Kernza® Perennial Grain

Value Chain Development in Central Minnesota

August 2022

Agricultural Utilization Research Institute

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Agricultural Utilization Research Institute

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On behalf of:

Stearns County Soil and Water Conservation District

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In support of a project funded by:

The Minnesota Environment and Natural Resources Trust Fund

Contents

About this Report

Over the past three years the Agricultural Utilization Research Institute (AURI) took part in a project led by the Stearns County Soil and Water Conservation District (SCSWCD) focused on accelerating perennial crop production to protect water resources in Central Minnesota. The Minnesota Environment and Natural Resources Trust Fund provided funding for the project as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). The Trust Fund is a permanent fund constitutionally established by the citizens of Minnesota to assist in the protection, conservation, preservation and enhancement of the state's air, water, land, fish, wildlife and other natural resources.

AURI Project Activities

Working in collaboration with project partners at SCSWCD, the University of Minnesota Forever Green Initiative (FGI) and the Pope Soil and Water Conservation District, AURI led efforts for project activity 3: develop value chains for food and non-food applications of Kernza® perennial grain and native prairie seeds and biomass.

AURI's work included the following activities:

1. Development of value chains using Kernza in food uses.
    a. Map, develop and report on Central Minnesota value chains utilizing Kernza in food and beverage products.
    b. Evaluate Kernza for inclusion in food applications.
    c. Provide technical information on the handling, storage and use of Kernza ingredients, and on formulation of food application concepts for Minnesota companies.
    d. Report on the market in Central Minnesota and statewide.
2. Coordination with project partners to provide information and content at educational events, forums and field days on market opportunities for Kernza.
3. Development of value chains using Kernza in non-food uses, including feed, fiber and fuel.

The overall goal of AURI's work is to support development of a sustainable value chain for Kernza, resulting in new opportunities for Minnesota farmers and businesses to produce and utilize a crop that offers environmental benefits and protects water quality in Minnesota's wellhead protection areas.

AURI Mission and Project Team

AURI's central mission is to foster long-term economic benefit for Minnesota through value-added agricultural products. In order to pursue this mission, AURI provides a broad range of services aimed at expanding markets, developing new uses and improving processes. AURI's unique mix of facilities, professional staff and network of partners combine to provide a one-of-a-kind resource that focuses on creating more value for Minnesota's agricultural products.

As part of its work on this project, AURI engaged a strong, internal project team with a wide variety of skills and areas of focus to pursue its technical, value chain development and outreach work in support of the project. AURI's project team included the following individuals:

Technical Team

- Luca Zullo, Ph.D. - Senior Director of Science & Technology
- Alan Doering - Senior Scientist, Coproducts
- Riley Gordon - Principal Engineer (Principal Investigator)
- Lolly Occhino- Senior Scientist, Food
- Michael Stutelberg, Ph.D. - Scientist, Chemistry
- Ben Swanson- Scientist of Food & Nutrition
- Abel Tekeste - Associate Scientist, Coproducts

Supply Chain Development Team

- Jennifer Wagner-Lahr - Senior Director of Business Development & Commercialization
- Alexandra Diemer - Business Development Director of Novel Supply Chains
- Matthew Leiphon - Project Manager
- Jason Robinson - Business Development Director, Food
- Dillon McBrady- Supply Chain Intern, University of Minnesota Carlson School of Management

AURI Connects Team (Outreach and Dissemination)

- Nan Larson - AURI Connects Manager
- Erik Evans - Director of Communications
- Lisa Martinez - Communications Coordinator
- Dan Skogen - Director of Government & Industry Relations

Project Title:	Accelerating Perennial Crop Production to Prevent Nitrate Leaching – *Activity 3: Value chain development of* Kernza® *in food and non-food uses*
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Executive Summary

AURI, in partnership with the Stearns County Soil and Water Conservation District (SCSWCD), advanced efforts to develop Kernza value chains for both food and non-food uses. This continuation of work began with an earlier investment of LCCMR funds related to Kernza and the potential to create a market for perennial crops offering a multitude of ecosystem services. Kernza studies have shown benefits including soil health regeneration, erosion prevention, habitat and perhaps most critical to the work in this study – water quality improvements. The City of Cold Spring in Central Minnesota has long struggled with sourcing water with lower nitrate content and has invested in expensive infrastructure to remove contaminants. Kernza could potentially grow in areas north of Cold Spring that have been designated as a wellhead protection area. This project partnered with private landowners to grow the Kernza. AURI's efforts focused on creating a value chain for local Kernza processing and demand. The reason was simple: if strong demand existed, farmers could see incentives to grow the crop through market forces. Activities included:

- Mapping, developing and reporting on Central Minnesota value chains utilizing Kernza in food, beverage and non-food uses (feed, fiber and fuel). Early on assistance from a University of Minnesota Carlson School of Business graduate student explored value chain and pricing models. AURI staff assessed the potential for Central Minnesota businesses to participate in the value chain in preparation for pilot projects and outreach efforts.
- Evaluating Kernza for inclusion in food applications in partnership with Northern Crops Institute (NCI) in Fargo, North Dakota. NCI conducted scale up milling of Kernza flour and tested both refined and whole grain flour in various food products, at various inclusion rates, for the identification of optimal end uses.
- Conducting a value analysis of the straw and hulls from Kernza to identify possible end uses and theoretical market values for these crop components. The team primarily focused on value opportunities such as feed, fuel and bedding. However, after reviewing the Kernza straw composition, AURI connected with C2Renew in Fargo, ND and supplied them with 200 pounds (lbs) of ground Kernza straw to develop a biocomposite material. C2Renew had success creating 500lbs of biocomposite pellets combining the ground straw with a poly-lactic acid (PLC) resin and showcased the material by thermal forming discs. In the future, they plan to use residual pellets for molding beer mugs which would be distributable amongst many of the project partners. The Sasya LLC work surrounding high value extractable sugars in Kernza straw is also available within this report.
- Providing technical information on the handling, storage, ingredient utilization, and formulation of food and beverage application concepts for Minnesota companies. AURI partnered with Rahr Malting Company to malt several hundred pounds of cleaned and dehulled Kernza for distribution to regional breweries for experimentation. A report outlining considerations and benefits of malting Kernza is included.
- Partnering with several businesses in the region, supplying them with cleaned and dehulled Kernza grain from the Stearns County 2020 harvest to work with, to grow the supply chain and knowledge base.

- Reporting on the Kernza market in Central Minnesota and statewide.
- Coordinating with project partners to provide information and content at educational events, forums and field days on market opportunities for Kernza. Due to the COVID-19 pandemic, several planned outreach efforts were cancelled or took on a different format than expected (e.g.: webinars, etc.). However, AURI was able to convene an in-person group under the Fields of Innovation platform which focused the first event of its kind around Kernza, as well as multiple virtual events.

Assessing the Value Chain in Central Minnesota

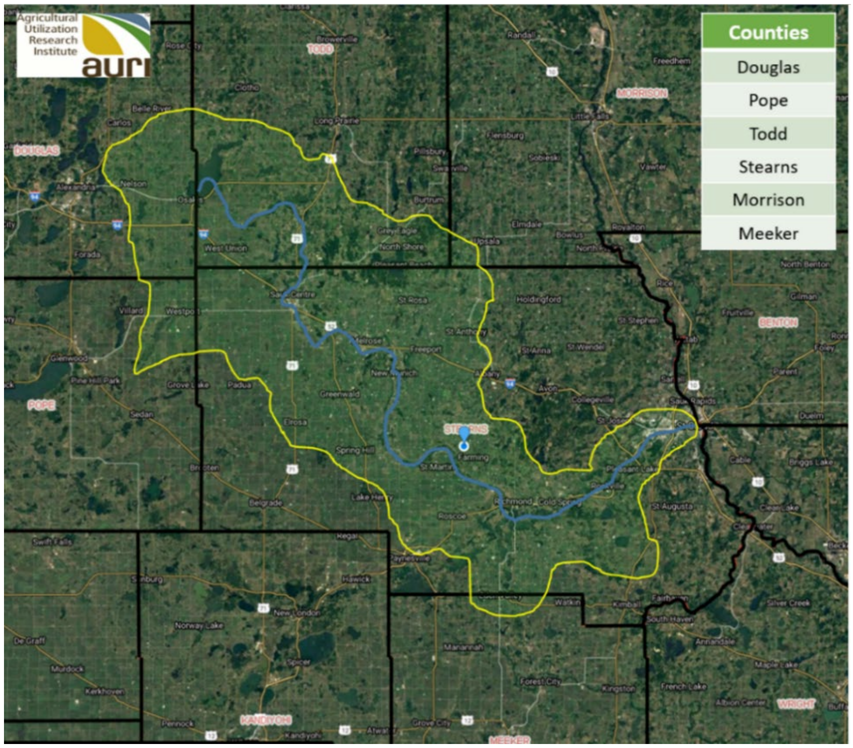
Defining the Region

For the purposes of this report, the definition of Central Minnesota is the counties wholly or partially within the Sauk River Watershed, which covers the area of focus for water protection activities associated with the wider LCCMR-funded project. The Sauk River Watershed lies in the heart of Central Minnesota, encompassing a complex system of streams and 374 lakes, and covering over 1040 square miles.[i] The watershed extends from just east of Alexandria to the Mississippi River near St. Cloud. The Sauk River meanders about 120 miles, and flows near the cities of Sauk Centre, Melrose and Cold Spring. The Sauk River watershed offers a unique opportunity to plant and harvest Kernza perennial grain, as the ground is particularly sandy, and nitrate run-off can be detrimental to the water system.

In a 2012 report, the Minnesota Pollution Control Agency identified overland run-off as one of the major stressors to the watershed.[ii] Over 50% of the land cover in the Sauk River watershed contains cultivated cropland, so erosion due to snowmelt and precipitation delivers sediment, nutrients and other materials (manure, pesticides, etc.) to aquatic life in the watershed when crops aren't planted on the land. Because Kernza is a perennial crop with a deep root system, it catches the potential run-off and keeps it from entering the water system, in turn preserving the aquatic life therein.[iii]

When researching potential end-users for Kernza products in Central Minnesota, the Agricultural Utilization Research Institute (AURI) predominately focused on counties across the Sauk River Watershed. These counties include Douglas, Pope, Todd, Stearns, Morrison and Meeker. (See Figure 1)

Figure 1: Map of Sauk River Watershed[iv]



Regional Demographics

The Minnesota State Demographic Center estimates that the total population of the six-county area in 2019 was 290,859, with a total of 114,897 households. Stearns County has the highest population at 160,211, with its major population center of St. Cloud having a population of around 67,000, according to the state's most recent estimates. (See Table 1)

Table 1: Estimated Population and Household Size- Central Minn.

County	Year	Population[v]	Households	PPH
Douglas	2019	38,220	16,713	2.26
Meeker	2019	23,256	9,324	2.46
Morrison	2019	33,368	13,395	2.45
Pope	2019	11,139	4,931	2.23
Stearns	2019	160,211	60,587	2.53
Todd	2019	24,665	9,947	2.45
Total		**290,859**	**114,897**	**2.53**

The 2020 decennial census showed a total regional population of 291,278. Data on household demographics for the decennial census was unavailable as of June 2022, so the 2019 figures still offer utility as a guide to the number and size of households in the region. The statewide "persons per household" estimate in 2019 was 2.53— identical to the Central Minnesota average. St. Cloud, the region's trade and population center had a population of 68,881 in the 2020 census— an increase of 4.6% since the 2010 count.

Median household incomes in the area range from $54,502 in Todd County, to $65,430 in Douglas County. Each county in the region has a median household income below the Minnesota state median household income of $73,382. (See Table 2)

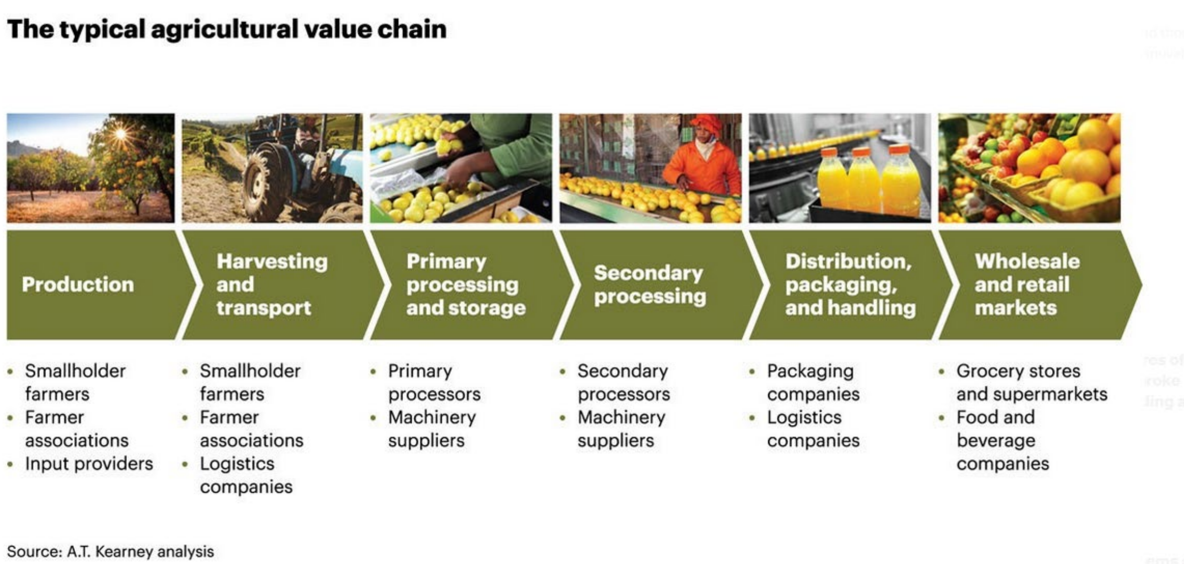
Table 2: Median Household Income, Central Minn.

Median Household Income	
Douglas	$65,430
Meeker	$63,841
Morrison	$58,826
Pope	$62,878
Stearns	$65,244
Todd	$54,502
Minnesota	$73,382
Source: U.S. Census Bureau 2020 American Community Survey- 5-year estimates	

Defining the Value Chain

Value chain analysis is an important exercise for an emerging crop such as Kernza. In agriculture, the value chain incorporates the progression of a crop from farm to table. At each step of a value chain, additional "value is added" to the product. Value chain analysis provides a useful means to evaluate the potential to strengthen the participation of private entities along the various steps from the field to the plate. The figure below provides a typical view of an agricultural value chain and formed the basis for the AURI's efforts.

Figure 2: Agricultural Value Chain



A well-developed value chain creates a pathway (and often multiple pathways) for agricultural products. This was the driving force behind AURI's work: to create a strong demand "flow" for the Kernza harvested from Central Minnesota farms. It is important to note that the bulk of this work occurred in the midst of the worldwide COVID-19 pandemic. While the pandemic created complexity, it highlighted the challenges of complicated, long supply chains. Thus, this work took on new meaning as it focused on shorter and local supply chains.

> *"The U.S. agri-food system faces many of the same challenges as other sectors in delivering reliable, accessible, and affordable products, as well as unique or amplified vulnerabilities. Common vulnerabilities include transportation bottlenecks from aging infrastructure, labor shortages, cyber security threats, and competition issues resulting from market concentration in business sectors. In addition, the agri-food system possesses at least two features that cause it to have unique or amplified supply chain vulnerabilities. First, even temporary disruptions to food supply chains immediately affect nearly every American household, as food needs to be frequently purchased and consumed daily. Second, agricultural production is seasonal and highly exposed to (abiotic and biotic) environmental stresses, and products are often highly perishable. These features warrant both general and specific measures to strengthen agri-food supply chain resilience both domestically and abroad."*
>
> *- USDA Agri-Food Supply Chain Assessment: Program and Policy Options for Strengthening Resilience*[vi]

Generally speaking, understanding value chains is a critical component of AURI's work. AURI focuses on adding value to Minnesota's agricultural products. The organization's work includes business development, commercialization and technical assistance at multiple stages along the value chain, including primary processing and storage, secondary processing, distribution, packaging and handling, as well as wholesale and retail markets. Identifying opportunities to optimize and innovate existing value chains is a common theme. From the identification of new value streams for undervalued waste products to the development of new products and technologies, AURI staff assist over 100 clients annually with product and process innovation. More recently, the organization has started to apply this expertise to new and emerging crops and industries.

Staff identified companies that could play a role in helping to establish a Kernza industry and a cluster in Central Minnesota. The main idea was to establish a hyper local value chain beginning with farmers growing Kernza as a cash crop and coordinate progress through to the processing, distribution and ultimately retail segments to reach the consumer.

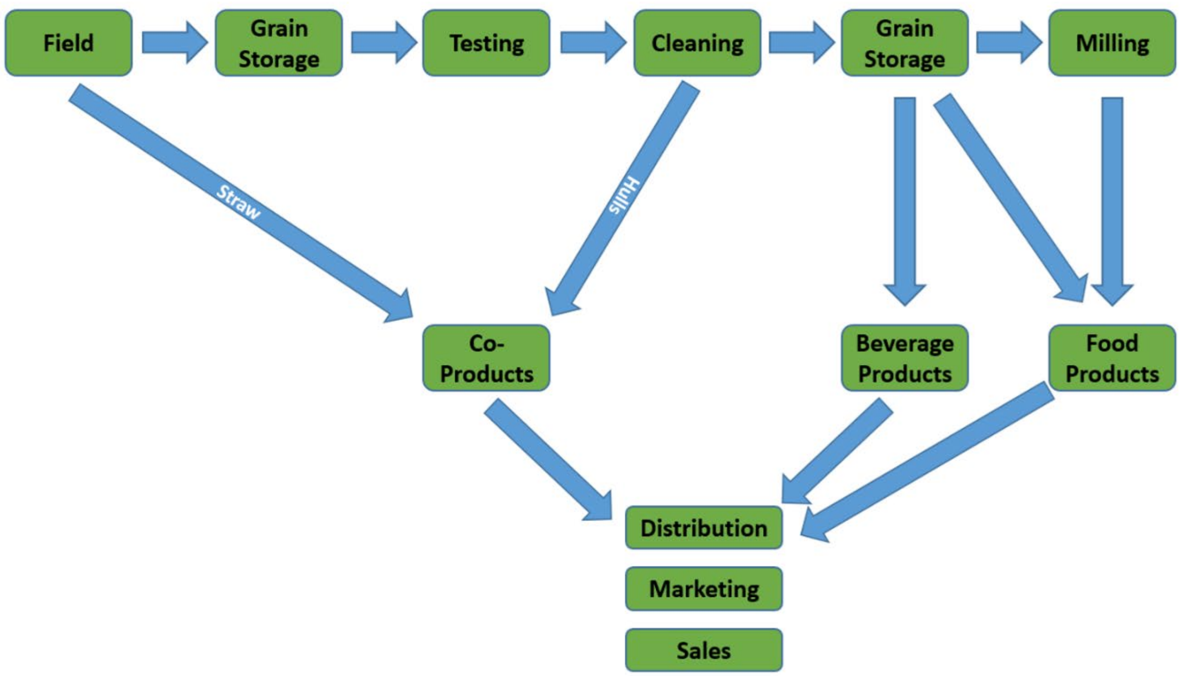
Kernza Value Chain

In 2019, AURI staff began to look at the value chain for Kernza as an initial phase of work. The team zeroed in on companies already active in the Central MN region that could fulfill critical steps along the value chain. As a point of introduction, the team explored several supply chains mostly focused on food products. Of note, the team examined milling, beverage manufacturing (brewing and distilling), and bakery and bread products. The team also investigated the potential uses for Kernza coproducts as feed and as a feedstock for biopolymers.

The Kernza supply chain starts with the seed dealers supplying the seed to farmers for planting. Other inputs, such as fertilizer and chemicals, are sourced from ag retailers. As of 2021, at two Minnesota-based companies, including Albert Lea Seed and MNL, have licenses to "grow, buy, sell, and distribute the MN-Clearwater variety Kernza seed."[vii] As of July 2022, MNL listed a price of $100 per acre for MN-Clearwater seed.[viii] Growers who are interested in buying seed must obtain a license to produce the crop. Licenses are issued to growers by the Land Institute, which is committed to "bringing [the] crop to scale in a responsible manner,"[ix] in an effort to "mitigate risk to our grower partners."[x]

Upon harvest, the grain is either stored or tested for immediate delivery to buyers, while the straw is baled for coproduct opportunities. After testing, the grain is cleaned or dehulled. A detailed mapping of the Kernza supply chain is provided below (See Figure 3).

Figure 3: A Supply Chain Map of Kernza in Central Minnesota



For the purposes of this report, AURI analyzed supply and demand for each step of the supply chain and identified Central Minnesota businesses at each step for pilot projects. AURI also reached out to key businesses outside of Central Minnesota with background and abilities that could support supply chain development. In addition to identification of key current and potential stakeholders in Central Minnesota, this process resulted in the identification of potential gaps in the region's supply chain where infrastructure was lacking or underdeveloped. While the main focus was supply chain development in Central Minnesota, the overall supply chain included individuals and organizations throughout Minnesota and beyond, to engage the right stakeholders and access wider markets. AURI reached out to businesses inside and outside of Central Minnesota with the ability to fill gaps and pursued pilot projects to bolster overall supply chain development efforts.

Supply from the Field: Measuring Production

According to the Land Institute's latest "State of Kernza" report, Minnesota lead the nation in Kernza acreage in 2021, with 1,417 acres under production by 57 growers.[xi] Over one third of the nation's Kernza acres are in Minnesota. Minnesota's 57 growers also accounted for nearly 40% of the nation's Kernza growers, underscoring the state's leadership in bringing the crop to market. Minnesota is in a strong position to develop markets for Kernza due to supply and strong demand among processors, buyers and consumers, coupled with indicators of relatively strong interest around the crop. (See Table 3)

Table 3: Kernza: Acreage and Growers Nationwide

State	Acres	Percentage of U.S. Acres	Growers	Percentage of U.S. Growers
Minnesota	1,417	33.9%	57	38.5%
Kansas	930	22.2%	29	19.6%
Montana	498	11.9%	6	4.1%
South Dakota	278	6.6%	5	3.4%
Wisconsin	272	6.5%	17	11.5%
Nebraska	217	5.2%	4	2.7%
Oklahoma	100	2.4%	1	0.7%
Colorado	92	2.2%	3	2.0%
Illinois	86	2.1%	6	4.1%
Wyoming	60	1.4%	4	2.7%
California	58	1.4%	1	0.7%
New Mexico	45	1.1%	1	0.7%
North Dakota	40	1.0%	1	0.7%
Iowa	38	0.9%	4	2.7%
New York	31	0.7%	6	4.1%
Idaho	20	0.5%	1	0.7%
Michigan	1	0.0%	1	0.7%
Ohio	1	0.0%	1	0.7%
Total, Nationwide	4,184		148	
Source: The Land Institute, "State of Kernza," Kernza.org				

Production in Central Minnesota

While 2021 data was not collected by region in Minnesota, 293 acres of Kernza were grown in Central Minnesota in 2020. These acres made up 22% of the total Kernza acreage in Minnesota at the time. (See Table 4). Since the region is a prime area for intermediate wheat grass given the crop's water protection benefits, there is strong potential for regional acreage to grow as the value of Kernza continues to be communicated to local farmers and groups develop programs to encourage adoption and markets for Kernza-based products.

Table 4: Kernza Grown in Minnesota in 2020 by Region

Region	# of Plantings	Total Acres	% Total Acres	Avg. Size in Acres
Central	12	293	22%	24
SE	14	200	15%	14
SW	11	394	30%	36
Warroad/Roseau	5	296	23%	59
N/A	2	40	3%	20
WI	5	87	7%	17
Total	**49**	**1,310**	**100%**	**27**

According to the Forever Green initiative[xii], 931 acres of Kernza were planted in Minnesota in 2020. (See Table 5) 2020 plantings represented 70% of the state's total acreage to date, reflecting a strong growth trajectory for the crop, with total acres under production growing by over 1,000% between 2017 and 2020. As the benefits of Kernza are communicated to the end-user and more mature markets and value chain connections develop, expectations are that these acres will rise to meet demand.

Table 5: Kernza Planted in Minnesota, 2017-2020

Year Planted	# of Plantings	Total Acres	% Total Acres	Avg. Size in Acres
2017	4	80	6.11%	20
2018	8	148	11.30%	19
2019	10	151	11.53%	15
2020	27	931	71.07%	34
Total	**49**	**1,310**	**100%**	**27**

Project Production

As part of this value chain development project, partners planted approximately 36 acres of Kernza. The Stearns County Soil and Water Conservation District identified and coordinated the plantings. One farmer planted the acreage on a combination of owned and rented fields. Harvesting of this crop occurred in August 2020 and yielded around 18,000 pounds of Kernza perennial grain, providing a yield of approximately 500 pounds per acre. After cleaning and dehulling a total of 11,700lbs of the grain on two separate occasions over the duration of the project, AURI received a total of about 6,500lbs of cleaned and dehulled grain for pilot projects. At the close of this project, AURI currently had 3,300lbs of cleaned and dehulled grain, 1,000lbs cleaned and in-hull grain and 2,000lbs of non-cleaned and dehulled grain. The remaining grain will be reserved for Kernza pilot projects as part of ongoing LCCMR funded projects.

Testing

Currently, grain quality testing is a gap in the supply chain for Central Minnesota. While AURI has conducted several tests and researched equipment needs for testing, there were no identified companies within the Central Minnesota market providing Kernza-specific testing services. While testing standards may change as the market matures, the Land Institute's "Kernza Identify Preserved Program Guidelines" note that "tests on Kernza destined to be food must be tested for the following: Purity, DON, moisture and protein."[xiii] In addition to tests for vomitoxin (DON), AURI looked at options for aflotoxin testing to assess the overall quality for food use. This project recommends the testing take place prior to cleaning or dehulling. If multiple lots will be stored together, the recommendation is to also test before blending lots to avoid unnecessary cross contamination.

While Kernza-specific services were not available, labs with experience handling wheat and other grain crops do offer testing services. During the project, AURI utilized State Grain Inspection in Savage, Minn. to conduct 24-hour turnaround DON and aflatoxin testing for the 2020 crop. Several labs in Minnesota and surrounding states will run these tests for a relatively low fee, however, when faced with the situation of combining multiple lots in one bin, it was important to find labs with the ability to run tests and report results within one day of sample receipt to ensure quick results and minimal delays before transferring the grain to stable, secure storage. AURI plans to further study optimal storage conditions for Kernza under a new LCCMR funded project in partnership with the Stearns County Soil & Water Conservation District.

Cleaning/Dehulling

Kernza requires cleaning and dehulling to prepare the whole grain for use. This is one of the larger challenges when it comes to processing Kernza, as the grain is smaller than wheat and other small grains and can require specialized knowledge and machinery to process. In previous LCCMR-funded research,[xiv] AURI identified and reviewed various cleaning equipment options manufactured by Bratney Company. (See Table 6)[xv]

Figure 4. In-hull vs. Dehulled Kernza®

Table 6. Cost Estimates of Cleaning and Dehulling Equipment Setup Options for Kernza (Provided by Bratney Company)

Cleaning Equipment	Fanning Mill, Dehuller, Aspirator, *Gravity Table*** and Color Sorter			Fanning Mill, Dehuller, Aspirator and Color Sorter		
Throughput (ton/hr)	1	3	5	1	3	5
Price	325-375k	690-790k	950-1200k	280-330k	605-705k	780-1030k

Cleaning and Dehulling Options in Minnesota

In Minnesota, several small businesses focus on cleaning and dehulling specialty grains, and several have increased their activity in the last few years as Kernza production has increased. AURI worked with Sprowt Labs/Perennial Pantry as they experimented with different machines for cleaning/dehulling Kernza. Another business which may play a future role is Forsberg in Thief River Falls, which produces dehulling machines. Additionally, MNL (formerly known as Minnesota Native Landscapes) in Otsego, Minn. has experience cleaning various native grass seeds. During the project, AURI experts met with the team at MNL to gauge their interest in handling the crop. They expressed interest and have begun to offer cleaning and dehulling services "for both seed quality and fully dehulled for grain quality."[xvi]

Cleaning and Dehulling - Central Minnesota

During the project period, AURI did not identify any businesses with experience in cleaning and dehulling Kernza in Central Minnesota. Cleaning of grain used during the project was done by companies at facilities outside the region who had prior experience with the crop or were actively working with growers to develop experience and capacity. While there may be businesses that have equipment or technology that could be adapted for cleaning and dehulling Kernza, they have yet to develop capacity.

Given the limited volume of production in the region, specialty cleaners with grain handling experience outside the region may continue to be the best option for processing in the short to medium term. However, if acreage increases, processors in and around the region may begin to explore options for toll processing.

Milling

Minnesota has a rich milling history and once held the title of "Flour Milling Capital of the World."[xvii] While the number of flour mills has declined, there is still a notable milling industry in the state. AURI staff were keen to identify smaller mills given the likelihood they would be more agile and allow for experimentation with a lower volume of a new and emerging grain. Of particular note for this project was Swany White Flour Mills, located in Freeport, Minn. (Stearns County)

Pilot Projects

AURI worked closely with Swany White Flour Mills in Freeport, Minn. to pilot milling of Kernza. Swany White is a small-scale flour mill and was open to working with new and novel grains to make flour. Its hammermill can grind flour down to 1/64" and process around 500lbs/hr. Swany White also utilized a stone mill to test Kernza milling. Researchers dialed in the mill to its finest gap setting, but the resulting flour was still too coarse by AURI and other end users, when compared with the hammermilled flour. During pilot runs, the hammermill worked well to produce a sufficiently fine whole grain Kernza flour. Throughout the duration of the project, Swany White worked with AURI to mill flour for samples and larger lots. As a result, Swany White gained experience milling Kernza and now offers toll milling services to produce Kernza flour. For further information on the scope of AURI's work with Swany White throughout this project, see the pilot project report section later in this report.

Beverage Products

One of the Kernza end products showing signs of opportunity is beer. Patagonia launched a Kernza beer in 2016 and noted the grain added a "subtle spiciness" to the pale ale.[xviii] In the last three years, there have been a variety of Kernza beers launched, including several in Minnesota.[xix] While most brewers are using around 10-20% of Kernza for in the grain mix, they are still "looking for ways to experiment with it, try it out in products, [and] bring it to market."[xx]

In the last decade, the microbrewing industry exploded in Minnesota. According to a 2021 University of Minnesota study, Minnesota was home to 183 breweries.[xxi] While the Twin Cities is a major hub for breweries, there has been tremendous growth throughout the rest of Minnesota. Regarding Kernza, multiple breweries in Minnesota produced beer with Kernza. In Central Minnesota and beyond, a wide variety of brewers have experimented with Kernza in their products. As the supply of grain and malts grows, this trend will likely continue.

Kernza-based distilled products are also a market with notable potential. Kernza-based spirits are under development by several distilling companies in Minnesota and may provide an outlet for grain with quality issues that make it less suitable for use in food products and brewing.

