Structural Sugar Profile of Fiber Residues from High-Cannabinoid Hemp and Potential for Value-Added Fermentation

Hanah T. Rheay & Catherine E. Brewer

Association for the Advancement of Industrial Crops, Annual Meeting – August 30, 2023

College of Engineering | Department of Chemical and Materials Engineering

NM STATE

BE BOLD. Shape the Future.
New Mexico State University

Overview

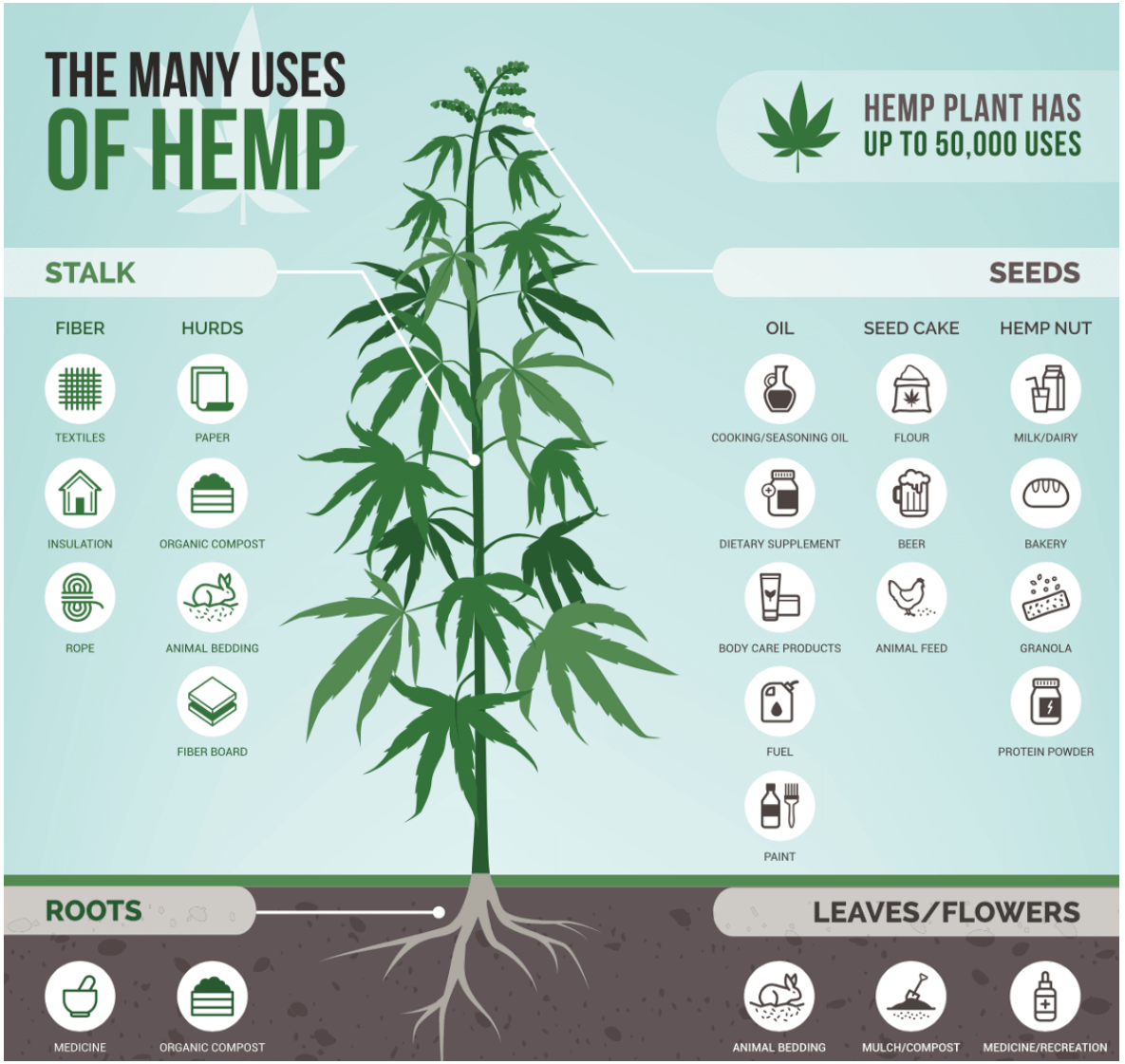
- **Hemp Field Trials at NMSU**
  - Challenges with Fiber/Grain Types
  - Yield of High-Cannabidiol Varieties

- **Future of Hemp in NM**

- **Knowledge Gap: Fibers from High-Cannabinoid Crops**
  - Waste Fiber Characterization
  - Potential Economic Value-Added
  - Next Steps

Hemp Background

- Hemp is defined as *Cannabis sativa* with ≤ 0.3% total tetrahydrocannabinol (THC)
- U.S. re-legalized crop in 2018, following nearly 70 years of prohibition



