On the Road to a New Sweet Sorghum Industry in the USA

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USDA

HECKEMEYER MILL

SORGHUM CHECKOFF

Presentation Outline

- Key value added products from sugar feedstocks – the "Sugar Platform"
- Advantages of sweet sorghum over other crops
- USDA-ARS New Orleans research on sweet sorghum
- Largest operational sweet sorghum biorefinery in USA: Heckemeyer Mill, Sikeston, Missouri, USA
- Overcoming processing problems with help of USDA scientists

Sugar Platform

Biomass Conversion Technologies

BIOCHEMICAL
Sugar Fermentation Platform

CHEMICAL
Oleochemical/Chemical Platform

THERMOCHEMICAL
Gasification Platform

Fuels, Chemicals, Energy & Co-products

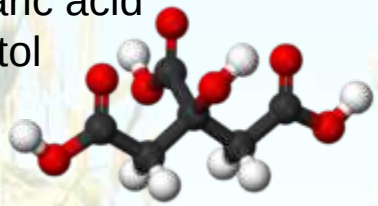
Key Value Added Products from Sugar Feedstocks

"Sugar Platform"

– From Chemical or Biocatalytic Processes

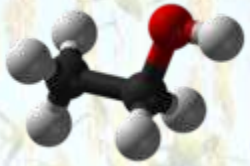
C6

Citric acid → Food preservative
Gluconic acid → Food acidulent
Lysine → animal feed
HMF → plastics
Glucaric acid
Sorbitol



C2

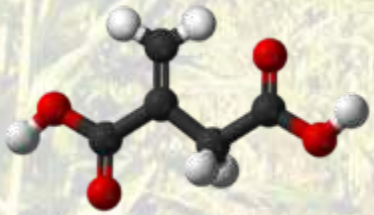
Ethanol → Liquid fuel
Acetic acid → Wood glue
Glyoxylic acid → skin care products



C6 or C5 Sugars

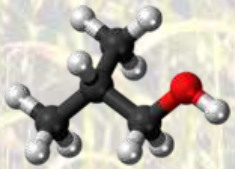
C5

Furfural → Industrial solvents
Levulinic acid → Rubber/resins
Xylitol → low calorie sweetener
Glutamic acid
Itaconic acid



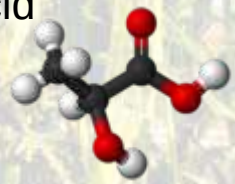
C4

Butanol → Liquid fuel
Succinic acid → Polymers/ surfactants/adhesives
Aspartic acid
Butanediol



C3

Lactic acid → PLA Biodegradable plastic
1,2-Propanediol
3-Hydroxy Propionic acid
Acrylic acid



The Development of the Sugar Platform Will Depend On:

- Application of chemical and bio-catalysts to transform sugars into useful biobased chemical intermediates and downstream products
- Successful scaling up of biocatalysts from "proof-of-concept" experiments on a laboratory scale to commercial industrial process scale - only beginning to emerge
- Availability of economic, readily-available source or sources of sugar feedstocks (expected to transition to ligno-cellulosic derived sugars)
  - At present mainly focused on corn, cassava starch, and sugarcane molasses
- Availability of stable, transportable, and storable feedstocks for year-round use