AURI identified several breweries and distilleries in Central Minnesota that could be potential producers of Kernza-based beverages. (See Table 7)

Table 7: Breweries and Distilleries

Business	Type	Location	County
Bad Habit Brewing	Brewery	St. Joseph	Stearns
Beaver Island	Brewery	St. Cloud	Stearns
Pantown Brewing	Brewery	St. Cloud	Stearns
Third Street Brewhouse/Cold Spring Brewing	Brewery	Cold Spring	Stearns
Minnewaska House Brewing	Brewery	Glenwood	Pope
Starry Eyes Brewing	Brewery	Little Falls	Morrison
22 Northmen Brewing	Brewery	Alexandria	Douglas
Copper Trail Brewing	Brewery	Alexandria	Douglas
Naked Viking Brewing	Brewery	Glenwood	Pope
Back Shed Brewing	Brewery	St. Cloud	Stearns
Panther Distillery	Distillery	Osakis	Douglas
Ida Graves Distillery	Distillery	Alexandria	Douglas

Throughout the course of the project, AURI worked with Minnewaska House Brewing and Beaver Island Brewing to develop pilot projects producing Kernza-based beers. During exploration of potential distilling industry opportunities, AURI also connected with NETZRO, a Minneapolis-based food upcycling company to explore options for use of distiller's grains, including Kernza. While the team did not identify a distilling pilot project for development during the project, AURI technical staff identified opportunities for further work that will be pursued as part of new LCCMR-funded projects.

Malting

Kernza beer market development will drive opportunities for malting Kernza. Demand for malt Kernza will likely depend on the qualities brewers seek. Kernza is useable as both a malted product and an unmalted adjunct grain in brewing recipes, similar to how wheat is used in beer.

While Central Minnesota does not have any malting companies, Minnesota does have several maltsters of varying sizes that may serve as potential producers of malt Kernza. For example, Rahr Malting Company, of Shakopee, is a major international producer of base and specialty malts for the brewing industry. During this project, AURI technical staff collaborated with experts at Rahr to examine the malting process for Kernza. A report from this work (see Appendix D) concluded that Kernza had "strong potential for malting and brewing applications."

Food Products

Kernza has a variety of potential uses in food products, from its simplest form as whole grain, to flour, flatbread, crackers, bread, pasta and mixes. As with wheat, this wide array of potential uses for Kernza provides an abundance of opportunities for Minnesota's food industry.

According to the Minnesota Department of Employment and Economic Development (DEED), the state's agricultural production and processing industries "generate over $112 billion annually in total economic impact."[xxii] The Minnesota restaurant industry alone boasted over 10,500 restaurants with $10.7 billion in estimated annual sales in 2018.[xxiii] While the COVID-19 pandemic created major challenges for the industry, leading to shutdowns and closures throughout the state, the sector has begun to bounce back. According to a spring 2022 survey by Hospitality Minnesota, 70% of food-service establishments projected that "summer revenue will meet or surpass pre-pandemic levels" in 2022.[xxiv]

Artisan grains, including Kernza, are attracting more interest from Minnesota food producers. Groups such as the Artisan Grains Collaborative, a midwestern network that includes millers, bakers, chefs, and food manufacturers, have hosted events in Minnesota to discuss growing industry interest in artisan grains including Kernza. Their Minnesota Grains Gathering highlighted the role that artisan grains can play as "a vital and growing part of the Minnesota economy," while bringing together key stakeholders to discuss how the state's agricultural industry can develop and meet increased demand for artisan grain-based products.[xxv] Central Minnesota's Kernza stakeholders are well positioned to play a key role in these efforts.

Central Minnesota

Central Minnesota is home to many restaurants, bakeries, food co-ops and other retail food establishments. As of 2022, there were 363 licensed "retail food handlers" in the six-county region selling food "other than restaurant food" that is "purchased to eat off the premises".[xxvi] [xxvii] This classification includes "grocery stores, convenience stores, bakeries, meat stores, wineries [and] brewery taprooms" that sell food for human consumption "directly to the consumer or indirectly through a delivery service."[xxviii]

In addition to these retail food handling operations, the region is home to 39 licensed wholesale food handlers, which "predominantly hold food and sell to other businesses for resale."[xxix] Central Minnesota is also home to several wholesale food producers and manufacturers. As of 2022, the Minnesota Department of Agriculture (MDA) reported there were 78 producers in the six-county area licensed to make food and sell it to other businesses for resale.

While there are a wide variety of food retailers, wholesalers and manufacturers in the region, not all entities are a good fit for Kernza, particularly while the crop remains limited in supply and costs remain comparatively high. AURI identified five potential wholesale Kernza grain/flour retailers (See Table 8) and seventeen restaurants/bakeries (See Table 9) in region for potential pilot projects.

Table 8: Wholesale Kernza Grain/Flour

Business	Type	Location	County
Good Earth Food Co-op	Co-op	St. Cloud	Stearns
Minnesota Street Market, Food & Art Co-op	Co-op	St. Joseph	Stearns
Sprout	Food Hub	Little Falls	Morrison
The Purple Carrot Market	Co-Op	Little Falls	Morrison
Natural Food Co-Op	Co-Op	Litchfield	Meeker

Table 9: Restaurants and Bakeries

Business	Type	Location	County
Backwards Bakery/Collegeville Artisan Bakery	Bakery	Collegeville	Stearns
Bello Cucina	Restaurant	St. Joseph	Stearns
Coborn's	Grocer/Bakery	Multiple	Multiple
Cold Spring Bakery	Bakery	Cold Spring	Stearns
College of St. Benedict/St. John's Dining Services	Food Service/Bakery	Collegeville	Stearns
Jules Bistro (pizza)	Restaurant	St. Cloud	Stearns
Krewe	Restaurant	St. Joseph	Stearns
Artisan Naan Bakery	Bakery	St. Cloud	Stearns
St. John's Bread	Bakery	Collegeville	Stearns
Albany Home Bakery	Bakery	Albany	Stearns
Melrose Bakery	Bakery	Melrose	Stearns
The Local Blend	Restaurant	St. Joseph	Stearns
Bart's Bakery	Bakery	Sauk Centre	Stearns
Belgrade Bakery	Bakery	Belgrade	Stearns
Little Falls Bakery and Deli	Bakery	Little Falls	Morrison
Roers Family Bakery	Bakery	Alexandria	Douglas
Jacobs Lefse Bakeri	Bakery	Osakis	Douglas

During the project period, AURI team members communicated with owners of several of these businesses to share information about Kernza and discuss potential pilot projects. As a result of this outreach, AURI was able to pursue pilot projects and share samples for product development with several interested businesses. Collaborations of particular note included Artisan Naan Bakery, Coborn's and Krewe. The "pilot projects" section of this report includes a full report on the Artisan Naan project.

Coproducts

It is difficult to create a market for co-products of a crop that is still in its early stages of market development. In this case, Kernza straw and hulls have potential for use in feed or bedding products.[xxx] The use of the co-products as feed or bedding will be at the farm level initially. Once there is a more sizeable Kernza crop, thus creating more biomass volume, more potential co-product use opportunities will surface. Later in the report, the performance of Kernza hulls and straw in various co-product opportunities is discussed in greater detail.

Post-Harvest Aggregation

Given the limited production in Central Minnesota, the small volumes of Kernza grain are managed with on-farm storage. Long-term storage requirements for the grain would be similar to those for other small grain crops, such as wheat.

As production increases in the region, options for off-farm storage may become necessary. Coordination is necessary between grower groups, such as the Perennial Promise Growers Cooperative, and processors, wholesalers and end-users to ensure safe storage, quality testing, and transit. Much of the market in Central Minnesota is likely to consist of smaller lots of grain for processing and use by toll processors and small-scale end-users. In the near term, much of the coordination of these transfers and associated storage and transport will be facilitated through direct “grower to buyer” transactions.

As the market matures, there may be more interest from third-party buyers and wholesalers interested in handling and storing the crop to meet emerging demand. Companies such as Healthy Food Ingredients (HFI) in Valley City, N.D., have already tentatively entered the market, cleaning and storing grain for sale to end users. While outside grain handlers like HFI have been active in the Central Minnesota market, opportunities may emerge for specialty grain buyers based in the region as production volume and demand rises.

As Kernza becomes a more established crop, local grain buyers may become an outlet for post-harvest aggregation and marketing. As of July 2022, Central Minnesota (six-county region) was home to 27 facilities licensed by the state of Minnesota to buy and store grain. (See Table 10) These range from small independents and farmer cooperatives to large corporate grain buyers, offering a range of potential outlets depending on the size and scope of Kernza production in the region.

Table 10: Facilities Licensed to Buy and Store Grain

NAME	CITY	COUNTY
ARCHER DANIELS MIDLAND CO	SAINT CLOUD	STEARNS
B & S GRAIN LLC	FARWELL	POPE
CENTRA SOTA COOPERATIVE	UPSALA	MORRISON
CENTRA SOTA COOPERATIVE	ALBANY	STEARNS
CENTRA SOTA COOPERATIVE	SAINT MARTIN	STEARNS
CENTRAL REGION COOPERATIVE	COSMOS	MEEKER
COLD SPRING COOP	COLD SPRING	STEARNS
ECKER FEED SERVICE LLC	NEW MUNICH	STEARNS
ELROSA GRAIN & FEED INC	ELROSA	STEARNS
FAMO FEEDS INC	FREEPORT	STEARNS
GENOLA GRAIN CO INC	GENOLA	MORRISON
HOLDINGFORD MILL LLC	HOLDINGFORD	STEARNS
J V PAPPENFUS ELEVATOR INC DBA GREENWALD ELEVATOR	GREENWALD	STEARNS
KLC FARMS ROASTING INC	SAUK CENTRE	STEARNS
KULUS FEED STORE INC	FLENSBURG	MORRISON
LUXEMBURG FEED SERVICES INC	SAINT CLOUD	STEARNS
MIDWEST PROTEIN LLC	GROVE CITY	MEEKER
OLSONS CUSTOM FARM SERVICES INC	STAPLES	TODD
OSAKIS CREAMERY ASSN	OSAKIS	DOUGLAS
PIERZ COOPERATIVE ASSN	PIERZ	MORRISON
PRO AG FARMERS COOPERATIVE	CLARISSA	TODD
PRO AG FARMERS COOPERATIVE	EAGLE BEND	TODD
PRO AG FARMERS COOPERATIVE	BRANDON	DOUGLAS
PRO AG FARMERS COOPERATIVE	GARFIELD	DOUGLAS
REGAL ELEVATOR INC	BELGRADE	STEARNS
ROSCOE FEED & GRAIN	ROSCOE	STEARNS
SUNRISE AG COOPERATIVE	BUCKMAN	MORRISON
Source: Minnesota Department of Agriculture, Licensing Information Search- July, 2022[xxxi]		

Valuation

Market prices for Kernza perennial grain remain quite high compared to other small grains, likely due to low supply and limited channels for marketing as the crop is still in the early stages of supply chain development and market formation. In early 2022, Minnesota Kernza stakeholders reported prices for Kernza grain ranged from approximately $4.50 per cleaned pound for conventionally raised grain to $6.00 per cleaned pound for organically raised grain. Growers also reported that buyers appeared to be willing to pay a premium over the organic price of grain with a regenerative organic certification.[xxxii]

As part of this work, AURI utilized a graduate student intern from the Carlson School of Management at the University of Minnesota to assist in the mapping of businesses in Central Minnesota who could participate in a Kernza value chain. This intern conducted research around pricing strategies as well as collecting Kernza pricing information from various sources. This information is in Appendix R of this report: "Kernza: Demand, Valuation and Market Segmentation."

Pilot Project: Artisan Naan Bakery

St. Cloud, Minn.

Project Focus: Baked Good Applications
Uses/Products: Flatbreads – Naan and Pita

Pilot Partner

Artisan Naan Bakery (artisannaan.com) is a small batch, specialty bakery owned and operated by Tahir Sandu and Gwen Williams in St. Cloud, Minn. Originally founded at a smaller location in St. Joseph, Minn. in 2014, Tahir and Gwen relocated operations to its current location in 2020. The bakery's product portfolio consists of fresh naan, naan pizza crusts, pita pockets, hand pies and whole pies. As of January 2022, wholesale customers included: Lunds & Byerlys, Wedge Community Co-Op, Eastside Food Co-op, Linden Hills Food Co-Op, Seward Community Co-Ops and Lakewinds Food Co-Ops in the Twin Cities and central Minnesota, as well as Good Earth Food Co-Op in St. Cloud, Minnesota Street Market in St Joseph and City Center in Princeton.

Project Overview

The Agricultural Utilization Research Institute (AURI) partnered with Artisan Naan Bakery to commercialize naan and pita flatbreads utilizing whole grain Kernza flour milled at Swany White in Freeport, Minn.

Initially, AURI provided enough whole grain Kernza flour to support development of flatbread-style naan and pita for consumer feedback at the St. Cloud Farmer's Market in June 2021. Shortly thereafter, Artisan Naan began to sell Kernza naan to wholesale customers in the Twin Cities metro, with the first deliveries in August 2021.

Product Development Process

AURI first contacted Artisan Naan in August 2020 via a survey of Central Minnesota businesses that may have interest in developing new market opportunities with Kernza whole grain flour. Gwen Williams, co-owner of Artisan Naan Bakery, responded with significant interest and the pilot project officially kicked off in January 2021 with delivery of roughly a pound each of a fine grind hammer-milled flour and a coarse grindstone ground flour.

Figure 5. Kernza® Flatbreads – First Kernza® Naan Production (May 14, 2021); Kernza® Pita Pockets on display at Lunds & Byerlys, Maple Grove, MN (Jan 28, 2022

)

Initial baking results indicated a preference for the fine grind hammer-milled flour at a 25% Kernza whole grain / 75% white patent flour ratio:

> *We preferred the way our naan dough came together with the finer flour, which could have been because the wheat flour we use has a similar grain size to the fine flour. The stone ground flour, as a dough, seemed wetter and less resolved so the feel in our hands was different with the stone ground—it felt grainy; the finer flour dough had a feel in our hands more like our standard naan dough—smooth, not grainy.*

Four of us ate the Kernza naan from both flours. Two of us enjoyed both equally and two of us preferred the way the finer flour felt in the mouth. [There was] very little notable difference in bread density or crumb structure. Ultimately, the preference for the finer flour wasn't overly pronounced nor strong.

As it relates to Kernza to patent flour ratio, we tried a 25/75 Kernza to patent; 35/65 Kernza to patent; and a 75/25 Kernza to patent. We were pleased with all the results, with the 75/25 Kernza to patent being a much bolder tasting naan—approaching the boldness of a light rye bread. The 25/75 Kernza to patent and the 35/65 Kernza to patent were very similar in taste; milder than a rye, but still the whole grain flavor [and] a nutty tone came through. The deciding factor was the then-projected cost per pound of the Kernza flour. Since the 25/75 and the 35/65 were very similar in taste, we went with the 25/75 to keep costs down. We also went with the lower ratios because the sunflower oil (in our vegan version of naan) tasted better in the lower Kernza ratio breads. I think if the cost of Kernza flour per pound came down such that we could flip the ratio around, then we would also make the bolder 75/25 Kernza to patent naan.
– Gwen Williams

Following the initial bake testing, AURI delivered fifty pounds of fine grind hammer milled whole grain Kernza flour from Swany White in March 2021. It was used to prepare naan for the St. Cloud Farmers Market in June 2021, with the preferred 25% Kernza whole grain / 75% white patent flour blend. In preparation, AURI attended the first production scale bake of Kernza naan in May 2021.

After a month of directly selling Kernza naan at the Farmers Market and the bakery storefront, Artisan Naan decided to sell Kernza flatbread products (including naan and pita pockets) to wholesale customers in the Twin Cities metro, with the first deliveries in August 2021. To facilitate this distribution expansion, AURI prepared nutrition fact panels for both the Kernza naan and pita pockets and provided guidance to Artisan Naan on establishing a stable supply chain for Kernza whole grain flour.

After six months in expanded Twin Cities distribution, Artisan Naan provided the following feedback in February 2022 on the usage of six different production lots (defined as combinations of Kernza varietal, production location and day, and growing location) of Kernza whole grain flour, as they worked to establish a stable supply chain:

At this juncture, the bakery has used (6) different Kernza flours, and what I mean by (6) different Kernza flours pertains to the source, the miller and the lot. We have baked with AURI supplied pilot project flour milled by Swany White Mills. We have baked with (2) lots of MN Clearwater flour milled by Baker's Field & Flour: I am using lot to refer to milling days (I believe their source was one batch of grain). And we have baked with (3) lots of C5 flour sourced through Sustain-a-Grain in Kansas. The (3) lots of C5 were labeled as different lots and were likely from different growers (based on the variation in color of the flour); and these could have been milled at different mills—we don't know the milling situation in Kansas.

The (6) different Kernza flours differed in the fineness of the milled flour, and for our baking purposes created no issues for us in mixing the dough or in baking of the breads. The greatest variation in the (6) different Kernza flours was the color of the flour.

> "**Baking bread with Kernza has enabled our bakery to expand and diversify its fresh bread products, with the Kernza Naan being our first whole-grain naan to find committed, repeat customers.**"
>
> *Gwen Williams, Co-Owner, Artisan Naan Bakery*

The bakery has used two commercially milled Baystate Milling whole grain wheat flours for a few years, and we will see some variation in the color of flour, but the general dominant color has remained consistent over time. By dominant color, I mean it ranges from yellowish, to brownish, to grayish, for example. We doubt any customers have noticed a difference in baked product color, because that would require the customer to remember the pita pocket from 3 months ago was slightly darker or deeper brown; but we have noticed at the bakery.

Compared to the Baystate Milling whole grain wheat flours, the Kernza flours had a much wider range in color: from a speckled snowy owl (brown, white, tan mixture), to a khaki speckled flour (brown, khaki, green-khaki, little bit of white), to a yellow-leaning khaki speckled flour (pale-golden yellow, khaki, brown, little white), to a gray-brown speckled khaki flour (basically the khaki with not much yellow hues at all, but a grayish brown). The different flour colors produced different color baked breads, and some customers may have noticed the difference in color over time—although none have told the bakery so. In the baked product, the different colors of flour are particularly noticeable where caramelization has occurred on the naan or pita. The yellow-leaning speckled flour produces very attractive reddish-brown caramelized spots (attractive from our personal standpoint).

We would emphasize that as far as the bakery is concerned, we believe this difference in color of our baked naan or pita is no problem; for us, our customers or our sales. But we can imagine that for some bakeries, this lack of consistency may be an issue.

Finally, the (6) different Kernza flours all produce the same characteristic "Kernza aroma" when baking, and we have not discerned any difference in taste between the (6). Smells and tastes are even more difficult to describe than colors but let me say by "Kernza aroma" we mean that there's a certain "whole grain" aroma that is distinct, even from the Baystate Milling whole grain wheat flours. It's very pleasant.
- Gwen Williams

Project Outcomes

As a result of this project, Artisan Naan has been able to diversify its product portfolio with its first whole-grain Kernza product to find consistent and stable demand. Additionally, Artisan Naan is proud to claim that it is the first Minnesota bread bakery to place any Kernza bread on grocery store shelves in the Twin Cities metro, with firm plans to place Kernza bread in more stores by early spring 2022. Finally, resulting from their need to establish a consistent supply, Artisan Naan was instrumental in providing regular feedback to AURI and the newly formed Perennial Promise Kernza® Grower's Cooperative (http://www.perennialpromise.com/) on the needs of commercial users of whole grain Kernza flour. This feedback will help facilitate establishment of a stable whole grain Kernza flour supply chain in Central Minnesota.

Pilot Project: Beaver Island Brewing

St. Cloud, Minn.

Project Focus: Brewing Applications
Uses/Products: Beer - Saison

Pilot Partner

Co-owned by Matt Studer, Nick Barth and Chris Lamb, Beaver Island Brewing Co. has operated since 2015 in a downtown St. Cloud taproom, offering a wide variety of craft beer to Stearns County residents. Since opening its taproom nearly seven years ago, Beaver Island has expanded to a dedicated facility near the St. Cloud Airport to keep up with demand.

Project Overview

The Agricultural Utilization Research Institute (AURI) partnered with Beaver Island to develop a craft beer utilizing Kernza. The team at Beaver Island conducted initial internal sensory testing of the grain to determine the best beer in which to utilize Kernza. They then brewed 10-15 barrels of the beer and served it in the taproom.

Figure 6. Kernza® Saison brewed by Beaver Island using Kernza® grown in Stearns County, Minnesota.

Beaver Island patrons that tried the beer received a consumer questionnaire to gather anonymous feedback and distributed onsite utilizing a QR code that guests scanned to complete the survey. AURI compiled and analyzed the feedback to help with business development of future pilot projects.

Product Development Process

AURI reached out to Beaver Island Brewing, the largest brewery in Stearns County. After initial introductions, conversations with Beaver Island's Brewmeister, Chris Lamb focused on where Beaver Island Brewing could utilize Kernza in its existing product lines. A Saison was chosen as the style of beer with which to test the Kernza inclusion. This pilot project utilized malted, hulled Kernza for the formulation and was provided to Beaver Island by Rahr Malting Company. Overall, 200lbs of malted Kernza and 25lbs of Kernza hulls were shipped to Beaver Island for the brewing of the Saison. Kernza hulls were utilized due to concerns that the Kernza inclusion could create issues with lautering and transfer of the beer from the mash tun to the boil kettle. Kernza hulls were substituted for rice hulls due to their appearance and to investigate whether Kernza hulls were usable instead for recipes where lautering/drainage was a concern.

For the formulation, Kernza substituted for the wheat in the original formulation and replaced at a 1:1 ratio, which accounted for roughly 20% of the final grain bill. Due to the size of the berries, the Kernza was added directly to the mash tun, separate from the other grain in the formulation. Besides the Kernza and Kernza hull replacements, the Saison formulation and brew day process were the same. During the brew day project leaders noted that the Kernza hulls made an excellent substitute for rice hulls and Chris was able to transfer the beer at full speed with no issues. The beer went through its boil phase, then cooled in a fermentation tank where it fermented for 3-4 weeks, after which it was kegged and served on tap at Beaver Island's downtown St. Cloud taproom.

Prior to serving, a questionnaire was created to help gather information from consumers. The full questionnaire and its results can be found in the Appendix. The questionnaire included 11 questions related to the consumer's familiarity with Kernza, overall liking of the beer, purchasing and general demographic inquiries. AURI then provided a QR code to Beaver Island to distribute the anonymous survey in its taproom.

Figure 7. Beaver Island Brewmeister brewing the Kernza® Saison at its St. Cloud taproom.

Project Outcomes

The Beaver Island Brewing pilot project was able to supply the following notes on the usage of the grain:

- The Kernza berries were very small compared to its usual grain. Beaver Island added grain directly to the mash as Brewmeister was concerned that the grain wouldn't work with the grain auger.
- Kernza hulls were effectively used as a replacement for rice hulls to help mitigate any issues with lautering of the beer during the brew day. Potential to utilize as a substitute for rice hulls in other formulations.
- Grain performed well and achieved original target gravity. The pH was slightly lower than expected (~0.1 point lower than expected).
- At the current usage rate for the Saison, the Kernza didn't appear to have any noticeable effect on the final color of the product.
- The pilot project noted Kernza added a slight nutty flavor profile to the final product, though not as much as during the mash/boiling of the beer.
- The consumer questionnaire yielded 34 unique responses and valuable feedback for utilization in future Kernza projects and business development.

As a result of this project, Beaver Island Brewing not only added a new beer to its menu, but was also able to work with AURI to gather valuable consumer feedback. For detailed results of this consumer survey see Appendix F. Overall, the majority of survey participants were unaware of Kernza, and even fewer had tried Kernza in a product. Even without the recognition of the grain, the overall response to the beer was significantly positive with almost 90% of participants liking the beer moderately or greater. Many of the participants reported that they would like to try other Kernza products because it's sustainable and to support local businesses and farmers. The demographic of this particular consumer study was typically male, middle aged and earning between $50,000 and $100,000 a year.

> **"The Kernza added a nice nutty profile to the beer, and it has been a success in our tap room."**
>
> *Chris Laumb, Brewmaster, Beaver Island Brewing Co.*

Pilot Project: Minnewaska House Brewing Co. & Grill

Glenwood, Minn.

Project Focus: Brewing Applications
Uses/Products: Beer - Cream Ale

Pilot Partner

Minnewaska House Brewing Co. & Grill in Glenwood, MN, is owned and operated by Darren and Angie Anderson. Established in 2004 and inspired by Darren's grandfather (one of Minnesota's first beer distributors), the Minnewaska Supper Club was renovated to include a small brewery onsite, leading to the production and selling of a line of craft beer alongside a bar and grill menu. In tandem with their Brewmeister Grozio Blevins, the brewery now has an extensive list of craft beer on tap.

Project Overview

The Agricultural Utilization Research Institute (AURI) partnered with Minnewaska to develop a craft beer utilizing Kernza. To start, internal sensory testing determined which beer variety would best highlight the Kernza grain. Once the variety was determined, Minnewaska brewed roughly 30-40 gallons of the beer in its onsite brewery.

Figure 8. Minnewaska House Brewing tapped its first keg of Kernza® Cream Ale in the Spring of 2021.

Product Development Process

AURI first reached out to Minnewaska House through a mutual connection with the Pope County Soil and Water Conservation District SWCD. After initial discussion with the team on the benefits and uses of Kernza in brewing, Minnewaska agreed to participate in a pilot project to brew a beer incorporating Kernza grain. Product development began with a conversation with the Brewmeister at Minnewaska House about what the goals of utilizing Kernza in a beer. AURI provided its one-page brewing document about the overall characteristics that Kernza to Minnewaska. Next, they reviewed the tap list to determine a suitable fit for incorporation of Kernza. Roughly 20lbs of unmalted Kernza was sent to Minnewaska for the brewing test.

After some initial sensory tests, Minnewaska's Cream Ale was selected as a suitable candidate due to its style and the potential for Kernza to contribute a nutty aroma and flavor. In addition, the Cream Ale contained another ingredient replaceable directly with Kernza without worry of interfering with the beer's profile. For the pilot trial, Minnewaska replaced the malted white wheat already in the formulation with unmalted Kernza at a 1:1 ratio and this was the only change to the Cream Ale.

The Kernza inclusion rate was roughly 10% to start due to concerns of a stuck sparge during the initial mash step. There were no observable issues during the lautering process and Minnewaska noted it would try to increase the usage rate in the future. After 3-4 weeks of fermenting, the batch was kegged and served to the general public, and the beer received a positive reception. Informal responses indicated that not only did patrons enjoy the beer, they liked the idea of using Kernza due to its environmental benefits, including reduction of soil erosion, protection of water quality and support for local farmers.

Figure 9. Minnewaska House Brewing Brewmaster Grozio Blevins getting ready to add the Kernza® grain to its Cream Ale.

Project Outcomes

Minnewaska House Brewing supplied the following notes on the usage of the grain after brewing with it:

- The Kernza berries were very small compared to its usual grain. This could be an issue for breweries that can't readily adjust the mill's gap setting for a proper crush.
- The numbers on brew day were good, pre-boil gravity and original gravity going into the fermenter were on target and the pH was 0.2 points lower than predicted.
- Going into the fermenter, the Kernza didn't appear to have any noticeable effect on color and the cooled wart did have a slightly nutty flavor and aroma.
- After fermentation, the color of beer was slightly darker but not drastic. The nutty flavor and aroma noted after the mash did not appear to carry through to the keg.

As a result of this project, Minnewaska not only added a new beer to its menu but also expanded its experimentation in brewing with Kernza to another of its regular beers, the Blonde Ale. There are also plans to utilize it in a sour beer. This project supplied AURI with crucial feedback on how Kernza behaves in a brewery and how it differs from production at a benchtop scale.

Pilot Project: Stengel Grain Cleaning

Milbank, SD

Project Focus: Grain Cleaning and Dehulling
Uses/Products: Kernza Grain from Combine

Pilot Partner

Stengel Seed and Grain is a 40-year-old family business owned by Doug Stengel focused on cleaning all types of grain and beans for the organic food industry. With six cleaning lines and four-color sorters, the company can run different products simultaneously to efficiently meet the needs of customers. Stengel's father and grandfather began grain cleaning their seeds while farming. And though the process of cleaning grain hasn't changed much over the last 100 years, the equipment used has incorporated modern technology. Today's food industry requires near perfection in product purity, and this often requires very specialized equipment to achieve. Stengel Grain frequently builds customer specific machinery to meet the customers' needs.

-Sourced from StengelGrain.com

Project Overview

Stengel Seed and Grain expressed an interest in working with Kernza and serving as a mid-level processor for cleaning and dehulling in the Midwestern region. The Agricultural Utilization Research Institute (AURI) first met the group at a Kernza field day in Madison, Minn. where an information exchange took place about the experience of cleaning and dehulling the grain. Further conversation led to Stearns County Kernza (dirty from the combine) connecting with Stengels for test cleaning.

Figure 10. AURI and members of the Perennial Promise Growers Co-op discussing Stengels cleaned Kernza® grain.

Product Development Process

AURI provided Stengel Seed and Grain with about 400lbs of dirty Kernza grain from the Stearns County Region 2020 harvest for cleaning. AURI also provided Stengel with cleaning and dehulling information it had learned throughout the project, including screen sizes for various equipment, to help select a processing method to clean the grain. Stengel took it from there and 'worked their magic' to clean and dehull the grain.

Project Outcomes

Stengel was able to clean and dehull the grain just as well (if not better) than AURI's processes identified throughout the project. The process differs slightly than what AURI identified, indicating multiple process methods exist to obtain a highly pure end-product for the grain or seed market.

As a result of this project, Stengel Seed and Grain developed knowledge and experience in the Kernza cleaning and dehulling process and has indicated interest in becoming a mid-scale cleaning and dehulling facility as the supply chain develops. The Perennial Promise Growers Co-op has initiated discussions with Stengel to be a toll processor for the grain.

Pilot Project: Swany White Flour Mills Ltd

Freeport, Minn.

Project Focus: Flour Milling and Baking Mixes
Uses/Products: Hammermilled and Stone-Ground Whole Grain Flour; Pancake Mix

Pilot Partner

Swany White is an organic and specialty flour producer located in Freeport, Minn. The mill and its direct predecessors have been in operation since the 1890's, and has been owned by the Thelen family since 1903. Currently, Gary and Sharon Thelen run the mill, with the present facility's construction coming after the destruction of the historic mill in 2011. Swany White currently produces and sells a variety of flours and baking mixes made with organic and specialty grains.

Figure 11. Kernza® in the hopper of Swany White's Hammermill equipment.

Project Overview

The Agricultural Utilization Research Institute (AURI) partnered with Swany White to explore different milling technologies with Kernza. Initial tests used 100 pounds of clean, dehulled MN-Clearwater Kernza grain.

Swany White's flour hammermill milled half of the grain using a 2/64" screen, and the other half was milled on its 30" Stone Mill with the plate gap set as narrow as possible.

Process Development Process

Once the two milling techniques achieved whole grain Kernza flour, AURI conducted a particle size analysis on the flours to determine fineness, discovering that the hammermilled flour was ultimately much finer, with 100% passing through a #20 sieve compared with only 65% of the stone ground flour. AURI shared samples of the flour to a few end-users and the feedback was unanimously in favor of the finer grind produced via the hammermilling method. From that point forward, flour samples produced for other pilot projects were hammermilled using a 2/64" screen.