Graphic: CBD vs Hemp - The Crop of 50,000 Uses. (2022). Bloodhound Hemp Farms. https://www.bloodhoundhempfarms.com/post/graphic-cbd-vs-hemp-the-crop-of-50-000-uses

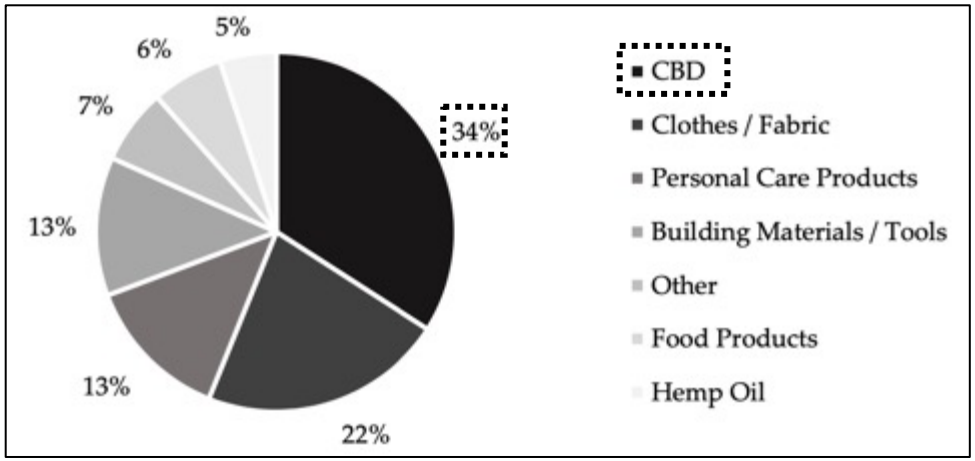
Types of Hemp

- Types of hemp:
  1) CBD/essential oil;
  2) grain;
  3) fiber

- Different morphology, physiology, and chemical profile between types

- Current US market is dominated by cannabidiol (CBD) products

Different hemp types: (left) CBD-type; (right) industrial-types



Kolodinsky, J., Lacasse, H., & Gallagher, K. (2020). Making hemp choices: Evidence from Vermont. *Sustainability*, *12*(15), 1–15. https://doi.org/10.3390/SU12156287.

Hemp Research at NMSU

- NMSU initial variety trial work in 2019
  - Support: Navajo Nation
  - Work was not continued

- Phytoremediation trial (2019-20)
  - Support: BHP/Rio Algom Mining
  - Focus on legacy uranium/radium mines in northwest NM

- Expanded variety trials (2021-22)
  - Support: COE (2021), AES (2021-22), CESFAS (2021-22), WSARE (2022-23)

NM STATE
BE BOLD. Shape the Future.
College of Agricultural, Consumer and Environmental Sciences
Agricultural Experiment Station

BHP
Rio Algom

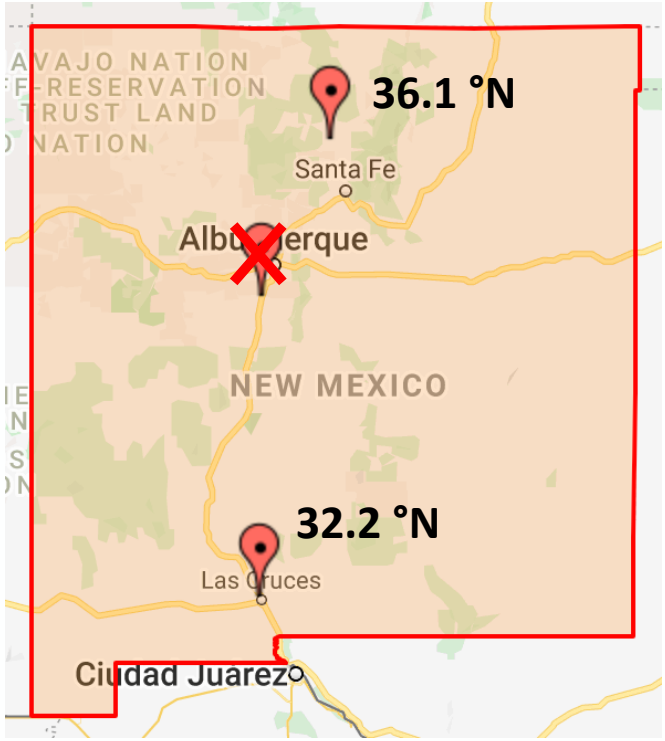
NM STATE
BE BOLD. Shape the Future.
College of Engineering

NM STATE
BE BOLD. Shape the Future.
College of Agricultural, Consumer and Environmental Sciences
Center of Excellence in Sustainable Food and Agricultural Systems

WESTERN SARE
Sustainable Agriculture Research & Education

2022 Field Trials

Plot Management Details				
Location	***Planting***	***Harvest***	***Treatment Plot***	***Common Plot***
Leyendecker Plant Science Research Center (south)	April 18	Sept. 13	Water stress: 50% lower frequency	Bi-weekly fertilizer application (12-4-8) Water application minimum once per week
Sustainable Agricultural Science Center at Alcalde (north)	May 13	Sept. 28	Organic: OMRI certified organic fertilizer (11-3-8)	



Varieties & Planting Densities		
Variety	***Type***	***Planting Method***
The Wife	CBD	Transplants, 3 ft spacing
Sweetened	CBD	
Orion 33	Fiber/Grain	Direct seeded at 40 lbs/acre
Félina 32	Fiber/Grain	
Futura 83	Fiber	

NM STATE **BE BOLD.** Shape the Future.

