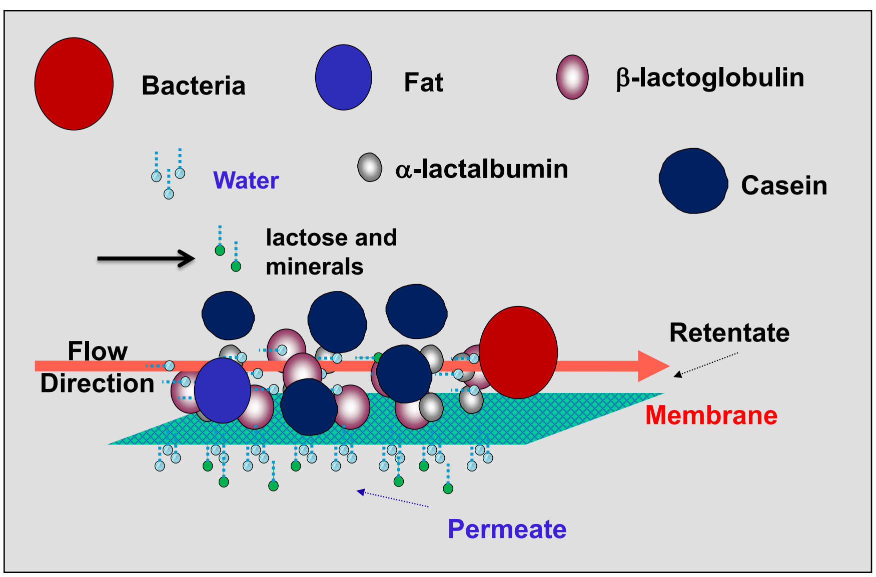
Milk microfiltration



Schematic diagram of pH impact on casein



Milk ultrafiltration at reduced pH



Use of Lactose and Co-products

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Daniel Gallaher

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College of Food, Agricultural
and Natural Resource Sciences

University of Minnesota
Driven to Discover℠

Definition of a prebiotic

- Not digestible in the small intestine (i.e. a dietary fiber)
- Fermented in the large intestine
- Increases proportion of beneficial bacteria (e.g. bifidobacteria)
- Has a beneficial effect on the host (i.e. us)

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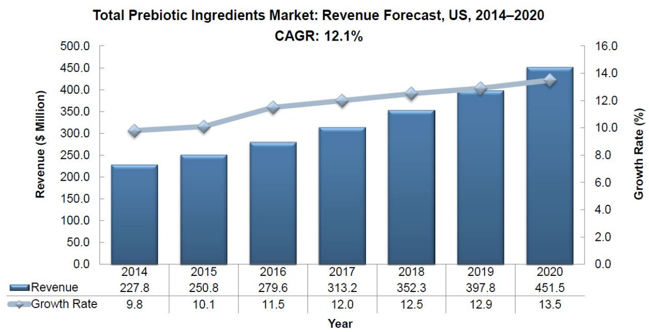
The market for prebiotics is growing steadily



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What is polylactose?

Polymerized lactose

- Polymerized on twin screw extruder
- Catalyzed by citric acid and heat
- Purified via a mixed bed carbon and ion exchange column

Final product

- 51% soluble **polylactose** fiber
- 20% free lactose
- Residual glucose and other materials

Polylactose on the extruder

Before and after purification

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Why polylactose?

- Lactose is a byproduct of dairy processing
- Eliminated via acid whey streams & deposited into landfills
- Polymerizing it for functional fiber use is cost-effective & environmentally friendly

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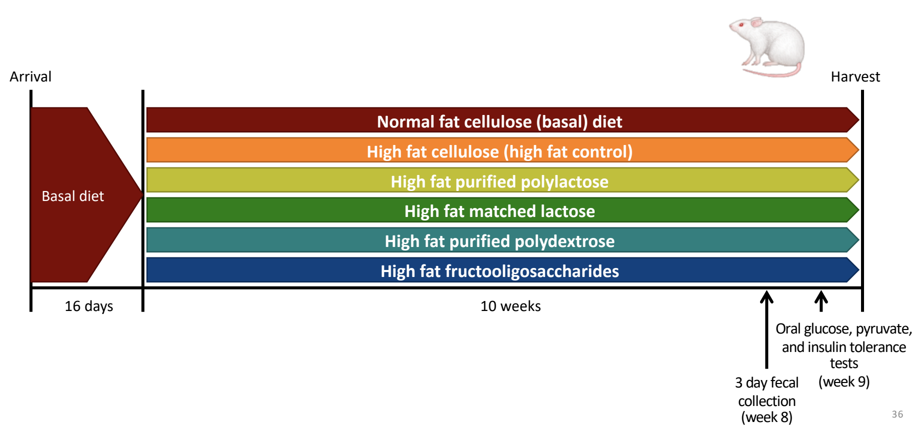
Used diet-induced obese rats to determine if polylactose is a prebiotic



