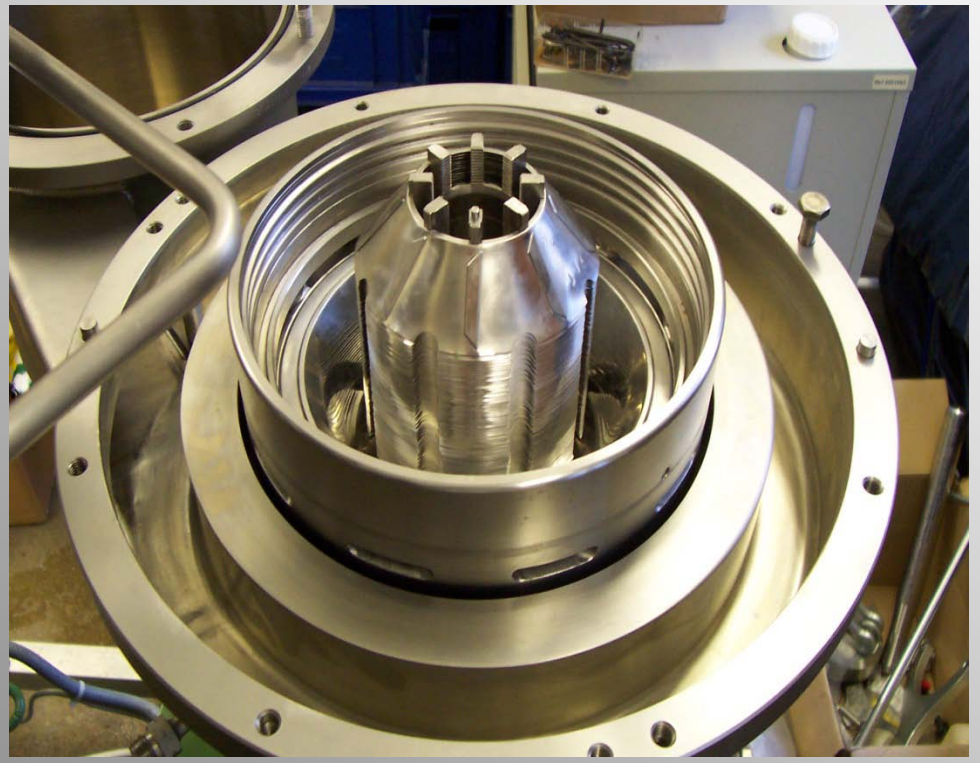
Centrifuges in Brewing

Paul H. Chlup



MBAA Mid-South Meeting

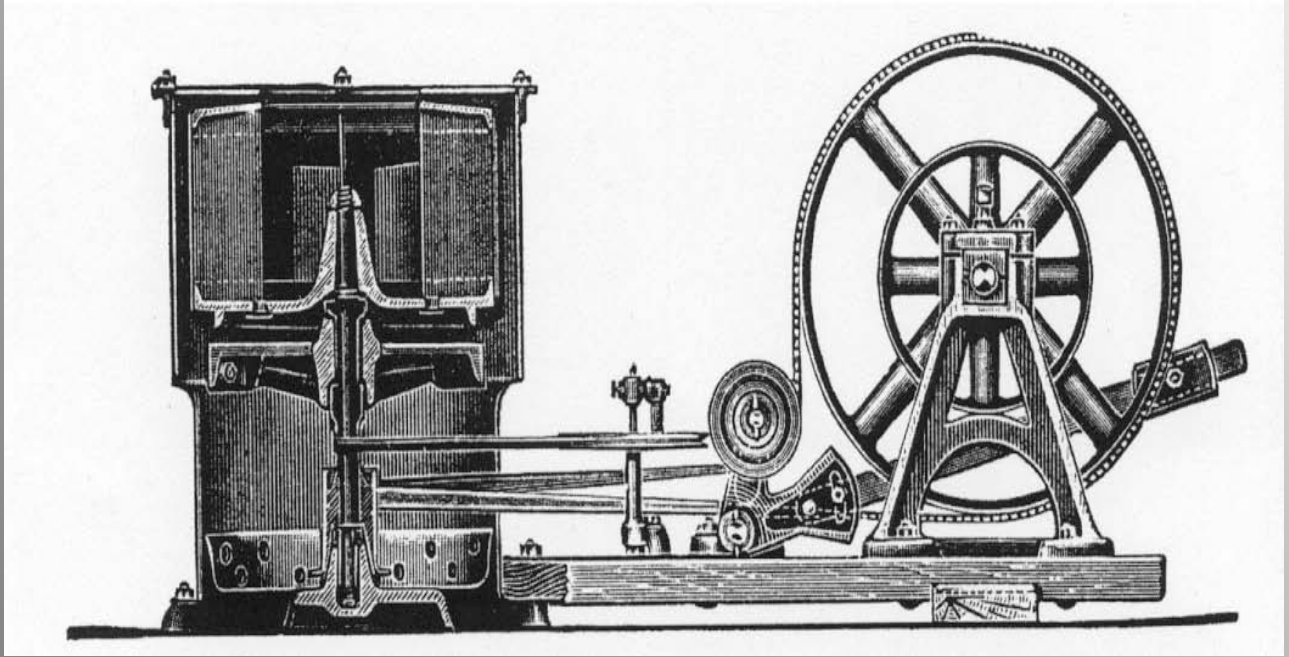
11th June 2011

Overview

- History
- Applications in Breweries
- Design and Operating Principles
- Particle Separation Theory
- Results
- Conclusions

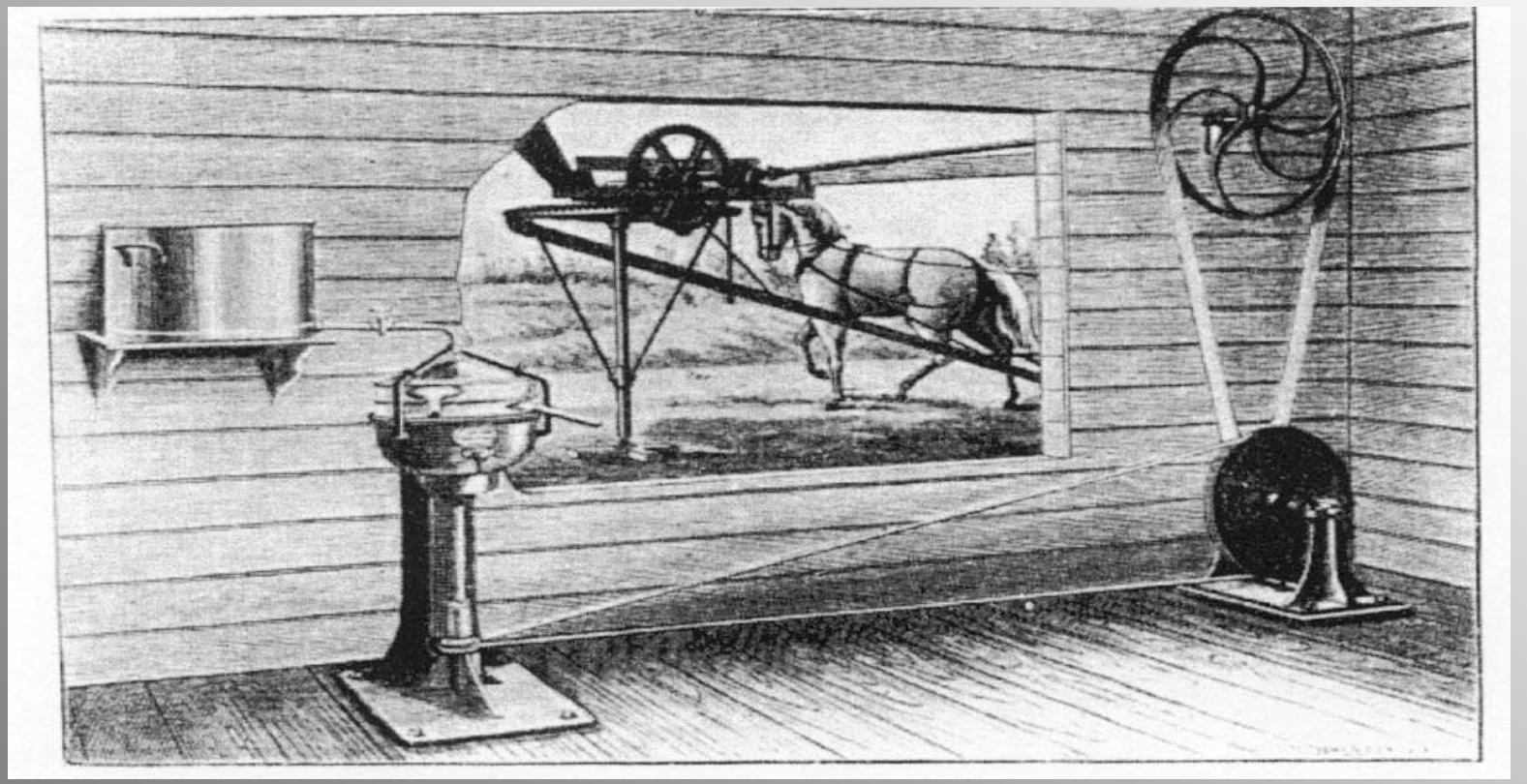
History

- 1852 L. v. Babo had the idea to separate corpuscles from blood with the help of centrifugal forces
- 1857-1859 Transfer of this technique into dairies
- 1877 First efficient application in the industry