Challenge: Fiber/Grain Production at Low-Latitudes

- ***PREMATURE FLOWERING***
  - Reproductive structures appear as early as 2 weeks after seeding for some varieties

- Hemp is photoperiod sensitive

- Most industrial genetics are sourced from northern latitudes

Plants exhibiting premature formation of female (top) and male (bottom) reproductive floral structures

- Vegetative → Reproductive: terminal flowering (CBD/grain) or pollination (fiber) in 50% of individuals

Growth Stages Key	
	Sowing
	Vegetative Growth
	Reproductive Growth / Maturation
	Harvest

E. Orion 33 (2022)

	Days in Season	April	May	June	July	August	September
Expected	138-143			~ 100 days			
Leyendecker	148		44				
Los Lunas	140		50				
Alcalde	138		55				

F. Felina 32 (2022)

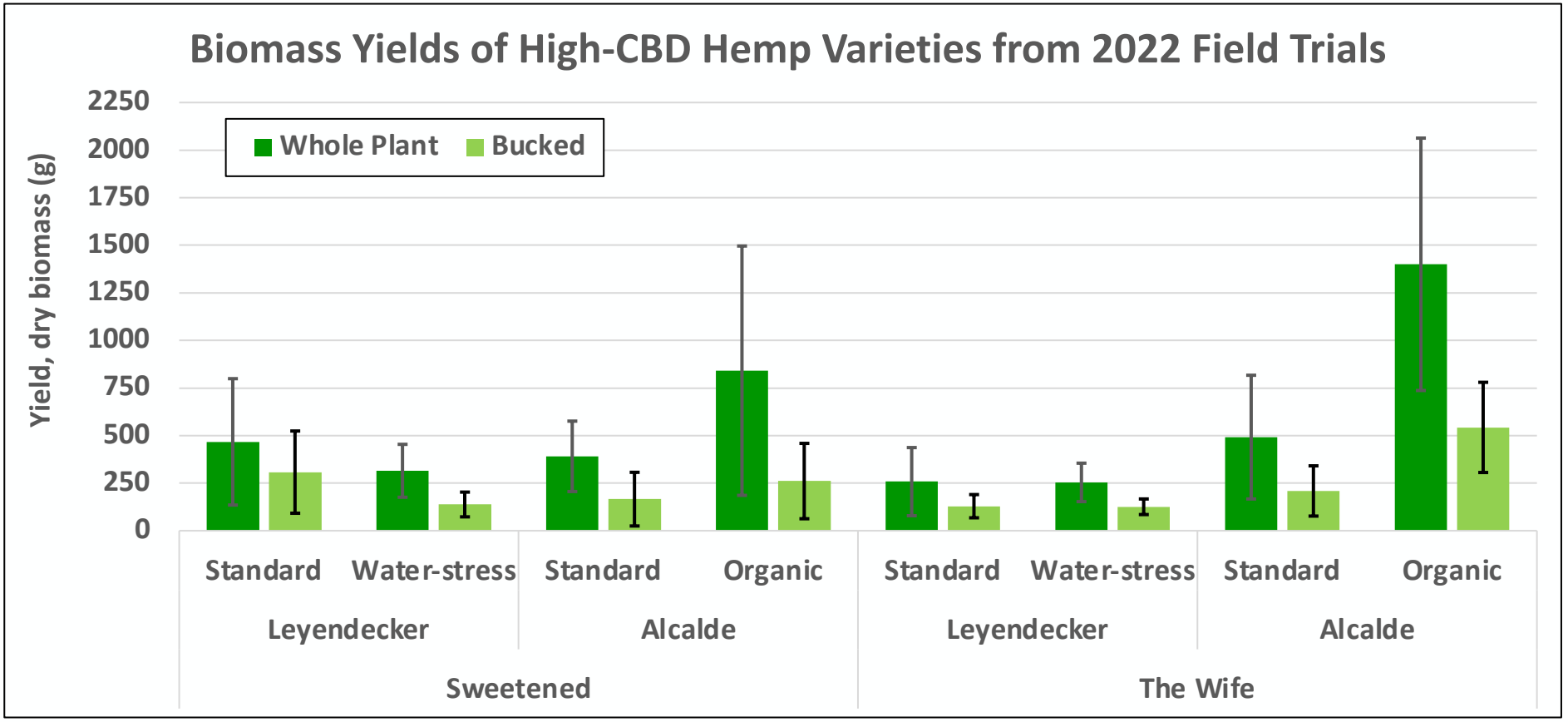
	Days in Season	April	May	June	July	August	September
Expected	133-138			~ 100 days			
Leyendecker	148		44				
Los Lunas	140		50				
Alcalde	138		55				