Project Outcomes

Flour produced during the initial trials was bagged in small 18-ounce packages for use as samples for businesses and end-users interested in trying Kernza flour. Several other pilot projects developed as part of AURI's Kernza commercialization activities were also conducted using flour milled during these trials. AURI also developed a flour specification sheet for Swany White, which is attached in the overall report.

Swany White also produced a Kernza flour pancake mix, replacing about 20% of wheat flour in the mix with the hammermilled Kernza flour. About 120lbs of this mix was produced for a Kernza educational event at ROCORI High School in Cold Spring, Minn. where AURI contracted with a mobile pancake caterer to grill and serve Kernza pancakes and gather consumer feedback. (See Appendix G)

As a result of this project, Swany White gained knowledge and experience of the Kernza milling process and is interested in milling more Kernza in the future. Swany is now able to serve as a toll processor, providing a key service to develop a regional value chain. Today, Swany White has the capacity to produce up to 500lbs/hr of flour, which will be a useful scale to produce small to medium quantities of Kernza flour for end-users in and beyond central Minnesota.

Feedback from End Users- Kernza Samples

As part of the product development process, AURI collaborated with the University of Minnesota's Forever Green Initiative (FGI) to provide samples of Kernza perennial grain and Kernza-based ingredients to potential end users and culinary experts identified by FGI. Several of these testers provided feedback about their experience working with the samples they received. Comments included the following:

"Raw Grain Brewers noted a nutty aroma when dealing with the raw grain prior to milling. Milling was challenging given the kernel size and our current pilot mill setup. Our crush was on the coarser side. I would suspect that we would have greater success using one of our larger mills as we have much more control over both feed rate and roller gap size. Brewing We used Kernza at a rate of 40% of the total grist. While we anticipated some challenges, we experienced no issues with lautering this beer. This could partially be due to the coarser nature of the crush. Our efficiency was a bit lower than our expectations, but not by much. We treated the anticipated extract of Kernza similar to unmalted white wheat. I couldn't find any information on the gelatinization temperature of Kernza. Maybe a better approach would have been to use a cereal cooking process. The final product was well received by the staff that participated in evaluating this trial (see below). We ran a hedonic test as opposed to description in an attempt to gauge the overall interest in Kernza as an ingredient. One taster commented on the aroma as being spicy, biscuity, and grainy. There were also mentions of the beer as having a full body with a medium astringent/bitter finish. "

- Allagash Brewery Pilot Team on Brewing with *Kernza Grain*

"Cooked both 66% and 34% Kernza inclusion macaroni pasta made at Northern Crops Institute. The 34% pasta is more akin to a whole wheat pasta and difficult to pick up Kernza flavor. In the 66% Kernza inclusion, the flavor really shines through (slightly grassy and nutty). The shape also held better than the 34% inclusion and the darker color suggests a difference from traditional whole wheat or soba.

Both pastas were cooked in rapidly boiling salted water until al dente, about 8 to 9 minutes, then drained

As a home cook, I would prefer the higher percentage of Kernza. Its color and flavor indicate that it is DIFFERENT and that difference will justify seeking it out, knowing that it has innumerable benefits to the environment as well as human health."

-Beth Dooley (Culinary Professional) on *Cooking Kernza Pasta*

"We liked the 100% (Kernza inclusion) elbow pasta very much. cooked up good, not gummy at all. 10 minutes boiling."

-Brenda Langton (Culinary Professional) on *Cooking Kernza Pasta*

"Used in brownie recipe to great success, tested in pasta machine and we are exploring for a cracker"

-Waconia High School Chef on *Baking with Kernza Flour*

"Anecdotal feedback from brewers, grain is hard to brew with. Would prefer malted, milled or flaked"

- Maltwerks on *Brewing with Kernza grain*

"I was able to run our first test batch of Kernza through our extruder this afternoon. This batch was made with 100% Kernza and a mixture of eggs and water to hydrate. The beginning ratio was 1000G Kernza, 130G eggs, 360G water. Once I began mixing it, I added 100G of extra Kernza and used 400G total of the water/egg mixture. End ratio was 1100G Kernza and 400G water/egg mixture.

The noodle I made was Bigoli, which is a larger diameter spaghetti noodle. This was really my only option because of the consistency of the Kernza. We generally only use semolina and sifted flour when we extrude pasta, when there are inconsistencies in the flour itself those inconsistencies will get caught in our dies and not make consistent shapes. Because Bigoli is just a straight shot out of the die we can get away with the flour not being the same consistency.

The flour behaved very similarly to buckwheat and our GF flour mix we get from Bob's Red Mill. It's very humid right now in the kitchen so the noodles are not as brittle as GF or buckwheat noodles get when they sit at room temp for 30-45 minutes. That said, I would guess that we would need to increase the hydration in the winter time to prevent the noodles from breaking.

I was able to cook these noodles as well. Cook time is over double our normal cook times. We usually cook our noodles for 2-4 minutes, Kernza noodles went for 8-9 minutes and still could have gone a touch longer. They held up when cooking and didn't break up over the cooking time which usually happens when you take fresh pasta that long in water. Flavor is really nice, it might be a bit much for some that are used to traditional, mass produced pasta.

Anyway, that was the first go. I've had recommendations to cut the Kernza with other flours but for the first go around I like to see how different flours behave with our more standard recipe for extruding. If I were to cut it with a different flour we would still run into the same extruding issue unless we sifted the flour further but the cook time might not be as long with a blend of flours."

-Aliment Pasta on *Extruding & Cooking Kernza Pasta*

AURI Process Development: Cleaning and Dehulling

AURI partnered with Perennial Pantry and Healthy Food Ingredients (HFI) to clean and dehull grain for pilot project utilization. As part of the project, AURI purchased small-scale cleaning and dehulling equipment to demonstrate processing and to provide small volumes of cleaned, dehulled grain to end users participating in Kernza market development. AURI's food grade laboratory in Waseca, MN, houses this equipment.

The speed of rotation on the impact huller is actively adjustable, with a higher speed correlating to a higher first pass efficiency of hull removal. There is an equilibrium to find the speed which optimizes the first pass efficiency without resulting in a significant number of broken kernels. Broken kernels can negatively affect germination rates if the grain is dedicated to planting or used for malting.

The optimal dehuller rotation speed on the model 7F impact huller was determined to be 2,100-2,400 rpm, which resulted in first pass efficiencies in the 60-65% range. Both the indent feed and drum rotation speed can be actively adjusted to control throughput of grain. The indent also has an adjustable arm (See Figure 15) that allows operators to alter the amount of lifts (grain falling in a pocket) and tailings (grain too long for a pocket). The goal of the process run (See Figure 14) was to get a clean in-hull fraction with no dehulled kernels for a malting partner looking to compare dehulled and in-hull Kernza during the malting process. To obtain a clean in-hull fraction, one must adjust the drum arm to obtain a small percentage of in-hull grain in the dehulled stream. Alteration of the arm around the drum allows for control over this separation. Vice versa, the arm is adjustable to produce a cleaner dehulled fraction, leaving some dehulled kernels in the tailings, if that is the primary stream of interest.

AURI also evaluated the use of a color sorter for effectiveness of removing small black weed seeds and ergot. A Meyer color sorter removed the remaining impurities after initial cleaning (See Figure 16). Figure 17 shows the grain before and after the color sorter, with the latter being 99.7% free of foreign material. Kernza handlers should consult with the end-user to decide the necessary level of purity before investing in a color sorter. In some cases, it may not be necessary to color sort the grain. If setting up a general Kernza processing facility with various end users and differing lots of grain moving through the facility, AURI recommends a color sorter as the last optional step in the cleaning line.

AURI also visited with Stengel's Seed & Grain and MNL to share processing information and to discuss the potential to become future cleaning and dehulling facilities. AURI provided Stengel's with four totes of uncleaned grain from the 2020 Stearns County harvest. Stengel's processed the grain using a fanning mill, impact huller and color sorter to achieve 99.7% clean grain utilizing information provided by AURI related to screen sizes and equipment. Stengel's is interested in becoming a mid-scale cleaning and dehulling facility for Kernza once the quantity is available to justify involvement (semi-loads at a time). Stengel's is primarily an organic cleaning facility but could accommodate conventional cleaning. The Perennial Promise Growers Co-op, in conjunction with AURI and UMN, have had several conversations with Stengel's to become a viable small to mid-level cleaning and dehulling facility.

Figure 12. Lab Scale CIMBRIA Indent Separator with 7.9mm drum for in-hull/dehulled Kernza® separation

Figure 13. Forsberg Model 7F lab scale impact huller

Figure 14. Impact Separator 'in-action' producing in-hull grain for malting

Figure 15. Cleaned Dehulled (right) and In-hull (left) Kernza® after indent separation. (Center) shows adjustable arm to alter grain cuts

Figure 16. Meyer Color Sorter Adjusted for Cleaning Ergot and Small Black Weed Seeds from Kernza®

Figure 17. Kernza® before (top right) and after (bottom left) Meyer Color Sorter

Table 11. Updated Dehulling Information.

Dehuller Model	Calculated Efficiency (on first pass)	Estimated Cost	Estimated Throughput
Forsberg Model 2	42% (1190 RPM)	$10k	200-300lb/hr
Forsberg Model 7F	30%-55% (1800-2400 RPM)	$7k	200-300lb/hr
Forsberg Model 7F (Stainless Steel Contact Parts)	35% (1800 RPM) 60% (2100 RPM) 65% (2400 RPM)	$10k	200-300lb/hr
Forsberg Model 15D (Stainless Steel Contact Parts)	40% (1800 RPM) 60% (2100 RPM) 65% (2400 RPM)	$18k	1000lb/hr
Forsberg Model 15D	40-65% (1800-2400 RPM)	$12k	1000lb/hr
Schule FKS 500	90%+	$30k	3500lb/hr
Buhler	55% (1300 RPM) 70% (1600RPM)	$49k	3500lb/hr*
Codema VSH - 2096	95%	$22K	3000lb/hr*

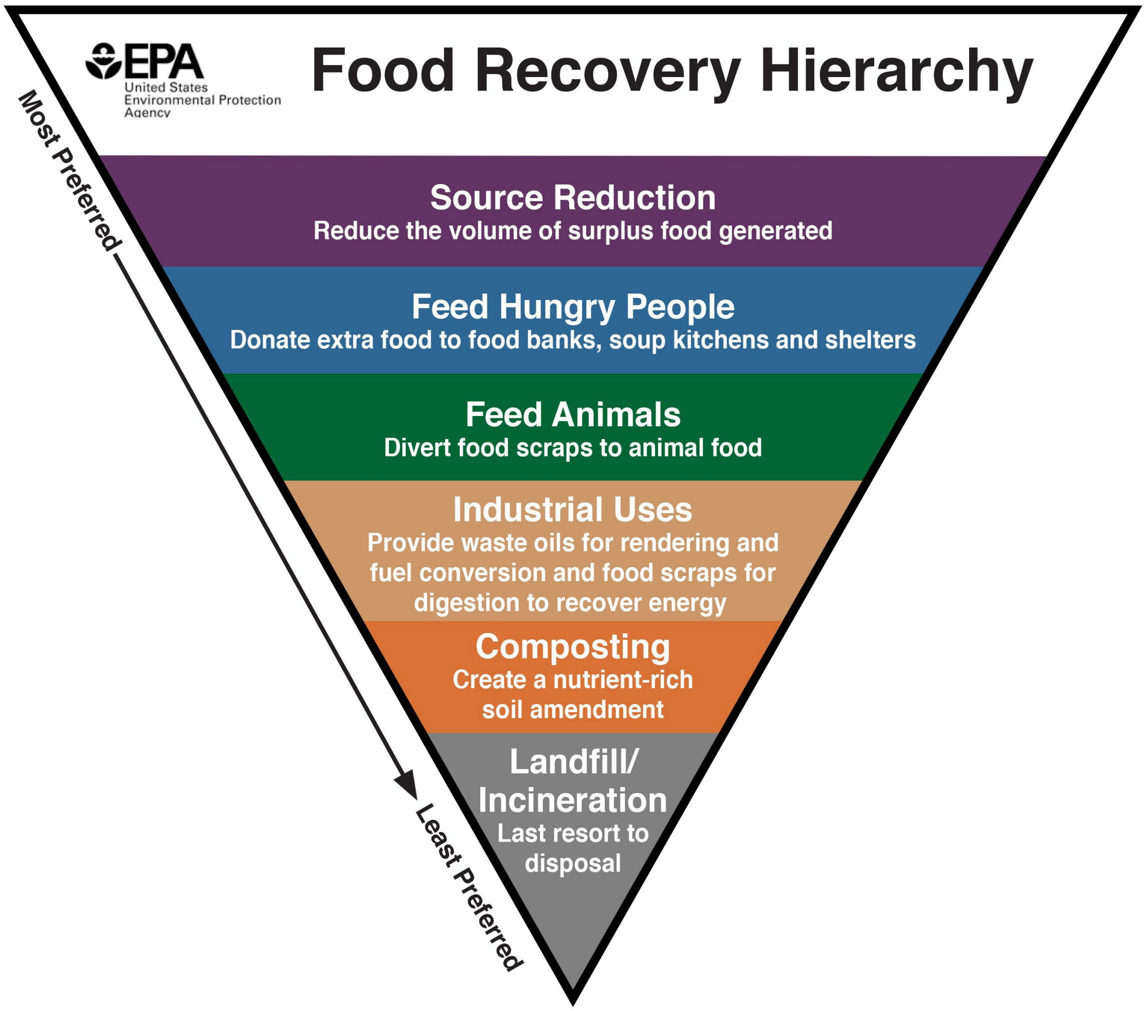
***Forsberg 7F numbers as tested at AURI**

Coproduct Evaluation

The commercial viability of many crops depends on the valorization of the byproducts. In the case of Kernza, the main byproducts or coproducts (a byproduct that has value) are the hulls and the straw. AURI's Coproducts Team in Waseca, MN conducted an analysis of the hulls and the straw from various perspectives to evaluate its use as animal bedding material, animal feed and a biobased fuel. The Waseca team estimated theoretical market values for these materials, noting prices would also depend upon available volumes. A smaller volume Kernza operation will have difficulty finding a consistent market for these materials, but localized use in turkey barns, animal feeds or biomass energy to heat in farm buildings would be viable for smaller volumes.

It is desirable to identify market viable options for coproducts that add the greatest value. In other work developed by AURI around food waste, the following graph has served to demonstrate the idea of adding the greatest value and has applicability as a guide to coproducts market assessment.

Figure 18: Recovery Hierarchy



Kernza Straw and Hulls as Bedding Material

AURI Coproduct Pilot Lab Protocol and Results
Kernza Straw Poultry Bedding Evaluation

Purpose
Evaluate the performance of various Kernza byproducts for sorbency and ammonia control.

Background
AURI developed a database of various poultry bedding materials focusing on sorbency capability as well as potential control of ammonia release.

Table 12: Sorbency and Ammonia Release: Tested Materials				
Product	**NH3 30 min. (PPM)**	**NH3 24 hours (PPM)**	**NH3 Day 6 (PPM)**	**Sorbency (g liquid/g product)**
Large wood flakes - Pine	25	0.4	0.5	1.37 (137%)
Small wood flakes – Pine (<1/2 inch)	10	0.28	0.2	2.36
25% sunflower hulls / 75% small wood flake	60	0.8	0.2	2.07
50% sunflower hulls / 50% small wood flake	36	0.25	0.25	1.78
Grass screenings (loose form)	7 (avg. of 2 test)	0.5 (avg. of 2 test)	0.8 (avg. of 2 test)	1.02
Grass screenings pellet	9	0.3	0	5.27
Small wood flake with 20% black carbon	19	0.23	0.15	2.09
Wood pellet	24	0.21	0.4	1.06
Ground corn cob (1/2" hole screen)	13	0.2	0.25	2.69
Barley hulls	11	0.1	0.12	1.78
Oat hulls	26	7	7	2.96
Paper pulp (dried)	32	2.4	1.5	3.02
Commercial blend	5	0.3	0.4	6.76
Ryegrass straw	9*	0.6	0.25	1.07
Ryegrass straw (ground)	11	0.5	0.4	3.98
Ryegrass straw pellet	24	2	0.35	5.36
Kernza straw (ground)	4*	0.3	<0.25	4.02
Kernza Hulls	9*	1.2	0.25	2.57

Ammonia Protocol:

1. Utilize one Kernza screening and one Kernza straw sample (ground) at a 60% moisture content.
2. Using 5% household aqueous ammonia, bring the test samples to 0.5% ammonia on a wet basis.
3. Moisture content in the original bedding material and ammonia were taken into account prior to water additions.
4. Place bedding in a four-inch-deep Pyrex dish and leave exposed to atmosphere (uncovered).
5. Record ammonia release content at 30 min., 24 hours, and day 6 using Drager Ammonia test tube method.

6. Blend 0.5 pounds household ammonia with required water; blend with dried straw/screenings. Evaluate ammonia release at 30 min., 24 hours, and day 6.
7. 60% moisture target

Table 13: Ammonia Testing Results

Blend – 1 lb. batch	Moisture content in product (lbs.)	Ammonia (household 5%) Addition (lbs.)	Water addition (lbs.) 60% Target	NH3 24 hrs. (PPM)	NH3 Day 6 (PPM)	NH3 Day 10 (PPM)
Kernza Screenings	0.18 (9%)	**0.5# Ammonia** (0.475 lbs. of water in ammonia)	**0.27# added H2O**	9	1.2	0.25
Kernza Straw	0.18 (9%)	**0.5# Ammonia** (0.475 lbs. of water in ammonia)	**0.27# added H2O**	4	0.3	Trace (<0.25)

***Caution: Low ammonia level readings may be due to fluid passing to the bottom of test container**.

Kernza straw comparison to other bedding sources

Initial results indicate Kernza straw and Kernza hulls could serve as excellent animal bedding materials. The ammonia control of both products was significant, and Kernza straw in particular displayed ammonia control consistent with widely used, conventional products and blends in the industry today. The straw also has a high sorbency, with the ability to absorb four times its weight in water. Additional testing to identify the effect Kernza straw and hulls have on ammonia mitigation (i.e., ammonia-binding or volatilizing) would be valuable, as would determining if the high sorbency rate found in Kernza straw is a positive attribute for bedding performance, or a detriment.

Table 14: Kernza Straw and Hulls as Fuel

Values on As-is Basis	Moisture (%)	BTU/lb	Ash (%)	Sulfur (ppm)	Chloride (ppm)
Kernza Straw	13.84	6860	4.05	1033	3140
Kernza Hulls	9.03	7035	9.88	1690	1400

The energy values of both the Kernza straw and hulls also indicate worthwhile fuel sources. However, considerably high ash content, especially in the hulls, is less desirable from a maintenance perspective when considering materials for biomass burners. The elevated chloride levels are also a concern for residential scale burners since biomass burner equipment is highly susceptible to wear and corrosion as a result of chloride compounds forming HCl and damaging equipment surfaces. The Pellet Fuel Institute recommends, ash content be no higher than 1% and chloride levels no higher than 300ppm in bio pellets for residential use. Commercial or industrial use, however, has a higher tolerance. Nonetheless, the Kernza numbers are still substantially higher for both ash and chloride than levels preferred for fuel feedstocks. Perhaps the largest barrier to utilizing these feedstocks as biofuels, and reason for keeping them in a feed stream, is the significantly low price of natural gas. Based on the fuel analysis, AURI identified a theoretical value of Kernza straw and hulls to be competitive with other common fuel commodities based on dollars per million BTU's. These estimated dollar values are shown in Tables 15 and 16.

Table 15. Theoretical Value of Kernza Straw as Heating Fuel – Per Ton comparative value with other common fuel sources

Natural Gas $8/Dekatherm	Propane $1.60/Gallon	Wood $250/ton	Shell Corn $5.65/Bushel
$107	**$240**	**$204**	**$200**

Table 16. Theoretical Value of Kernza Hulls as Heating Fuel – Per Ton comparative value with other common fuel sources

Natural Gas $8/Dekatherm	Propane $1.60/Gallon	Wood $250/ton	Shell Corn $5.65/Bushel
$110	**$247**	**$210**	**$203**

Table 17. Feed Analysis of Kernza Straw and Hulls

	Crude Protein	TDN	ADF	aNDF	Lignin	Fat	Ash
Kernza Straw	6.28%	55.27%	43.17%	66.20%	5.98%	2.21%	5.33%
Kernza Hulls	10.98%	55.97%	37.52%	54.01%	6.41%	2.39%	11.71%

Kernza crude protein is better than average straw (6.28% for Kernza vs. an average of 3.5-6% for barley, oat, or wheat straw.) Feed energy is greater than most straws with a TDN (Total Digestible Nutrients) for Kernza at 55.2% compared to 39% for most straws. If feeding to dairy cattle prior to calving, it may be necessary to watch the potassium level. Sharpness of hulls cutting up throats of animals is also an issue that may need addressing via additional processing (milling). This added step of milling would increase the feed cost and therefore impact its competitiveness.

Table 18. Theoretical Value of Kernza Straw and Hulls as Animal Feed

Product	$3.50/bu. corn & $300/ton SBM & $130/ton Alfalfa Hay Value per ton at 10% moisture content	$4.50/bu. corn & $375/ton SBM & $175/ton Alfalfa Hay Value per ton at 10% moisture content
Kernza Straw	$86/ton	$109/ton
Kernza Hulls	$110/ton	$140/ton

It's important to note the values stated above are based solely upon the TDN and crude protein values of the coproducts. These are not reflective of the products' current market value, and price discovery has yet to occur. These potential feed products would also require Association of American Feed Control Officials (AAFCO) certification and an international feed number to legally market as a feed product.

Kernza Straw as a Biocomposite

In order to assess Kernza straw use in bio composite materials, AURI partnered with c2renew. c2renew is a material designer and custom compounding firm located in Fargo, North Dakota. Materials experts at c2renew worked with AURI to develop a bio composite incorporating Kernza straw as a natural filler in a bio derived resin. The tests led to the production of 25kg of polylactic acid (PLA) Kernza biocomposite pellets, with c2renew reporting that the Kernza straw "processed well in the extruder and appears to be a viable option as a bio-based filler for other PLA based formulations." AURI and c2renew will use the material in ongoing testing focused on development of injection molded products as part of the next LCCMR-funded Kernza project led by SCSWCD.

The full report from c2renew about the biocomposite trials can be found in Appendix E.

Sugar Extraction from Kernza Straw

In order to better examine the potential value-added opportunities associated with Kernza straw, AURI contracted with Sasya LLC (Sasya) a St. Paul, Minnesota based biotechnology company, to perform sugar extraction trials. The type of sugars in the straw also helps identify an ideal potential market (e.g., feed or fuel). For example, sugars extracted from the straw could be utilized in fermentation applications to create high value chemicals. The research indicated the presence of potentially valuable sugars in Kernza straw which may be worthy of further study and utilization research. Sasya's report can be found in Appendix M.

Storage and Handling

While AURI did not conduct any storage or shelf-life analysis for this project, the team was able to frame elements necessary to understand shelf-life for future work under another LCCMR project. Moisture levels, hull presence, microbial activity and mold/yeast presence are a few storage variables that will be explored in future research.

At this stage, AURI recommends following storage shelf-life guidelines for wheat or barley since these are the most similar to Kernza. A kill step for flour (such as baking by the consumer), will likely be the expectation as in the wheat industry. Storage of Kernza should be in a cool, dry area in either individual super sacks or feed bags. Keeping the grain below 14% moisture should ensure Kernza maintains its condition but the preference is to dry the grain to 8-12% moisture. Estimates show grain between 8-12% moisture should remain stable for two or more years. Once milled, the flour will likely have a shelf life between six months to one year, depending on the environment and moisture content. It's important to note this guidance is preliminary, based on similar grains. Further testing and research is needed to truly understand the recommended storage practices for Kernza grain.

Based on storage conditions of similar grains, such as wheat and barley, a storage temperature of under 60 degrees Fahrenheit (F), and relative humidity under 70%, should be safe for Kernza grain between 8-12% moisture. Storage under 40F could eliminate the possibility of mold formation and insect activity. A good guideline, if storing grain in the bin, comes from a University of Minnesota Extension paper on storing wheat and barley[xxxiii1]. Extension advises maintaining the grain temperature to within 20F of the outside temperature, to avoid any moisture migration or relative humidity issues. This paper also states that winter bin storage temperatures for wheat and barley in Minnesota are ideally about 25F. Again, further testing and research is necessary to validate this for Kernza.

Additional research on off-flavoring and oxidation effects of Kernza also has merit based on concerns raised by several industry contacts. Further testing to identify if there are advantages to storing grain after cleaning and dehulling, compared with dried, raw grain would be interesting to explore. The University of Minnesota examined the stability of Kernza through storage and after steam treatment. UMN graduate student Amy Mathiowetz, under the guidance of her advisor Dr. Pam Ismail, conducted the work summarized in the thesis paper entitled "Evaluation of the Chemical and Functional Stability of Intermediate Wheatgrass (Thinopyrum Intermedium) Over Storage and in Response to Steam Treatment"[xxxiv2]. The study concluded that Kernza or Intermediate Wheat Grass (IWG) had competitive storage stability when compared with hard red wheat. Due to IWG's lower lipoxygenase activity, lower hydroperoxide content and overall higher antioxidant content, IWG held its functionality over storage significantly better than hard red wheat. Secondly, this study concluded and provided information that, by using a steam treatment on the grain prior to storage, the storage stability could increase.

Food Product Development

AURI/Northern Crops Institute Collaboration

To assess Kernza's utilization in food products and its viability as a commercial food industry ingredient, AURI partnered with the Northern Crops Institute (NCI) at North Dakota State University in Fargo, North Dakota. As part of its mission to support regional agriculture and value-added processing, NCI operates laboratories focused on milling, pasta production, food processing, and baking process development, offering a unique portfolio of facilities and expertise with the ability to assess multiple potential uses of Kernza.

AURI contracted with NCI to "explore various food applications using whole grain and refined Kernza flour and provide expert insight on using Kernza as a refined flour vs. whole grain flour based on both food application results and milling considerations." As part of this work, NCI coordinated with AURI food scientists to develop research protocols and test the use of Kernza in multiple food applications, including pasta, crackers, tortillas, donuts, and sourdough breads. A full report of NCI's work and results is included in this report, and can be found in Appendix A.

AURI food scientists used the sample food products produced by NCI during its work to perform sensory analysis testing. This analysis included multiple different products, including crackers, pasta, donuts, and tortillas. Products were made with both whole grain and refined Kernza flour at multiple inclusion rates. For a more detailed summary of the analysis of each NCI product application by AURI scientists, please refer to Appendix B.

Prior evaluation of Kernza indicated potential as an ingredient substitute for wheat, in both whole grain and berry form since it is a cousin of wheat and has some similar attributes.

In baking applications, there are a number of differences from wheat to consider when using Kernza. It has a higher dietary fiber and protein content than wheat, indicating a nutritional profile advantage over whole wheat. However, Kernza also has a higher fat content, which increases its rancidity potential, and a lower level of glutenin and starch, which limit Kernza dough's ability to form viscoelastic networks. As such, Kernza flour is best suited for higher percentage use in baking applications where volume is not an important attribute, such as in flatbreads, tortillas, or sweet baked goods like cookies. For applications such as loaf bread, Kernza flour, whether refined or whole grain, may be substituted for conventional wheat flour at up to 50% of the total flour blend. However, as the fraction of Kernza in the flour blend increases, bread attributes such as volume, texture, taste and color will be severely impacted. Sourdough processing indicates some advantage in increased Kernza usage rates, but this needs to be studied in more detail before a definitive recommendation can be made. Recommended usage of Kernza flour in standard loaf bread applications should be significantly lower than 50% to achieve traditionally acceptable products.

Other evaluated applications of Kernza included pasta and crackers. Research showed significantly higher levels of Kernza to be acceptable in these applications, based on the sensory attributes of aroma, flavor, and color for these products,. In the case of pasta, Kernza whole grain flour was found to be useable at up to 66% of the total flour blend, though the recommended usage level is 34% to avoid an impact on cooked weight and texture. In the cracker application, higher levels of whole grain Kernza flour were acceptable, at up to 75% of the total flour blend.

Based on the evaluations conducted by AURI and NCI, the use of Kernza as a food ingredient will face two challenges:

- Kernza is not a direct substitute for conventional wheat in most applications. As such, the recommendation is to use it as an adjunct to conventional wheat flour, typically in lower levels as part of a blend. As the percentage of Kernza in a blend increase, products will typically develop undesirable flavor, texture, and product performance characteristics. In some cases, significant testing is necessary to design an acceptable product.
- Establishment of a stable and reliable Kernza supply chain, detailed elsewhere in this report, is ongoing. As a result, the per pound price of Kernza is significantly higher than conventional wheat. This will limit Kernza inclusion rates in all product applications, independent of product attributes, unless consumers are willing to pay a premium (thus far, this hypothesis is untested).

Wheat Marketing Center: Milling Assessment

Based on guidance from milling experts at the Northern Crops Institute, AURI contracted with the Wheat Marketing Center in Portland, Oregon, to perform milling tests with a specific focus on the production of refined Kernza flours. Partners recommended WMC for this work based on their deep experience working with the soft wheats grown in the Pacific Northwest, which NCI technicians felt would be useful in assessing Kernza milling techniques.

The Wheat Marketing Center's trials indicated that Kernza can be used to produce a quality refined flour, but that overall yields were quite low (42.9%) when compared to the extraction rate on wheat flours (76.9%) reported by U.S. millers in 2021.[xxxv] This low extraction rate combined with high current costs of Kernza grain is likely to be a barrier to development and production of refined flour products.

A full copy of the Wheat Marketing Center's assessment can be found in Appendix C.

Kernza Ingredient Specifications

Establishment of commercially viable ingredients in the food industry requires appropriate documentation for ingredient buyers. One of the most crucial documents for ingredient buyers is a specification, or technical data sheet, which details the attributes of that particular ingredient. To accelerate acceptance of Kernza as a commercially viable ingredient, AURI scientists developed a standard ingredient specification for both a coarse and fine grind Kernza flour produced at Swany White Mills. These specifications were built from analytical data gathered throughout the course of this project and can be found in Appendix K and Appendix L.

Brewing With Kernza

AURI learned through this project that Kernza is a viable option to utilize in brewing beer and holds notable potential as a brewing ingredient. Whether in a milder cream ale or a farmhouse saison, the addition of Kernza yielded appealing attributes. The assumed color and flavor additions of including Kernza in a beer turned out to be more muted than initially thought. While still noticeable at the lower levels (10-20% of the final grain bill), the Kernza did not have as large of an impact as hypothesized by team members and brewers. Kernza grain when added to a brewer's grain bill, did not appear to create any issues with the lautering (separation of wort and spent grain) of the beer as was first thought. Originally experts thought that the β-glucan levels observed in Kernza could lead to issues with stuck sparges, but no such issues were observed during the two pilot batches conducted at Beaver Island Brewing and Minnewaska House Brewing.

The size of the Kernza berries was the biggest concern voiced by breweries. Due to the berries being roughly one-fifth the size of traditional wheat berries, brewers expressed concerns that the berries could be too small for milling on current equipment, as well as moving through a breweries grain auger prior to addition to the mash. A larger berry size would make the integration of Kernza into breweries at a larger scale easier.