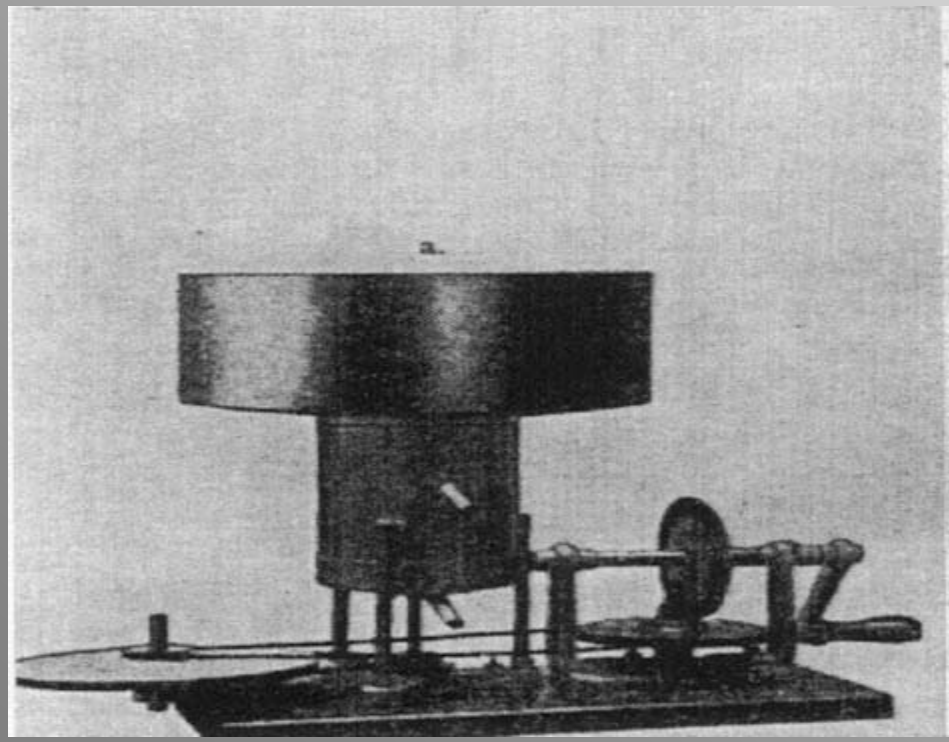
History

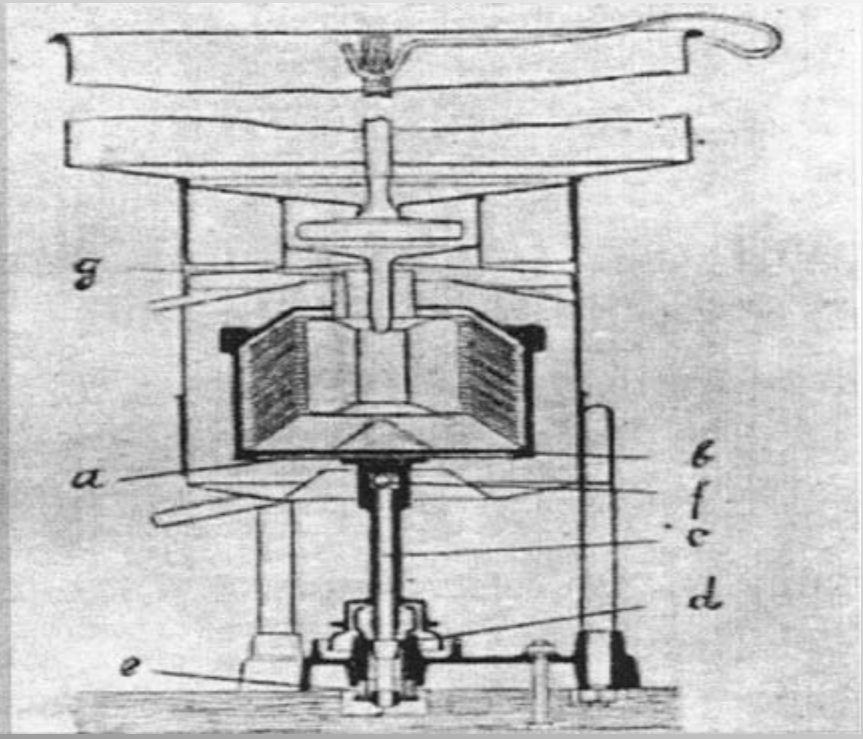
- **1878 Gustav de Laval built the prototype of a centrifuge**
- **1883 He improved the design of the centrifuge**



History

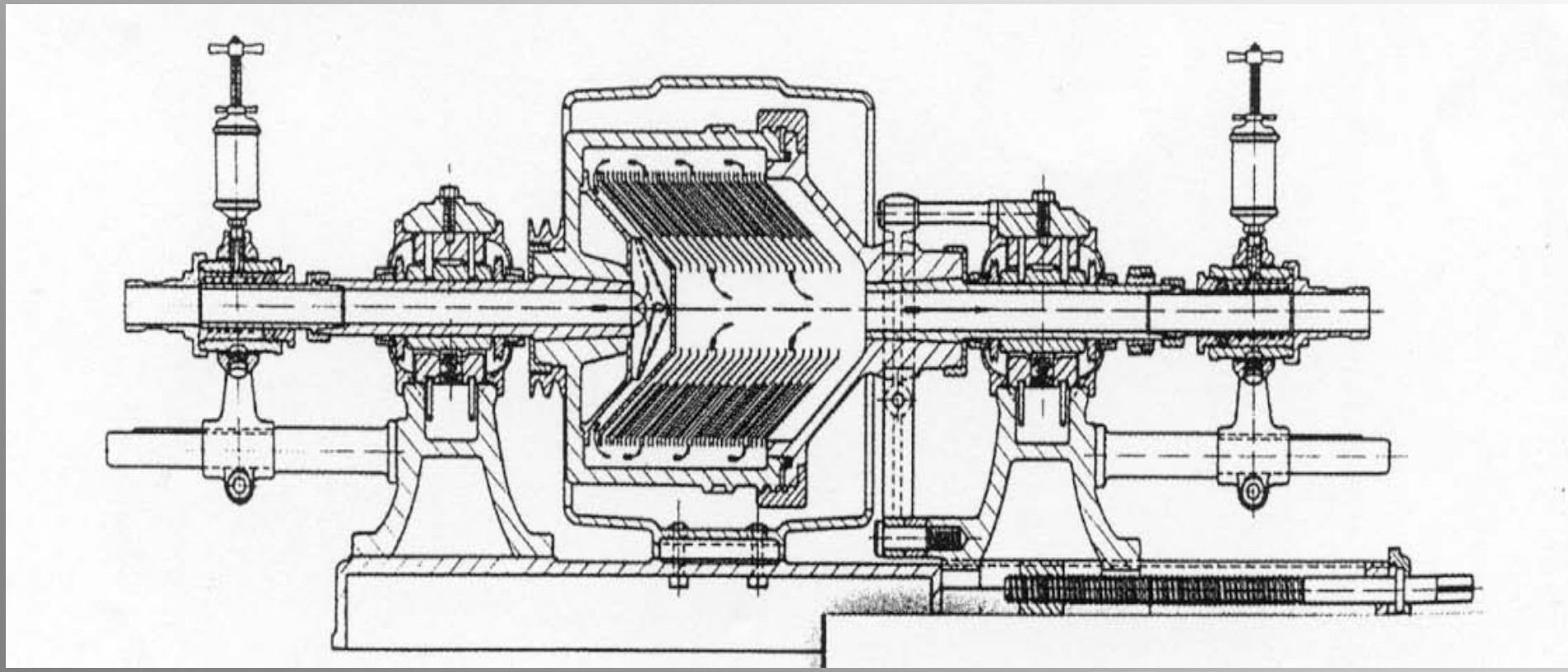
- 1889 Freiherr von Berchtolsheim invented the disc stack centrifuge
- 1890 de Laval bought the licence and gained market leadership
- 1893 WESTFALIA produced the first milk centrifuge





History

- 1903 The first centrifuge for yeast separation
- 1907 WESTFALIA built the first beer centrifuge



The Three Main Forces Used to Separate Mixtures

- Gravity
- Magnetic
- Centrifugal forces

Faster separation of solids from liquid phases in a continuous process is possible using centrifugal forces.