Sweet Sorghum

Advantages of Sweet Sorghum over Other Crops for Biofuels and Bioproducts

Adapts well to adverse environments
- Requires relatively low inputs

Very high energy balance
- Comparable efficiency as sugarcane

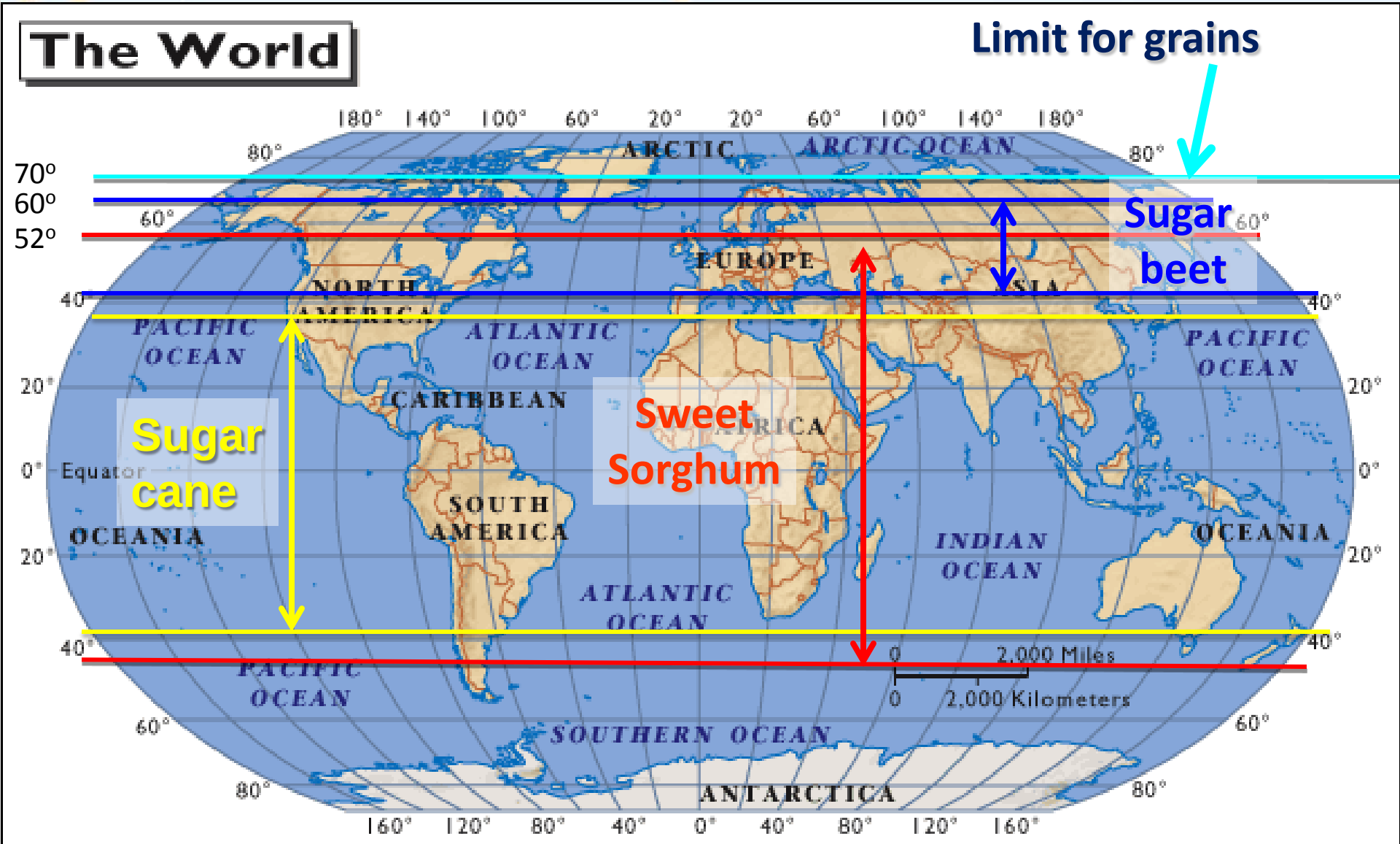
1 - 2 crops per year (Temperate)
- Improves economics immensely

Can be processed with a dual feed stock
- Makes it a low cost seasonal crop
- Sugarcane and sugar beet

Can be used in existing ethanol factories
- Much easier to ferment than corn with higher ethanol output potential

Genetic improvement potential is HUGE
- Hybrid and tailor made sweet sorghum cultivars

World Map Depicting Approximate Areas Where Sweet Sorghum, Sugarcane, and Sugar Beet can be Grown



Adapted from Debor (2009).

USDA-ARS Sweet Sorghum Research

Objectives of the New Sugar & Energy CRIS Project

2014-2019

- **All objectives and sub-objectives are focused on solving industry problems after discussions with numerous industrial stakeholders**

Interrelationships of New Project Objectives

Develop Technologies That Enable Growth and Profitability in the Commercial Conversion of Sugarcane, Sweet Sorghum, and Energy Beets into Sugar, Advanced Biofuels, and Bioproducts

Sugarcane for Sugar Manufacture

Sweet Sorghum and Energy Beets for Advanced Biofuels and Bioproducts Manufacture

Objective 1. Develop commercially -viable technologies that reduce undesirable effects of starch and color on processing and end–product quality

Objective 2. Develop commercially-viable technologies that reduce or eliminate undesirable effects of high viscosity on sugar processing and end-product quality.