As part of the brewing pilots, AURI was able to conduct consumer surveys and gather consumer feedback regarding Kernza usage. (See Appendix F) Surveyed consumers liked the idea that Kernza could provide positive benefits to the environment as well as offer an opportunity to help support local farmers and businesses. AURI looks forward to continuing to partner with breweries in the region and the state to assist them with sourcing Kernza and providing technical assistance to brew with Kernza. Another avenue AURI would like to explore further is using Kernza in the grain bill for distilling. AURI plans to pursue distilling projects as part of a second SCSWCD-led Kernza project funded by LCCMR, which will be active through June 2024.

Rahr Malting Company: Malting and Brewing Trials

As part of the project's focus on assessing Kernza's use in brewing applications, AURI contracted with the Rahr Malting Company Technical Center to perform malting and brewing trials at its research facilities in Shakopee, Minnesota. As one of the leading malting companies in the United States, Rahr has extensive experience in the development of ingredients for use in fermented beverages. The Rahr Technical Center includes a micromalt lab that performs pilot malting experiments, and a small pilot brewery that allows staff to "perform real-world trials on malt, hops, yeasts, and other ingredients."[xxxvi]

Working in collaboration with AURI and the University of Minnesota, Rahr's technical experts performed a series of Kernza trials to determine if it is "best suited for malting in its in-hull or dehulled form." Dehulled malted Kernza from these tests was used for pilot brewing, producing a small batch of "Kernza Hazy Ale" for process and sensory analysis.

Results of the trials were positive, with Rahr reporting that "despite some challenges" the overall process was "a positive and successful one." Of particular note were positive results during sensory analysis of the beer, with Rahr's technical experts noting Kernza having "strong potential for malting and brewing applications."

As part of its work, the Rahr Technical Center produced a full report detailing their process and outcomes. A copy of this report can be found in Appendix D.

Outreach and Dissemination

Events

Despite challenges presented by the COVID-19 pandemic, the Agricultural Utilization Research Institute (AURI) developed and participated in multiple in-person and virtual outreach events throughout the duration of the project. During these events, AURI team members built connections with supply chain stakeholders and shared information about the Kernza perennial grain market, as well as product development opportunities in Minnesota.

Over the last three years, AURI outreach efforts in support of Kernza market development included the following events and activities:

- AURI Connects: From Field to Glass: Innovation in Brewing and Distilling
    - October 10, 2019
    - AURI hosted an informational and networking event at "Food Ag Ideas Week" focused on discussing new opportunities to use local ingredients (including Kernza) in craft brewing and distilling.
    - 96 participants
- Land Institute 2020 Kernza Conference (Virtual Event)
    - June 11, 2020
    - Riley Gordon, AURI principal engineer, presented on Kernza processing and handling at the Land Institute's annual Kernza conference.
- Rosholt Research Farm Field Day (Virtual Event)
    - August 13, 2020
    - AURI staff presented on Kernza uses and supply chain development activities in Central Minnesota.
- AURI Connects: Fields of Innovation: Exploring Market Opportunities for Kernza Perennial Grain (Webinar)
    - October 30, 2020
    - AURI hosted a webinar featuring Tessa Peters, Crop Stewardship Manager for The Land Institute, and Christopher Abbott, Co-Founder of Sprowt Labs and Perennial Pantry, to discuss market opportunities for Kernza in Minnesota.
    - 113 participants
- AURI Connects: Fields of Innovation- Emerging Agricultural Opportunities
    - December 7, 2020
    - As part of 2020's virtual "Food Ag Ideas Week," AURI hosted a Fields of Innovation webinar focused on highlighting new and emerging crops and markets in Minnesota. The event included presentations and panelists that shared information about Kernza and its potential.
    - 90 participants
- Kernza Field Day: A-Frame Farm
    - July 8, 2021

    - AURI staff attended a field day at A-Frame Farm in Madison, Minn. to share information and connect with growers and other potential supply chain partners.
- ROCORI FFA Kernza Field Day
    - July 17, 2021
    - AURI partnered with the Rocori High School FFA and the University of Minnesota's Forever Green Initiative to host a Kernza-focused field day at the school's test plots in Cold Spring, Minn.
- Rosholt Research Farm Field Day (In-Person)
    - August 19, 2021
    - AURI staff participated in and made presentations to participants on "Adding Value to Kernza: An Update on AURI's Efforts to Identify Processing Methods and Early Supply Chain & Market Opportunities for Kernza in Minnesota."

Figure 19- Rocori FFA Kernza® Field Day

- Twin Cities Startup Week
    - September 2021
    - AURI Food Team members attended and shared information about Kernza, its environmental benefits and potential uses in upcycled food products.
- Northern Crops Institute Cereal Innovators Webinar
    - November 10, 2021
    - Exploring Markets for Kernza Perennial Grain
    - AURI technical experts and staff from the University of Minnesota's (UMN) Forever Green Initiative presented an overview of the crop, its potential uses and ongoing efforts to develop new markets for Kernza.

Figure 20- Rocori FFA Kernza® Field Day

- Supply Chain Development - Key Stakeholder Meeting
    - December 3, 2021
    - AURI and the Forever Green Initiative convened a meeting of key supply chain participants, including growers, processors and end users at Swany White Milling in Freeport, Minn. to discuss ongoing market development activities and plan future collaborations.
- 2021 Prairie Grains Conference

- December 8-9, 2021
- AURI's supply chain team shared information about Kernza with grain industry stakeholders at the Minnesota Association of Wheat Grower's annual "Prairie Grains" conference in Grand Forks, ND.

Figure 21- Prairie Grains Conference

- Minnesota Farm Bureau Leadership, Education, Advocacy and Promotion (LEAP) Conference
  - January 28, 2022
  - AURI's business development team gave a presentation on Kernza and its potential uses to approximately 100 participants during tours of NETZRO's food production facility in Minneapolis, Minn.
- UMN Forever Green Initiative Kernza Gathering
  - March 7, 2022
  - Dundas, Minn.
  - AURI team members attended a conference of key Minnesota stakeholders to share information and discuss ongoing efforts to support current and prospective Kernza growers in Minnesota and the Upper Midwest.
- Kernza Con22
  - April 21-23, 2022
  - AURI business development staff attended the Land Institute's annual Kernza conference in Salina, Kan. to network with key stakeholders, share information about the project and provide an update on value-added and market development activities in Minnesota.
- Lake Pepin Legacy Alliance - Kernza Fest
  - June 18, 2022
  - Lake City, Minn.
  - AURI staff attended and presented its market development activities, in collaboration with partners from the Forever Green Initiative, Perennial Promise Growers Cooperative and Perennial Pantry.

Information Sharing and Promotion

In addition to participating in events, AURI took part in several other activities to share information about the project, spread information about Kernza and support supply chain development for the crop in Central Minnesota.

- Rocori FFA Test Plot
  - AURI worked with the University of Minnesota (UMN) and the Rocori High School FFA chapter to establish a Kernza test plot near the school in Cold Spring, Minn. and shared information about the crop and its environmental benefits with students. AURI staff also met with the City of Cold Spring to discuss the merits of the crop given the city's inclusion in a wellhead protection area.

Figure 22- Kernza® Test Plot- St. Cloud

- Project Test Plots
  - AURI collaborated with the Stearns County Soil and Water Conservation District, Pope Soil and Water Conservation District, Forever Green Initiative and Rocori High School FFA to place informational signs at project test plots to raise awareness about the crop in the region.
- AURI Fields of Innovation: Innovator Profiles (See Appendices H and I)
  - February 2022 - Artisan Naan Bakery
  - March 2022 - Beaver Island Brewing
  - AURI highlighted in its online "Innovator Profiles" series two Stearns County businesses that are developing Kernza-based products. The profiles showcased the businesses, Kernza and the products developed with AURI support during the project.
- Informational Sheets (See Appendices O through Q)
  - AURI technical experts shared two-page guides with information on Kernza and its potential uses to spread information about the crop and its potential value-added uses. These two-page informational sheets, which AURI developed during earlier LCCMR-funded research[xxxvii], provided key technical information on the handling and use of Kernza grain. The documents were made available online, distributed at events and shared with other supply chain partners for further dissemination.
  - The information sheets included:
    - Brewing with Kernza® Perennial Grain
    - Kernza® Perennial Grain as a Cereal Grain
    - Kernza® Perennial Grain in Baking Applications
    - Kernza® Perennial Grain: Cleaning & Dehulling Process

Media Coverage

Outreach efforts during the project included sharing information with local media, which led to two feature articles in regional newspapers. AURI also highlighted one of the project's pilot partners in its quarterly publication, Ag Innovation News.

- Country Acres- *"Something new to study. First Kernza crop an opportunity for Rocori FFA"*
  - June 18, 2021
  - Country Acres focused on the FFA test plot and field day, Kernza's environmental benefits and work done by the Stearns County SWCD, University of Minnesota, AURI and other regional partners to bring the crop to Central Minnesota. The article noted the role of the Legislative-Citizen Commission on Minnesota Resources' (LCCMR) support in these efforts and included interviews with multiple key project team members including Stearns County SWCD administrator Dennis Fuchs.
- St. Cloud Times- *"What's so special about Kernza? 4 lessons from a Cold Spring field day about the new crop"*
  - June 21, 2021
  - The St. Cloud Times published an article about the Rocori FFA Field Day hosted in partnership with AURI and the Forever Green Initiative. The article included interviews with project team members Dr. Jacob Jungers and AURI's Jen Wagner-Lahr.
- AURI Ag Innovation News
  - April 2022
  - AURI's Ag Innovation News included a note about St. Cloud's Artisan Naan Bakery and its work with AURI to develop Kernza-based products.
- AURI Ag Innovation News
  - July 2022
  - The July issue of Ag Innovation News included a full-page article on the "Fields of Innovation: Innovator Profile" highlighting Artisan Naan Bakery.

Expanding the Value Chain: Monetizing Environmental Benefits

As a perennial crop, Kernza contributes positively to ecosystem services, including building soil organic matter, providing soil structure and stability to prevent erosion and improving water holding capacity. It is an important food source and habitat for beneficial insects and pollinator species and used by game and other wildlife for feed and shelter. Improvements also exist off-farm, impacting water and soil conservation, and increasing biodiversity. Because of Kernza's ability to enhance its surrounding ecosystem, farmers can stack environmental benefits and diversify economic opportunities.

There is an emergence of market programs to reward farmers and ranchers who are seeking to implement climate-adaptive, regenerative agricultural practices. These ecosystem services marketplaces aim to

1. Incentivize farmers to transition to alternative growing practices or systems, namely those that enhance water quality, improve soil health, sequester carbon, increase diversity and/or incorporate cover crops with more traditional rotations like soy and corn, and
2. Create high-value credits, akin to carbon markets, which companies can purchase to offset their supply chain emissions.

One example is the Ecosystem Services Market Consortium's (ESMC) Eco-Harvest market program, which launched in May 2022. ESMC is a non-profit, public-private partnership that received $10.3 million in grant funding from the Foundation for Food & Agriculture Research (FFAR) to research and develop projects and programming to advance its end-to-end digitized technology platform to monitor and monetize positive environmental impacts resulting from altered agricultural production activities. Quoting ESMC's launch language, "Participating producers have autonomy to decide which practice changes are best suited to their operation based on a menu of specific practices/systems. Producers pay no fees and do not have to purchase subscriptions or inputs to participate in Eco-Harvest. The measured outcomes of their practices, turned into [rigorous and standardized] credits, are sold to corporate buyers in the agricultural supply chain…[to] meet their reporting requirements."

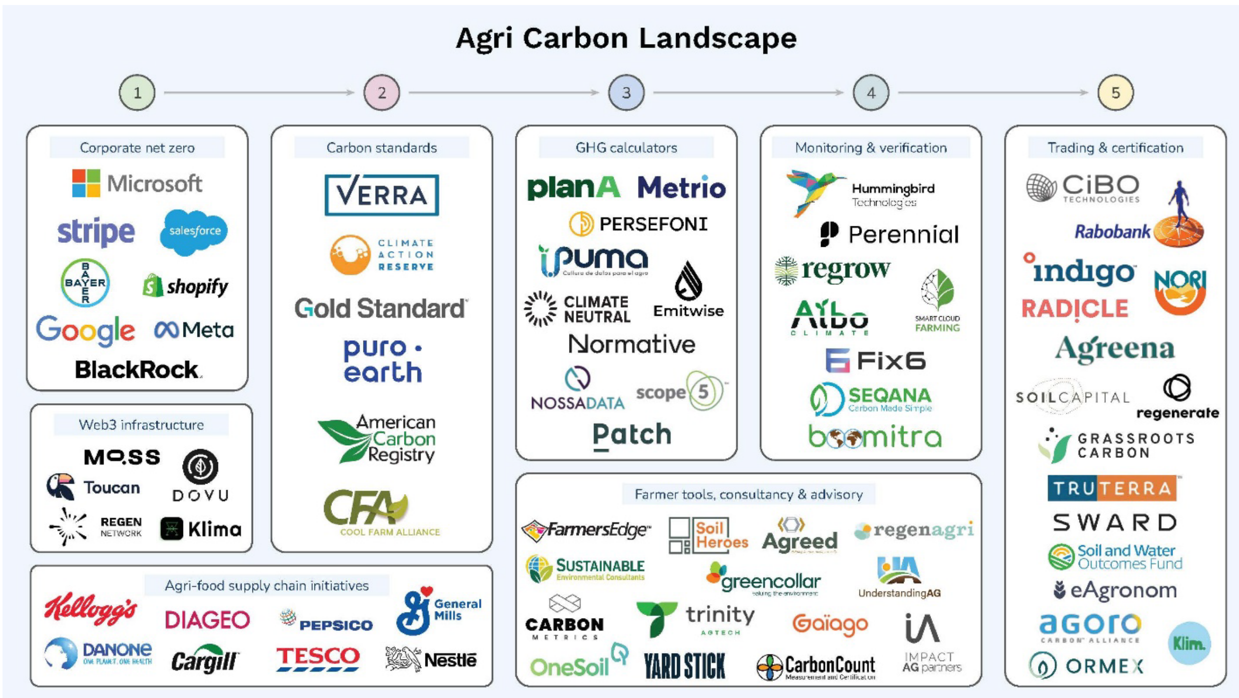
Eco-Harvest's marketplace will enforce clear, standardized, rigorously tested and scalable participation for growers and says claims and terms will not change from year to year. Additionally, depending on the number of growing practices and their verified impacts, producers will be able to stack payments as the market program grows, which may further enhance its value proposition.

ESMC has partnered with corporations such as General Mills, who devised a 7-year roadmap and invested $3 million toward expanding acreage under the program, as well as The Nature Conservancy.

It is worth noting that some certifiers offer payments for the number of practices implemented (e.g.: cover crops, no till, buffer strips, etc.), and others, as technology for soil metrics improve, pay farmers for validated outcomes that improve soil health. The latter may increase participation among progressive farmers who were implementing alternative farm practices before these marketplaces were available to them.

Hummingbird Technologies (a satellite-based metric that evaluates how alternative practices change the landscape) has created a visual of additional marketplace stakeholders in the agri-carbon landscape.[xxxviii] (See figure 23) Each of these play a role in the marketplace to monitor, validate, certify and trade credits based on the environmental impacts of different agricultural practices. While this visual does not fully encapsulate all market participants, it offers a pathway for how groups verify and facilitate carbon sequestration in the U.S. food production system.

Figure 23: Carbon Landscape



In January 2021, the Land Institute released a new report evaluating opportunities for ecosystem services payment programs for Kernza growers. The report highlighted several different programs in various stages of development that may offer an opportunity to monetize ecosystem services provided when producing Kernza. At the time of the report, programs focused on creating and monetizing carbon and water quality credits for environmentally impactful crops were in development. These programs, if successfully launched, will likely present economic opportunities for Kernza producers. According to one of the highlighted program developers, the focus is on building markets "where the revenue model is aligned with the farmer getting paid as much as possible."[xxxix]

Conclusion and Next Steps

AURI will continue to support the development of the Kernza industry through these LCCMR grant partnerships. The grant partnership with the Stearns County Soil and Water Conservation District yielded vital information and continued to develop AURI's internal expertise around Kernza. AURI was able to build small scale cleaning and dehulling capacity at its Waseca pilot lab site as well as define theoretical values for Kernza' s coproducts, including bedding, fuel, and feed. AURI was instrumental in defining the scope of the NCI's food product development and milling research, as well as leading several pilot projects introducing Kernza to potential market opportunities in MN. AURI, along with the UMN Forever Green supply chain development team, made significant strides in tying together potential value chain players across Minnesota, including processors to clean and dehull the grain, millers to create flour, and several end users including bakers and brewers. In addition, AURI partnered with groups such as C2Renew, Rahr Malting Company, the Wheat Marketing Center and Sasya LLC to explore utilization opportunities for Kernza and its coproducts. Finally, despite the challenges presented by working on this project during the COVID-19 pandemic, AURI conducted and participated in several events throughout this project to disseminate information and bring more awareness to Kernza.

Next steps for AURI's Kernza work are already underway with the launch of a new Kernza LCCMR project, led by the Stearns County Soil and Water Conservation District again. AURI will conduct in depth drying and storage studies. AURI will also continue working to engage small businesses and industry in pilot projects to further awareness while providing applied research and supply chain development assistance necessary to successfully bring Kernza into the marketplace.

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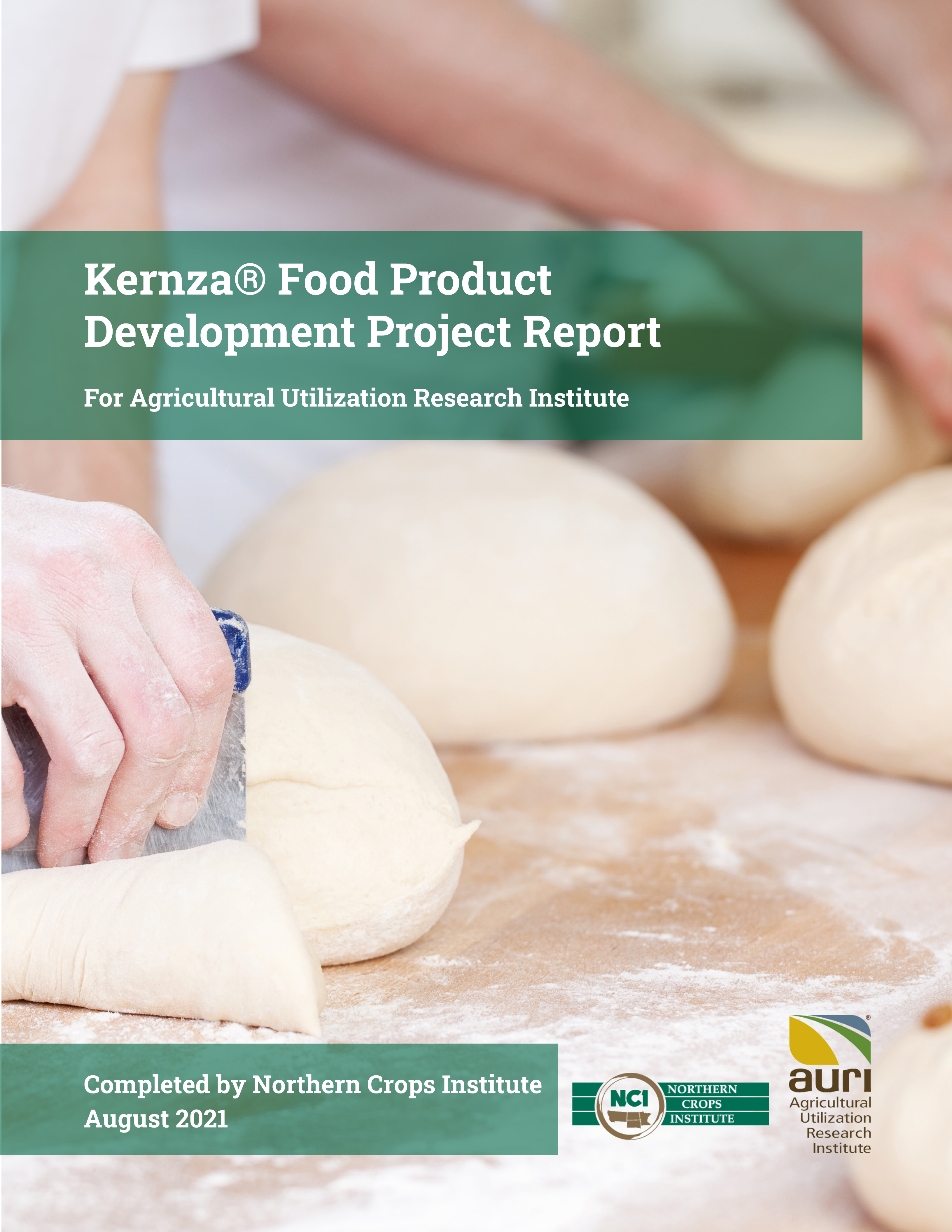
Appendices

APPENDIX A

Food Product Development Project Report
(Northern Crops Institute)



Kernza® Food Product Development Project Report

For Agricultural Utilization Research Institute

Completed by Northern Crops Institute
August 2021

NORTHERN CROPS INSTITUTE

auri
Agricultural Utilization Research Institute

TABLE OF CONTENTS

PROJECT OBJECTIVE

Explore various food applications using whole grain and refined Kernza flour and provide an expert insight on using Kernza as a refined flour vs. whole grain flour based on both food application results and milling considerations.

SUMMARY

OF PRODUCT AND PROCESS OBSERVATIONS, ALL PRODUCTS

PASTA

Kernza treatments had a nutty flavor. As the level of whole Kernza flour increased, the final cook weight decreased and cook loss increased. Pasta made with 34% whole Kernza flour would be the best level to try going forward because it had only a slightly lower cooked pasta weight and softer firmness than the control.

CRACKERS

While all Kernza treatments (refined and whole) resulted in crackers that required a lower force to break compared to the 0% Kernza control, refined Kernza flour was more difficult to mix than the whole grain. As the level of refined Kernza flour increased, the harder the mixer motor worked. While all treatment resulted in acceptable, although more tender, crackers, the limitation for refined Kernza will likely be processing the dough at levels above 50% flour replacement.

TORTILLAS

All tortillas passed the roll test and didn't break after being rolled. From our studies, using 10% whole Kernza or 10-25% refined Kernza is the most likely treatment to be an acceptable tortilla.

DONUTS

For both whole and refined Kernza treatments, the texture firmness was higher than the control at 10 & 25% levels, but then decreased at 30% Kernza levels. It seems that a level of 25% Kernza would be the best. 30% whole Kernza donuts had large, unappealing holes inside of the donut.

SOURDOUGH BREAD

In whole Kernza treatments, as the level of whole Kernza increased the loaf volume noticeably increased and texture firmness notably decreased. However, in refined treatments, as level of Kernza increased, the loaf volume only slightly increased and the texture firmness only slightly changed and didn't trend one way or the other.

TORTILLAS, CRACKERS, & DONUTS

These products made with refined Kernza flour required noticeably less time to mix. No change in mix time was noted when whole Kernza flour was used.

SUMMARY
OF WATER ABSORPTION PROPERTIES AMONG PRODUCTS

Overall, water absorption of doughs made with refined or whole Kernza flours decreased as the level of Kernza flour increased. Analyzing the flours for starch damage and particle size may give some insight to this observation.

PRODUCT	EFFECT ON WATER ABSORPTION AS WHOLE KERNZA FLOUR INCREASED	EFFECT ON WATER ABSORPTION AS REFINED KERNZA FLOUR INCREASED
PASTA	DECREASED	NO CHANCE TO OBSERVE
CRACKERS	DECREASED	DECREASED
DONUTS	DECREASED	DECREASED
TORTILLAS	STAYED THE SAME	DECREASED
SOURDOUGH BREAD	DECREASED	STAYED THE SAME

RECOMMENDED KERNZA FLOUR LEVELS IN PRODUCTS

In the table below, recommended “next step” Kernza flour levels for each of the products tested are identified based on our overall opinions of the processing and analysis of the products. Because sensory tests were not completed on the products, recommendations are based on informal team sensory evaluations, without formalized consumer feedback.

PRODUCT	HIGHEST ACCEPTABLE WHOLE KERNZA FLOUR LEVEL (BAKERS %)	HIGHEST ACCEPTABLE WHOLE KERNZA FLOUR LEVEL (FORMULA %)*	HIGHEST ACCEPTABLE REFINED KERNZA FLOUR LEVEL (BAKERS %)	HIGHEST ACCEPTABLE REFINED KERNZA FLOUR LEVEL (FORMULA %)*
PASTA	34%	34%	NO OBSERVATION	NO OBSERVATION
CRACKERS	100%	65%	50%	33%
TORTILLAS	10%	5%	10%	5.5%
DONUTS	20%	10%	20%	10%
SOURDOUGH BREAD	10%	4.5%	10%	4.6%

* Formula % based of the product formula used in NCI project and will change for different recipes.

DELIVERABLE 1
KERNZA MILLING

75lbs of clean Kernza was sent to the Wheat Marketing Center (WMC) where the Kernza was milled into refined flour (also known industrially as patent flour) and shipped back to Northern Crops Institute (NCI) for comparative analyses with refined Kernza flour produced at NCI.

At Northern Crops Institute, Kernza grain was milled on a combination of a Creason Roller Mill and a Fitzpatrick Hammer Mill.

The milling began with two passes through the Creason Roller Mill followed by 5 passes through the Fitzpatrick Hammer Mill resulting in a total of 7 passes through the mills. Details of the milling process including feed rates, screen sizes and roll gaps can be seen in the Kernza Milling Parameters Chart.

Flour was fractionated into the three different streams of the flour: refined flour, shorts and bran. Refined flour, shorts, and bran were combined to make the whole wheat flour.

PASS	MILL TYPE	2ND BREAK ROLL GAP (MM)	SCREEN SIZE (MM)	FEED RATE (RPM)	MILL RATE (RPM)	SIEVE 20	SIEVE 30	SIEVE 40	SIEVE 44	SIEVE 60	SIEVE 80	THRU SIEVE 150	
1	CREASON ROLLER	0.178	-	-	-	TO PASS 2	TO PASS 2	-	-	TO PASS 2	-	REFINED FLOUR	
2	CREASON ROLLER	0.05	-	-	-	TO PASS 3	TO PASS 3	-	-	TO PASS 3	-	REFINED FLOUR	
3	FITZPATRICK HAMMER	-	0.79	15	7200	-	TO PASS 4	-	-	TO PASS 4	SHORTS TO PASS 7	REFINED FLOUR	
4	FITZPATRICK HAMMER	-	0.56	15	7200	-	-	-	TO PASS 5	TO PASS 5	SHORTS TO PASS 7	REFINED FLUR	
5	FITZPATIRCK HAMMER	-	0.05	15	7200	-	-	-	TO PASS 6	TO PASS 6	SHORTS TO PASS 7	REFINED FLOUR	
6	FITZPATRICK HAMMER	-	0.033	15	7200	-	-	TO PASS 7	-	TO PASS 7	2ND STREAM HIGH ASH	REFINED FLUR	
7	FITZPATRICK HAMMER	-	0.033	15	7200	-	-	-	-	-	-	-	3RD STREAM HIGH BRAN

Kernza Milling Parameter Chart

KERNZA MILLING REPORT

1st pass through second break roll gap @ .178 mm

20 mesh 30 mesh 60 mesh 150 micron - everything through 150 micron collected as refined flour. 67lbs. All scalped material run through for 2nd pass.

2nd pass through second break roll gap @ .05

20 mesh 30 mesh 60 mesh 150 micron – everything through 150 micron collected as refined flour. 45lbs. All scalped material run through Fitzpatrick Hammer Mill.

3rd pass through .79 screen on hammer mill 15 feed rate RPM 7200 milling RPM

30 mesh 60 mesh 80 mesh 150 micron – everything through 150 micron collected as flour.
Scalp on 30 mesh & 60 mesh sent to 4th pass on Fitzpatrick Hammer Mill.
Scalp on 80 mesh saved for pass through .033 screen on Hammer Mill.

4th pass through .56 screen on hammer mill 15 feed rate RPM 7200 milling RPM

44 mesh 60 mesh 80 mesh 150 micron – everything through 150 micron collected as flour.
Scalp on 44 mesh and 60 mesh sent to 5th pass on Fitzpatrick Hammer Mill.
Scalp on 80 mesh saved for pass through .033 screen on Hammer Mill.

5th pass through .05 screen on hammer mill 15 feed rate RPM 7200 milling RPM

44 mesh 60 mesh 80 mesh 150 micron - everything through 150 micron collected as flour.
Scalp on 44 mesh and 60 mesh sent to 6th pass on Fitzpatrick Hammer Mill.
Scalp on 80 mesh saved for pass through .033 screen on Hammer Mill.
80 mesh material kept separate form coarser material from this point.

6th pass through .033 screen on hammer mill 15 feed rate RPM 7200 RPM

40 mesh 60 mesh 80 mesh 150 micron – everything through 150 micron collected flour.
Scalp on 40 mesh and 60 mesh sent 7th pass on Fitzpatrick Hammer mill.
Scalped material on 80 mesh screen collected as 2nd stream high ash flour.

7th pass through .033 screen on hammer mill 15 feed rate RPM 7200

This material collected as 3rd stream high bran.

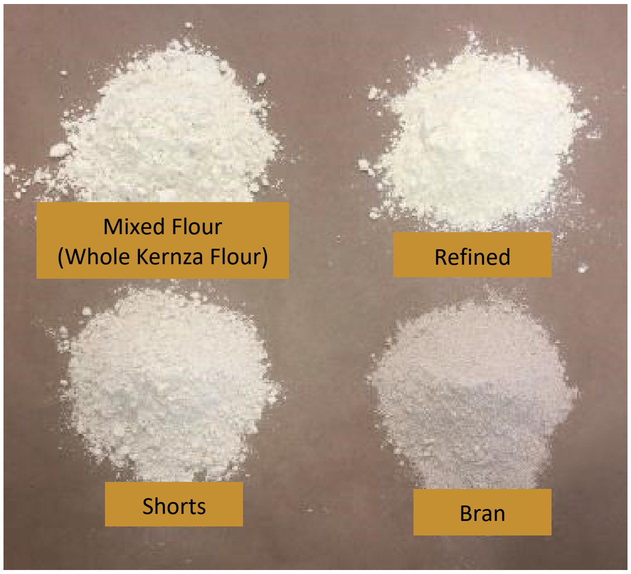
After the milling process we had three streams. Total weight of combined streams = 778.8lb.

Refined Flour = 345.7 lb. – 44.4%.
High Ash Flour = 242.3 lb. – 31.1%
Bran = 190.8 lb. – 24.5%

MILLING STREAMS

The milling process resulted in three streams:

STREAM	MASS (LB)	PERCENT (%) OF TOTAL
REFINED FLOUR	345.7	44.4
HIGH ASH FLOUR	242.3	31.1
BRAN	190.8	24.5
TOTAL MASS	778.8	100



At the end of the milling process, the refined flour, high ash flour and bran fractions were mixed together to form the "mixed flour," (whole Kernza flour). The whole Kernza and refined flours were both analyzed in products described later in this report.