G. Futura 83 (2022)

	Days in Season	April	May	June	July	August	September
Expected	112-117			~ 100 days			
Leyendecker	148		55				

Total vs. Bucked Biomass

- 34-69% of total crop weight was fiber across all samples

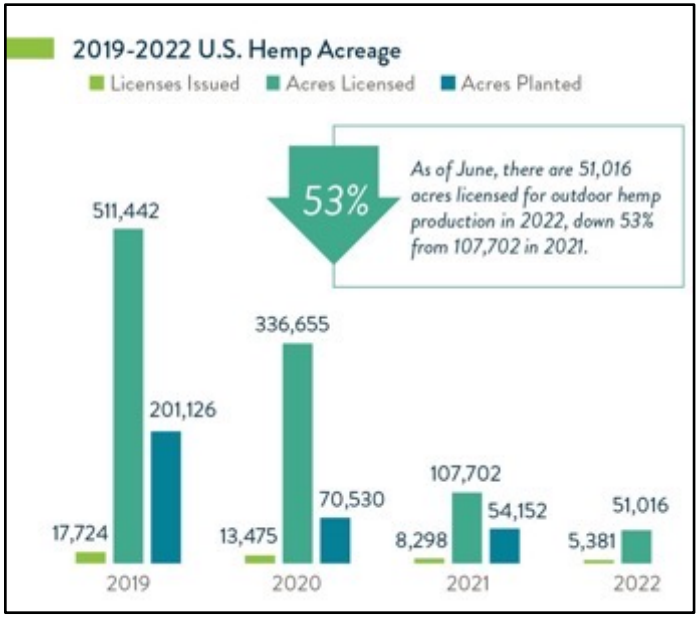


Bucking: to strip herbaceous biomass from stalks/stems
(bucked yield = leaf + flower)

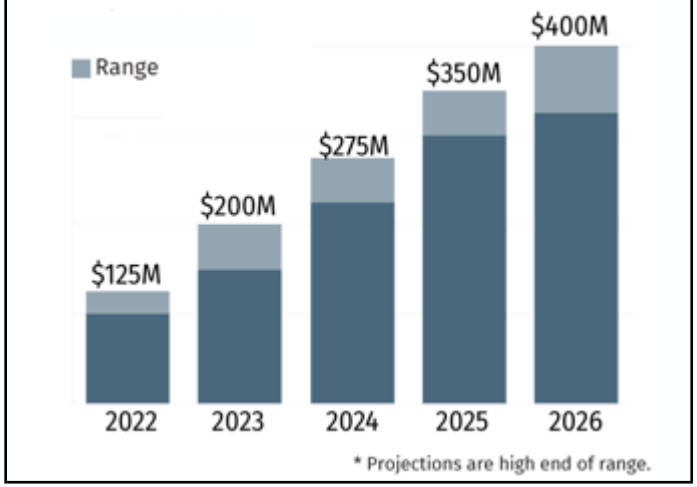
Why does this matter?

Hemp's Future in New Mexico

- Industrial hemp production slow to develop
  - Difficulty growing grain/fiber varieties at low latitudes
  - Limited access to processing
- Legal recreational/medicinal markets
  - 851 producer/micro-producer licenses issued
- Many hemp growers have switched to recreational production



Projected revenues from adult-use recreational *Cannabis* in NM (MJBiz©, 2022)