Objective 3. Develop commercially-viable technologies to increase the stability and lengthen storage of sugar feedstocks.

Objective 4. Develop commercially-viable technologies for the biorefining of sugar crop feedstocks into advanced biofuels and bioproducts.

Objective 5. Identify and characterize field sugar crop traits that affect sugar crop refining/ biorefining efficiency, and collaborate with plant breeders in the development of new cultivars/ hybrids.

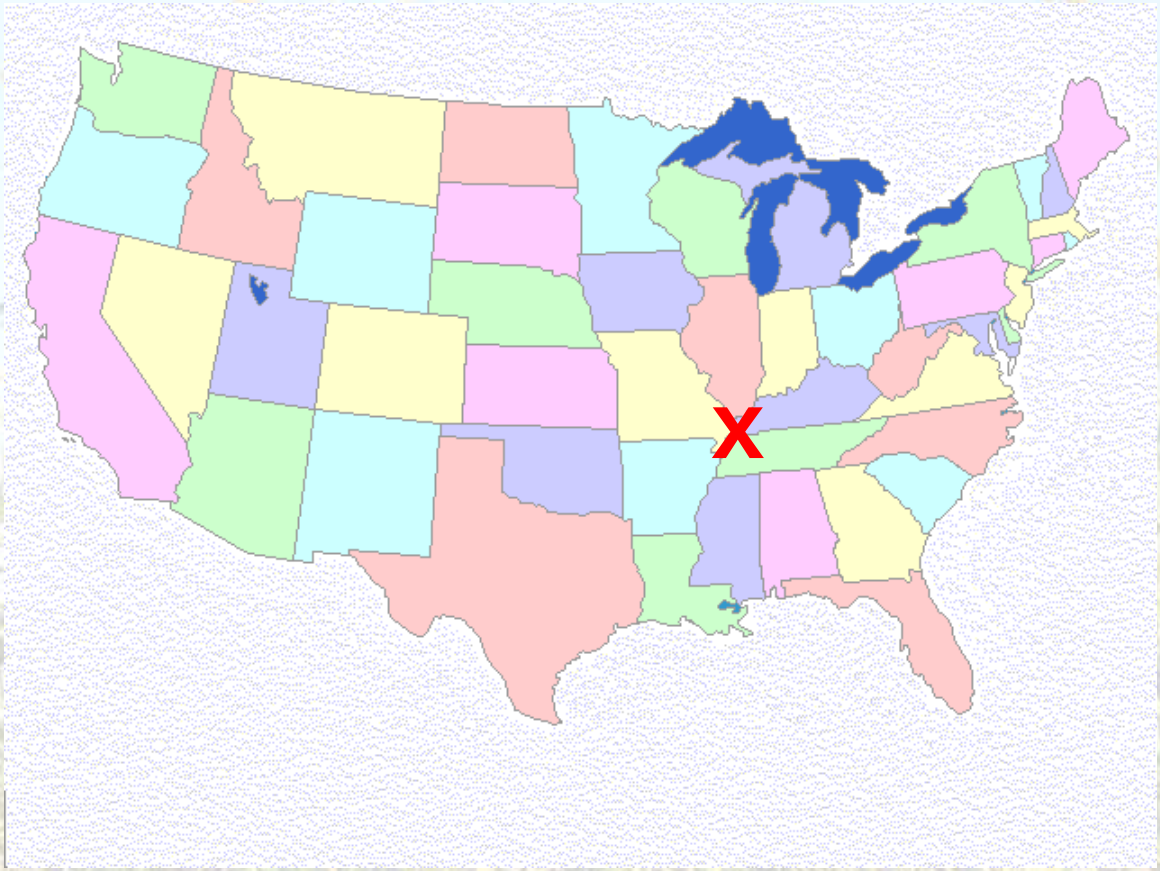
Objective 6. Develop, in collaboration with commercial partners, technologies that enable production of marketable products from residues and by-product streams.