The centrifugal forces and mass forces cause separation of the components in a mixture according to their mass

Separation Principles

- Stokes Law under centrifugal gravity is defined as:

$$VsG = \frac{(\rho_p - \rho_l) r (\omega d_p)^2}{18u}$$

- Centrifugal forces generate magnitudes of 20,000 times the earth's gravitational constant

- The density difference between solid and liquid phases in a mixture is the driving force for centrifugal sedimentation

- Centrifugal field is not constant and varies linearly dependant on radius

Applications Of Centrifuges In The Brewing Industry

- Economic drive to reduce processing time has led brewers to look for ways to shorten fermentation and maturation times
- Centrifuges increase brewery throughput as they decrease production time
- Beer clarification is a function of settling distance through which the particle has to travel
- Horizontal tanks settle yeast out quicker but due to space requirements and fermentation efficiency CCVs are favored

Applications Of Centrifuges In The Brewing Industry

- Cropping of non-flocculent yeast at the end of primary fermentation
- Reducing the yeast quantity from green beer before the start of secondary fermentation
- Beer recovery from cropped yeast

Applications Of Centrifuges In The Brewing Industry

- Separation of the hot break after wort boiling
- Removal of cold break at the completion of maturation
- Treatment of effluent

Advantages of Centrifuges

- Rapid and efficient clarification
- Most consistent clarity of beer
- Equipment can be sterilized
- Filter aids are not required or reduced

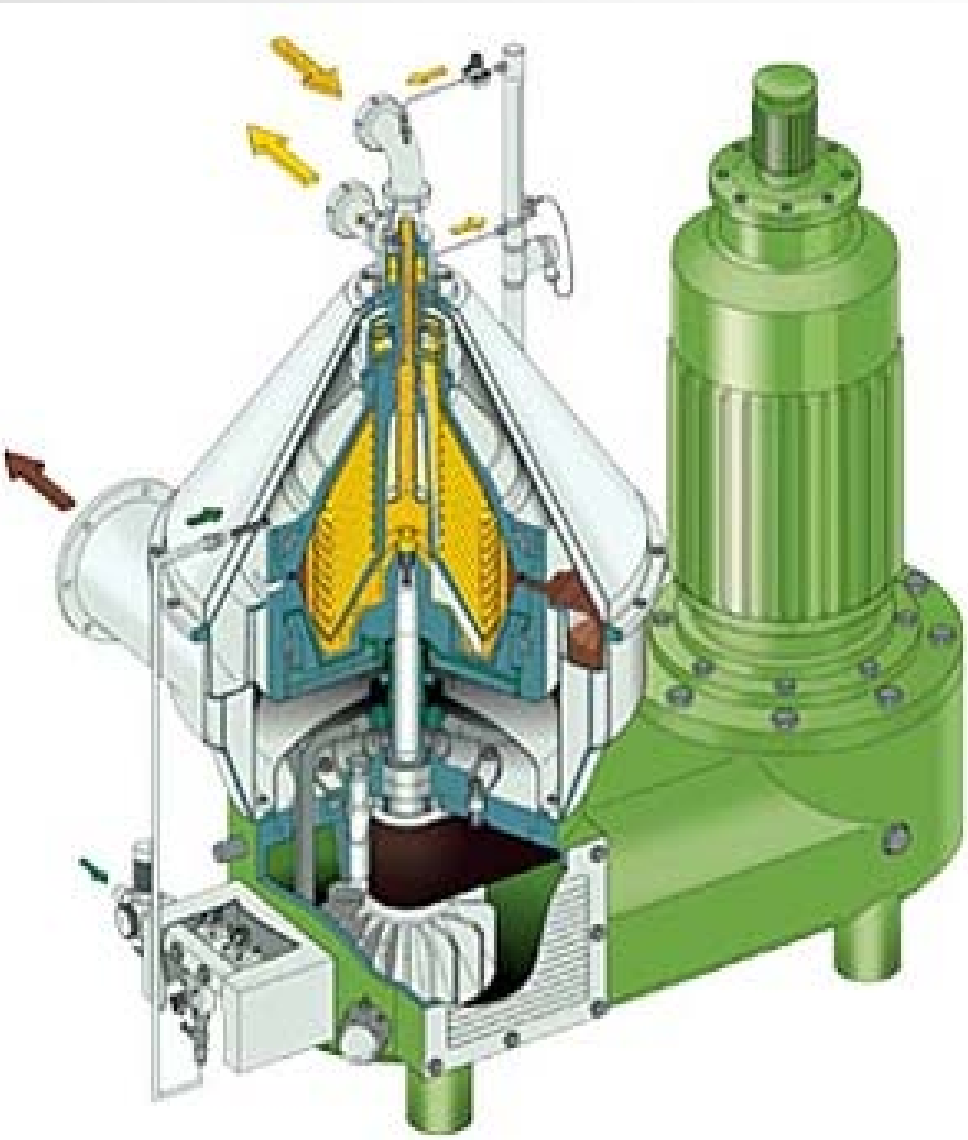
Advantages of Centrifuges

- Space requirements are small
- Most are self cleaning
- Operate continuously
- Lower beer losses with minimal oxygen pick-up

Disadvantages of Centrifuges

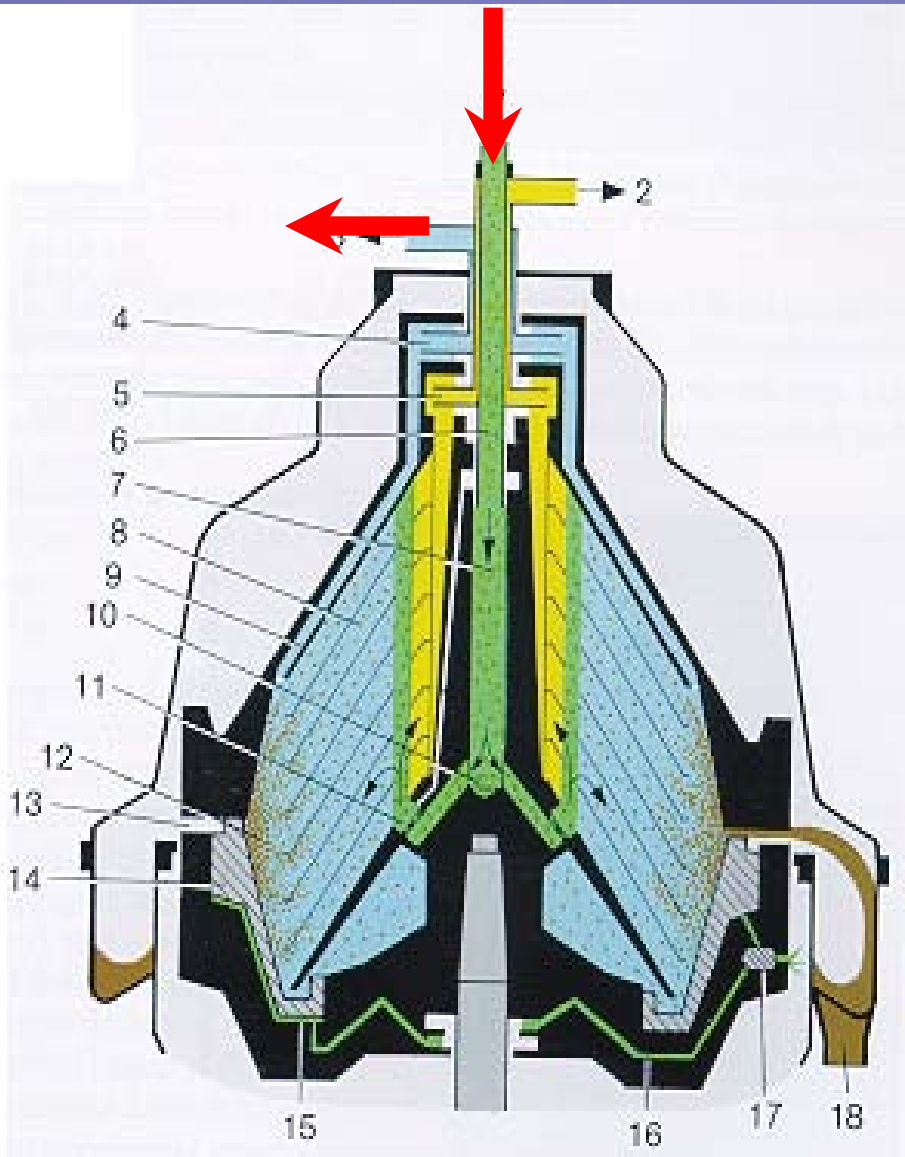
- High Maintenance costs
- Mechanical break-up of large particles
- Increased mechanical stress influence yeast quality
- There may be oxygen pickup and high noise levels