KERNZA MILLING NOTES

A comparison of whole wheat Kernza made on a Hammer Mill, with the whole wheat Kernza made on a roller mill, and Hammer Mill combination, would be helpful. Hammer milling is the cheapest option, but the roller mill and Hammer Mill combination allows for the collection of a fairly pure Kernza refined flour, and secondary high fiber product with low protein levels. The operator could combine these two streams as done at NCI to make the whole wheat flour.

Both of the milling options described above would require the use of a Sieve Box with a basic set up as shown in Chart 1. The number of screens needed in each sieving compartment would be minimal. As a cost saving measure, neither of the milling options requires a purifier. In NCI's opinion, a standard roller mill with multiple roll stands, sifters, and purifiers may be too expensive to use when milling Kernza, especially if the operator wanted to build a cost-effective mill specifically for Kernza mill fractions.

DELIVERABLE 2
FLOUR ANALYSIS ON WHOLE GRAIN AND REFINED FLOURS

Kernza flours made at NCI and WMC were analyzed for the attributes listed in the following table. Moisture, protein, ash contents, and solvent retention capacity was completed at NCI. Total fat, starch, and fiber contents were conducted at Medallion Labs, Minneapolis, MN.

ANALYSIS	ANALYSIS	DEHULLED WHOLE GRAIN	NCI WHOLE GRAIN KERNZA FLOUR	WMC REFINED KERNZA FLOUR	NCI REFINED KERNZA FLOUR
UNITS	UNITS	RESULT	RESULT	RESULT	RESULT
TEST WEIGHT	LBS/BU.	48.8			
MOISTURE	%	-	7.8	11.6	8.8
PROTEIN	(14% MB) %	-	17.2	15.7	15.3
PROTEIN	(DRY BASIS) %	-	20.0	18.3	17.7
ASH	(14% MB) %	-	2.1	0.5	0.6
ASH	(DRY BASIS) %	-	2.4	0.6	0.7
FAT	%	-	2.6	1.2	-
TOTAL STARCH	%	-	39.0	47.0	-
INSOLUBLE DIETARY FIBER	%	-	11.8	2.7	-
SOLUBLE DIETARY FIBER (GRAVIMETRIC)	%	-	4.4	2.0	-
SOLUBLE DIETARY FIBER (HPLC)	%	-	2.3	2.5	-
SOLUBLE DIETARY FIBER TOTAL	%	-	6.7	4.5	-
TOTAL DIETARY FIBER	%	-	18.5	7.2	-

				STANDARD SRC VALUES	STANDARD SRC VALUES
ANALYSIS	ANALYSIS	NCI WHOLE GRAIN KERNZA FLOUR	WMC REFINED KERNZA FLOUR	HRS WHOLE WHEAT FLOUR	HRS REFINED FLOUR
UNITS	UNITS	RESULT	RESULT	RANGE	RANGE
SOLVENT RETENTION CAPACITY	H2O (%, 14% MB)	90.23	57.38	85 TO 100	65 TO 70
SOLVENT RETENTION CAPACITY	NA2CO3 (%, 14% MB)	107.67	70.46	80 TO 100	80 TO 90
SOLVENT RETENTION CAPACITY	SUCROSE (%, 14% MB)	158.26	111.38	105 TO 120	105 TO 115
SOLVENT RETENTION CAPACITY	LACTIC ACID (%, 14% MB)	88.41	74.59	> 120	> 140

Solvent Retention Capacity (SRC) is an analytical test that is used to predict baking performance. SRC is the weight of the solvent held by the flour after centrifugation. The four solvents, water, 50% sucrose, 5% sodium carbonate, and 5% lactic acid, are used separately to produce four SRC values for each flour sample. The lactic acid values indicate glutenin characteristics which indicates gluten quality. The sucrose solution indicates pentosan characteristics. The sodium carbonate indicates levels of starch damage in the flour. The water solvent indicates water absorption levels in the flour.

The SRC rates were higher in whole grain Kernza flour as compared to HRS whole wheat flour, for all solvents except lactic acid. This would indicate that whole grain Kernza alone could have higher levels of starch damage, and higher pentosans, yet lower gluten quality. Water absorption was within range of HRS whole wheat flour.

When comparing the refined flours, SRC values were actually lower for H2O, lactic acid, Na2CO3, and lactic acid. Respectively, this indicates less water absorption, gluten strength, and starch damage. The sucrose levels, indicating pentosan levels, is within a normal range for refined HRS flour.

It is important to note that the SCR results are on Kernza flour samples alone, not as blended flour product. In this project, only the pasta and crackers included 100% Kernza flour comparisons. Tortillas, donuts and sourdough breads reached a maximum of 30% inclusion rates. So in these formula mixes, the SRC implications would likely be closer to the standard flour ranges.

DELIVERABLE 3
PASTA

3.1 SUMMARY OF OBSERVATIONS FOR PASTA

PROCESSING

Typically, when adding whole grain in pasta processing, the more whole grain added, the more water that is needed. In this case, the opposite was true. As the level of whole Kernza increased, the water added decreased.

COLOR

The pasta got darker as more Kernza was added.

COOKING QUALITY

As the Kernza levels increase the cooking loss increases. Cooking loss is the amount of solids lost into the pasta water during cooking.

TEXTURE

The firmness of the cooked pasta decreased as the amount of Kernza increases.

SENSORY

The addition of Kernza added a nutty flavor and a gritty texture to the pasta which is typical when adding whole grain to pasta.

3.2 METHODS
PRODUCTION

Macaroni pasta was produced at NCI on the Demaco Pasta Press. Four formulas were produced at varying levels of whole Kernza flour inclusion. The formulas produced were:

- 100% durum semolina
- 34% whole grain Kernza, 66% durum semolina
- 66% whole grain Kernza, 34% durum semolina
- 100% whole grain Kernza.

3.3 RESULTS AND DISCUSSION

Pasta was analyzed using the AACC method 66-50.01 – pasta and noodle cooking quality – firmness. Cooking quality and texture results for macaroni samples are shown in the following table.

ANALYSIS	UNITS	100% SEMOLINA MACARONI	34% KERNZA MACARONI	66% KERNZA MACARONI	100% KERNZA MACARONI
COOKING TIME	MINUTES	6.75	6.75	6.25	5.25
DRY PASTA WEIGHT	G	25.20	25.02	25.05	25.05
COOKED PASTA WEIGHT	G	59.30	58.05	56.56	53.70
WEIGHT INCREASE	%	135.32	132.01	125.79	114.37
COOKED LOSS	%	4.16	5.00	5.08	5.44
COLOR (MACARONI)	L*	85.41	69.49	66.81	64.72
COLOR (MACARONI)	A*	-3.33	2.79	3.62	3.90
COLOR (MACARONI)	B*	31.47	17.79	18.83	18.86
COLOR (FLOUR BLENDS)	L*	81.13	82.04	82.48	82.78
COLOR (FLOUR BLENDS)	A*	-0.49	-1.15	-0.90	-0.80
COLOR (FLOUR BLENDS)	B*	19.72	19.55	17.14	15.81
TEXTURE - FIRMNESS	G	550.16	474.54	447.75	389.75
TEXTURE - WORK OF SHEAR	G.CM	121.97	128.96	142.54	114.80

Changes were noticed in cooking quality and results with the inclusion of whole grain Kernza. Specifically, the cooking time and cooked pasta weight decreased while cooking loss increased. Since there was very little difference in dry pasta weight, this indicates that increased Kernza was lost during cooking. Typical cooking loss is related to increased starch in the cooking water. 34% inclusion rate seems to be relatively close enough to the 100% semolina check sample.

For color, increased inclusion rates had a noticeable darkening effect on the pasta as was exhibited with lower L* scores. This was pronounced in the final macaroni samples, but no trend was observed in the flour blends.

Pasta firmness after cooking was considerably less with increasing rates of Kernza whole grain flour, yet no trend was noticed with the work of shear, wherein the 66% inclusion rate was the highest and the 100% Kernza was actually the lowest, even lower than the semolina check.

34% KERNZA

66% KERNZA

100% KERNZA

DELIVERABLE 4
CRACKERS

4.1 SUMMARY OF OBSERVATIONS FOR CRACKERS

MIXING

Increased % of Kernza decreased the amount of water required. Whole Kernza had a crumbly dough appearance.

SHEETING/CUTTING

All were easy to cut, refined flour was stickier.

BAKING

Crackers from refined flour stuck to the pan slightly.

COLOR

The higher % of whole Kernza had a darker color.

TEXTURE

Refined flour crackers had an airy appearance. Kernza inclusion decreased the force required to break the cracker.

4.2 METHODS

Crackers were made using a modified version of the USDA chemically-leavened cracker baking procedure found at https://www.ars.usda.gov/midwest-area/wooster-oh/corn-soybean-and-wheat-quality-research/docs/cracker-baking-procedure.

INGREDIENT	FORMULA (G)
TOTAL FLOUR	500
SHORTENING	60
WATER	145
FINE GRANULATED SUCROSE	45
AMMONIUM BICARBONATE	6.25
SALT	3.75
SODIUM BICARBONATE	6.25

TREATMENTS

TREATMENT	WHOLE WHEAT FLOUR (G)	WHOLE KERNZA FLOUR (G)	ALL PURPOSE FLOUR (G)	REFINED KERNZA FLOUR (G)
100% WHOLE KERNZA	0	500	-	-
75% WHOLE KERNZA	125	375	-	-
50% WHOLE KERNZA	250	250	-	-
25% WHOLE KERNZA	375	125	-	-
100% WHOLE WHEAT	500	0	-	-
100% REFINED KERNZA	-	-	0	500
75% REFINED KERNZA	-	-	125	375
50% REFINED KERNZA	-	-	250	250
25% REFINED KERNZA	-	-	375	125
100% ALL-PURPOSE WHEAT	-	-	500	0

MIXING

Stage 1:
1. Weigh all ingredients into separate containers.
2. Place shortening in mixing bowl and mix on speed 2 to distribute.
3. Pour fine granulated sucrose into the water and stir to dissolve.
4. Add ammonium bicarbonate to the dissolved sucrose and stir until dissolved.
5. Add liquid to shortening and mix on speed 2 for 1 minute, scraping with a spatula every 15 seconds.

Stage 2:
1. Mix flours, salt and sodium bicarbonate together and then add to the water and shortening.
2. Mix on speed “stir” for 10 minutes. While stirring, monitor the feel of the dough. Add just enough water to form a mold-able dough, recording the amount of water that is added.
3. Divide the batch into four portions and make 4 dough balls.
4. Cover dough balls with plastic to prevent drying.

SHEETING

1. Flatten the dough ball to about 1 ½”.
2. Set the sheeter dial to 15mm and sheet 2x.
3. Repeat step two by sequentially decreasing the dial setting and sheeting the dough 2x at each of the following settings: 12, 10, 8, 6, 4, 2, 1 and 0.31mm.

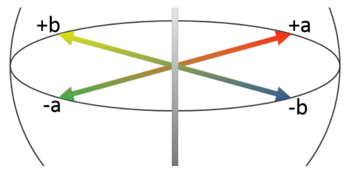
CUTTING AND BAKING

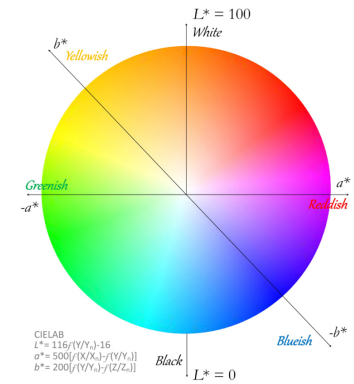
Oven temperature: 500F. Place mesh baking sheet to pre-heat in oven at least 5 minutes before sheeting the dough.

1. Transfer sheeted dough to wooden table and dock with a roller docker.
2. Cut dough into 1 ¼” squares.
3. Remove mesh baking sheet from oven and transfer dough squares to the hot sheet.
4. Place sheet in oven and bake for 1 ½ minutes.
5. Remove pan from oven and immediately remove crackers from pan.
6. Allow to cool before bagging.
7. Allow crackers to sit overnight before analyzing for color and texture.

COLOR

A Konica Minolta colorimeter was used to read the L*a*b* values. Four crackers were placed together to form a larger square and the colorimeter was positioned on the four crackers to take a reading. Readings were taken on three sets of four crackers and results are presented as averages in this report.





IMAGES COPIED FROM HTTP://WWW.FSW.CC/COLOR-SPACES/ ON JULY 1, 2020.

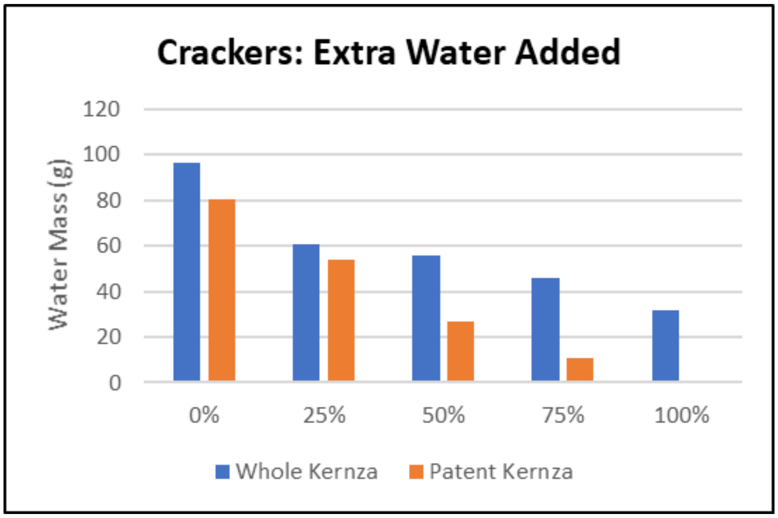
TEXTURE

A TA XT Plus Texture Analyzer with the Wafer-BIS3-KB method was used. The slotted insert was secured on the TA90 Heavy Duty Platform and the knife edge probe was attached to the load-cell. Two crackers were placed side by side and centered over the slot. The probe was lowered to move completely through the product, breaking the cracker. Maximum force was measured in three sets of two crackers for each treatment and results are presented as averages in this report.

BEFORE BEGINNING MIDDLE END

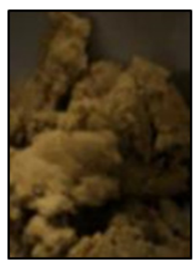
4.3 RESULTS AND DISCUSSION
MIXING

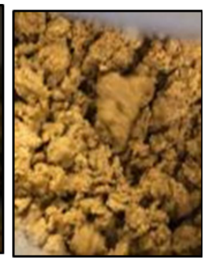
Generally, the whole Kernza doughs had a crumbly dough appearance while the refined Kernza doughs had a smooth appearance. The higher the amount of Kernza, the less water needed to form a pliable dough.



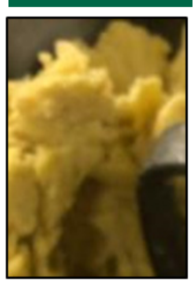

25% WHOLE KERNZA


50% WHOLE KERNZA


75% WHOLE KERNZA


100% WHOLE KERNZA


25% REFINED KERNZA


50% REFINED KERNZA


75% REFINED KERNZA


100% REFINED KERNZA

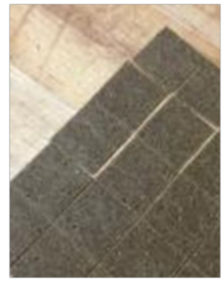
SHEETING AND CUTTING

All doughs were easy to sheet and cut, although the refined Kernza treatments stuck to the counter a little bit more than the whole Kernza.

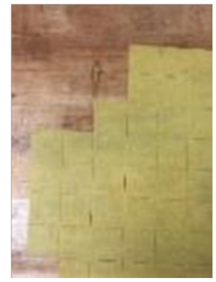
SHEETER

SHEETER SETTINGS

DOCKING AND CUTTING



100% WHOLE KERNZA



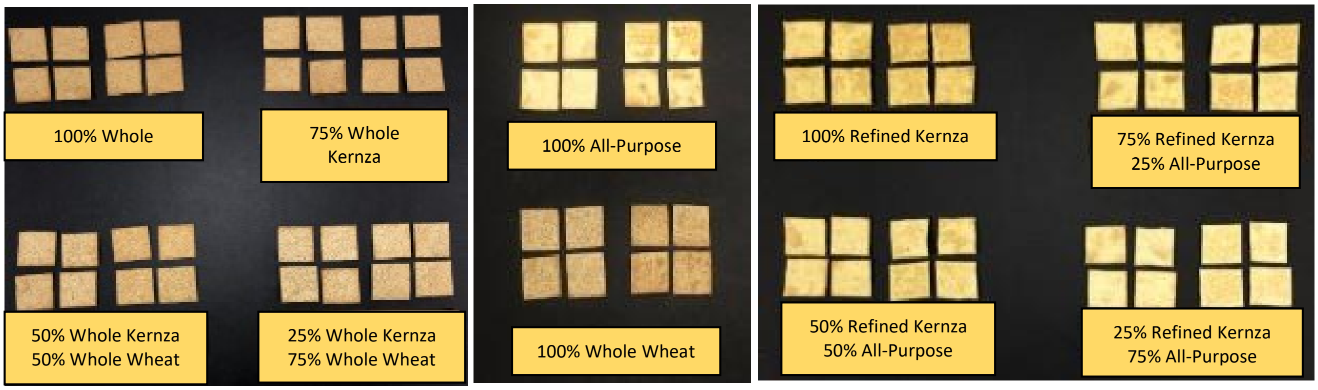
75% REFINED KERNZA

BAKING

The baking process began as soon as cut dough squares were placed on the hot baking sheet. Therefore, the squares that were placed on the sheet first were baked a little longer than those placed on the sheet last. Therefore, when choosing which crackers to analyze for color and texture, the very darkest ones were discarded and not analyzed.

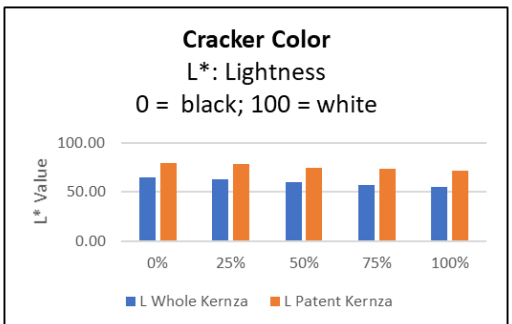
Crackers baked with whole Kernza slid off the pan with ease. Those made with refined Kernza stuck to the pan a small amount and needed a bit of nudging to remove from the pan.

FINISHED PRODUCT



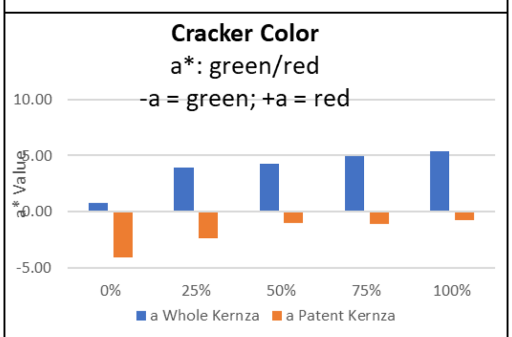
COLOR

Visually speaking, the higher the level of whole Kernza, the darker the cracker, and the higher the level of refined Kernza, the brighter yellow the cracker.



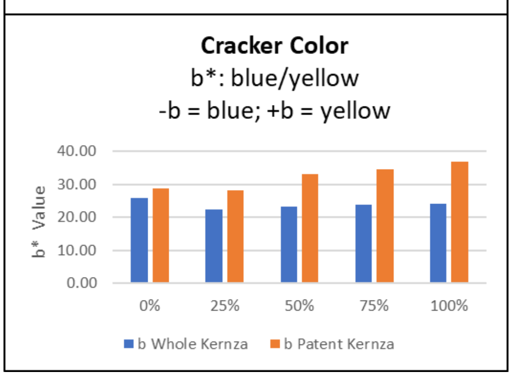
L* value (black/white):

The lower the level of Kernza, the higher the lightness level, L.



a* Value (green/red):

Generally, the higher the level of Kernza in the crackers, the more the a-value shifts toward red. Whole Kernza tends to shift slightly towards red, whereas refined Kernza crackers tends to shift slightly towards green.



b* Value (blue/yellow):

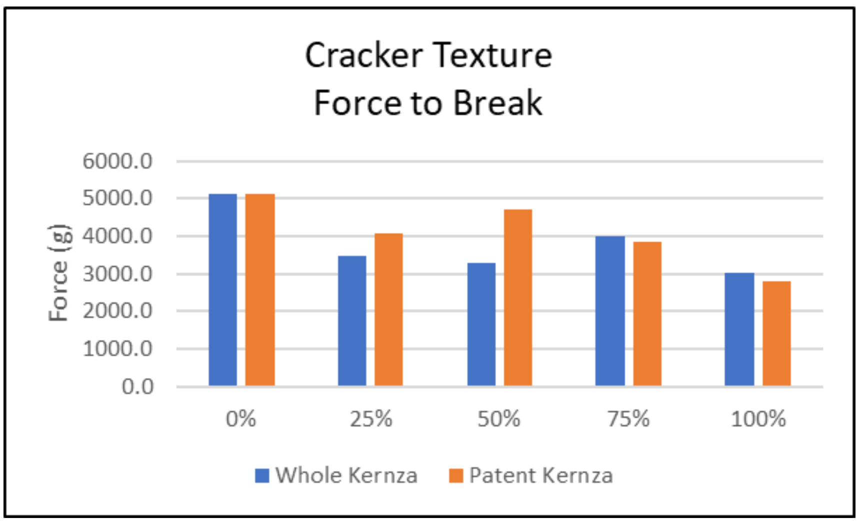
The most notable difference between the crackers in b-values exists between the whole vs. the refined crackers. Refined Kernza crackers had a higher b-value (shift towards yellow) than the whole Kernza crackers. In both the refined and whole Kernza crackers, the b-value decreased as the percent Kernza decreased.

TEXTURE

Visually, the refined Kernza crackers had an airy appearance while the whole Kernza crackers had a dense appearance. Crackers with 0% Kernza required more force to break than those with Kernza. At 25% and 50% inclusion rates, the refined Kernza flour required more force, yet at the higher inclusion rates, the whole Kernza flour requires slightly more force.

WHOLE KERNZA AND WHOLE WHEAT FLOURS

REFINED KERNZA AND ALL-PURPOSE FLOURS



DELIVERABLE 5
TORTILLAS

5.1 SUMMARY OF OBSERVATIONS FOR TORTILLAS

PROCESSING

Mixing times decreased as refined Kernza levels increased. The extensibility of the dough decreased as Kernza levels increased. The water added remained the same with the whole Kernza flour. The water added decreased as levels of refined Kernza increased.

COLOR

Increasing refined flour increased the yellowness of the tortilla. Increasing the whole Kernza flour increased the darkness of the tortilla.

DIAMETER

The diameter of the tortilla increased with higher inclusion of Kernza.

TEXTURE

The tortillas were less firm and easier to tear as the Kernza levels increased.

5.2 METHODS
FORMULATIONS

The same formula was used for both whole and refined Kernza treatments:

	CONTROL, 0% WHOLE OR REFINED KERNZA	CONTROL, 0% WHOLE OR REFINED KERNZA	10% WHOLE OR REFINED KERNZA	10% WHOLE OR REFINED KERNZA	20% WHOLE OR REFINED KERNZA	20% WHOLE OR REFINED KERNZA	30% WHOLE OR REFINED KERNZA	30% WHOLE OR REFINED KERNZA
INGREDIENTS	BAKER'S %	G	BAKER'S %	G	BAKER'S %	G	BAKER'S %	G
WHOLE WHEAT FLOUR	100	500	100	450	100	400	100	350
WHOLE GRAIN KERNZA FLOUR	0	0	100	50	100	100	100	150
BAKING POWDER	1.5	7.5	1.5	7.5	1.5	7.5	1.5	7.5
SALT	2	10	2	10	2	10	2	10
SHORTENING	15	75	15	75	15	75	15	75
SUGAR	3	15	3	15	3	15	3	15
WATER	VARIABLE	VARIABLE	VARIABLE	VARIABLE	VARIABLE	VARIABLE	VARIABLE	VARIABLE

TORTILLA PROCEDURE

1. Mix dry for ingredients for 30 seconds. Add shortening and mix for 1 min.
2. Mix in water until optimal.
3. Cut the dough to 50g pieces and make them into balls.
4. Let the dough balls rest for 10-15mins.
5. Sheet the dough with Dough pro.
6. Bake the dough at 525°F for 1-2 mins.

TORTILLA ROLL TEST AND TEXTURE

For the tortilla roll test, three tortillas from each variable were rolled around a standard pencil and allowed to unroll. Once unrolled the tortillas were checked for any cracking. For texture, or firmness, the TA XT Plus Texture Analyzer was set up as shown in this picture. Three tortillas were tested for each variable.

5.2 RESULTS AND DISCUSSION

DOUGH CHARACTERISTICS

WHOLE GRAIN TORTILLAS

	CONTROL 0% WHOLE KERNZA	10% WHOLE KERNZA	20% WHOLE KERNZA	30% WHOLE KERNZA
WATER ABSORPTION (%)	70.0	70.0	70.0	70.0
WATER TEMPERATURE (°F)	68.1	69.1	68.3	68.4
MIXING TIME (MINUTES)	7.0	6.0	5.5	5.0
DOUGH TEMPERATURE (°F)	76.7	77.2	76.2	77.0
DOUGH WEIGHT (G)	945.0	948.2	948.8	947.2

For the while grain tortillas, there was no observed difference for water absorption, mixing time, dough temperature, or dough weight when 10% whole grain Kernza was used. At 20% inclusion however, the dough was stickier than the control, yet after mixing, the dough was still nice and extensible. When 30% Kernza was used, the dough was weaker, less extensible, and would tear very easily. In general, mixing time decreased as whole Kernza was increased. This suggests that with higher whole grain Kernza rates, the mixing time needs to be reduced and operators would need to be aware of stickier doughs that begin to tear during sheeting.

5.2 RESULTS AND DISCUSSION
DOUGH CHARACTERISTICS CONT.

REFINED TORTILLAS

	CONTROL, 0% REFINED KERNZA	10% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA
WATER ABSORPTION (%)	64.0	64.0	60.0	58.0
WATER TEMPERATURE (°F)	68.5	68.6	68.2	67.7
MIXING TIME (MINUTES)	7.0	7.0	5.5	5.0
DOUGH TEMPERATURE (°F)	77.0	76.1	76.4	76.2
DOUGH WEIGHT (G)	917.2	916.2	899.0	891.0

For the tortillas made from refined Kernza flour, the same trends were observed as with the whole grain Kernza flours. The 10% inclusion rate reacted similarly as the control, while increasing inclusion rates decreased mix time and increased dough stickiness. A slight loss in extensibility occurred at the 20% inclusion rate and increased with stickiness at the higher 30% inclusion rate.

When comparing whole grain to refined Kernza flours, the water absorption and subsequent dough weights were higher when whole grain Kernza was used. This is a similar outcome expected when whole grain and refined HRS flour would be used.

WHOLE GRAIN TORTILLA DOUGH BEFORE SHAPING

WHOLE GRAIN TORTILLA DOUGH IN THE OVEN. TORTILLAS NEED TO PUFF TO ENSURE THERE ARE LAYERS IN THE FINISHED PRODUCT.

10% REFINED KERNZA

30% REFINED KERNZA

TORTILLA CHARACTERISTICS

WHOLE GRAIN TORTILLAS

		CONTROL 0% KERNZA	10% KERNZA	20% KERNZA	30% KERNZA
DIAMETER	CM	15.3	16.4	16.9	17.8
ROLL TEST	YES/NO	N	N	N	N
COLOR	L*	60.36	55.58	55.03	54.7
COLOR	A*	7.01	7.99	8.14	7.97
COLOR	B*	18.47	20.46	22.01	21.48
TEXTURE	G	1031.7	834.6	711.4	690.1

REFINED TORTILLAS

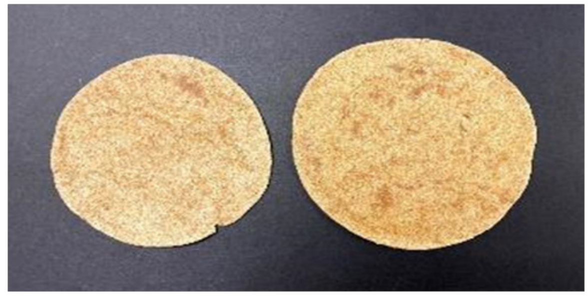
		CONTROL 0% KERNZA	10% KERNZA	20% KERNZA	30% KERNZA
DIAMETER	CM	15.8	17.3	16.9	17.4
ROLL TEST	YES/NO	N	N	N	N
COLOR	L*	79.17	78.42	78.19	80.1
COLOR	A*	-0.56	-1.51	-1.85	-2.42
COLOR	B*	19.2	23.02	26.29	27.26
TEXTURE	G	958.3	811.5	817.8	779.4

The diameter of the tortillas increased as the Kernza inclusion rate increased, occurring in both whole grain and refined flours. This is likely due to the decrease in gluten content as more Kernza is added. Less gluten in the tortilla means less resistance to extension which is shown in the larger tortilla diameter. This reduced extensibility was confirmed during mixing with less mix times and more extensible doughs. During the roll test, after the tortillas were unrolled, there were no observed cracks at any inclusion rate of either flour.

Kernza affected the color in both the whole grain tortillas and refined flour tortillas. In the whole grain tortilla, the tortillas got darker as more whole grain Kernza flour was added. This is shown in the L* value decreasing from 60.36 to 54.70. In the refined tortillas, tortillas with a higher Kernza content became more yellow in color. This is shown in the b* increasing from 19.20 to 27.26.

For texture results, the resistance to the texture analyzer probe decreased markedly as the inclusion rate of both Kernza flours increased. This resistance was higher for the whole grain flour at 10% inclusion, but higher in the refined flour at 20% and 30% inclusion rates.

WHOLE WHEAT CONTROL VS.
10% WHOLE GRAIN TORTILLA



WHOLE WHEAT CONTROL VS.
20% WHOLE GRAIN TORTILLA

WHOLE WHEAT CONTROL VS.
30% WHOLE GRAIN TORTILLA

WHOLE WHEAT	10% WHOLE GRAIN KERNZA	20% WHOLE GRAIN KERNZA	30% WHOLE GRAIN KERNZA

REFINED CONTROL VS.
10% REFINED KERNZA TORTILLA

REFINED CONTROL VS.
20% REFINED KERNZA TORTILLA

REFINED CONTROL VS.
30% REFINED KERNZA TORTILLA

REFINED CONTROL	10% REFINED KERNZA TORTILLA	20% REFINED KERNZA TORTILLA	30% REFINED KERNZA TORTILLA

DELIVERABLE 6
DONUTS

6.1 SUMMARY OF OBSERVATIONS FOR DONUTS

MIXING

Less water was required for higher Kernza inclusion. Mixing time decreased with higher rates of refined Kernza.

COLOR

Increase in refined Kernza resulted in more yellow internal crumb. Increase in whole Kernza led to darker internal crumb.

