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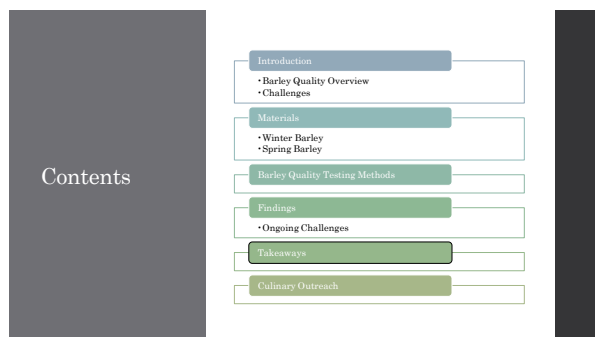
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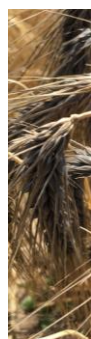
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- 'Developing Multi-use Naked Barley for Organic Farming Systems'
- Funded by USDA – Organic Agriculture Research Extension Initiative
- Grant numbers 2017-51300-26809 & 2020-51300-32179

- Evaluate under organic conditions:
  - Agronomic Performance
  - Animal Feed
  - Malting and Brewing Performance
  - Food Quality

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## Nutrition of a Barley Kernel

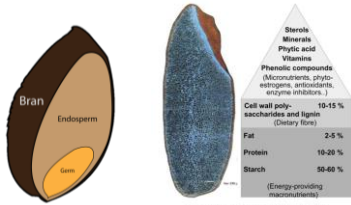


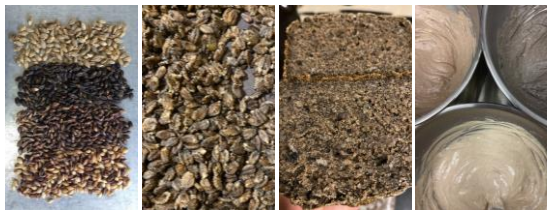
Fig. 1. The cereal grain is a versatile raw material.  
Prostamen R. (2012) Past and future of cereal grains as food for health. *Trends in Food Science & Technology* 25:58-62. doi: 10.1016/j.tfs.2012.02.003

**Table 2**  
Fiber Content of Several Whole Grains\*

Grain	Fiber (g/100 g)
Barley (rolled)	17.5
Brown rice (milled grain)	3.4
Millet	12.5
Coarse ground	7.5
Oats	10.8
Rye	15.1
Unpolished (white)	6.7
Whole (dark, whole)	12.2
Wheat (dark)	6.2

\*Source: U.S. Department of Agriculture, Agricultural Research Service, 2010. USDA National Nutrient Database for Standard Reference, Release 28. Retrieved from: <http://www.ars.usda.gov/food/nutrient/>

**Source: USDA, 2010**  
\*Source: U.S. Department of Agriculture, Agricultural Research Service, 2010. USDA National Nutrient Database for Standard Reference, Release 28. Retrieved from: <http://www.ars.usda.gov/food/nutrient/>



### Color

- Anthocyanins & Melanins
- Antioxidant function



## Protein

- Wheat (top) vs. Barley (bottom)
  - Differences in baking performance
- Many unknowns in barley protein quality

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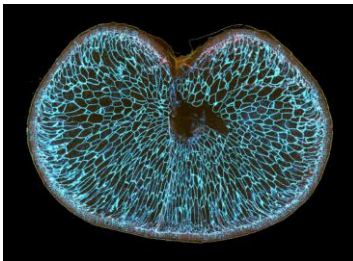
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## Barley $\beta$ -Glucan



VTT Technical Research Centre of Finland

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## Starch Type

- Non-waxy
  - ~ 25% Amylose; 75% amylopectin
  - $\beta$ -Glucan: 3 - 6%
- Waxy
  - ~ 5% Amylose; 95% amylopectin ratios
  - $\beta$ -Glucan: 6 -10%
- Same hydration (200%)
  - Non-waxy (Top)
  - Waxy (Bottom)

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## Challenges with Food Barley

- Substituting an ingredient for barley flour results in changes of sensory and processing characteristics
- Barley quality and functionality is not defined in systematic way
  - Diverse in composition, but limited information provided
  - Unpredictable performance
- Food barley breeding programs struggle as a result
- Need a research effort to improve whole grain barley foods

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## Research Questions

How do genetics and environment affect a chosen set of barley food quality traits?

What is a minimum number of traits that could usefully characterize the overall functionality of naked food barley?