Design Principles

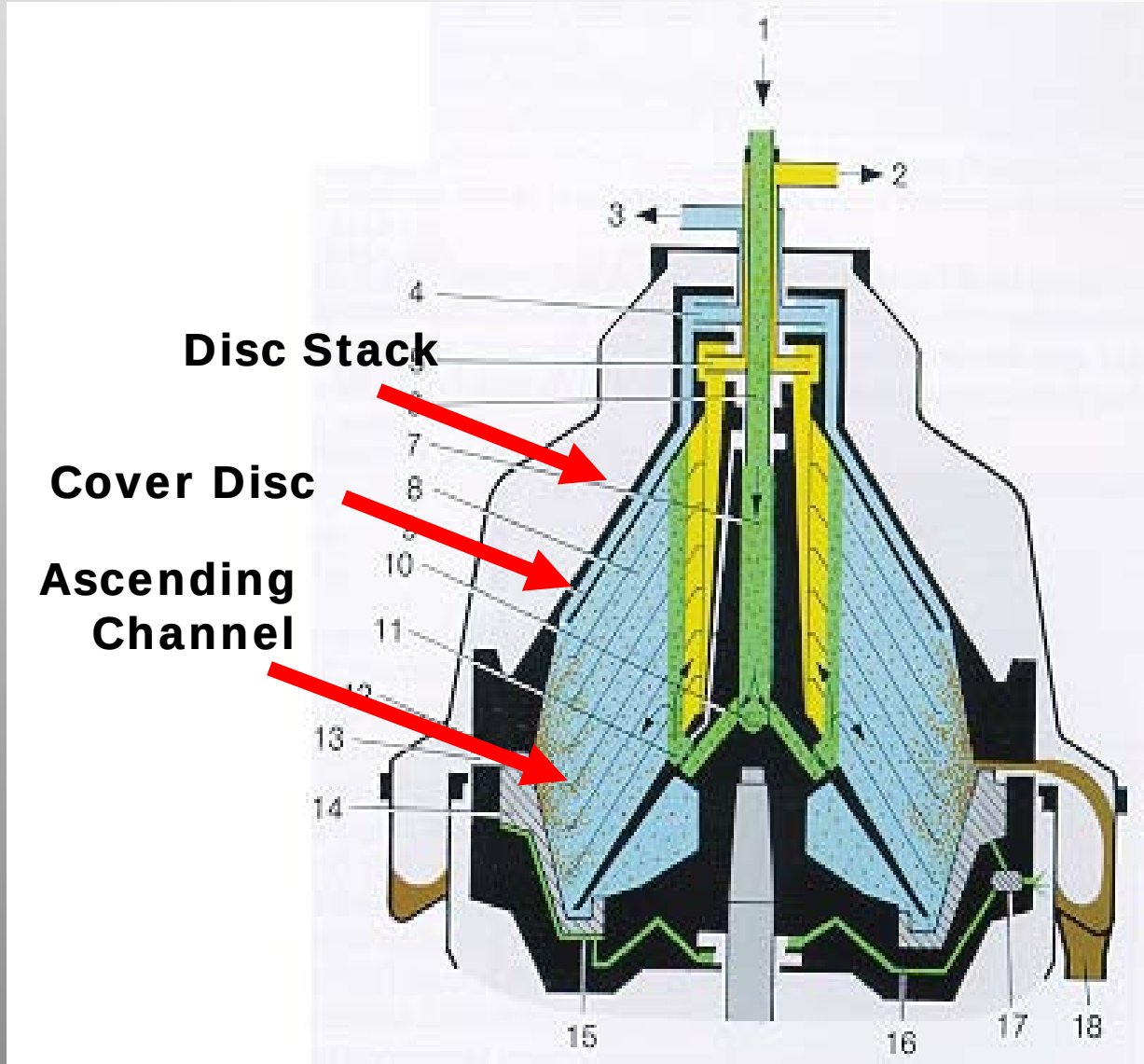


Design Principles

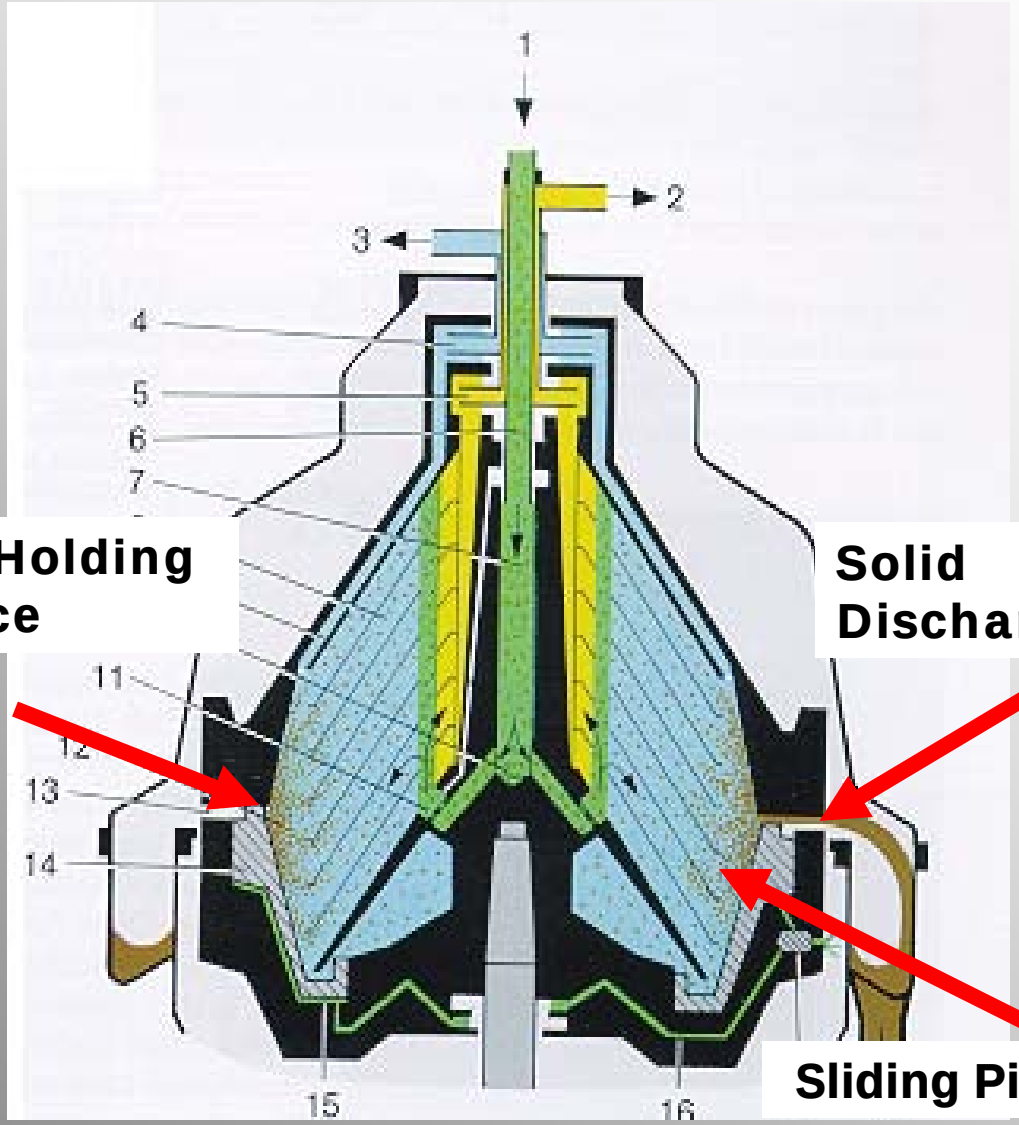
Infeed Tube
Product Discharge



Design Principles



Design Principles

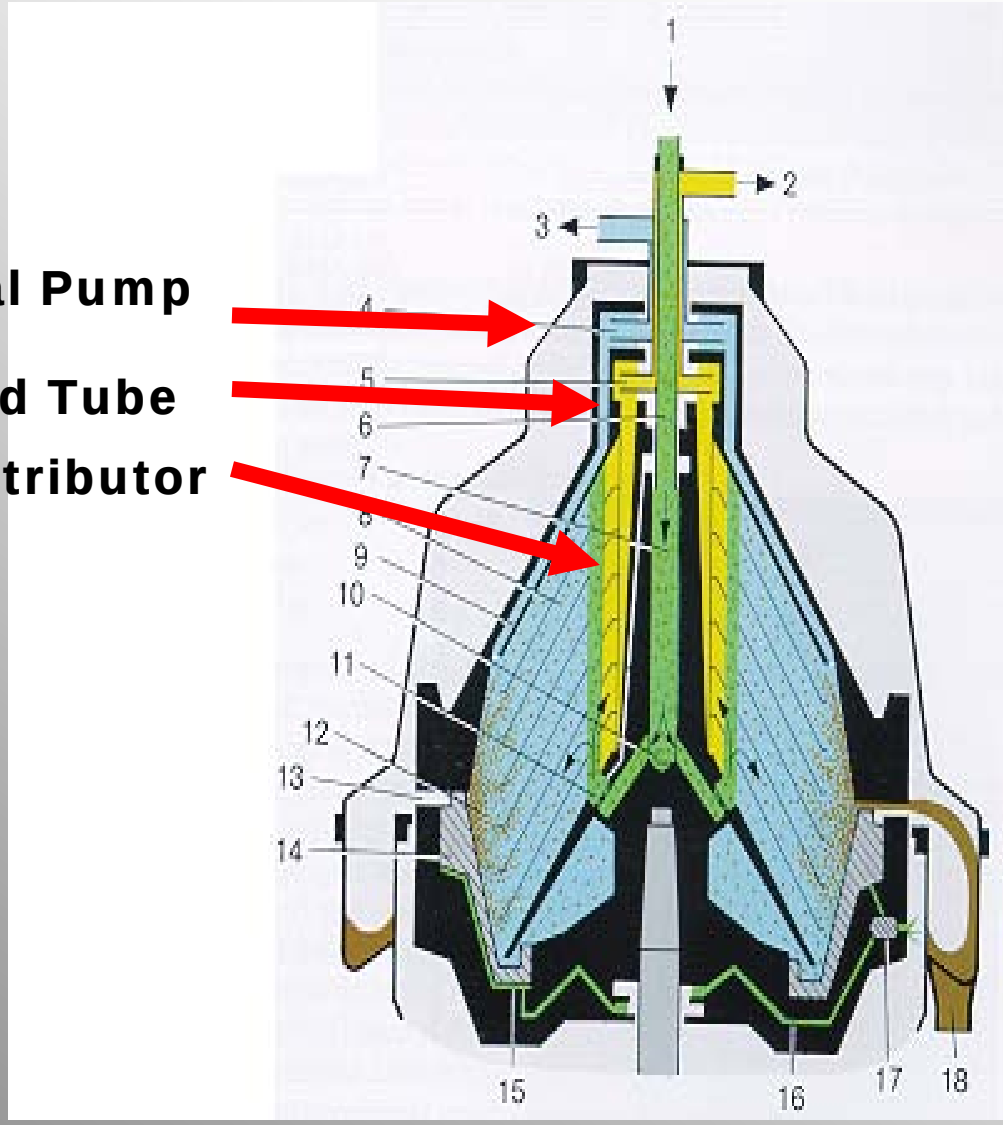


Design Principles

Centripetal Pump

Infeed Tube

Distributor

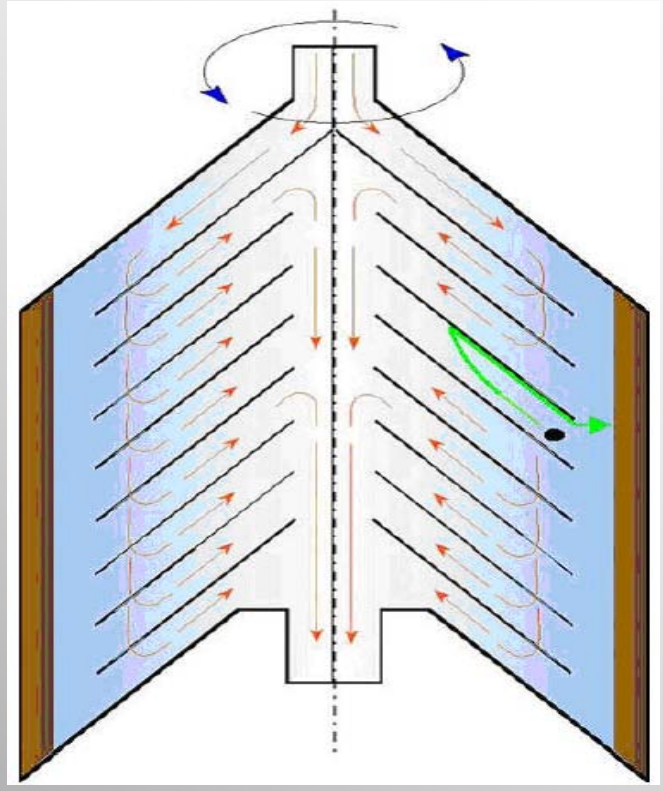


Operating Principles

Flow of solids is outward away from the axis of rotation

The lighter liquid is displaced to the upper side of the conical surface of the disk