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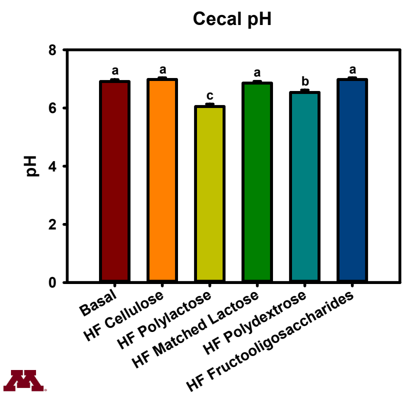
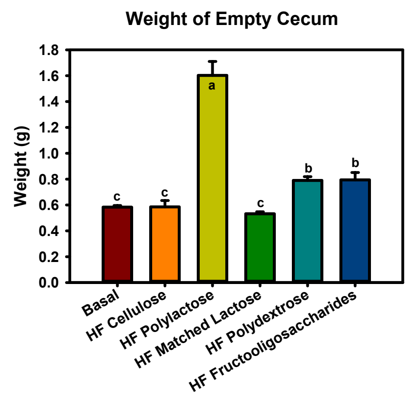
Polylactose is vigorously fermented





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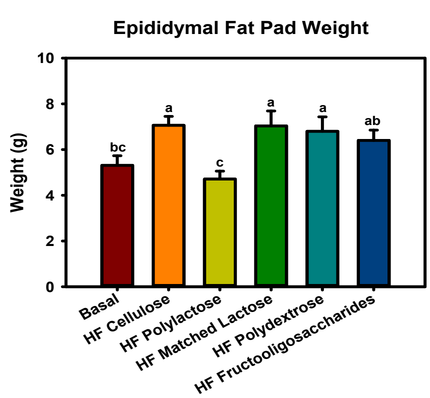
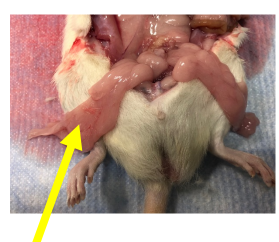
Polylactose animals showed **decreased adiposity** relative to high fat controls





Fat pad

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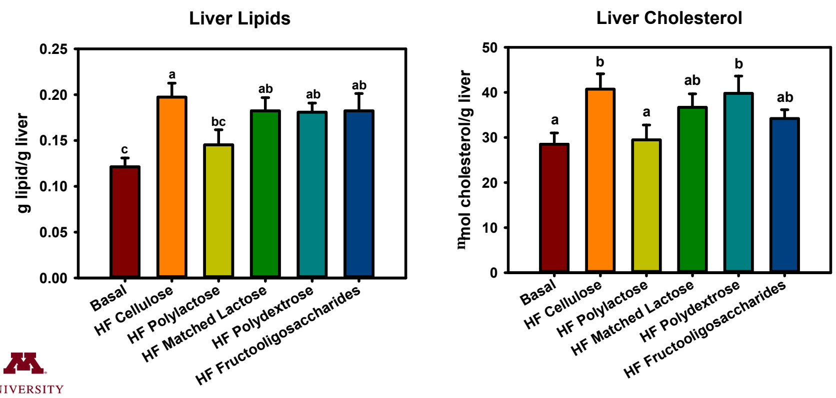
Polylactose animals had **decreased** liver lipids and liver cholesterol



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Growth performance, blood metabolites, rumen profile, and health of calves fed condensed whey solubles with starter pellets

Michaela Della
4/22/19

J. L. Anderson, N. D. Senevirathne, J. Osorio,
L. Metzger, and C. Marella
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Idaho Milk Products

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SOUTH DAKOTA STATE UNIVERSITY
College of Agriculture and Biological Sciences

Introduction

- Significant expenditure → optimal and cost-efficient calf rearing practices (Gabler et al., 2000)
- Early care impacts long-term growth, production, and longevity within herd
  (Davis- Rickner et al, 2011; Heinrichs et al., 2011; Soberon et al., 2012)
- Calves are born vulnerable
  - 2014 the US morbidity rate of 38.1% and a mortality rate of 5%. (Urie et al., 2018)
    - Under-developed immune system
    - Nonfunctional rumen

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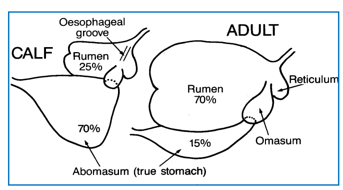
Introduction