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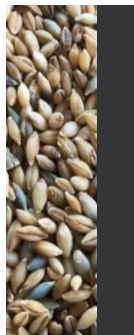
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## Materials

Winter Barley  
Spring Barley




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## Winter Materials

- Genotypes
  - 12 non-waxy
  - 3 waxy
- Locations
  - Corvallis, OR
  - Freeville, NY
- Harvest Years
  - 2018, 2019, 2020

Genotype	Breeding Program	Starch	Color
10.0655	Oregon State (OSU)	Waxy	White
10.0662	OSU	Waxy	White
DH133529	OSU	Non-Waxy	White
DH133535	OSU	Non-Waxy	White
AMAZE 10	Virginia Tech (VT)	Non-Waxy	White
VA15H-79WS	VT	Non-Waxy	White
Buck	OSU	Non-Waxy	White, Pale Blue
#STRKR	OSU	Non-Waxy	White, Pale Blue
10.1154	OSU	Non-Waxy	White
10.1986	OSU	Non-Waxy	White
10.1492	OSU	Non-Waxy	White
1_4	OSU	Non-Waxy	White
DH133783	OSU	Non-Waxy	White
DH140490	OSU	Waxy	White
DH140504	OSU	Non-Waxy	White

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## Spring Materials

- Genotypes
  - 11 non-waxy
  - 6 waxy
- Locations
  - Corvallis, OR
  - Freeville, NY
  - Madison, WI
  - Arlington, WI
- Harvest Years
  - 2018, 2019\*, 2020\*

Genotype	Breeding Program	Starch	Color
10.0655	Oregon State University (OSU)	Waxy	White
10.0662	OSU	Waxy	White
DH133529	OSU	Non-Waxy	White
DH133535	OSU	Non-Waxy	White
10WAN-129.6	Washington State University (WSU)	Non-Waxy	White
12WAN-106.12	WSU	Non-Waxy	White
BR28	OSU	Non-Waxy	Black
BR5	OSU	Non-Waxy	Black
CDC Ascent	University of Saskatchewan (USask)	Waxy	White
CDC Carter	USask	Non-Waxy	White
CDC Clear	USask	Non-Waxy	White
Havener	WSU	Waxy	White
Mag's song	WSU	Waxy	White
MS1084111-01	University of Minnesota (UMN)	Non-Waxy	White
MS1084115-03	UMN	Non-Waxy	White
Purple Valley	Landrace	Non-Waxy	Purple
5-36-OCOLOR	OSU	Waxy	Purple

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# Methods

Pre-cooking Traits  
Cooking Traits



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Methods

Pre-cooking traits

- Hardness Index (HI)
- Grain Protein (%)
- $\beta$ -Glucan (%)
- Flour Water Absorption
  - Water-Solvent Retention Capacity (W-SRC) (%)
  - Batter Flow (cm)

Cooking traits

- RVA Starch Pasting
  - Peak Viscosity (cP)
  - Breakdown (cP)
  - Peak time (min.)
- Cooked Whole Grains
  - Yield (%)
  - Texture (g)

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Batter Flow

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Methods

Pre-cooking traits

- Hardness Index (HI)
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  - Yield (%)
  - Texture (g)

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# RVA

Useful for determining starch type

Can detect pre-harvest sprouting (PHS)



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# Methods

Pre-cooking traits

- Hardness Index (HI)
- Grain Protein (%)
- $\beta$ -Glucan (%)
- Flour Water Absorption
  - Water-Solvent Retention Capacity (W-SRC) (%)
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  - Peak time (min.)
- Cooked Whole Grains
  - Yield (%)
  - Texture (g)

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# Texture Analyzer



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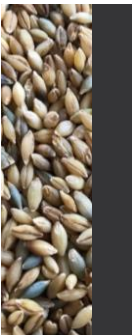
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# Findings



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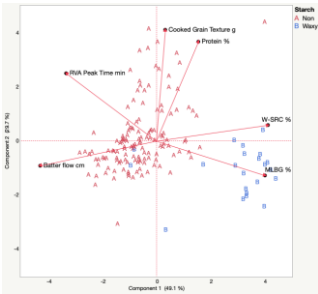
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## Winter PCA

- 6 traits explained most of the variability (78.8%)
- Starch type drives major differences
- Pragmatic endpoint



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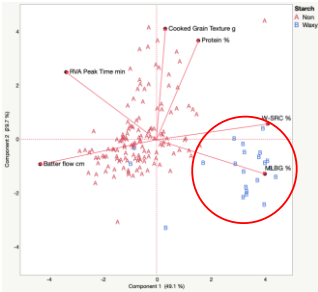
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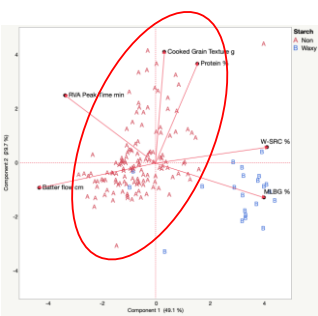
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# Winter PCA

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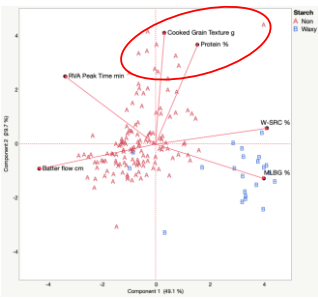
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# Winter PCA