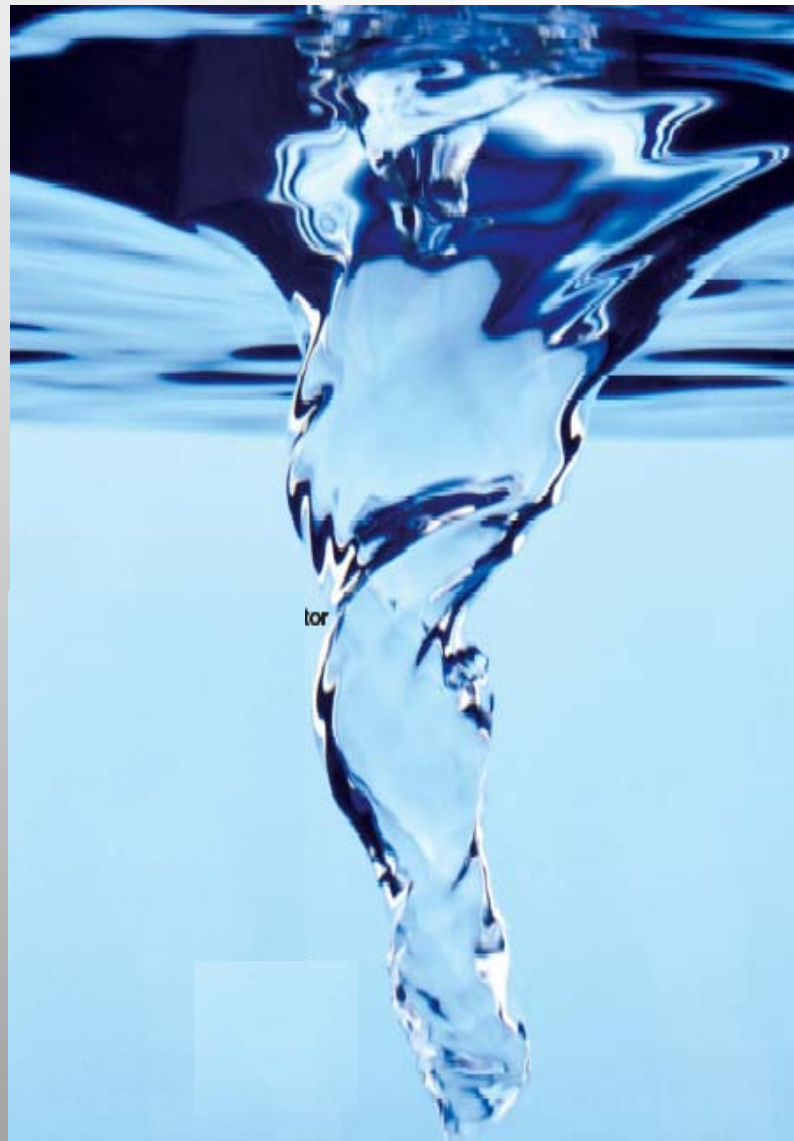
Operating Principles



- The sediment slides down the underside of the conical surface
- The liquid is displaced to the upper side of the conical surface

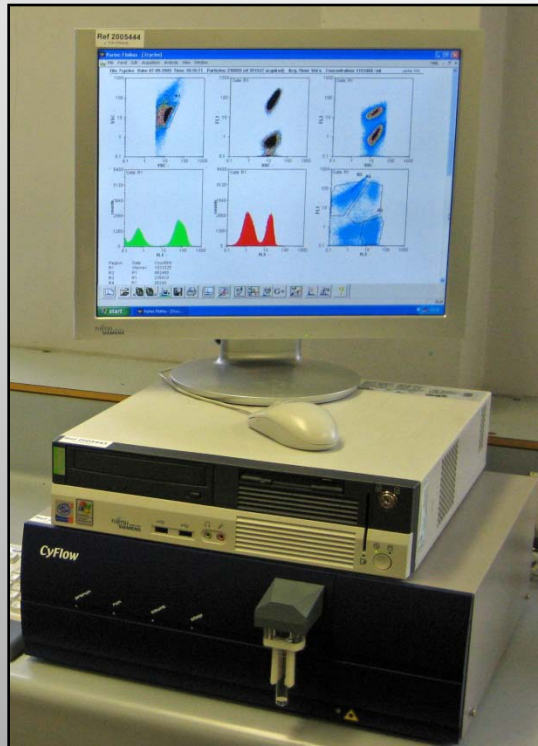
Experiment Objective

- Determine if the *G*-force is detrimental to yeast quality and beer stability
- Assessment of yeast physiological status as a function of the centrifugation cycle