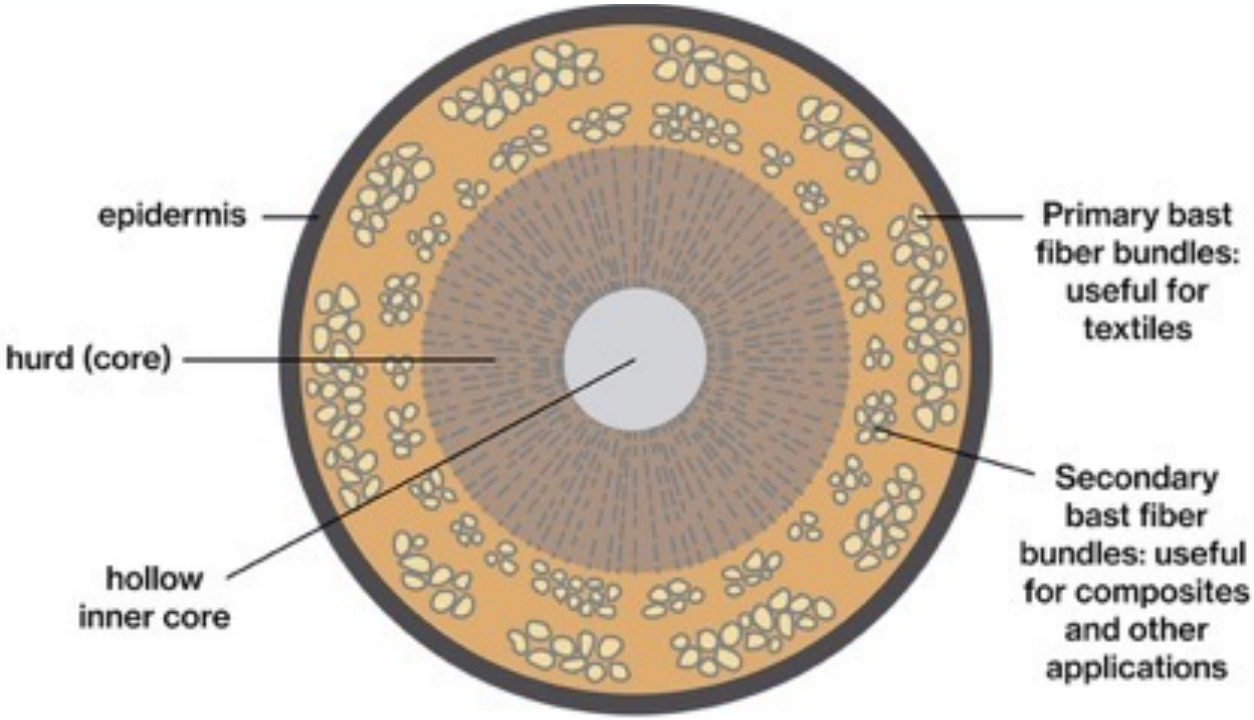
New Mexico Cannabis Control Division. (2023). https://qimw5q0w5j.execute-api.us-west-2.amazonaws.com/prod/plants.html

Singular, E. (2022). Midterm Review: A 2022 U.S. Hemp Production Outlook. New Frontier Data. https://newfrontierdata.com/cannabis-insights/midterm-review-a-2022-u-s-hemp-production-outlook/

Smith, J. (2022). New Mexico set to launch $400 million adult-use marijuana market likely to attract Texans. *MJBiz Daily*. https://mjbizdaily.com/new-mexico-set-to-launch-400-million-adult-use-marijuana-market-likely-to-attract-texans/

Hemp Fibers

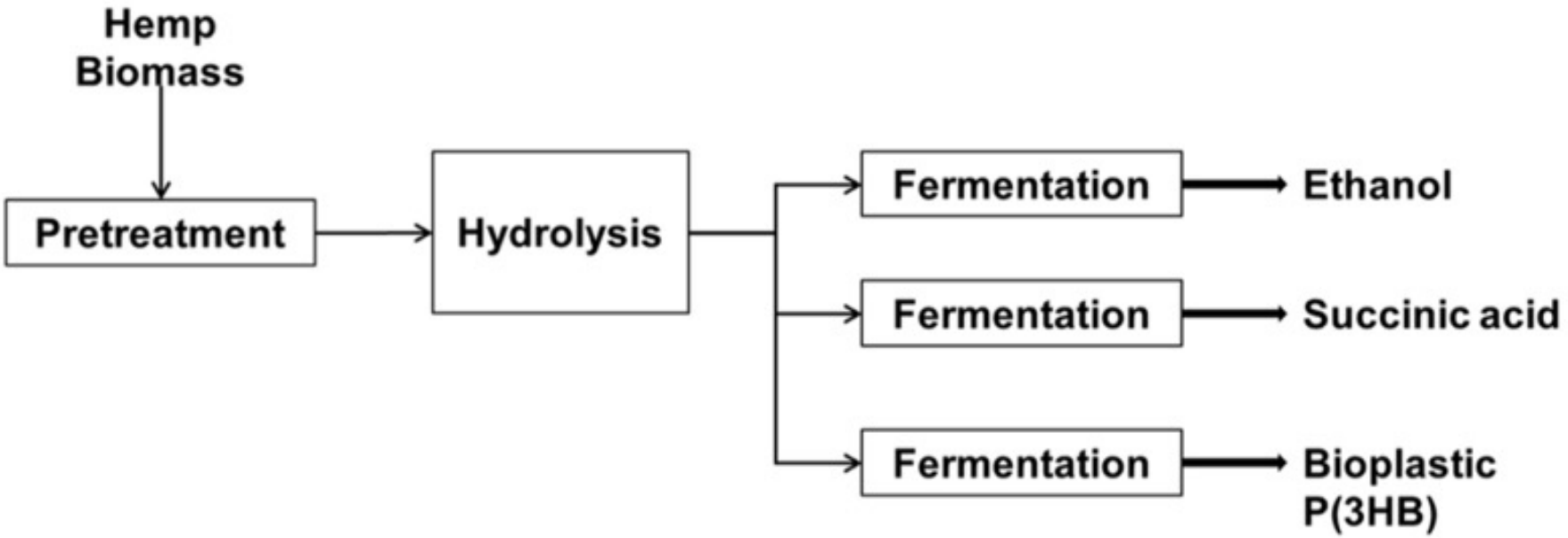
- Traditional processing requires a decorticator to separate bast/hurd
- Minimal information is available on fibers of high-cannabinoid varieties