SENSORY

No difference observed between 10% Kernza samples and controls. 20% refined Kernza was more tender and had no flavor difference. 30% refined exhibited no flavor differences, but was less soft.

TEXTURE

Donuts were harder when Kernza was used, except for the 30% refined flour level.

6.2 METHODS
FORMULATIONS

WHOLE KERNZA FORMULATIONS

INGREDIENT	WHOLE GRAIN CONTROL	WHOLE GRAIN CONTROL	10% WHOLE GRAIN KERNZA	10% WHOLE GRAIN KERNZA	20% WHOLE GRAIN KERNZA	20% WHOLE GRAIN KERNZA	30% WHOLE GRAIN KERNZA	30% WHOLE GRAIN KERNZA
	GRAM	BAKER'S %	GRAM	BAKER'S %	GRAM	BAKER'S %	GRAM	BAKER'S %
WHOLE WHEAT FLOUR	500	100	450	100	400	100	350	100
WHOLE GRAIN KERNZA FLOUR	0	100	50	100	100	100	150	100
SUGAR	92	18.4	92	18.4	92	18.4	92	18.4
SALT	7	1.4	7	1.4	7	1.4	7	1.4
INSTANT YEAST	8.5	1.7	8.5	1.7	8.5	1.7	8.5	1.7
NUTMEG	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1
EGG	69.5	13.9	69.5	13.9	69.5	13.9	69.5	13.9
MILK	310	62	288.2	57.6	266	53.2	251.8	50.4
BUTTER	77.5	15.5	77.5	15.5	77.5	15.5	77.5	15.5
VANILLA	3.5	0.7	3.5	0.7	3.5	0.7	3.5	0.7

REFINED KERNZA FORMULATIONS

INGREDIENT	0% REFINED KERNZA	0% REFINED KERNZA	10% REFINED KERNZA	10% REFINED KERNZA	20% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA	30% REFINED KERNZA
	GRAM	BAKER'S %	GRAM	BAKER'S %	GRAM	BAKER'S %	GRAM	BAKER'S %
ALL-PURPOSE FLOUR	500	100	450	100	400	100	350	100
REFINED KERNZA FLOUR	0	100	50	100	100	100	150	100
SUGAR	70	14	70	14	70	14	70	14
SALT	4	0.8	4	0.8	4	0.8	4	0.8
INSTANT YEAST	8.5	1.7	8.5	1.7	8.5	1.7	8.5	1.7
NUTMEG	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1
EGG	69.5	13.9	69.5	13.9	69.5	13.9	69.5	13.9
MILK	300	60	300	60	260	52	258	51.6
BUTTER	39	7.8	140	28	140	28	140	28
VANILLA	3.5	0.7	12.5	2.5	12.5	2.5	12.5	2.5

PROCEDURE

1. Mix on low speed for 1 minute. Increase speed and mix until fully developed.
2. Place in proofer 95F 85% RH for 1 hour.
3. Remove from proofer. Roll out dough to 1/4” to 1/2” thickness.
4. Cut into desired shapes and place on a greased pan put back in proofer for 20-30 minutes, until doubled in size.
5. Have oil heated to 370F. Place dough into oil for 1-1.5 minutes per side.
6. Remove from oil and allow to cool.

Color was measured using the Minolta Colorimeter using the L*a*b* scale. The donuts were sliced in half and the color was measured on the internal structure. The results are an average of three measurements. The external color was measured by placing the colorimeter on the outside of the donut to measure. The results are an average of three measurements.

Texture analysis (donut crumb firmness) - a modified AACC bread firmness method was used. The set-up is shown in the following picture:

6.3 RESULTS

MIXING CHARACTERISTICS

WHOLE GRAIN DONUTS

	0% WHOLE KERNZA	10% WHOLE KERNZA	20% WHOLE KERNZA	30% WHOLE KERNZA
ABSORPTION (%)	62.0	57.6	53.2	50.4
LIQUID TEMPERATURE (°F)	54.8	56.0	58.1	60.0
MIXING TIME (MINUTES)	8.0	8.0	8.0	7.5
DOUGH TEMPERATURE (°F)	75.8	80.1	82.5	83.3

REFINED KERNZA DONUTS

	0% REFINED KERNZA	10% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA
ABSORPTION (%)	60.0	60.0	52.0	51.6
LIQUID TEMPERATURE (°F)	39.4	46.0	50.8	54.4
MIXING TIME (MINUTES)	8.5	8.25	8.0	7.0
DOUGH TEMPERATURE (°F)	78.1	78.8	79.8	79.2

Similar to other products, the inclusion of Kernza led to reduction in needed water as measured by water absorption. Mixing time also decreased with added Kernza flours. Mixing time was similar between the two flours, yet longer at lower inclusion rates with refined flour and alternatively longer at 30% whole grain Kernza.

COLOR AND TEXTURE

WHOLE GRAIN KERNZA DONUTS

		CONTROL	10% WHOLE KERNZA	20% WHOLE KERNZA	30% WHOLE KERNZA
COLOR - INTERNAL	L*	63.33	62.44	59.48	56.76
COLOR - INTERNAL	A*	7.59	7.28	7.43	8.79
COLOR - INTERNAL	B*	23.40	23.35	24.52	26.86
COLOR - EXTERNAL	L*	38.46	36.09	33.91	34.15
COLOR - EXTERNAL	A*	17.22	15.45	13.56	14.23
COLOR - EXTERNAL	B*	19.71	16.46	13.14	12.39
TEXTURE	G	267.5	343.0	381.7	270.2

REFINED KERNZA DONUTS

		CONTROL	10% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA
COLOR - INTERNAL	L*	82.60	80.45	81.06	80.02
COLOR - INTERNAL	A*	-1.31	-1.84	-1.99	-2.12
COLOR - INTERNAL	B*	26.25	30.59	33.6	37.03
COLOR - EXTERNAL	L*	50.23	48.82	45.61	46.18
COLOR - EXTERNAL	A*	17.68	18.76	20.66	19.07
COLOR - EXTERNAL	B*	34.07	33.63	30.14	30.67
TEXTURE	G	148.1	208.2	188.6	134.6

The internal crumb of the whole Kernza donuts got darker as the amount of whole grain Kernza flour increased. This can be seen by the L* value decreasing from 63.33 to 56.76. For the refined Kernza donuts, the internal crumb became more yellow as the inclusion rate was increased. This can be seen by the b* value increasing from 26.23 to 37.03. A similar trend existed with external color from 0% to 20%, yet was slightly higher in L score at the 30% inclusion rate. Overall, the refined Kernza flour had higher L scores than the whole grain flours indicating darker colors than refined flour rates, for both internal and external measurements.

When measuring texture, the texture analyzer required more force when whole grain Kernza added. For refined Kernza flour, the 10 and 20% rates were firmer, but 30% refined Kernza was slightly softer than the check. Whole grain Kernza exhibited higher force at all rates compared to refined Kernza donuts.

WHOLE GRAIN CONTROL - DOUGH BEFORE PROOFING

10% WHOLE GRAIN KERNZA - DOUGH BEFORE PROOFING

25% WHOLE GRAIN KERNZA - DOUGH BEFORE PROOFING

REFINED CONTROL - DOUGH BEFORE PROOFING

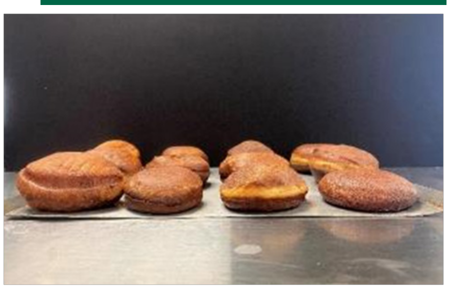
10% REFINED KERNZA - DOUGH BEFORE PROOFING

20% REFINED KERNZA - DOUGH BEFORE PROOFING

30% REFINED KERNZA - DOUGH BEFORE PROOFING

20% WHOLE GRAIN KERNZA - INTERNAL VIEW WITH VISABLE AIR POCKETS

30% WHOLE GRAIN KERNZA - INTERNAL VIEW WITH VISABLE AIR POCKETS



WHOLE GRAIN CONTROL | 10% WHOLE GRAIN KERNZA | 20% WHOLE GRAIN KERNZA | 30% WHOLE GRAIN KERNZA

WHOLE GRAIN CONTROL | 10% WHOLE GRAIN KERNZA | 20% WHOLE GRAIN KERNZA | 30% WHOLE GRAIN KERNZA

REFINED CONTROL

10% REFINED KERNZA

20% REFINED KERNZA

30% REFINED KERNZA

REFINED CONTROL	10% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA

REFINED CONTROL	10% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA

Regarding sensory observations in the final products, there was no noticeable difference between the 10% Kernza donuts and controls in both the whole grain and refined donuts. The 20% refined Kernza donut seemed more tender than the control with no flavor difference. The 30% refined Kernza has no flavor difference from the control, but wasn't as soft as the control. Frying seems to cover up any detectable flavor differences between the variables.

DELIVERABLE 7
SOURDOUGH BREAD

7.1 SUMMARY OF OBSERVATIONS FOR SOURDOUGH BREAD

MIXING

Decreased water needed for whole grain Kernza inclusion. Decreased proof time needed for both Kernza flours.

COLOR

Both Kernza flours were more yellow and darker with increased levels of Kernza.

LOAF WEIGHT

Both Kernza flours were heavier than controls.

LOAF VOLUME

Loaf volume was higher for refined Kernza, but lower for whole grain flour.

7.2 METHODS
FORMULATIONS

WHOLE GRAIN KERNZA

	CONTROL	CONTROL	10% WHOLE KERNZA	10% WHOLE KERNZA	20% WHOLE KERNZA	20% WHOLE KERNZA	30% WHOLE KERNZA	30% WHOLE KERNZA
	GRAMS	BAKER'S %	GRAMS	BAKER'S %	GRAMS	BAKER'S %	GRAMS	BAKER'S %
WHOLE WHEAT FLOUR	800	100	725	100	650	100	575	100
WHOLE GRAIN KERNZA	0	100	75	100	150	100	225	100
WHOLE WHEAT SOURDOUGH	314.4	39.3	314.4	39.3	314.4	39.3	314.4	39.3
WATER	616	77	616	77	592	74	568	71
SALT	22.4	2.8	22.4	2.8	22.4	2.8	22.4	2.8

7.1 SUMMARY OF OBSERVATIONS FOR SOURDOUGH BREAD CONT.

REFINED KERNZA

	CONTROL	CONTROL	10% REFINED KERNZA	10% REFINED KERNZA	20% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA	30% REFINED KERNZA
	GRAMS	BAKER'S %	GRAMS	BAKER'S %	GRAMS	BAKER'S %	GRAMS	BAKER'S %
BREAD FLOUR	800	100	725	100	650	100	575	100
REFINED KERNZA	0	100	75	100	150	100	225	100
SOURDOUGH	314.4	39.3	314.4	39.3	314.4	39.3	314.4	39.3
WATER	511.2	63.9	511.2	63.9	511.2	63.9	511.2	63.9
SALT	22.4	2.8	22.4	2.8	22.4	2.8	22.4	2.8

PROCEDURE

1. Add all of the ingredients, except salt, to a mixing bowl and mix on low speed for 1 minute. Increase speed to 2 and mix for 2 minutes.
2. Cover the bowl and rest the dough for 15 minutes. Add salt and mix on speed 2 for 5 more minutes.
3. Remove dough from mixing bowl and let bulk ferment at room temperature for 1 hour.
4. Fold dough and allow to bulk ferment for 1 hour.
5. Fold dough and bulk ferment for 20 minutes.
6. Scale the dough into 540g pieces and pre-shape into batard shape. Cover and rest for 15 minutes.
7. Shape the dough into a batard shape and place seam side up into a bowl with a floured couche.
8. Proof in bowls for 30 minutes at 80F and 80% RH.
9. Place covered bowls in refrigerator for 17 hours.
10. Place in proofer at 80F and 80% RH and proof until dough doesn't spring back when poked.
11. Remove from bowls and score top of dough.
12. Place into 425F deck oven for 20 minutes with 40 seconds of steam at the beginning.
13. Remove from oven and allow to cool before running quality tests.

7.3 RESULTS

WHOLE GRAIN KERNZA SOURDOUGH BREAD

	CONTROL	10% WHOLE KERNZA	20% WHOLE KERNZA	30% WHOLE KERNZA
WATER ABSORPTION (%)	77.0	77.0	74.0	71.0
WATER TEMPERATURE (°F)	90	84	88.1	82
TIME IN REFRIGERATOR (HOURS)	17	17	17	17
PROOF TIME (MINUTES)	150	150	120	110

REFINED KERNZA SOURDOUGH BREAD

	CONTROL	10% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA
WATER ABSORPTION (%)	63.9	63.9	63.9	63.9
WATER TEMPERATURE (°F)	58.0	55.6	80.5	79.4
TIME IN REFRIGERATOR (HOURS)	17	17	17	17
PROOF TIME (MINUTES)	180	180	125	122

For whole grain Kernza sourdough, water absorption in the dough decreased as whole Kernza flour inclusion rates increased. In the refined Kernza doughs, the water absorption remained the same across all inclusion rates. For both the whole grain Kernza and refined Kernza, there was a decrease in proof times as Kernza inclusion rates increased.

SOURDOUGH BREAD QUALITY, WHOLE GRAIN KERNZA

		CONTROL	10% WHOLE KERNZA	20% WHOLE KERNZA	30% WHOLE KERNZA
BAKED WEIGHT	GRAMS	496.5	504.6	504.1	513.1
COLOR - INTERNAL	L*	47.91	46.01	45.64	45.23
COLOR - INTERNAL	A*	7.74	7.63	7.66	7.78
COLOR - INTERNAL	B*	17.95	17.56	17.62	18.2
LOAF VOLUME	GRAMS	1142.4	1090.0	993.3	921.0
TEXTURE	GRAMS	792.3	762.7	1119.9	1295.0
C-CELL DATA					
SLICE AREA/PX		353451	320895	335760	318172
HEIGHT (AVG)/PX		456	453	445	437
BREADTH/PX		943	851	912	873
SLICE BRIGHTNESS		50.3	49.2	48.8	49.1
NUMBER OF HOLES		3	0.05	2.09	0.78
WALL THICKNESS/ PX		3.43	3.53	3.32	3.36
CELL DIAMETER/ PX		17.84	20.44	15.05	15.68
NON-UNIFORMITY		4.54	2.285	2.093	1.025
AVERAGE CELL ELONGATION		1.51	1.48	1.48	1.47
CELL ANGLE TO VERTICAL/°		-56.3	-53.6	37	75.3

The L* color score for the whole grain Kernza sourdough bread crumb shows that as whole Kernza levels increased the crumb color in the bread became whiter in color. The volume of the loaves decreased as Kernza inclusion rates increased. Often times as loaf volumes decrease the firmness of the crumb increases due to the bread crumb being more compact. This was seen in the whole grain Kernza sourdough breads; as Kernza levels increase the bread crumb became much firmer.

CONTROL



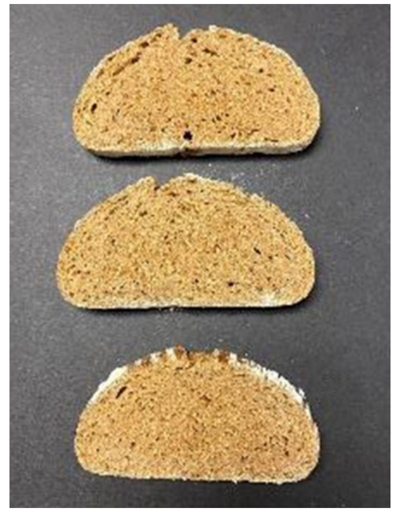
10% WHOLE GRAIN KERNZA SOURDOUGH



20% WHOLE GRAIN KERNZA SOURDOUGH



30% WHOLE GRAIN KERNZA SOURDOUGH



WHOLE GRAIN CONTROL	10% WHOLE GRAIN KERNZA	20% WHOLE GRAIN KERNZA	30% WHOLE GRAIN KERNZA

WHOLE GRAIN CONTROL	10% WHOLE GRAIN KERNZA	20% WHOLE GRAIN KERNZA	30% WHOLE GRAIN KERNZA

SOURDOUGH BREAD QUALITY, REFINED KERNZA

		CONTROL	10% REFINED KERNZA	20% REFINED KERNZA	30% REFINED KERNZA
BAKED WEIGHT	GRAMS	488.9	494.8	490.8	492.5
COLOR - INTERNAL	L*	74.30	72.49	71.99	68.46
COLOR - INTERNAL	A*	-0.1	-0.31	-0.54	-0.5
COLOR - INTERNAL	B*	20.49	22.88	23.37	25.77
LOAF VOLUME	GRAMS	1593.9	1673.5	1716.9	1661.01
TEXTURE	GRAMS	173.8	162.1	175.9	190.2
C-CELL DATA					
SLICE AREA/PX		541821	585124	549483	500988
HEIGHT (AVG)/PX		653	617	607	540
BREADTH/PX		998	1071	1080	1077
SLICE BRIGHTNESS		121.4	121.6	118.4	116.1
NUMBER OF HOLES		3.25	5.67	4.53	3.31
WALL THICKNESS/PX		3.65	3.72	3.68	3.69
CELL DIAMETER/PX		20.87	21.26	25.95	24.7
NON-UNIFORMITY		7.967	5.954	7.126	4.505
AVERAGE CELL ELONGATION		1.68	1.61	1.65	1.58
CELL ANGLE TO VERTICAL/°		-17.7	-20.4	-14.9	-27.1

The color of the crumb in the sourdough bread with refined Kernza flour became whiter and more yellow as Kernza levels increased. All the loaves containing refined Kernza flour had larger loaf volumes than the control, with the 20% level having the largest loaf volume. In regards to the texture of the bread crumb, 10% refined Kernza had a softer crumb than the control. The 20% refined Kernza bread crumb had a texture very similar to the control and the 30% refined Kernza bread crumb had a firmer texture than the control.

CONTROL

10% REFINED KERNZA

20% REFINED KERNZA



30% REFINED KERNZA



2021 KERNZA FOOD PRODUCT DEVELOPMENT PROJECT REPORT
For Agricultural Utilization Research Institute

Northern Crops Institute

APPENDIX B

Sensory Analysis: Northern Crops Institute Food Products

AURI Sensory Analysis:

Northern Crops Institute Food Products

Evaluation: NCI Kernza Cracker Variables (Feb – Mar 2021)
Summarized by: AURI

Overall Summary:
Refined Kernza Flour:

- Overall appearance is fairly uniform throughout inclusion rates, though puffiness/bubbles become more apparent at the higher rates.
- Aroma stays consistent throughout with only a hint of grainy/grassy at 100%.
- Texture seems to improve with higher inclusion rates, going from soft and doughy to crunchier and crisper.
- Flavor starts out fairly neutral with a slight sweetness but starts to develop a more pronounced grainy taste with higher levels.

Whole Grain Kernza Flour:

- Appearance is excellent throughout with only mild darkness noticed with increased rates. Similar trend noticed in aroma, very uniform throughout inclusion rates with a typical grainy, whole grain smell.
- Similar to the refined flour, texture seems to improve with higher rates, though the starting crisp/crunchiness is better at lower rates than refined flour.
- Again, similar to refined flour, issues with flavor start occurring at higher inclusion rates with 100% having a harsh burnt grain off flavor.

Recommendations:

1. Refined Kernza Flour: Suggested usage is roughly 50% as that's where optimal texture/flavor meet.
2. Whole Grain Kernza Flour: Suggested rate is slightly higher than refined with it being optimal at 75% for the same reason as refined flour.
3. Issue with texture could be solved through altered cook times or other baking methods to increase crispness and solidify texture more.

Evaluation: NCI Kernza Pasta Variables (Feb – Mar 2021)
Summarized by: AURI

Overall Summary:
Whole Grain Kernza Flour:

- The addition of whole grain flour significantly alters the color and increases with intensity with inclusion rates, though not dissimilar to other whole grain pastas.
- Aroma of whole grain flour is subtle at lower inclusions but drastically increasing with inclusion rates.
- Off-aromas start to occur at 100% rate.
- Slightly more dense and less spongey at lower rates with increasing intensity as rates increase.

- Higher rates also start to take on more grainy/gritty texture due to the whole grain flour becoming very noticeable at 100%.
- Whole grain/earthy flavor is noticed at lower levels and increasing with the higher levels.
- Bitter/astringent flavor becomes significant at 100%.

Recommendations:

4. Whole Grain Kernza Flour: Suggested maximum inclusion is 66% as higher rates the texture suffers as well as off flavors start to become significantly noticeable.
5. Texture/flavor issues attributed to whole grain flour. Would be interested to see what a refined flour could do instead and if that would solve issues or at least allow higher inclusion rates.

Evaluation: NCI Kernza Bread Variables (Feb – Mar 2021)
Summarized by: AURI

Overall Summary:
<u>Refined Kernza Flour</u>:

- As Kernza level increases differences noted as follows: color is similar, but crumb becomes more open, aroma is similar or slightly higher in sourdough notes, texture becomes denser and drier, the sourdough or sour flavor increases, and bread becomes more bitter. Meets expectations for sourdough bread up to 50% inclusion rates.
- Above 50% Kernza, bread became too tough and too dry with a more pronounced bitter flavor.

<u>Whole Grain Kernza Flour</u>:

- Bread becomes darker and denser (appearance and texture) as Kernza % increases.
- Flavor is stronger and more bitter as Kernza percent increases.
- Acceptability drops as percent Kernza increases with only 50% acceptability at 75% Kernza.

As expected, differences from control were exaggerated as the percentage of Kernza increases, but surprisingly, acceptability at higher levels of Kernza was similar or slightly better with the whole grain versus the refined flour. Recommendations:

6. Refined Kernza Flour: Maximum usage percentage recommended is up to 50 %.
7. Whole Grain Kernza Flour: Maximum usage percentage recommended also up to 50 %.
8. The chewy texture and strong fermented flavor of the sour dough bread allow for fairly high usage rates of Kernza without negative impacts. Use of whole grain is a bit more challenging in a bread system in general, and the control of whole grain sour dough bread was somewhat tough.

Evaluation: NCI Kernza Donut Variables (Feb – Mar 2021)
Summarized by: AURI

Overall Summary:

- <u>Refined Kernza Flour</u>: Crust gets darker in color and center becomes more noticeably yellow with added inclusion.

- Very little besides possibly a stronger aroma with added inclusion.
- The biggest difference is noticeable in the flavor and texture as the inclusion rates increase. With increased rates the donuts experienced slightly denser texture with the donuts becoming chewier.
- The flavor was fairly similar at the 25% rate but gained a more earthy/grainy taste with increased rates.
- Sweetness also decreased with the added inclusion rates.
- Would largely be considered acceptable as donuts at lower rates with acceptance tapering off as inclusion rates rise.

Whole Grain Kernza Flour:
- Significantly darker in appearance than the control.
- Fairly similar in aroma at lower inclusions with a grainy/earthy smell noticed at 75%.
- Texture is significantly different than control with the donuts having a much denser/chewier texture to them.
- Very bready in flavor with an unpleasant bitter aftertaste noted at all inclusion rates.
- Overall, not considered a donut; very unpleasant, bitter, and dense.

Recommendations:

9. Refined Kernza Flour: Max usage suggested at 50%, though preference could dictate acceptance at higher levels.
10. Whole Grain Kernza Flour: Unacceptable at all levels. Too bitter, dense, and dry for a fried donut product.
11. I don't believe acceptance of a whole grain donut is unique to Kernza, inherent nature of whole wheat flour is simply non-conducive to a fried donut due to products being too dense and bitter flavors overpowering the light and sweet taste that typically accompany a donut.

Evaluation: NCI Kernza Tortilla Variables (Feb – Mar 2021)
Summarized by: AURI

Overall Summary:
Refined Kernza Flour:
- Becomes more yellow in color as the percentage of Kernza increases.
- Little difference in aroma, texture, or flavor as % Kernza increases, slight increase in tortilla dryness and hardness, with a slight increase in grainy flavor.
- Meets expectations for a tortilla up to 50% inclusion rates, with any differences from control deemed to be indistinguishable when used as a carrier for fillings.
- Above 50% Kernza, product expectations were mixed, driven largely by lack of product structure (tortilla fell apart).

Whole Grain Kernza Flour:
- Product becomes noticeably darker/yellower, thinner, and flatter as Kernza % increases.
- Slight increase in grainy aroma as Kernza % increases. Density increases and structural integrity decreases as Kernza percentage increases and becomes noticeably drier.
- The grainy flavor and bitterness increase substantially above 50% Kernza.

- Acceptability as a tortilla drops as Kernza percentage increases, driven largely by bitter flavor, lack of product integrity, and dryness.

As expected, differences from control were exaggerated as the percentage of Kernza increases, though the differences were more acceptable when using refined flour versus whole grain flour. Recommendations:

12. Refined Kernza Flour: Maximum usage percentage is between 50-75%, with smaller differences from control at lower levels of Kernza.
13. Whole Grain Kernza Flour: Maximum usage percentage at 25% or lower. Above 25%, tortillas begin to lose structural integrity and whole grain bitterness overwhelms the product experience
14. When used as a carrier (as intended), flavor and texture differences were muted – though structural integrity issues become more prominent (food science tools, such as hydrocolloids, to improve product elasticity may be necessary to incorporate more Kernza into the formulation).

APPENDIX C

Kernza®: Experimental Milling
(Wheat Marketing Center)

Milling report
October 2020

Title: **Kernza: Experimental milling**

Investigators: **Dr. Jayne Bock, Technical Director, Wheat Marketing Center**
Mr. Bon Lee, Operations Manager, Wheat Marketing Center

Summary:

AURI is exploring best practices for milling and food applications of Kernza as part of a larger effort to provide information to grain producers, millers, and end users. Although Kernza is expected to be used primarily in whole grain applications, AURI would also like to understand best practices for refined flour milling to guide interested users. Milling notes and pictures of the refined flour milling process follow:

- An informal kernel hardness check on Kernza indicated kernel texture similar to soft wheat. As a result, the grain was tempered overnight to 14.5% according to soft wheat standards. Initial Kernza moisture was 10.7%.
- Milling was completed on a Miag Multomat instead of the Buhler MLU-202. The Miag offers better control over feed rate and roll gap settings than the Buhler, and this control is crucial to preventing milling issues when average kernel size is much smaller than that for wheat.
- **<u>Best refined Kernza flour milling practices and notes</u>**:
  - The mill warm-up was done by grinding 40 lbs of dry (non-tempered) hard red wheat. The warm-up wheat was cleaned out for 45 minutes with a brush and positive air flow.
  - The Kernza feed rate was to 202 g/30 sec (24.24 kg/hr), which is approximately half the feed rate typically used for regular wheat.
  - B1 break release through 24 SSBC was 17.1% (~45% for regular wheat) as determined by sifting the stream on a tabletop Great Western sifter for 1 minute. Roll gap settings were tightened due to smaller kernel dimensions.
    - Actual roll gap settings are specific to the individual mill. The more important targets are the B1 and B2 break release.
  - B2 break release through 24 SSBC was 46.4% (~63% for regular wheat) using the same sifter and time.
  - All break release ground grain was fed into the grain hopper to B1 toward the end of the feed. The feed rate was maintained at 202 g/30 sec.
  - The reduction section of milling did not require adjustment.
    - All ground grain behaves the same after B1 and B2.
  - All flour streams (minus offal streams) were blended to produce straight grade flour.
  - Appendix A shows the refined Kernza flour yield (42.9%) and mill stream breakdown.

Figure 1. The straight grade flour streams, in order of mill output from left to right: B1, B2, GR (Grader), B3, 1M, 2M, 3M, 1MR (1M Redust), 4M, and 5M.

Figure 2. The mill produces the following offal streams, in order of mill output from left to right: break shorts, bran, red dog, and red shorts.

Whole grain flour production methods, equipment, cost estimates, and yield potential:

There are two primary means of producing whole grain flour. The most popular in North America is the recombination method. In this process, the grain is roller milled as for a refined flour with all mill streams recombined and blended post-milling. The most common pilot-scale equipment for this type of process will be a larger experimental mill, such as the Bühler MLU 202 or Miag Multomat with further grinding of offal streams by other grinding equipment such as a hammer mill. These mills can accommodate grain quantities from ~40 – 600 lbs per 8 hr day depending on which option is selected. They are relatively easy to install, with the only requirement being proper air control and building construction to minimize grain dust explosion risks. The cost to purchase is ~$250,000 and up. The yield potential on this type of process is ~96 - 97%.

It should be noted that true pilot-scale options exist for roller mill systems, but they tend to require construction or refurbishing of a multi-story building to accommodate the equipment. As a result, the price is much higher than that for an experimental mill, running into $1,000,000+ territory depending on land availability, construction costs, and/or existing building refurbishment needs.

The second method of whole grain flour production is direct grinding of the whole kernel by attrition without separation of kernel components. Stone milling is the most common form of attrition milling. In this method, the whole kernel is ground between two stones, one of which is stationary while the other rotates to generate the grinding action. The most common pilot-scale equipment for this type of process will be a small stone mill. These mills are manufactured by a number of companies at various size scales, accommodating grain quantities from ~5 – 500 lbs. The are also relatively easy to install, again requiring some risk mitigation measures for the explosive potential of grain dust. The cost to purchase is ~$150,000 and up. The yield potential on this type of process will be similar to that for recombination, ~96 – 98% depending on whether the miller chooses to sieve and regrind large bran or partial kernels.

APPENDIX A

MIAG	**42.9%**	(g/30sec)		b1(% thru 24)	b2(% thru 24)	start time	finish time	milling time		Tempering Formula				
10/16/2020	Feed Rate	202	Break Release	17.1	46.4	8:48	10:29	1:41		(desired Mst-wheat Mst) X Weight / (100-desired Mst)				
Labnum	120211209	Total	38.4%	Weighments										
Passage	Tare	Net Weight	% of B1	1	2	3	4	5	6	7	8	9	10	11
B1	2090.0	2658	7.82%	4748										
B2	2075.8	4695.4	13.81%	5233	3614									
GRAD	2081.2	2872.8	8.45%	4954										
B3	1152.8	1066.2	3.14%	2219										
1M	2128.4	688.6	2.03%	2817										
2M	2091.8	1255.2	3.69%	3347										
3M	2081.8	757.2	2.23%	2839										
1MR	1987.4	140.6	0.41%	2128										
4M	2050.8	308.2	0.91%	2359										
5M	1470.6	146.4	0.43%	1617										
Suction	785	67	0.20%	852										
BRAN	781	16568	48.73%	3230	2994	2933	2983	2954	3166	2583	1973			
BK SHTS	785	1293	3.80%	2078										
RED DOG	1203.4	1302.8	3.83%	1708	1689	1516								
RED SHTS	935.6	249.4	0.73%	1185										
			100%											
Extraction	flour	14589	42.9%											
	feed	19413	57.1%											
		34002												
Kernzan grain for the first time														

APPENDIX D

Malting & Brewing with Kernza®
(Rahr Technical Center)

Malting and Brewing with Kernza®

RAHR TECHNICAL CENTER

Report by Juan Medina Bielski

Introduction

Rahr Technical Center's (RTC) work with Kernza® began with micromalting in 2019. This preliminary experience demonstrated Kernza's suitability for malting. In the spring of 2021, AURI and the University of Minnesota approached the RTC with an inquiring about malting and brewing with Kernza, and the proposal was accepted.