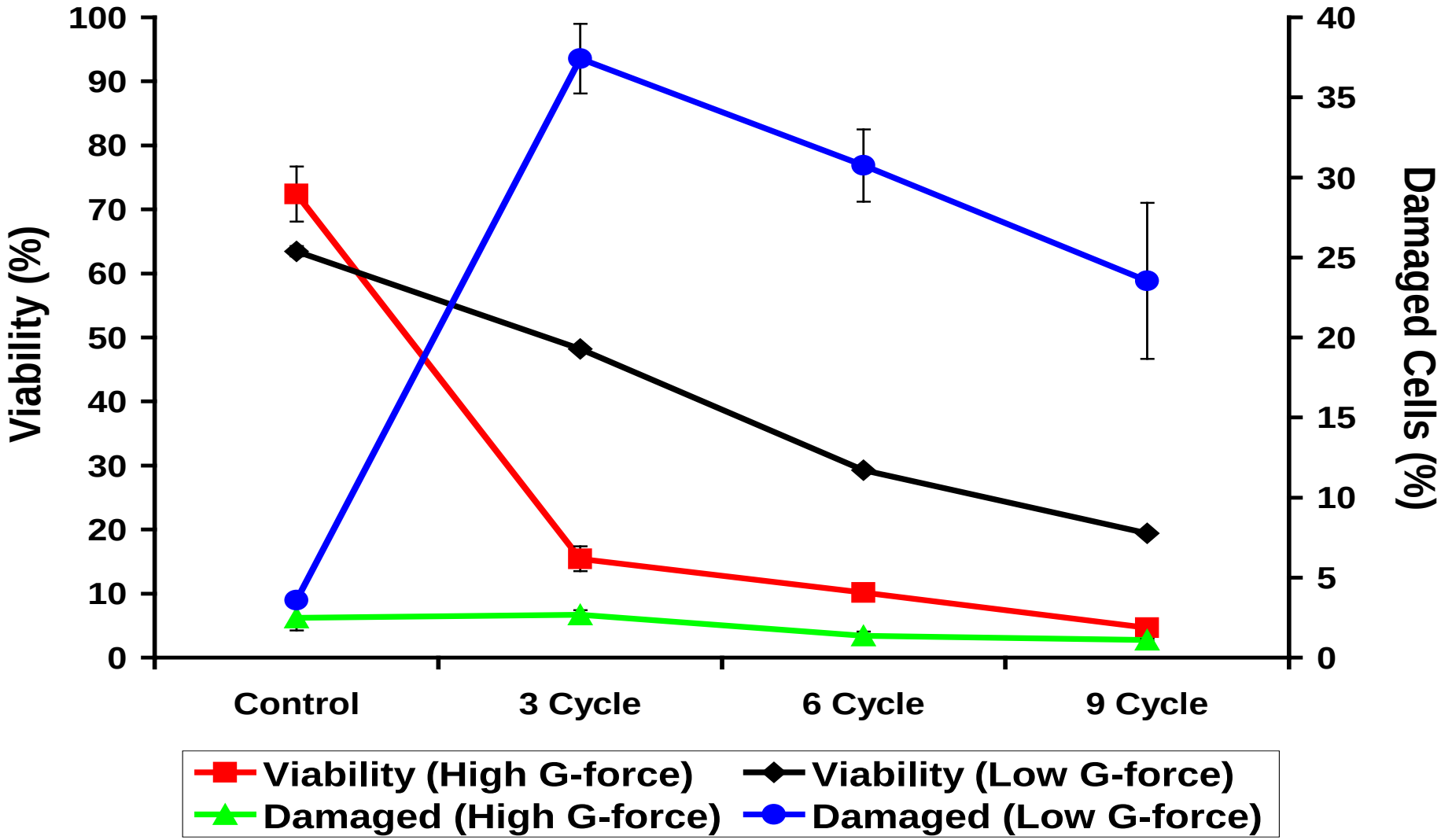


Experiment Parameters

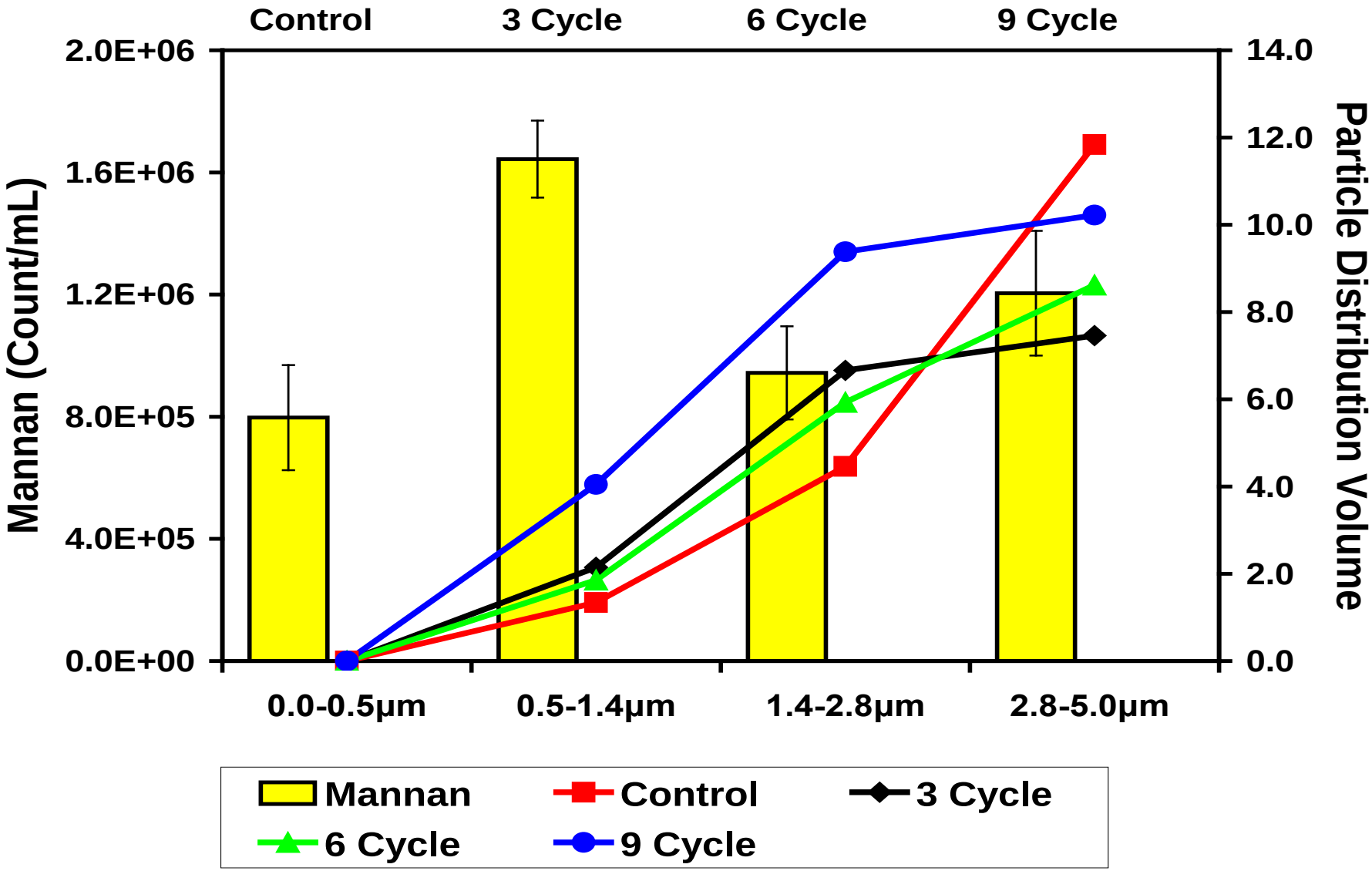
- Viability and Damaged Cells
- Mannan Residues and Particle Size
- Beer Haze
- Intracellular Glycogen and Trehalose in Viable Populations



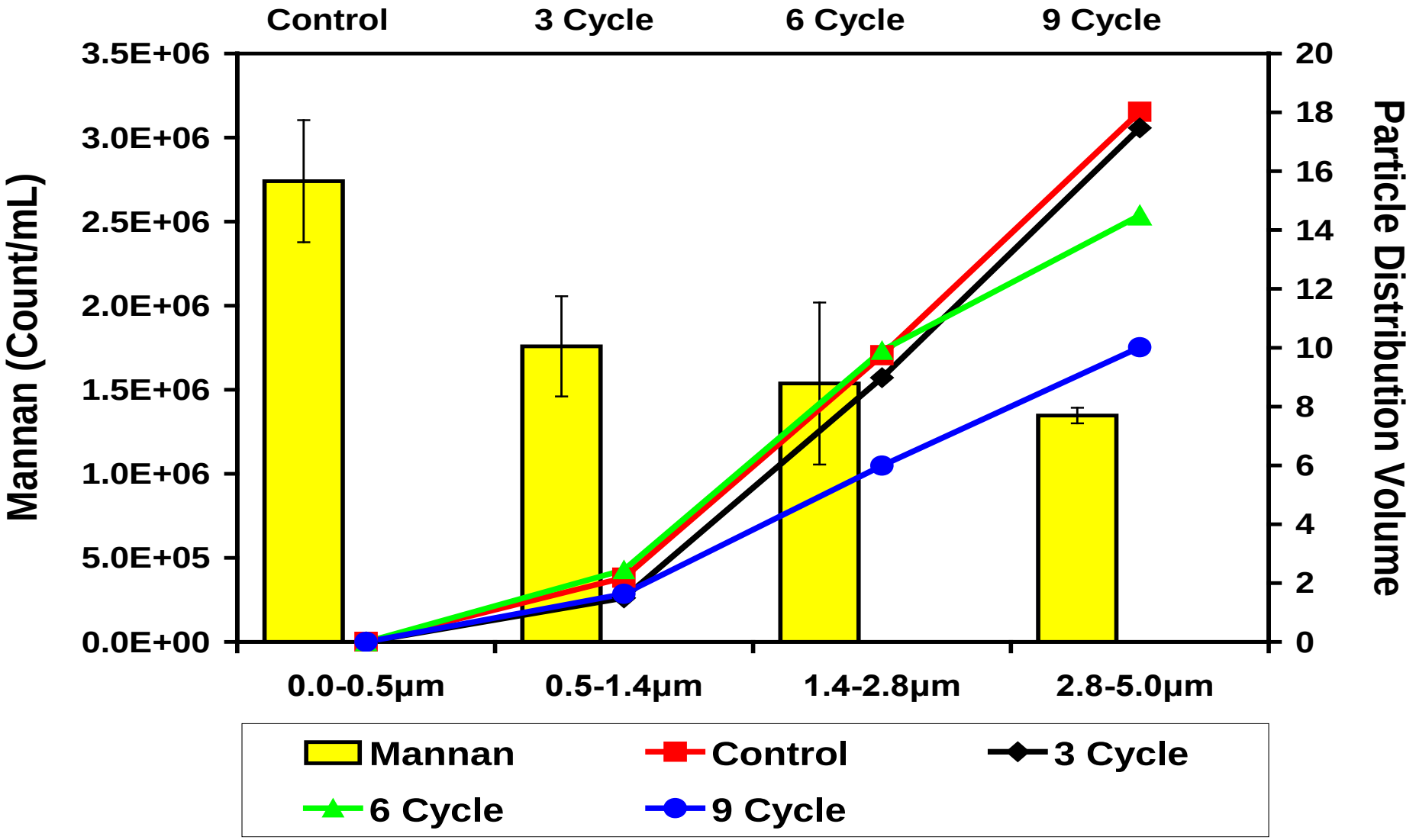
Viability and Damaged Cells As A Function Of *G*-force