Harvesting Hemp: Reflecting on Opportunities with the One Acre Exchange. (2020). Fibershed. https://fibershed.org/2020/09/16/harvesting-hemp-reflecting-on-opportunities-with-the-one-acre-exchange/

Saccharification and Fermentation to Bio-Based Chemicals

- Majority of literature evaluates only industrial hemp varieties



Reported bioprocessing routes for industrial hemp (Ji et al., 2021)

Ji, A., Jia, L., Kumar, D., & Yoo, C. G. (2021). Recent advancements in biological conversion of industrial hemp for biofuel and value-added products. *Fermentation*, *7*(1). https://doi.org/10.3390/fermentation7010006

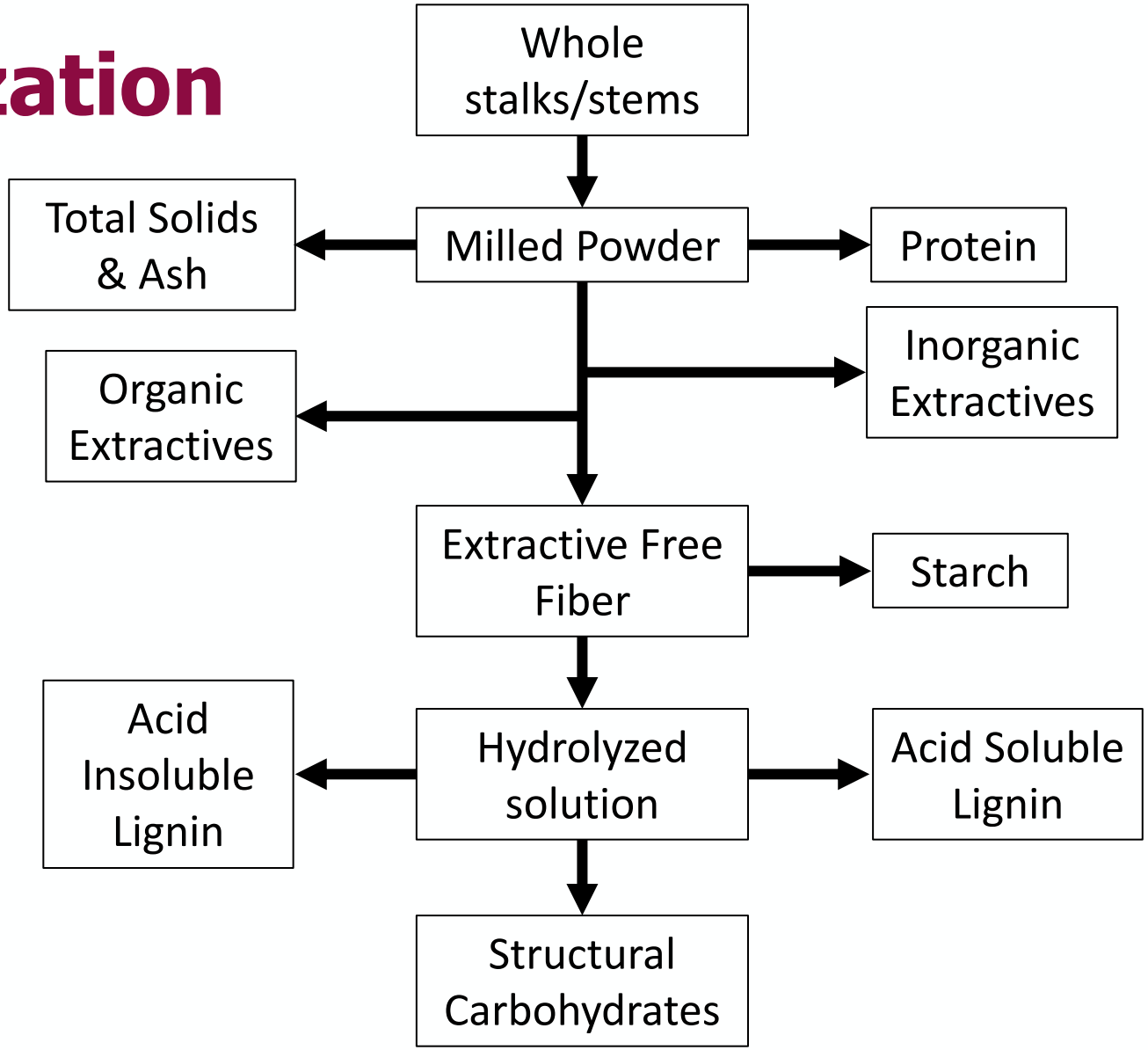
Comparison to Grain & Fiber Type Hemp

Table # – Reported Average Values for Structural Components in Untreated Hemp Fiber Samples				
Fiber Sample	*Glucan [%]*	*Xylan [%]*	*Lignin [%]*	*Reference*
Industrial hemp (Futura 75; < 1mm particle size)	36.5	17.0	21.9	Das et al., 2017
Industrial hemp (11 cultivars)	43.81-51.14	11.63-14.2	15.35-29.35	Das et al., 2020
Industrial hemp (Felina 32; conventional cultivation)	39.8	14.4	15.0	Kuglarz et al., 2014
Industrial hemp (Felina 32; organic)	42	14.8	13.2	
Industrial hemp (Fedora 17)	46.4	20.1	15.0	Kuglarz et al., 2016
Industrial hemp (unspecified variety; hurds only; 40-60 mesh sizes)	42.37	19.2	17.5	Moxley et al., 2008