- 6 traits explained most of the variability (78.8%)
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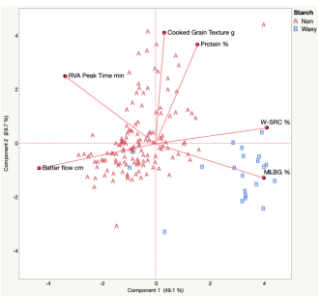
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# Winter PCA

- 6 traits explained most of the variability (78.8%)
- Starch type drives major differences
- Pragmatic endpoint



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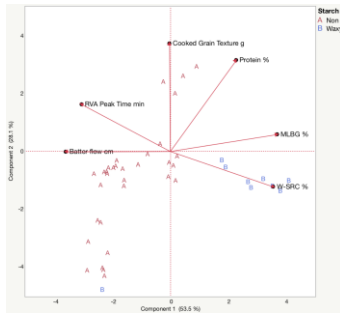
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## Spring PCA

- Same six traits as winter trial
- Vector map similar to winter results
- Starch type continued to drive major differences




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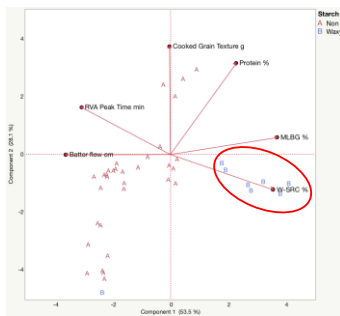
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## Spring PCA

- 6 traits
  - 81.6% of variance represented across PC1 & 2
- Low leverage traits same as winter trial
- Vector map similar to winter results
- Starch type continued to drive major differences




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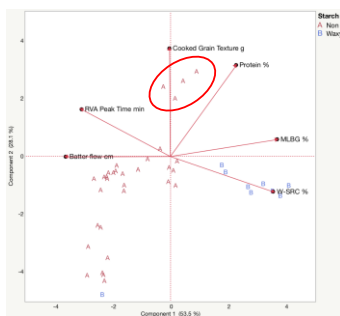
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## Spring PCA

- 6 traits
  - 81.6% of variance represented across PC1 & 2
- Low leverage traits same as winter trial
- Vector map similar to winter results
- Starch type continued to drive major differences




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## Challenges

- Smut
  - Corvallis Spring 2019
- Pre-harvest sprouting
  - Spring Trials

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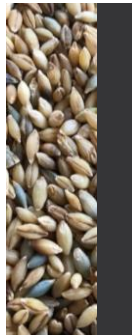
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## Pre-Harvest Sprouting

- Pre-harvest sprouting
  - Corvallis: 0%
  - Freeville: 38.1%
  - Madison: 53.3%
  - Arlington: 55.0%
  - 2018: 69.6%
  - 2019: 17.7%
  - 2020: 4.2%
- Need for sprouting resistance
- Selecting suitable growing locations




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## Takeaways

- Genotype and environment and their interactions had significant effects on naked barley composition and downstream functionality.
  - Genotype was always significant, but not always the largest influence
- A manageable number of six traits were identified that effectively characterize overall food barley functionality.
  - Non-waxy low protein barley
  - Non-waxy high protein barley
  - Waxy barley
  - Colored barley

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### Takeaways

- Breeding for sprouting resistance
- Continuation of linking functionality tests to end use quality
  - Which traits are best for pastries? Pancakes? Bread? Noodles?
- Increasing fiber intake while enjoying whole grain foods

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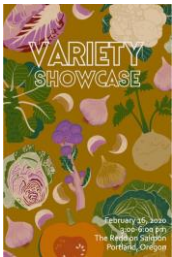
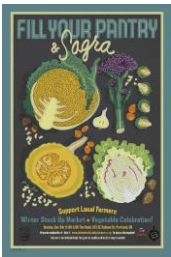
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### Culinary Outreach



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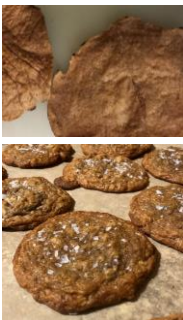
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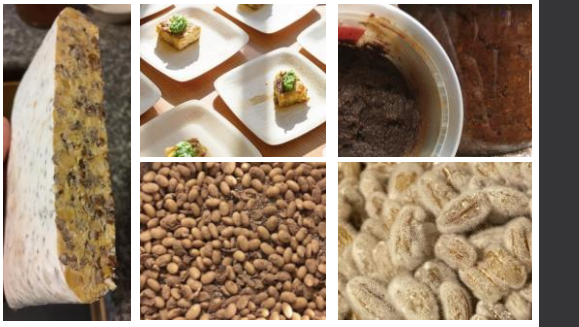
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## Acknowledgements



- Advisors
  - Andrew Ross, Brigid Meints, and Patrick Hayes
- Collaborators
  - University of Wisconsin Madison, Cornell, University of Minnesota, and UC Davis
- OSU Barley World
  - [www.barleyworld.org/](http://www.barleyworld.org/)
- Culinary Breeding Network
  - [www.culinarybreedingnetwork.com/barley-world](http://www.culinarybreedingnetwork.com/barley-world)
- eOrganic




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