Rumen Development



- Begins around week 4
  - fully developed after 1 year of life
- Bacteria population begin to develop quickly
  - stabilize around two months of life (Meale et al., 2017a)
- Products of fermentation: Volatile Fatty Acids (VFA)
  → Acetate, Propionate, Butyrate*
- Butyrate provides energy for epithelial proliferation
  → papillae growth (Baldwin et al., 2004)

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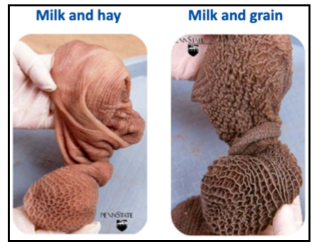
Introduction

Rumen Development- Starter Intake

- Critical for rumen development – readily fermented carbohydrates required
- Eases stress of weaning process (Hodson, 1971; Leaver and Yarrow, 1972)



(Heinrichs and Penn State; 2016)

- Intake at an earlier age leads to the rumen becoming functional sooner (Khan et al., 2016)
- Gut also plays key role in prevention of disease and nutrient uptake (Martin et al., 2010)

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Immune Development

- Colostrum is crucial for passive transfer of immunities
- Remain very susceptible first 12 weeks of life
  - Transitioning from maternal immunity to their own immunity
- Metabolizable energy will not go towards growth if immune system is compromised
- Weather, such as cold stress is an immune stressor (Ghasemi et al., 2017)
- Stress at weaning can be an immune compromiser

- Nutritional support for immune development
  - Antibiotic alternatives- Probiotics and Prebiotics

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Introduction

Immune Development- **Prebiotics**

- Fed to improve gut health and immunity
- Debate on Mechanisms
  - Compete for nutrients with harmful bacteria
  - Compete for attachment sites with pathogenic bacteria
  - Increase SCFA production in developing rumen
  - Stimulate immune system

    (Newman, 1994; Van Loo and Vancraeynest, 2008; Geigerova et al., 2017)
- Feeding oligosaccharides have been shown to improve
  - Improve fecal consistency scores (Heinrichs et al., 2003)
  - Encourage feed intake and ADG (Donovan et al., 2002)
  - Support intestinal epithelial development (Castro et al., 2016)

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Test Product: Condensed Whey Solubles

- Idaho Milk Products- developed CWS
- Main source: milk permeates
- By-product from manufacturing processes

Nutrients composition %	CWS	
	Mean	SD
DM	60.01	2.85
Ash	4.11	0.35
Crude Protein	1.91	0.24
Lactose	**25.33**	2.26
Glucose	7.27	0.55
Galactose	2.76	0.78
Prebiotics	**20.72**	1.98

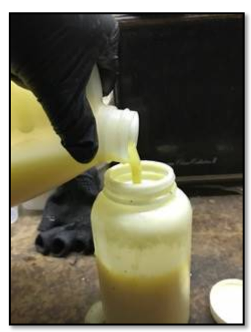

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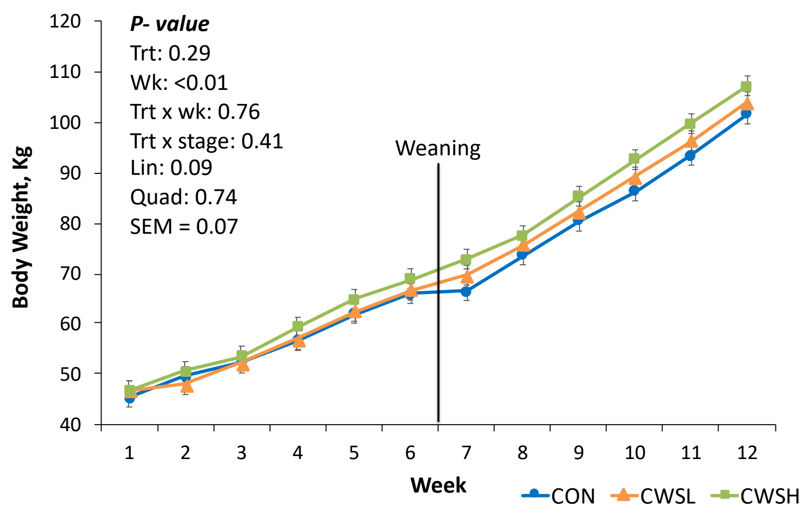
Figure 2. Body Weights



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Acknowledgements

- Dairy Mangement Inc and Midwest Dairy Association for funding
- SDSU Jack Rabbit council

MDFRC

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