Lead Scientist

Largest Sweet Sorghum Biorefinery in USA

HECKEMEYER MILL (2015)

Sikeston, Missouri, USA



- Poultry
- Cattle
- Timber
- Row crop sweet sorghum

HECKEMEYER MILL

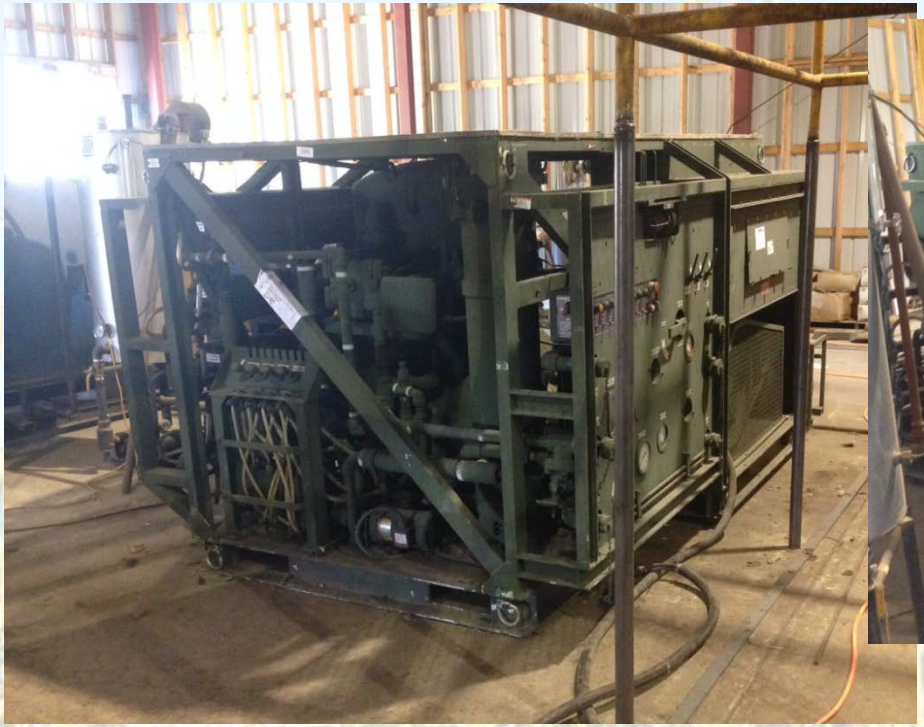
2015

HECKEMEYER MILL

HECKEMEYER MILL

HECKEMEYER MILL

HECKEMEYER MILL



HECKEMEYER MILL

Row-cropped sweet sorghum

HECKEMEYER MILL

- **Multiple Cultivars: e.g., M81E, Honey Drop, Dale, and KN Morris**
- **Plant late May/Early June**
- **Stagger the rotation for timely harvest**
- **Process from Mid August (depends on Juice Brix)**
- **Modified Forage Harvesting - up to 2.5 inch billets**