The first question asked was whether Kernza® would be best suited for malting in its in-hull or dehulled form. While there are benefits to both malting and brewing with grain that retains its hull, there are also benefits to naked grains. However, uniformity in the grain is also a very important quality. During the 2019 micromalting experience, the Kernza® came with hulls on, but it was manually dehulled easily shed hulls with handling, and the malting quality was not harmed. Based on these considerations, the project focused on dehulled Kernza®. AURI proceeded to obtain a dehulling service for a quantity of Kernza®. Due to concerns of potential damage through the dehulling process, AURI sent small samples of in-hull and dehulled Kernza® were then sent to RTC for testing.

Both samples were tested for germination by the ASBC 4 mL Germinative Energy method, resulting in 93% germinative energy for the both in-hull and dehulled samples. Moreover, upon inspection, all the kernels that failed to germinate did not appear to have any physical damage or removal of the embryo that might be attributable to the dehulling process. The typical minimum germination rate for malting quality grains is set at 95%, but for this novel grain, 93% was deemed acceptable to proceed with malting.

Micromalting

Since germination was equal for both in-hull and dehulled Kernza®, both advanced to micromalting for further comparison. The two samples were malted concurrently in separate cans in the Joe White micromalter under the same conditions, yet they yielded markedly different results. The steep out moistures were 40.2 % for the dehulled Kernza® and 52.5% for the in-hull Kernza®. Final malt quality differences likely arose from this primary disparity. The significantly higher moisture uptake by the in-hull Kernza® was presumably due to a combination of high absorbency of the hull material itself and to empty space within the hull that retains excess water by capillary action beyond the immersion of the steep.

During germination in micromalting, both forms of Kernza® grew very long (but solitary!) rootlets.

Apart from the differences in imbibition, another important difference due to the presence/absence of hull was the grain test weight. Once dehulled, the Kernza® achieved nearly double its bushel weight. Thus, an equivalent volume of in-hull Kernza® has nearly twice the mass of dehulled. Fortunately, the 1kg sample cans for this micromalting system were able to accommodate the full volume of equal mass for both samples. However, in a full-scale malt production scenario, the throughput in terms of fermentable material would be severely limited for in-hull Kernza® compared to de-hulled Kernza®, let alone compared to conventional malting grains. Lastly, the in-hull Kernza®, as previously noted, has a strong tendency to release its hull; by the time micromalting was completed, a large majority of kernels had shed hulls, so the final product was a mix of naked kernels and free hulls. In a production setting, the excess free hull hulls would be separated and considered lost yield.

Micromalting Recipe

- Nearly 7 days in total
- ***Steep***: 2-immersion
- ***Germination***: 96 hours
- ***Kiln***: high heat 77 °C

Photo: dehulled Kernza®(left) and in-hull Kernza® (right) in 1kg micromalting cans during day 2 of germination

Malt Analysis of Micromalted Kernza® vs Red Wheat Malt

Micromalt Analysis	Alpha Amylase	Beta Glucan	Bushel Weight	Color	NTU	DP	DON	Fine Grind	FAN	Fri-ability	Moist	pH	S/T	SP	TP	Visc
Dehulled	39.7	110	42.2	2.16	9.7	161	0.67	68.4	125	55.3	3.26	6.23	29.5	6.5	22.02	1.76
In-Hull	40.4	87	26.7	3.77	11.3	144	1.12	60.2	156		3.38	6.12	40.4	6.78	16.77	1.54
Red Wheat	55.7	45	46.3	2.86	7.7	159	.07	82.3	167		4.83	6.12	41.6	5.42	12.4	1.51

Micromalting Analytical Results

Overall, the differences in the Kernza® malt samples are easily explained by the presence or absence of husk. The overall modification of the in-hull Kernza® is higher (S/T higher, beta-glucan and viscosity lower), and this aligns with higher steep-out and germination moisture levels. The extract is much lower in the in-hull vs dehulled Kernza®, due to the inert, substantial hull. Due to the slender kernel size, even the dehulled

Kernza® is much lower in extract than wheat malt. Kernza® malts do resemble wheat malts (vs oats, rye, or barley malts), in both visual appearance and in some analytics: enzyme levels, low beta-glucan, and high viscosity. The high viscosity could be de to a high level of pentosans. The level of Deoxynivalenol (also known as DON or vomitoxin) is substantially higher in the in-hull sample. While this fact alone could be a regulatory concern and directly affect beer quality, there may also be further inferences to draw. Further microbiological analysis was conducted to compare the in-hull versus dehulled Kernza® micromalts.

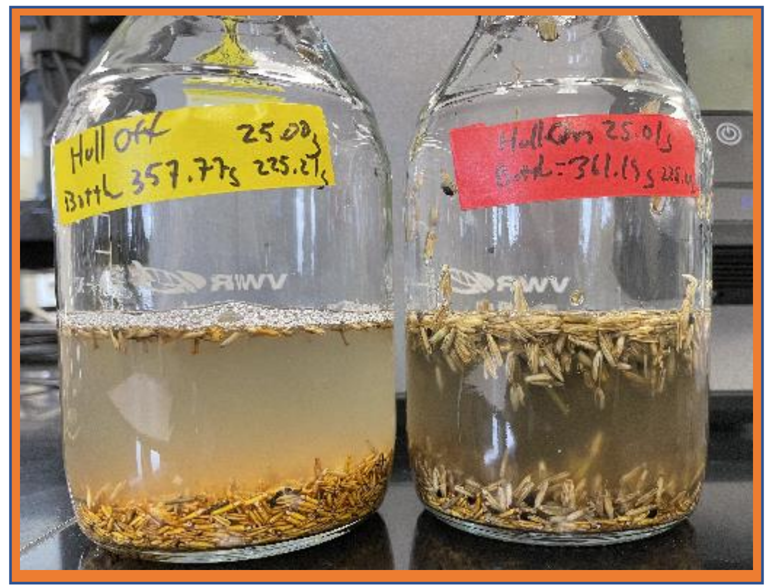
Microbiological Investigation of Micromalts

Both samples were assessed for total Aerobic Plate Count (APC) as well as yeast and mold counts. The method involves an aqueous extraction where the standard mass of the sample is 25 grams. Given the drastic difference in the number of kernels per 25 grams in dehulled versus in-hull, there is a bit of nuance in the results of this assay. Therefore, the analysis is presented in the nominal CFU/25g, as well as in a normalized rate of CFU/kernel. In the per-seed normalized measurement, the dehulled yields lower total APC while it yields higher total APC in the conventional per mass basis. More noteworthy is that the in-husk form of Kernza® carries dramatically higher yeast and mold count. The extraction process for the microbial analysis revealed a visual difference. The in-husk Kernza® produced an especially dark, turbid solution. It's important to note that this was after the malting process that employed two separate immersions. The conclusion to draw from this is that working with in-hull Kernza® at the brewery could present flavor and stability issues in the beer.

Micro Analysis of Micromalted Kernza®

Standard	Husk Off (cfu/25g)	Husk On (cfu/25g)
APC	17,000,000	15,000,000
YC	60,000	130,000
MC	50,000	130,000

Per Kernel	Husk Off (est. cfu/seed)	Husk On (est. cfu/seed)
Seeds/g	198	130
APC	3,434	4,615
YC	12	40
MC	10	40



Dehulled (left) and in-hull (right) Kernza in water for micro analysis. Note color and turbidity differences.

Pilot Malting

Based on the evaluations of the in-hull and dehulled samples, the dehulled Kernza® was selected for pilot malting. The RTC pilot malthouse is a 7-bushel capacity malting system designed to emulate the conditions of the Rahr production malthouses and produce enough malt for 2 brews in the Rahr Eagle pilot brewery. It was designed for use with barley and wheat, so anticipating issues stemming from the small kernel size, adaptations for the pilot malting vessels were fashioned from a fine stainless mesh in order to try to mitigate grain loss and clogging issues. In the end, the retrofits achieved mixed results, but fortunately, the worst-case scenario of drain and vent clogs did not materialize. In total, 3 dehulled Kernza® pieces were pilot malted, and one was discarded due to mold development.

The basic recipe in the pilot malt for the Kernza® pieces was a single immersion steep, a 5-day germination, and a kiln regime with an 85°C high heat step. However, departures from the intended recipe occurred due to technical difficulties stemming from hardware and software failures. Thus, while the final malt quality fell short of the expectations (based on micromalt outcome), the Kernza® itself was not the cause of the main problems. With the first piece, spray water and humification was shut off for the first two days of germination, causing the grain moisture to fall and slow down modification. The second and third pieces were germinated in the second germination vessel, and unfortunately, during these pieces, a bug in the software caused air recirculation to stick at 100%, which led to a hot, wet, and sticky grain bed. Unfortunately, the software bug wasn't discovered until much later with subsequent maltings. In the second piece, it led to extensive mold growth that made the piece unusable. Initially, the effect was attributed to poor airflow due to the Kernza® grain size, coupled with grain stickiness from extra water added in the germination vessel to compensate for the short steep regime. With the third piece, the Kernza® received less germination water to reduce grain surface moisture to mitigate the hypothesized issue. Unfortunately, since the issue was in fact a software bug, the grain temperature again started rising excessively and the grain started to smell of lactic acid bacteria, so before it got out of hand, the piece was pulled to the kiln at the end of the second germination day to prevent another spoiled piece.

The spoiled second piece was nonetheless pulled to the kiln for drying, and even though it did not yield a brew-worthy malt, it still provided some useful insight. The kiln recipe proceeded through to its end, with air-off temperature and differential pressure aligning with expectations, but upon inspection, the Kernza® had formed clumps and crevasses that allowed channeling to occur. This channeling effect led to inconsistent drying, so that inside the clumps were wet grain. A rake was used to break up the clumps and mix the grain, and then moderate heat and airflow were applied to finish the drying. Similarly, the third piece also exhibited this effect, but it was checked part way through the kilning regime so that the raking and stirring could be applied prior to the completion of the kiln recipe. What the second and third pieces had in common was high surface moisture, while the first piece was relatively dry. The first piece kilned exactly as expected. The high grain-surface moisture allowed the grains to stick together, so that as they dried and shrank, they clumped together. Also worth noting was that the first piece had more developed rootlets going into kiln, which helps to increase the interstitial spacing that improves airflow.

Malt Analysis

Pilot malts	Alpha Amylase	Beta Glucan	Color	Dias Power	Fine Grind	FAN	Moisture	pH	S/T	Soluble Protein	Total Protein	Viscosity
Piece 1	28.7	118	6.39	141	68.9	122	16.681	6.14	36.1	8.05	22.32	2.00
Piece 3	36.8	112	5.61	120	73.6	226	22.677	5.59	42.1	9.35	22.19	2.05

Interestingly, despite only having had 2 germination days, the third piece achieved greater proteolysis than the first piece that germinated for a full five days. This is presumably due to differences in germination moisture and temperature. Both pieces came out of steep with over 42% moisture. The first piece fell to 38% moisture by the second day of germination, while the third piece maintained 42% moisture till it went to kiln. Both pilot pieces reached an overall higher proteolysis compared to the dehulled micromalt sample. Besides that, color was higher and diastatic power lower for the two pilot pieces compared to the micromalt sample. This is mostly attributable to the higher heat applied in the pilot kiln regime. One important difference was that the micromalt sample had a much lower wort viscosity, while both pilot pieces analytically similar despite major differences in germination conditions. To put these analytical differences into context, the micromalt sample had a consistent cool temperature and moisture level throughout germination, but only had 4 days of germination, where the pilot pieces germinated under stressful conditions. The takeaway for malting is that germination under steady conditions (as with the micromalt) could potentially achieve a balanced modification with a viscosity more in line with a 6-row barley coupled with a moderate S/T in the low 40 range.

Different germination conditions also produced an aromatic difference in the two pilot malt pieces. The third piece having reached an anaerobic state picked up a slight sourdough aroma. Given the quantities needed for brewing, the two pieces were blended to reduce the variability in quality for brewers.

Custom 7 Bushel Pilot Malthouse at RTC

Brewing

At the RTC, a hazy IPA was brewed with an inclusion rate of 20.8% Kernza® by total extract contribution. Since the roller mill consistency was deemed to be insufficient for proper mashing, the Kernza® malt was further milled with the laboratory burr mill on fine grind setting. This yielded a fine Kernza® flour. From the malt analysis, the viscosity of the Kernza® was about 2 cP; while high compared to barley base malts (~1.5 cP), it was in line with red wheat malts and significantly lower than other grain malts, like rye that can exceed 4 cP. Rice hulls were employed in the mash to mitigate the high viscosity and fine milling applied to the Kernza®. Mashing and lautering proceeded without issues. The brewhouse and lautering efficiency were low for the brew (82.2 & 80.2%, respectively), but this efficiency reduction is consistent with the inclusion of rice hulls. The fermentation began with a wort of 13.6° Plato original gravity and finished with an apparent extract of 4.1 °Plato with 5.3% alcohol by volume. The resultant 58.7% RDF (real degree of fermentation) is a little low compared to a recent comparable brew that resulted in a 60.0% RDF and 5.45% ABV. A reduction in RDF can stem from various causes, but excluding the yeast and fermentation conditions (no problems observed), the fermentability of the grain would be the limiting factor.

Specific to this Kernza® malt, there might have been a curbed fermentability of carbohydrates due to the somewhat under-modified malt. An interesting facet to consider is the large amount of protein comprising the soluble portion of the malt. The protein that remains in the beer beyond fermentation would affect the density measurement used to calculate the RDF. Typically, the soluble protein levels of different malts don't vary substantially enough to noticeably influence the RDF, but given that the soluble protein was 50% higher than typical red wheat malts, it could have played a more significant role. The result can be seen with the naked eye, as one of the main sources of beer haze is protein-polyphenol complexes (polyphenols from hops). This Kernza® beer was intended to be hazy, and in the facet it performed excellently. Even 3 months from packaging, the beer retained strong haze.

Milling

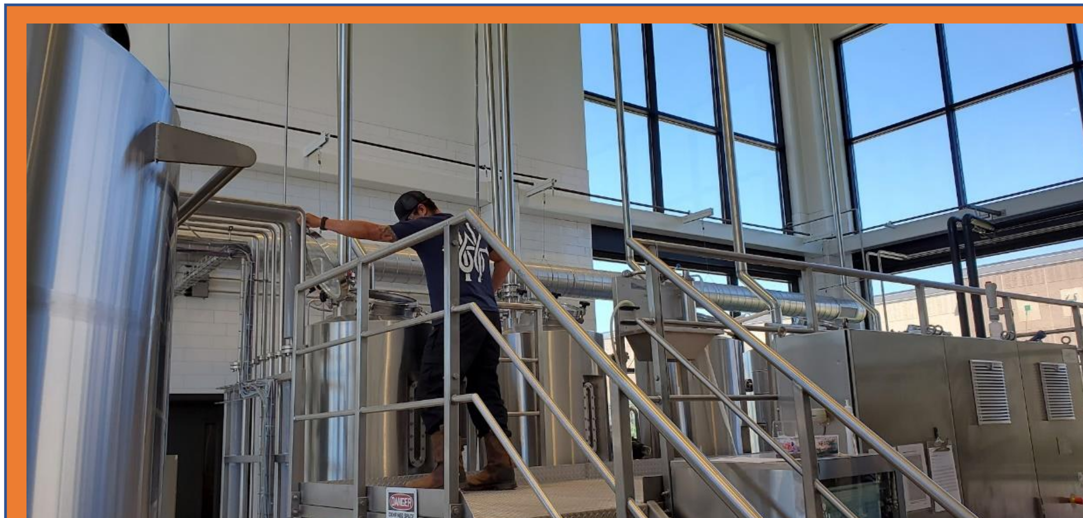
Due to the small kernel size, typical brewery roller mills cannot reach a small enough gap to thoroughly crush Kernza malt to the consistency typical of brewery grist. The Kernza pilot malt blend was nonetheless taken to the BSG Shakopee distribution center for milling and bagging to provide a minimum amount of milling, picture above.

Sensory Analysis

Two sensory evaluations were conducted to assess the influence of the Kernza® malt on the beer flavor. The first was a descriptive, round-table panel analysis. Top flavor descriptors for the beer were spicy, apricot, honey, breakfast cereal, pie crust, vegetal. In the round-table discussion following the tasting, the panel danced around describing different spices including allspice, clove, coriander, ginger, nutmeg, and white pepper, but the panel generally agreed the spicy aroma was elusive and unique.

The second sensory evaluation was an open-door event at the Rahr Bierstube where all Rahr employees were invited to take sensory notes and rate their liking. Twenty-five people assessed the beer. The average liking score was 6.9 out of 10. The top descriptors from this session were: honey, apricot, grainy, and fruity. While the sensory attributes were undoubtably influenced by the hops and yeast, it's worth noting that there were no dominant or significant negative attributes assigned to the grain. The unique spice characteristic perceived by the round-table panel likely stems directly from the malting, mashing, and fermentation of the Kernza®. Wheat and rye malts are well known to have an abundant capacity to release ferulic acid in mashing, which through fermentation can be converted into 4-vinyl-guaiacol that has a clove-like aroma. Kernza® may also be high in ferulic acid, and it may have other factors that augment the fermentation products and perceived spicy notes.

Kernza® Hazy Ale brewed at Rahr Eagle Pilot



Kain brewing the Kernza® Hazy at the Rahr Eagle Brewery

Conclusion

All in all, despite some challenges, the experience with Kernza® at the RTC was a positive and successful one. The positive beer sensory results indicate that Kernza® has a strong potential for malting and brewing applications. The main obstacle of small grain size will likely remain a headwind for widescale use, but it has proven be a manageable challenge. Given its promising properties for sustainability in agriculture, excitement for Kernza® continues to grow among prospective brewers and consumers. Floor malting might offer the kind of adaptability and special attention to get Kernza® into commercial level malting. The future looks especially brighter for malting and brewing with Kernza® with continuing breeding efforts toward larger, free-threshing kernels that will improve the grain's general appeal and utility.

Acknowledgements

- **Tim Sparks** and **Tim Brown** for pilot malt equipment modifications
- **Chris Wilhelmi** for malting consultation
- **Theresa Kukar** and Rahr Quality Lab team for malt analysis
- **Kain Escobar** and **Sean Tynan** for beer production and analytics
- **Emily del Bel** for sensory analysis and event organization
- **Dr. Xiang Yin** and **Dr. Pattie Aron** for project leadership

APPENDIX E

Kernza® Straw Compounding Trial
(c2renew)

Kernza Straw Compounding Trial

March 9, 2022

Rachel Workin – c2renew Inc. Fargo, ND

Proposed Work

c2renew was approached by AURI to develop a bio composite incorporating kernza straw as a natural filler in a bio derived resin. A formulation containing 15 wt% kernza straw was targeted for use with a blend of PLA base resins. The composite was compounded to assess how the kernza straw would perform during extrusion, produce pellets for injection molding, and to develop a technical data sheet.

Compounding Trial

The kernza straw provided by the Agricultural Utilization Research Institute (AURI) was compounded at 15 wt% with 42.5 wt% NatureWorks Ingeo 3001D polylactic acid (PLA) and 42.5 wt% NatureWorks Ingeo 5200 PLA. Prior to compounding, the kernza was dried in pans with a depth of 3 cm for 48 hours in a 110°C convection oven to remove any excess moisture. The PLA base resins were also dried in a desiccant polymer dryer for 8 hours at 60°C to prepare them for compounding.

Melt compounding was completed on a Nanjing Giant 43mm co-rotating twin screw extrusion system. Small, 5 kg batches of the formulation were hand blended and hand loaded into the primary feeder of the extruder to maintain material consistency in the feed hopper and limit separation of the ingredients during loading due to density differences and static electricity. There were no issues with bridging or rat holing in the feeder, and an agitating screw kept the materials from separating in the hopper. The twin screw extruder system used for compounding the biocomposite is shown in Figure 1 below.

Figure 1. 43mm Nanjing Giant Twin Screw Extruder

Screw speed was maintained at a low, constant RPM throughout the run to minimize degradation due to shear heat at higher speeds. Back pressure at the die ranged from 850-1050 kPa. A low temperature profile for PLA composites was maintained using electric heating bands and cooling water channels along the extruder. The melt temperature of the composite at the die was approximately 190°C.

From the die, strands were then pulled through a cooling water bath prior to strand pelletizing. Some mild off-gassing occurred at the die, and the melt strength of the strands was inconsistent, occasionally leading to broken strands that needed to be hand fed into the strand pelletizer once broken. Shorter straw particles, a lower loading of kernza, and/or a melt strength additive could assist in fine tuning the melt strength consistency for future compounding. Pellets were targeted to be approximately 2.5mm in length and width for consistent molding and melt flow index measurements. From the pelletizer, the pellets were then run through a modified spin dryer to remove excess moisture before being fed through a classifier to remove short and long pellets from the final product shown below in Figure 2.

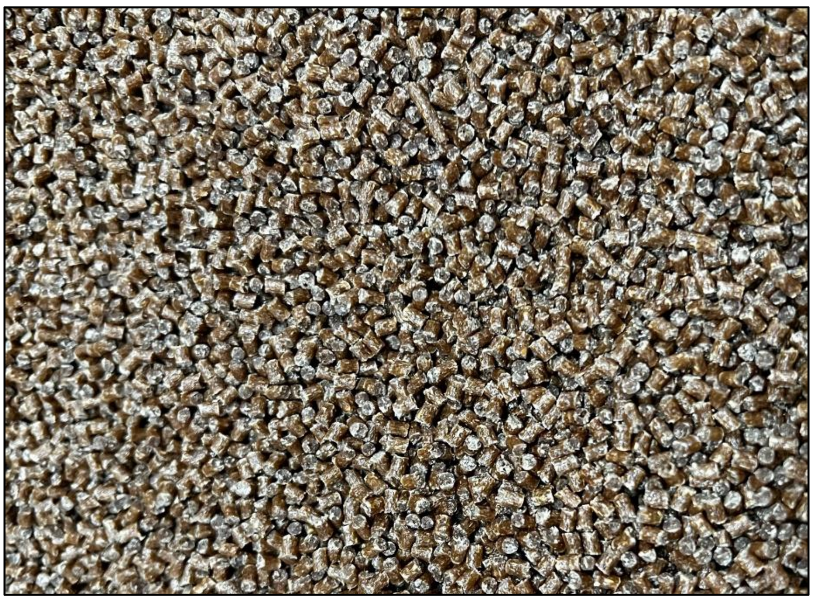


Figure 2. PLA/Kernza Biocomposite Pellets for Injection Molding

The final material was dried post-compounding in a Conair desiccant dryer for 8 hours at 55°C to stabilize it for storage and for future processing and testing. Overall, the kernza straw processed well in the extruder and it appears to be a viable option as a bio-based filler for other PLA based formulations.

Continued Development

Approximately 25 kg of the final biocomposite was produced for the mold trialing of future products. c2renew is continuing to partner with AURI to source a molder that can manufacture injection molded components utilizing the PLA/kernza biocomposite pellets produced in this trial. The pellets will also be used to mold tensile and flexural bars for testing to develop a technical data sheet that will follow this report and serve as a specification sheet for injection molders interested in trialing the composite. Sample plaques with three different surface finishes will also be produced to provide molders with a visual of the molded composite and a target aesthetic to dial in their processing conditions.

APPENDIX F

Consumer Survey: Beaver Island Brewing Pilot Project (AURI)

Beaver Island Brewing Co. Kernza Beer Consumer Survey

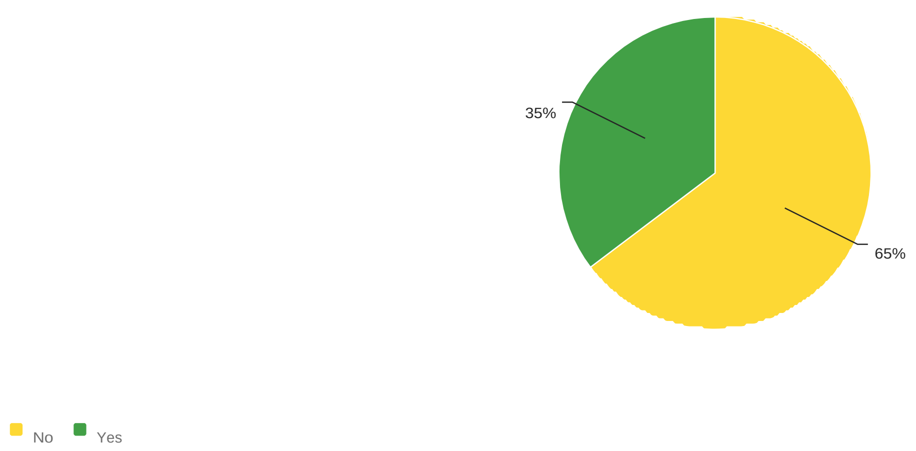
December 2021- February 2022

Survey Compiled By:
Ben Swanson- AURI Scientist of Food and Nutrition

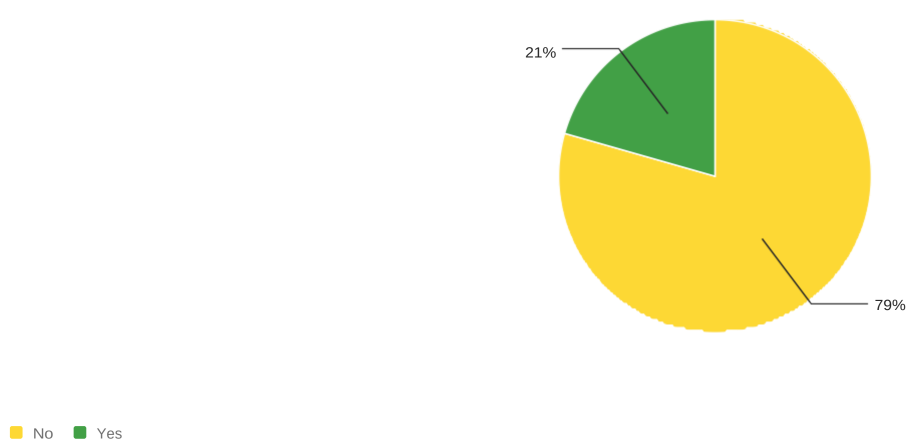
Beaver Island Brewing Co. Kernza Beer Consumer Survey

Between December 2021 and February 2022 Beaver Island Brewing Co. served a Kernza Saison at their taproom in St. Cloud, Minnesota. During that time period, 34 patrons participated in the survey via a scannable QR code. Their responses were recorded and compiled in the following report.

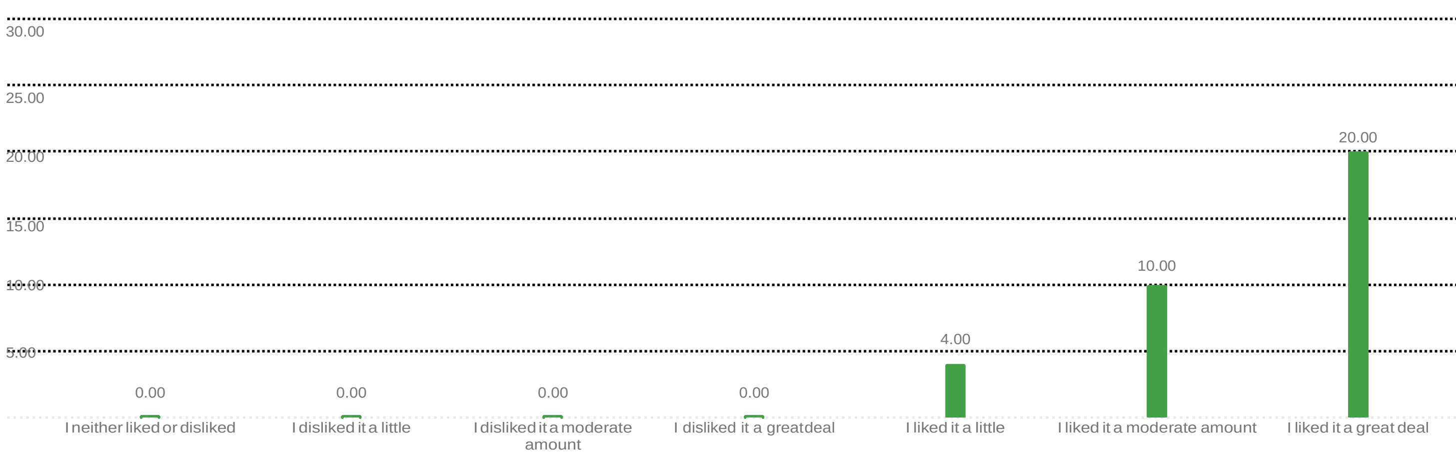
The beer you tried or are about to try contains Kernza® , a perennial grain. Have you heard of Kernza® before today?



Have you ever tried a product that contained Kernza® before today?



After having tried the product, please select the answer that best describes how you liked the product.



Please explain why you liked or disliked the product?

Tastes like wheat, which I'm not a huge fan of sorry

Different taste not experienced before. Nice &light

Mild barnyard flavor without being overwhelming. Easy drinking. Slight ester sweetness

Delicious!

Smooth tasting and no after taste

It's nice. Smooth with a pleasant finish. I enjoy the entire flavor palette

it was nice and light

I like it cuz my brother plants it and supplies it

Made a pretty nice light flavored beer! I think I would enjoy it in the summer a little more, but it finished nicely and worked well with our pizza.

The beer was crisp and flavorful.

Tasted good.

Taste like Hefeweizen which is our favorite type of beer. We love a sustainable product!

Cause it was good.

Very tasty!

I like that it was refreshing while still having full flavor

Smooth and mellow

Has a really good flavor with little after taste. Nice and smooth

A little sweeter than I would expect from a saison, and the finish seemed unusual to me.

Not a beer I really like.

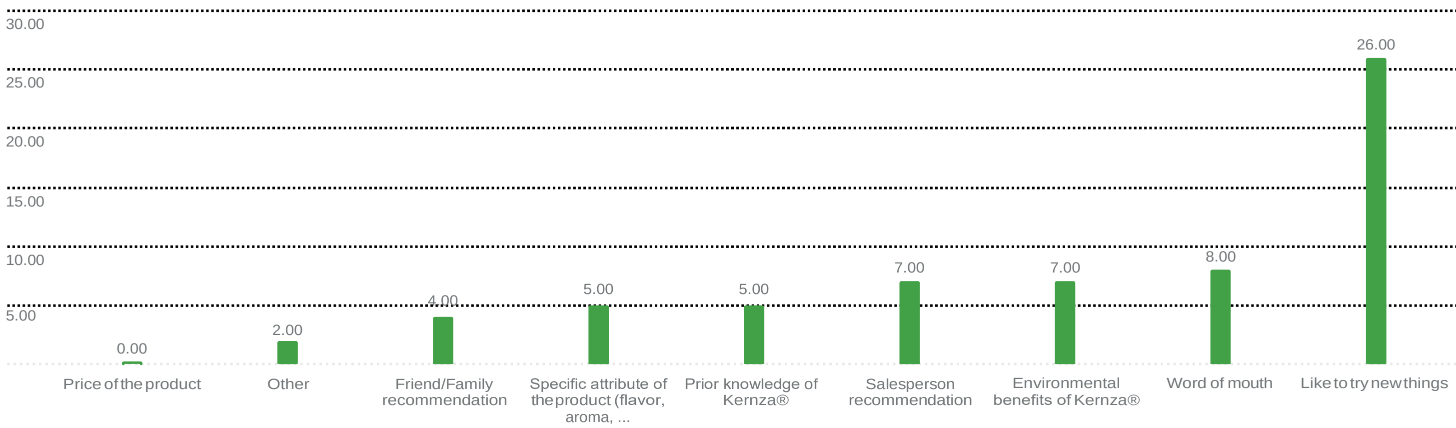
I like the flavor. Reminds me of a Hefeweizen type beer. It's not my normal style, but I would drink one again.