Industrial hemp (unspecified variety; powered; bast)	57.5	1.6	16.2	Singh et al., 2018
Industrial hemp (unspecified variety; powdered; shives)	42.9	19.9	23.9	
Industrial hemp (4 varieties)	33.56-44.52	10.62-15.48	17.92-21.48	Viswanathan et al., 2020
CBD hemp (ACDC x Cherry Wine)	32.63	12.90	16.98	
Industrial hemp (4 varieties)	40.12-42.71	12.53-16.56	14.56-17.79	Zhao et al., 2020a
Industrial hemp (Tygra)	40.66	13.25	15.74	Zhao et al., 2020b

How similar are fibers from high-CBD types to fiber/grain types?

Characterization of Waste Fibers

- Supplemental feedstock for other hemp bio-based chemicals?
- NREL Summative Mass Balance



Average Solids, Ash, and Extractives Content (w/w%)

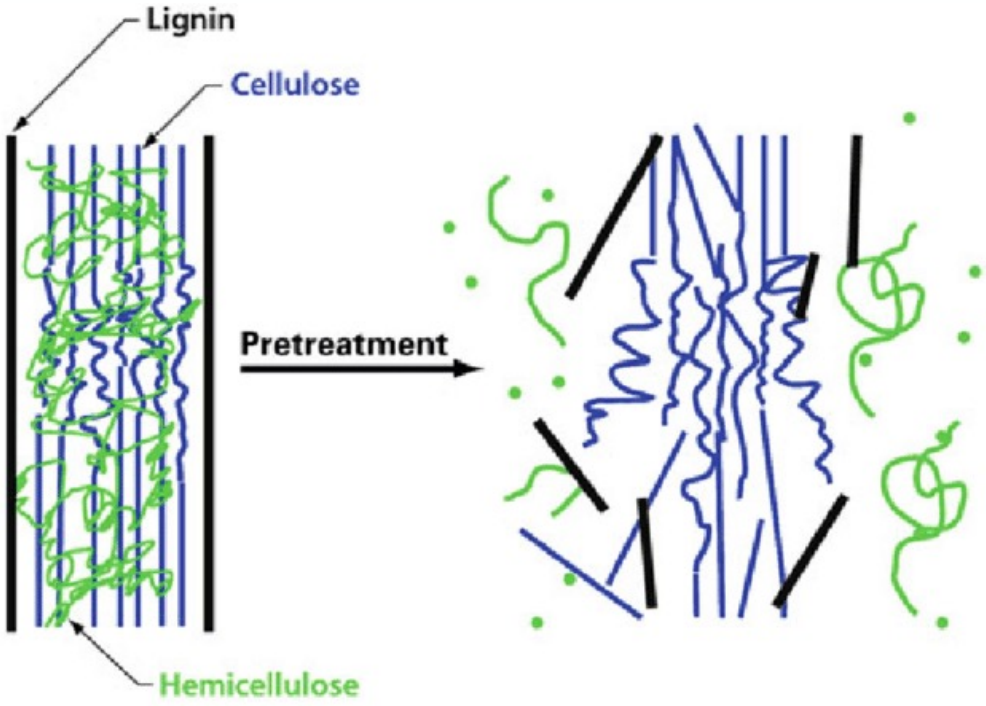
- Total Solids:
  oven 105 °C for 4 h
- Ash:
  muffle furnace at 575 °C for 4 h
- Total Extractives:
  Soxhlet extraction refluxed with water for 6-8 h; followed by ethanol for 12-16 h

Location	Variety	Treatment	Total Solids	Ash	Total Extractives
Leyendecker	Sweetened	Standard	94.6	5.2	16.4
		Water-stress	94.0	6.0	10.8
	Wife	Standard	93.7	5.4	15.1
		Water-stress	93.9	4.8	12.2
Alcalde	Sweetened	Standard	94.6	-	14.3
		Organic	94.3	-	-
	Wife	Standard	94.8	-	13.4
		Organic	95.4	-	13.3

Structural Components

- ***ONGOING***

- Dilute acid assisted hydrolysis
  - 72% H_2SO_4, 30 °C water bath for 1 hr
  - 4% H_2SO_4, autoclave, 121 °C for 1 h