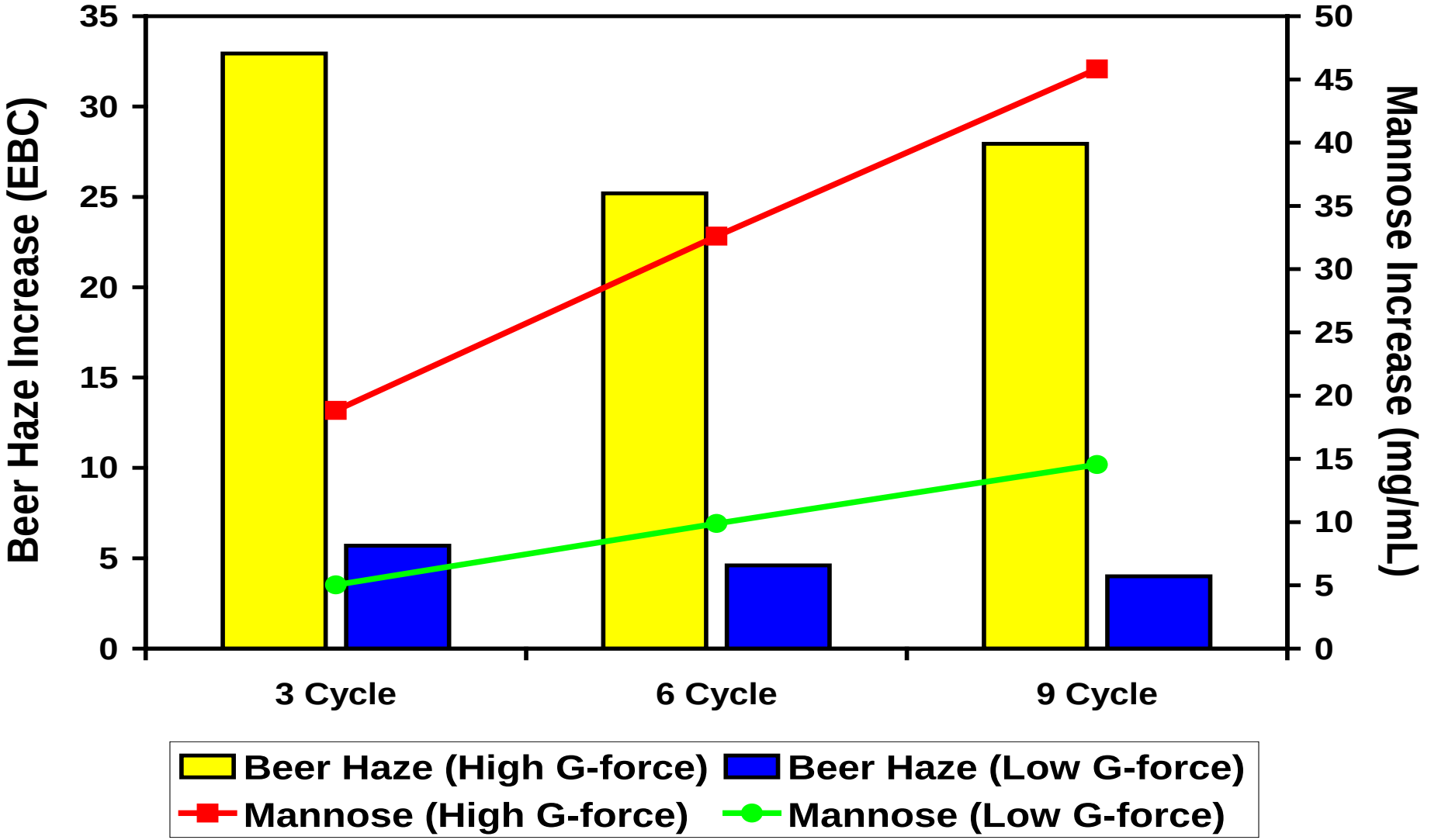
Mannan Residues and Particle Size As A Function of High *G*-force



Mannan Residues and Particle Size As A Function of Low *G*-force



Beer Haze As A Function Of *G*-Force



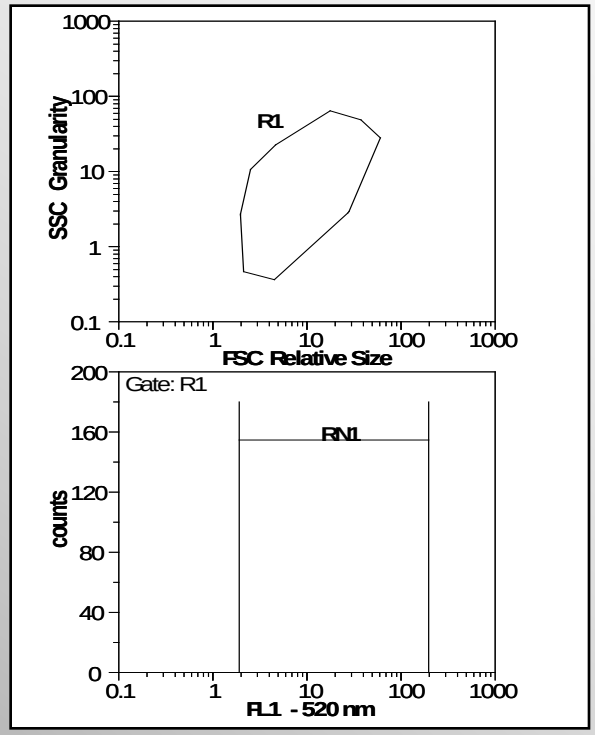
Intracellular Glycogen

- Consists of α-1,4 and α-1,6 glycosidic connected glucose units which serves as a major reserve carbohydrate

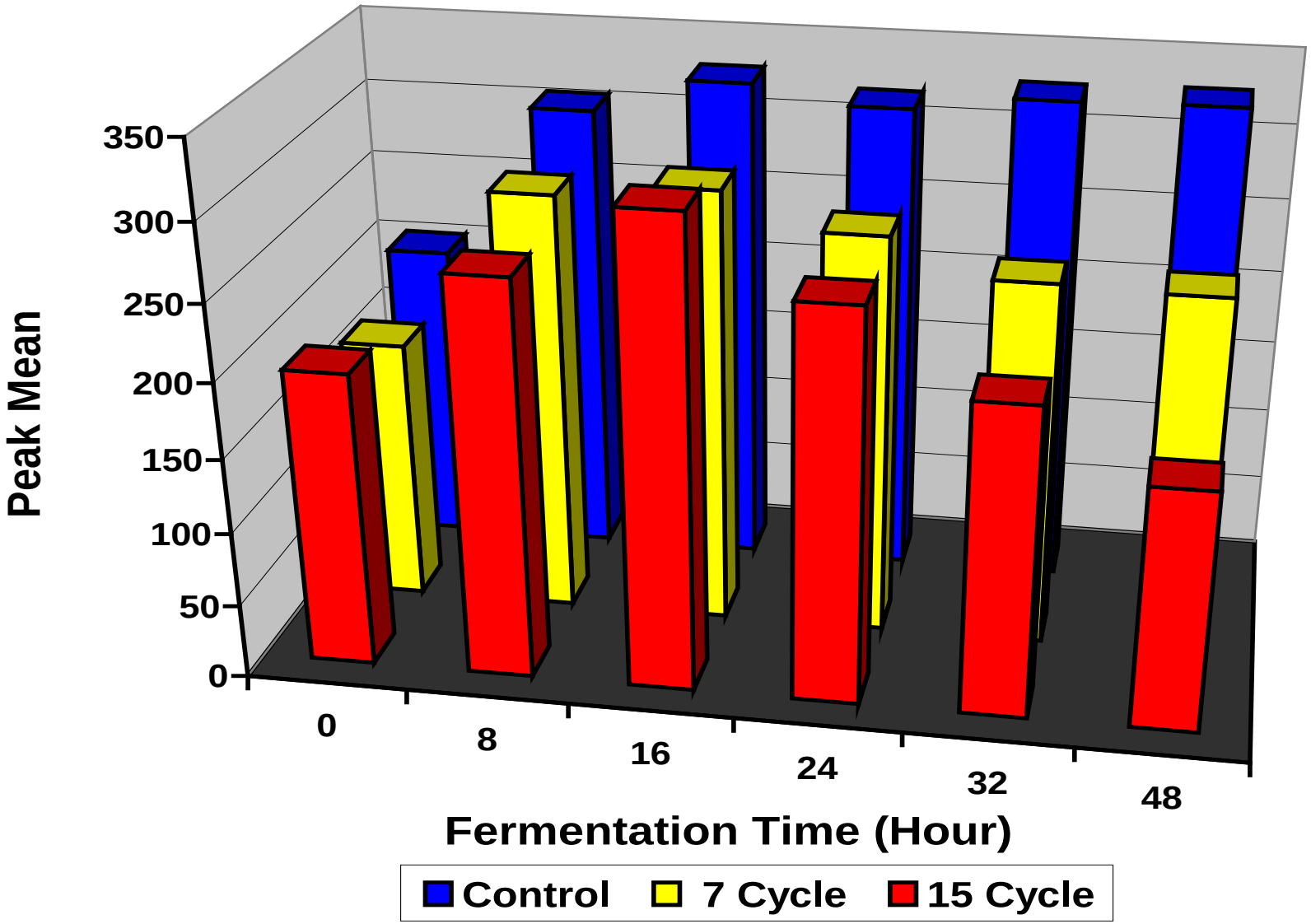
- Glycogen provides energy and carbohydrates for the synthesis of sterols and lipids during the aerobic phase of fermentation

- *Saccharomyces cerevisiae* is able to metabolize glycogen directly and release glucose

- Glycogen is accumulated in the early exponential phase and utilized during nutrient depletion