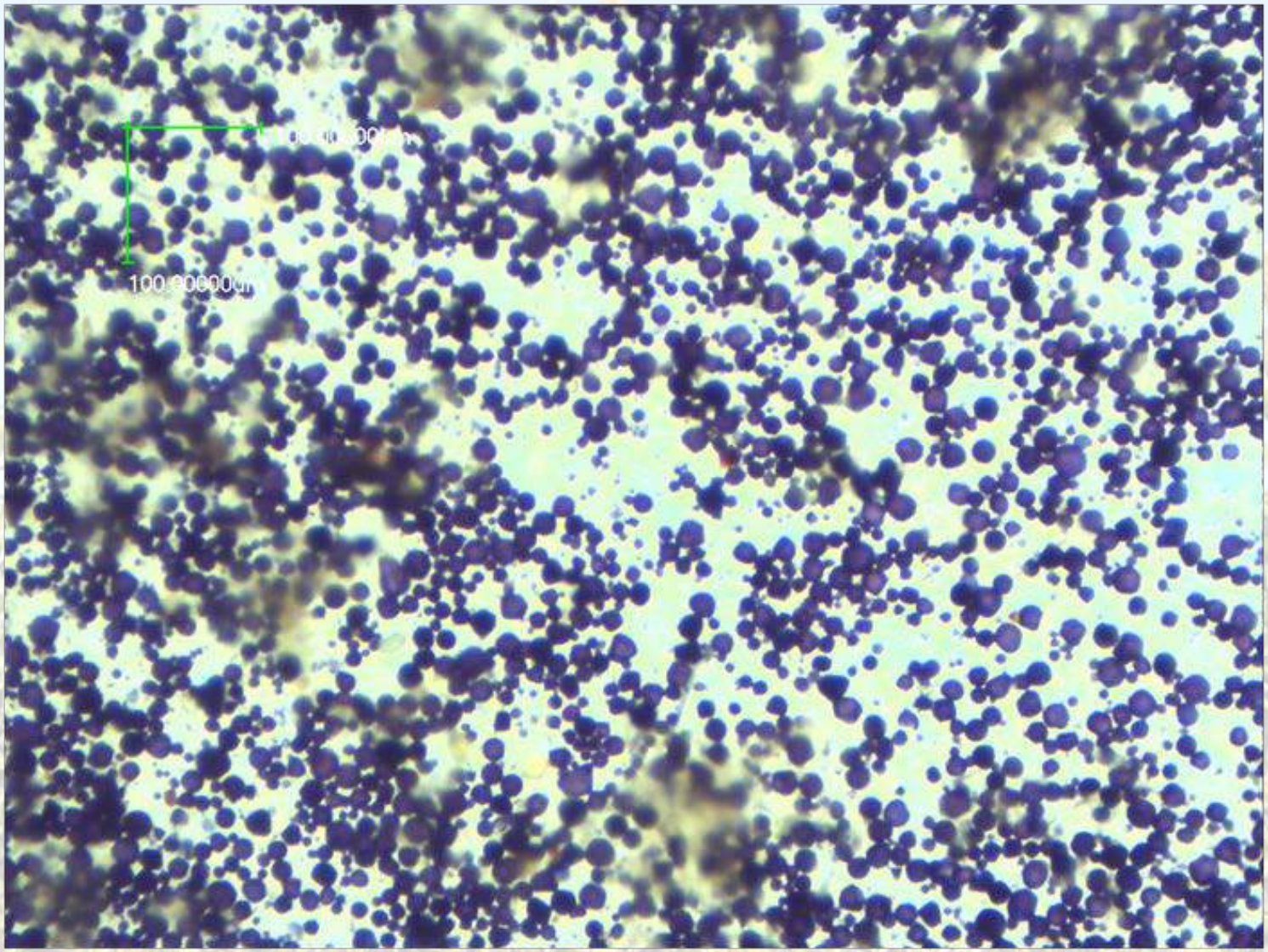
Double Tandem 4 ft Wide Roller Mill

Overcoming Processing Problems with Help of USDA Scientists

Aim: Large, Commercial Scale Manufacture of Food Grade and Non-Food Grade Syrup

August to October, 2014

Major Starch Problem



Eggleston et al (2015.). Sugar Tech

Eggleston Clarification Process

Heated, De-aerated Sweet Sorghum Juice

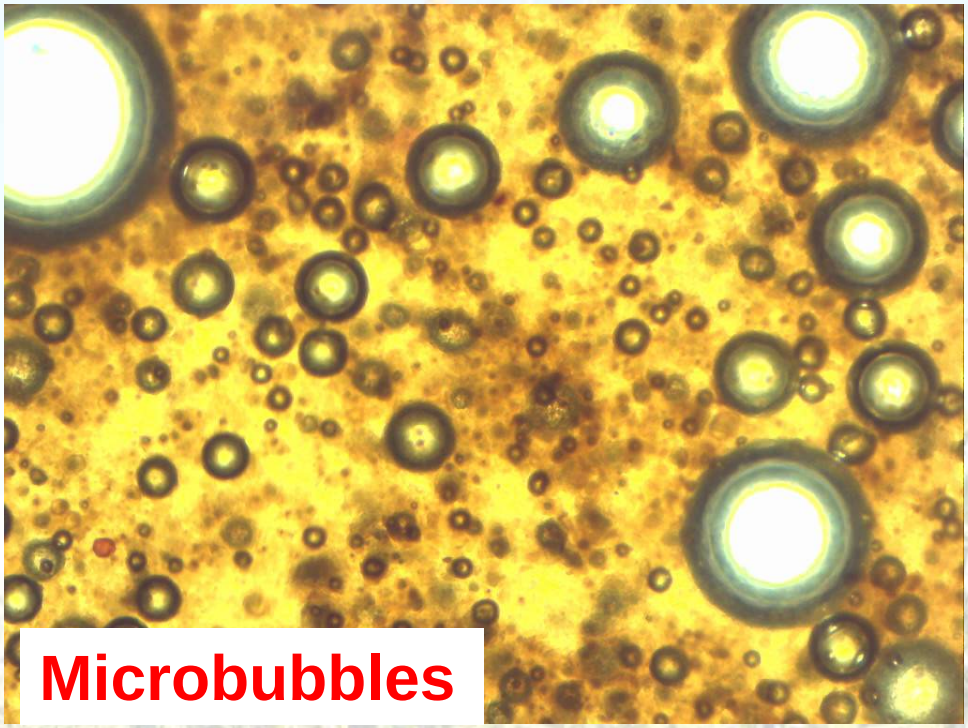
Formation of Flocs (Light Color) which are Starting to Precipitate

Clarified (Clean) Juice

92% Turbidity Removal over 1 hr

New Late Season Problem

Light Green Scum Formation on Surface of Clarification Tank



7.93 ± 0.52% protein on a dry wt basis