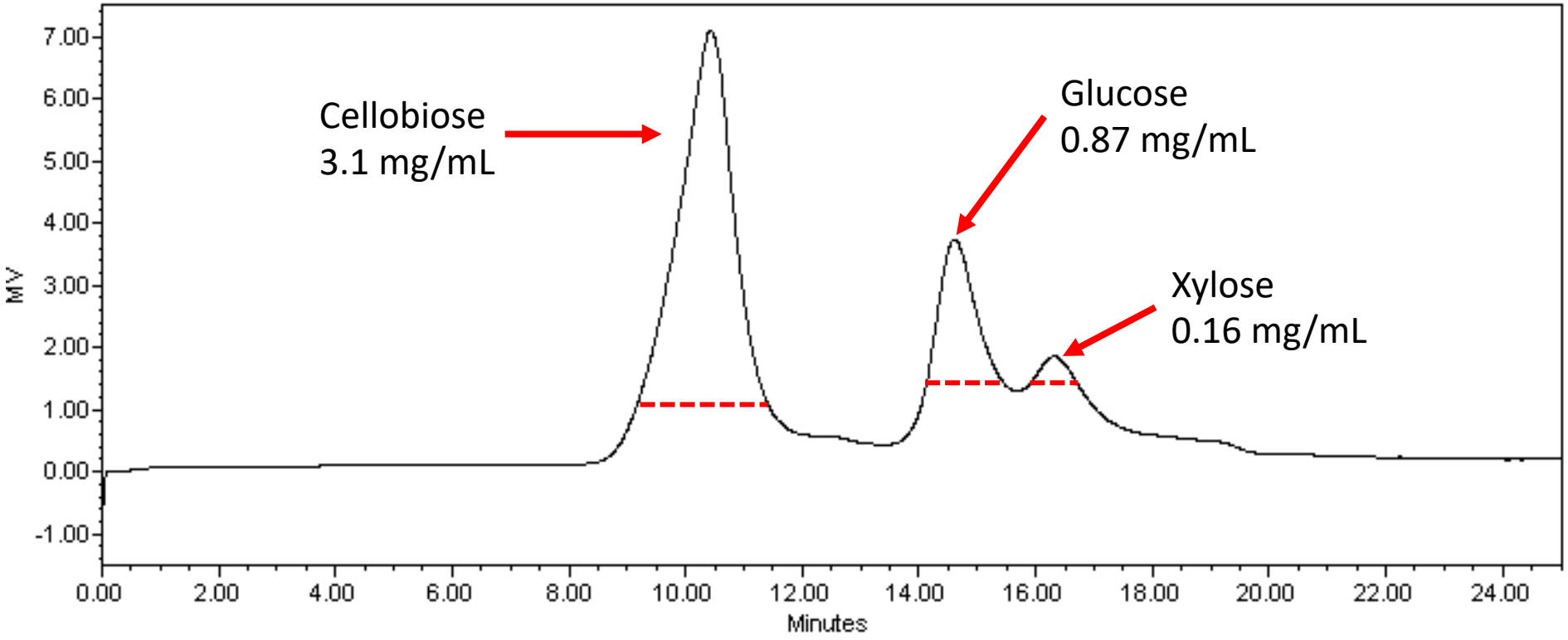


- Determine lignin from acid soluble/insoluble fractions and total sugars (glucose + xylose) in hydrolysis liquor

Ji, X., Huang, H., Nie, Z., Qu, L., Xu, Q., & Tsao, G.T. (2012). Fuels and Chemicals from Hemicellulose Sugars. *Advances in biochemical engineering/biotechnology. 128,* 199-224. https://doi.org/10.1007/10_2011_124

Structural Sugar Profile

- High performance liquid chromatography (HPLC):
  - Shodex sugar column
  - Water mobile phase
  - Refractive index (RI)



Can fibers from high-CBD hemp be used alongside industrial types as feedstock for bio-based chemicals?

Conclusion

Values in major compositional categories fall within ranges of reported for other industrial hemp types (*so far*)

Potential Economic Value-Added

- How much residual fiber material is available from high-cannabinoid production?

Given: 520,105 plants (current state count, NM Cannabis Control Division)

Assuming: Average flower yield of 1.5 lb as 60% of total plant weight

Biomass Availability:
40% of 2.5 lb gives 1 lb fiber per plant
1 lb/plant * 520k plants = 520k lb fiber

→ Estimate ~500k lb of fiber waste available annually
→ What is the value of biomass for bioconversion?

Next Steps

- Need to verify consistent behavior during pretreatment/conversion
  - Influence of physical properties on mixing?
  - Reactor design?

- What hydrolysis conditions result in the highest sugar yield?
  - Costs association with processing steps?

Additional Acknowledgements

- Dave Lowry, Ryan Garcia, and Rob Heyduck; additional superintendents, farm managers, and staff at field trial locations

- Undergraduate students from Brewer Research Group

- Rich Global Hemp for providing hemp material

Questions?

Contact Information

Hanah Rheay

New Mexico State University

Department of Chemical and Materials Engineering

handsr@nmsu.edu