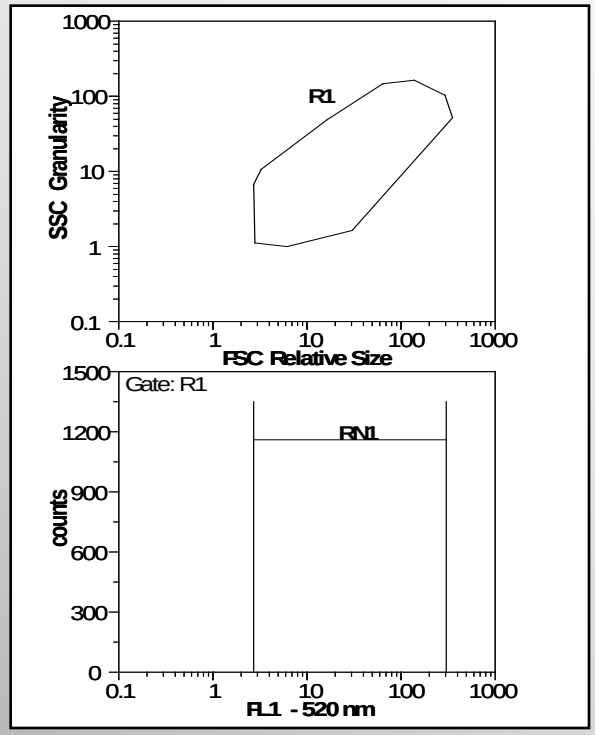


Intracellular Glycogen Viable Cells As A Function Of Fermentation Time

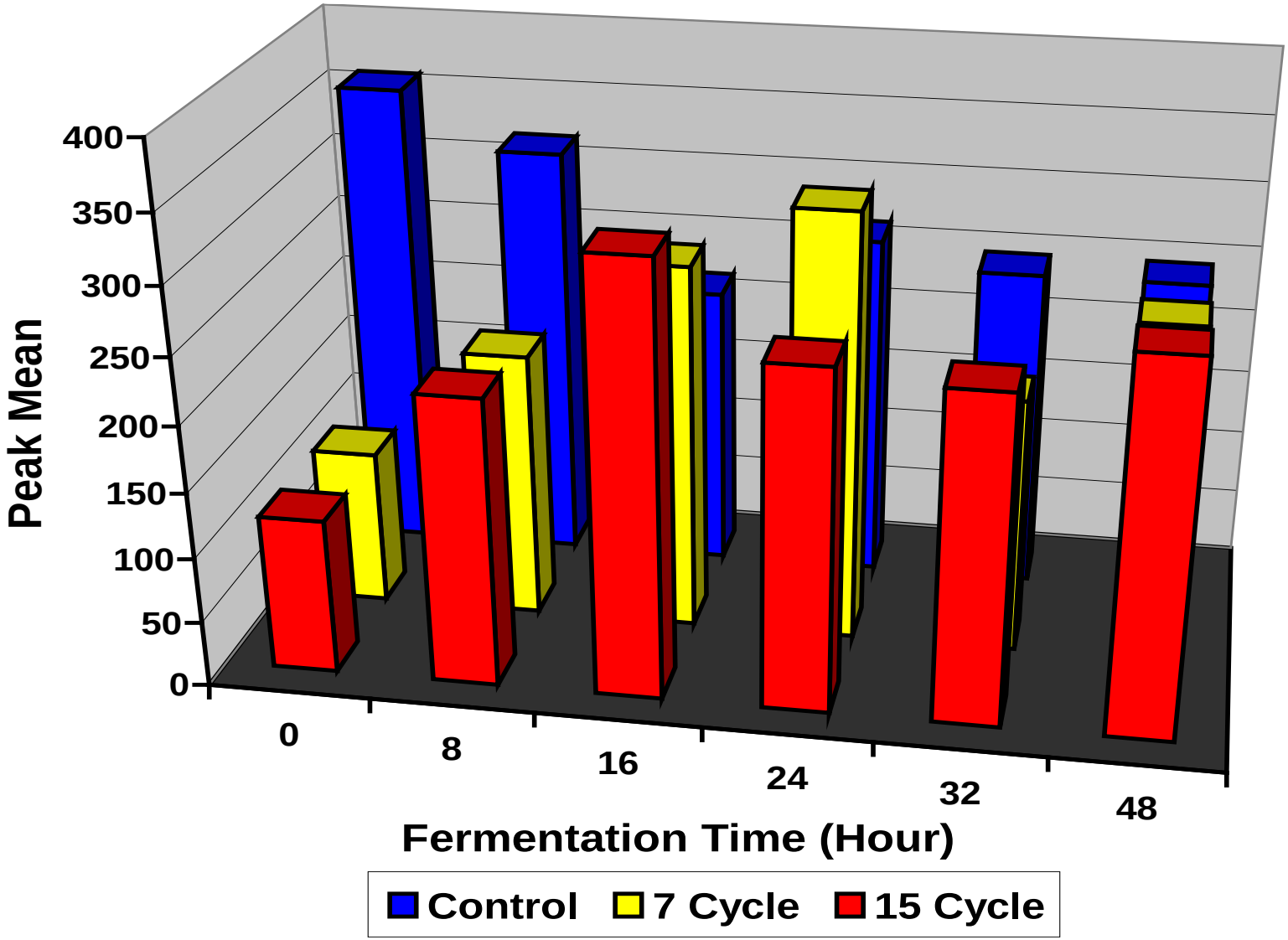


Intracellular Trehalose

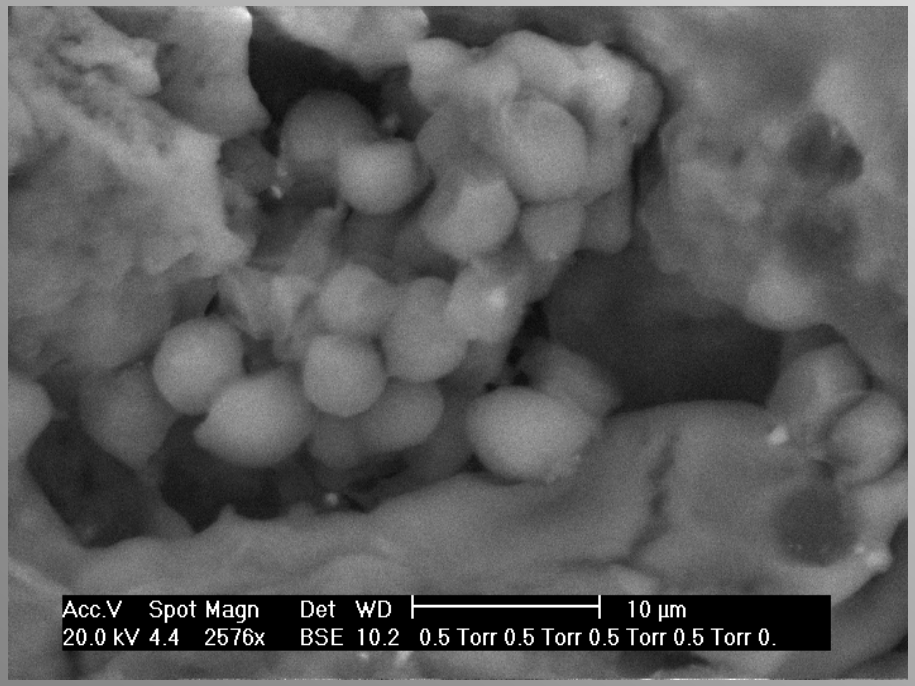
- Trehalose is a disaccharide of glucose which is linked via their reducing carbon atoms
- Assists in stabilizing the cell membrane during nutrient depletion and starvation
- Degree of stress resistance and the amount trehalose synthesized is dependent on the physiological state of the yeast
- Growing cells produced more trehalose in response to fermentation conditions

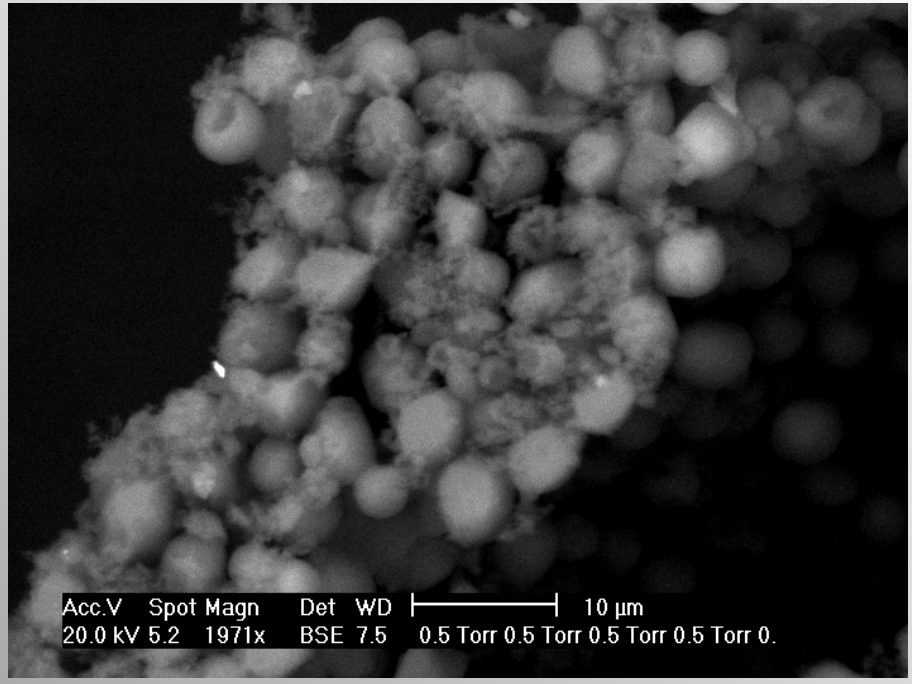


Intracellular Trehalose Viable Cells As A Function of Fermentation Time



ESEM Analysis of Yeast





Conclusions

- **Yeast cropping by disc stack centrifugation is detrimental to the physiological state of yeast cells**
- **Exposure to a high *G*-force resulted in a decrease in cell viability**
- **Shear stress coincided with increasing beer haze, particle size and mannan residues**
- **Yeast cells subjected to centrifugation have decreased intracellular trehalose and glycogen concentrations**

Acknowledgements

Professor Graham Stewart

MBAA Mid-South

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