- **Has to be skimmed off or filter pressed**
- **Highlights seasonal variations that warrant further investigation**

Syrup (Long-Term) Storage

SORGHUM CHECKOFF

Overall Process and Supply Chain for Syrup Production at Heckemeyer Mill

Extraction → De-aeration → Settling → Heating → Clarification → Evaporation






ensiled bagasse

sediment

mud

High Value Cattle Feed

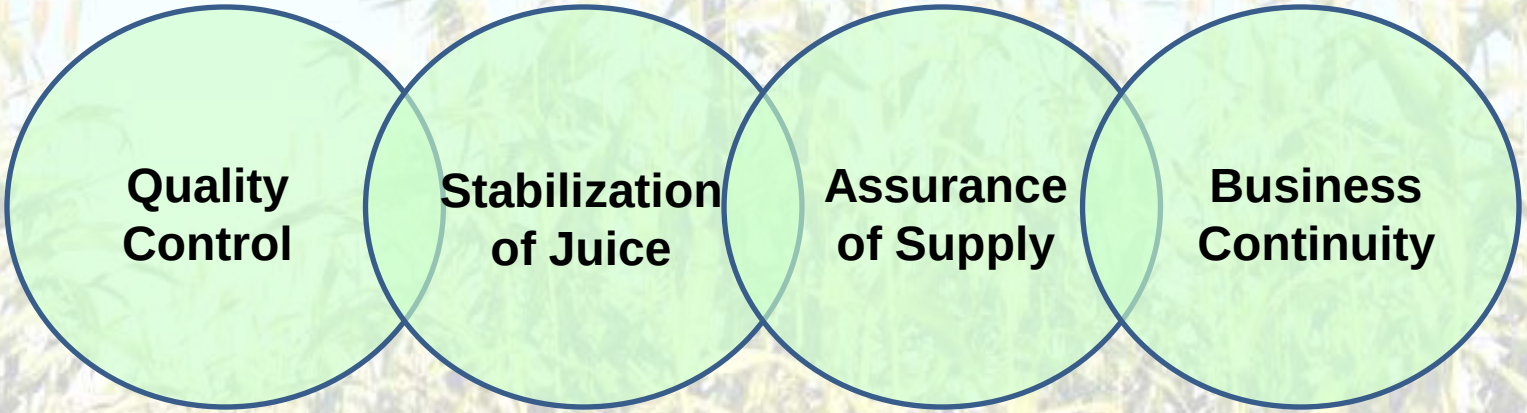
V. minimal waste processing

2015 Process and Supply Chain for Syrup Production at Heckemeyer Mill

Extraction → De-aeration → Settling → Heating → Clarification → Evaporation





- Capacity of Mill is 90 tons/hr which is approx. 120 acres/day or 24,000 gals of 80 Brix syrup/day


Thank You