The balance in this beer is phenomenal.

I would like a little more flavor. But the flavor it has is good.

Please explain why you liked or disliked the product?

Why did you decide to try the product with Kernza® today? Check all boxes that apply.

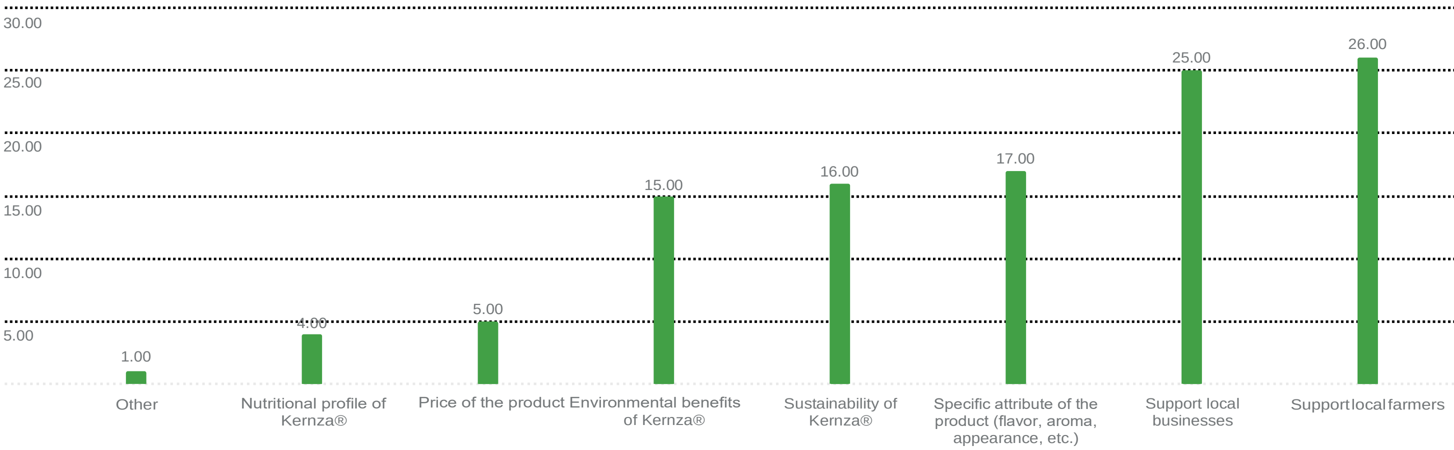


Other motivation to purchase:

Saison style of beer is a favorite.

No more results to show

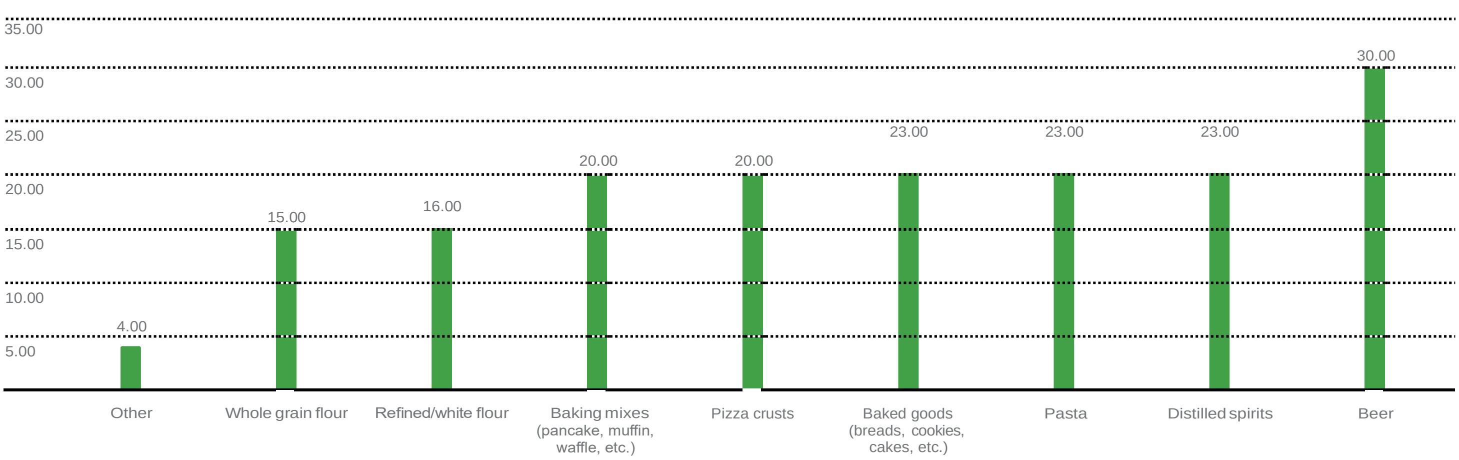
What would motivate you to try this product again? Check all boxes that apply.



Other motivation to purchase:

No data found - your filters may be too exclusive!

Which other products made with Kernza® would you be interested in trying? Check all that apply.



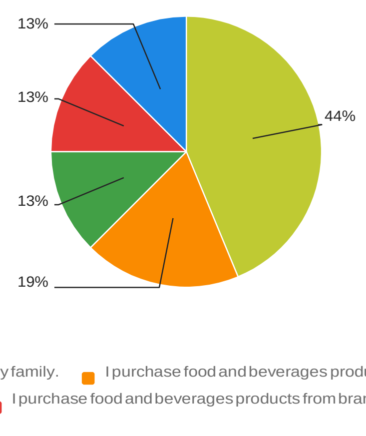
What other product made with Kernza® would you be interested in trying?

we paired the beer with pizza from artisan naan bakery and it made a FANTASTIC pizza crust. partner does a lot of baking and having access to the flour would be fantastic.

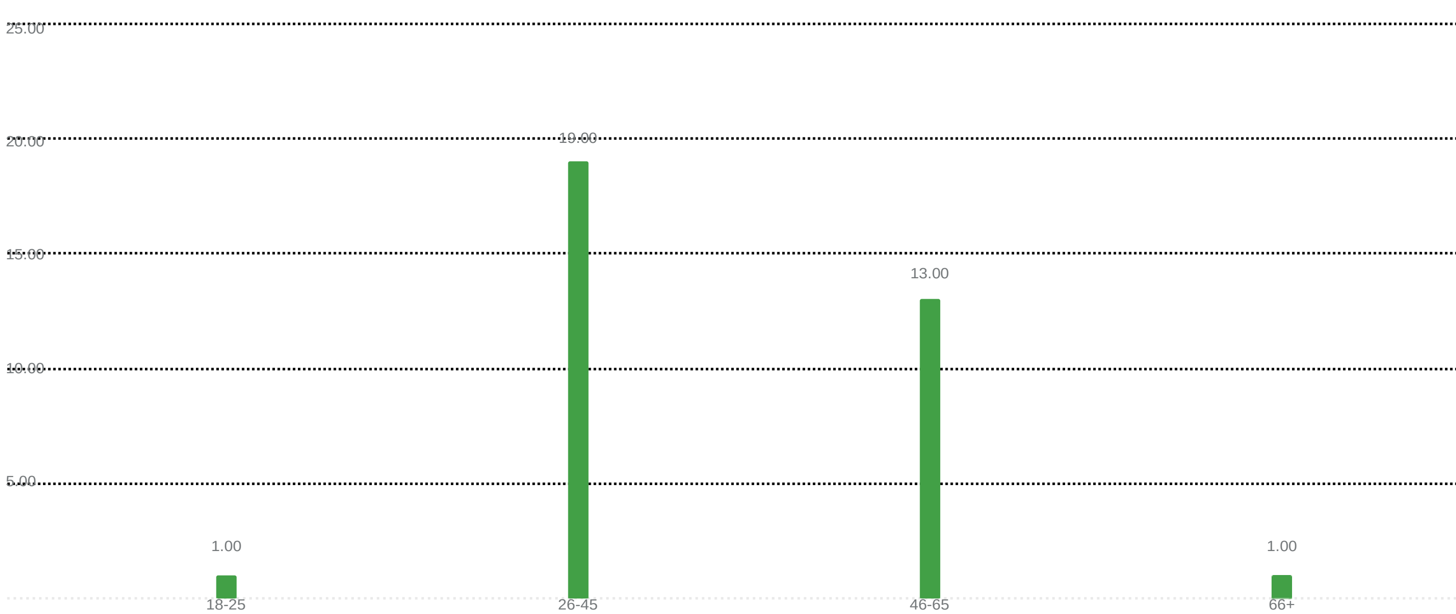
I would like it as a flour to cook with for myself as well as a hard alcohol

No more results to show

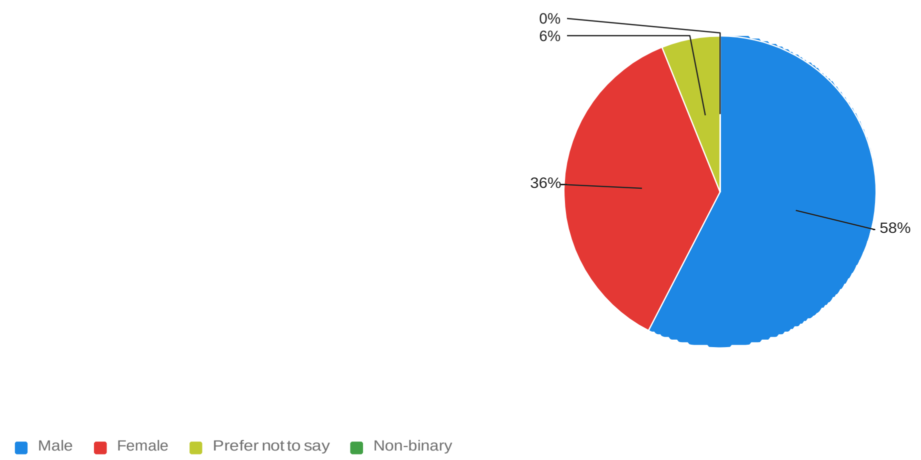
Please select the statement that best describes you:



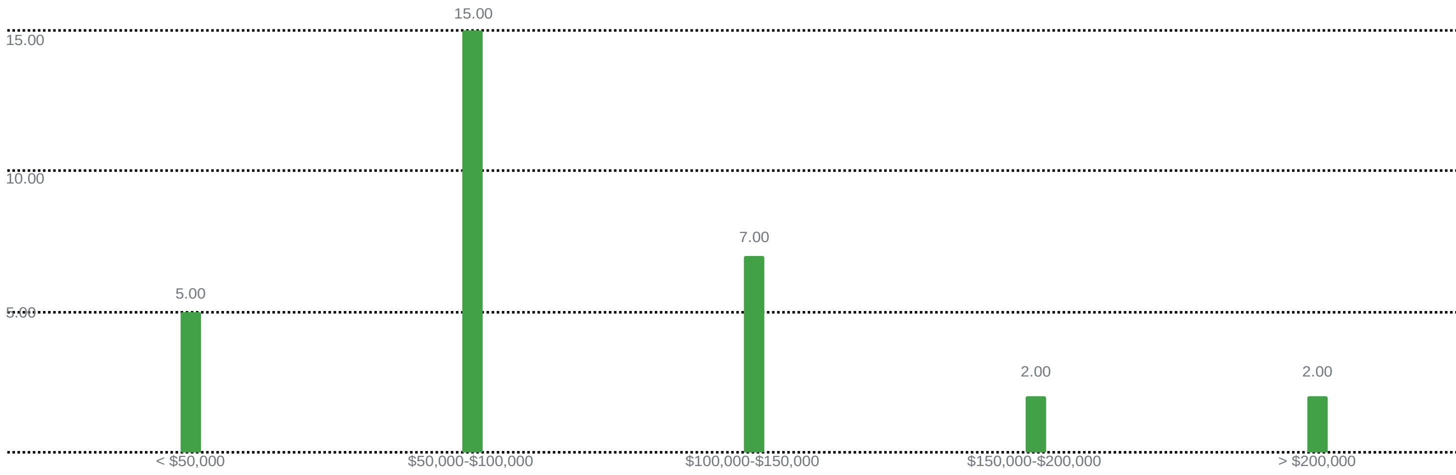
What is your age?



Gender:



What is the approximate income of your household?



APPENDIX G

Consumer Survey: Rocori FFA Kernza®
Field Day (AURI)

Rocori FFA Kernza Field Day Consumer Survey

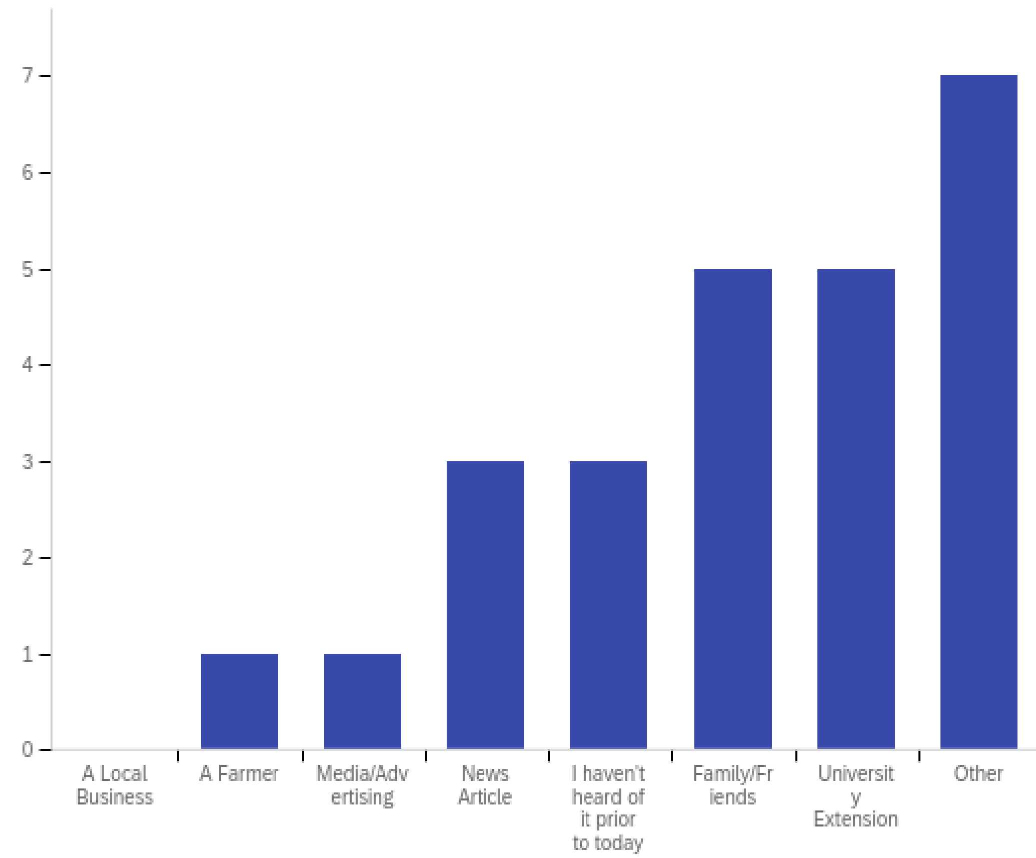
July 17th, 2021

Survey Compiled By:
Ben Swanson- AURI Scientist of Food and Nutrition

Rocori FFA Kernza Field Day Consumer Study

On July 17th, 2021, Rocori's FFA held a Kernza Field Day where Kernza pancakes were served to attendants. 20 attendants participated in the survey either through written responses or a mobile survey. Their responses were recorded and compiled in the following report.

Q1 - Prior to today's event, where have you heard about Kernza®?

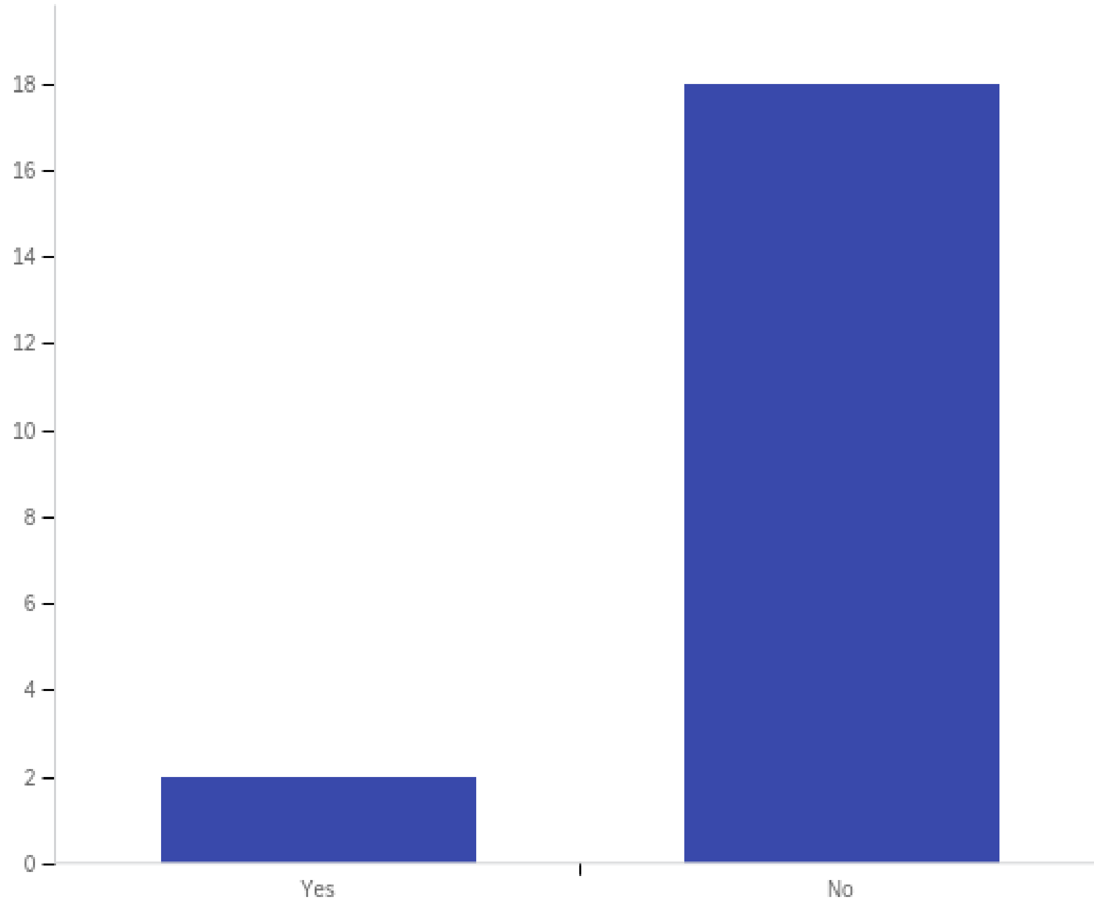


#	Answer	Count
30	Family/Friends	5
31	A Farmer	1
32	A Local Business	0
33	Media/Advertising	1
34	News Article	3
35	University Extension	5
36	I haven't heard of it prior to today	3
38	Other	7
	Total	25

Q2 - Where else have you heard about Kernza® from?

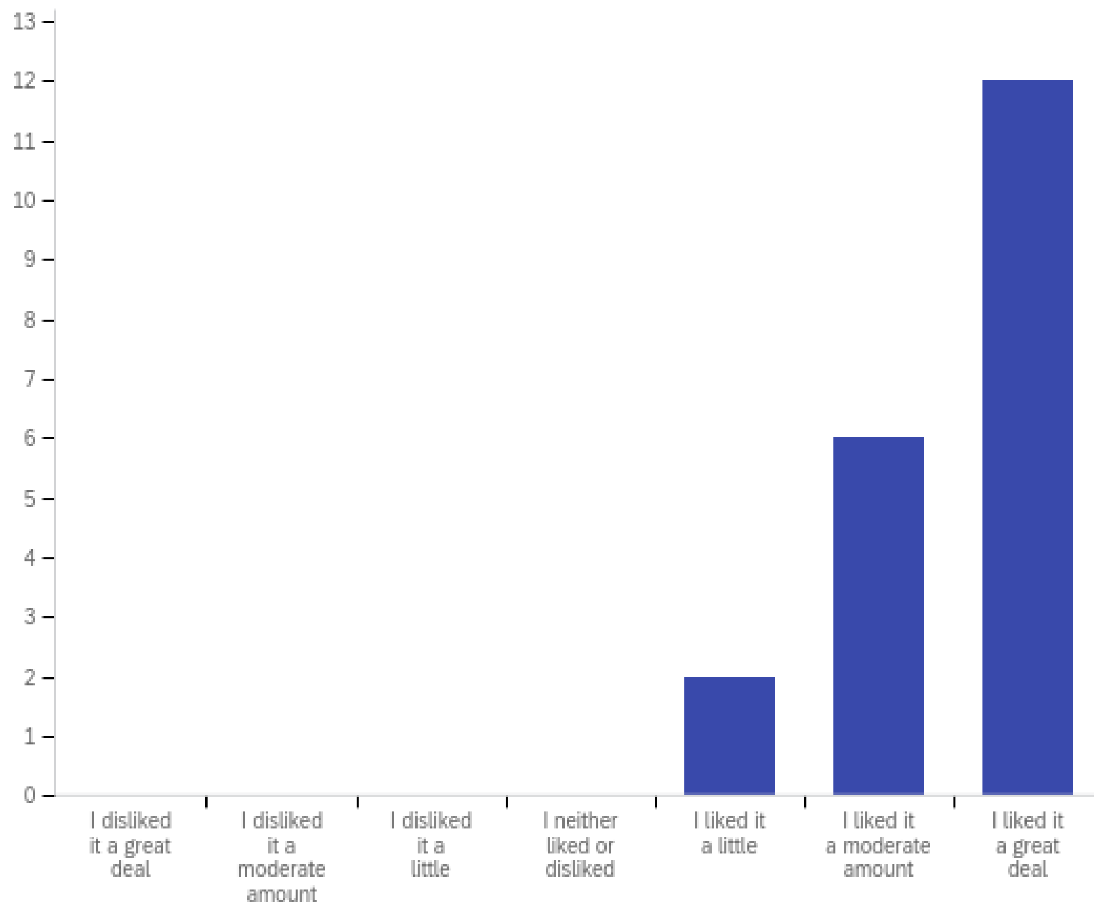
Where else have you heard about Kernza® from?
Country Acres
FFA
FFA
FFA
FFA
5 years ago at an organic conference
ROCORI Ag/FFA

Q3 - Have you ever tried a product that contained Kernza® before today?



#	Answer	%	Count
21	Yes	10.00%	2
22	No	90.00%	18
	Total	100%	20

Q4 - After having tried the product or products with Kernza® in them, please select the answer that best describes the product or products.

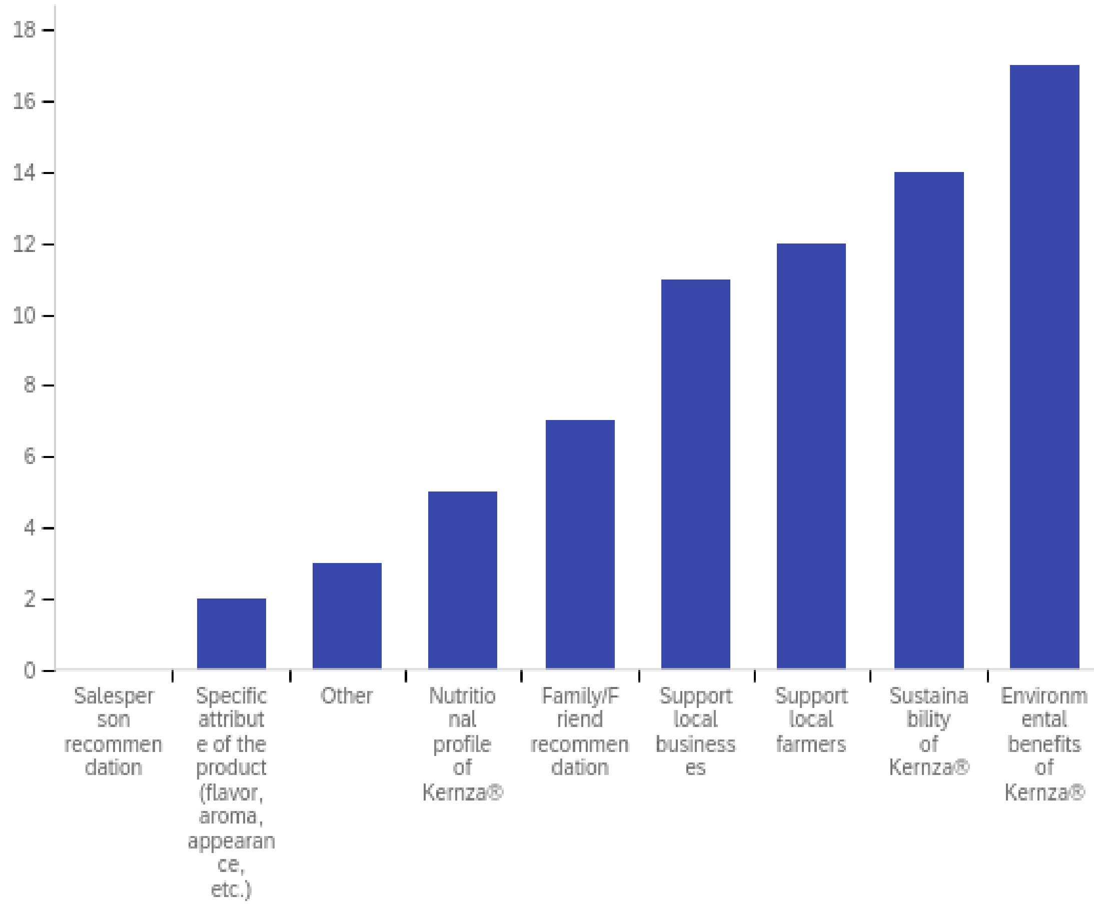


#	Answer	%	Count
1	I disliked it a great deal	0.00%	0
2	I disliked it a moderate amount	0.00%	0
3	I disliked it a little	0.00%	0
4	I neither liked or disliked	0.00%	0
5	I liked it a little	10.00%	2
6	I liked it a moderate amount	30.00%	6
7	I liked it a great deal	60.00%	12
	Total	100%	20

Q5 - Please explain why you liked or disliked the product?

Please explain why you liked or disliked the product?
The flavor was good but not great.
The pancakes had a good texture and taste.
The pancakes tasted good.
It had a whole grain taste, but yet melted in your mouth.
The taste of the pancakes was great.
It tasted great in the pancakes!
Taste was ok, but I'm really enthusiastic about the future of perennial grains.
Tasted similar to other whole wheat products.
The texture was good in the pancakes. Wouldn’t have been able to tell a difference.
The bars tasted good and I like the environmental aspect
Love that it is a perennial.. and tastes awesome!!
Good Flavor
Tastes pretty good!

Q6 - What would motivate you to buy a product with Kernza®? Check all boxes that apply.

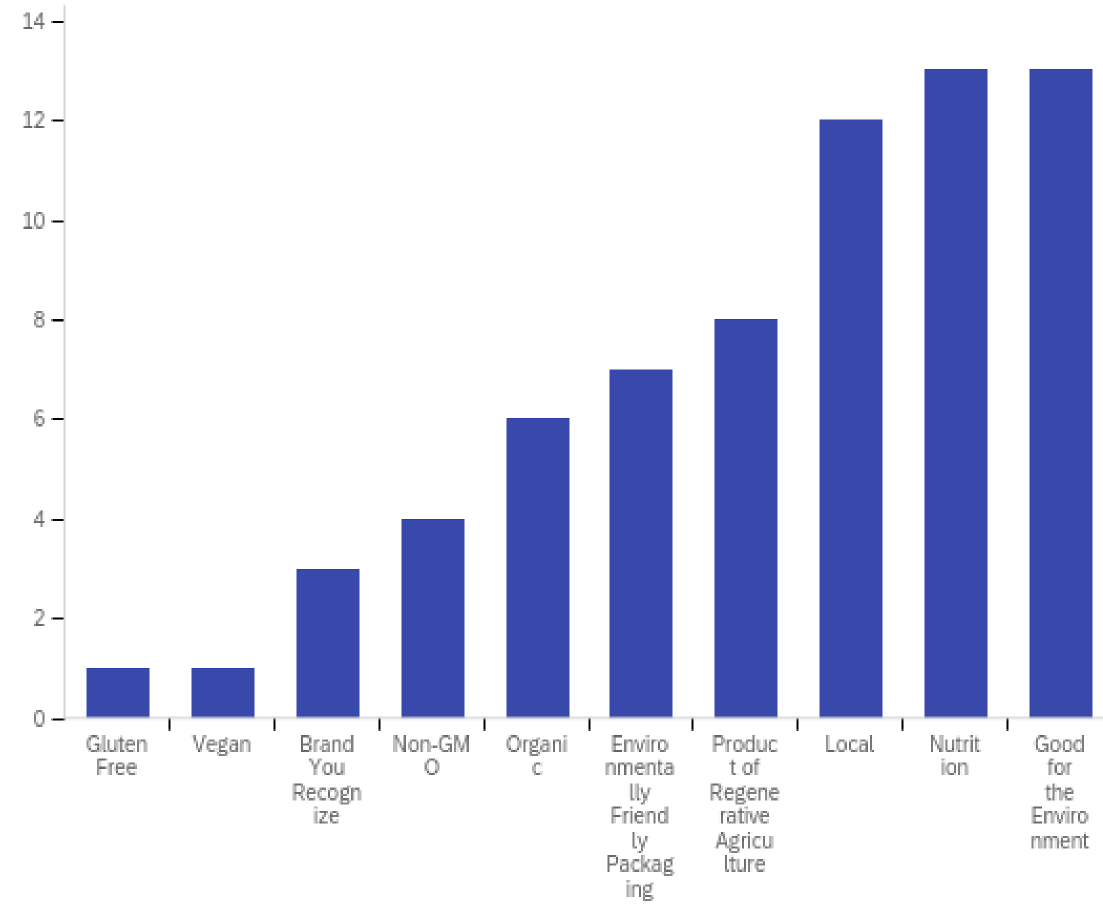


#	Answer	Count
1	Environmental benefits of Kernza®	17
3	Sustainability of Kernza®	14
4	Support local businesses	11
5	Support local farmers	12
6	Specific attribute of the product (flavor, aroma, appearance, etc.)	2
7	Nutritional profile of Kernza®	5
8	Other	3
9	Family/Friend recommendation	7
10	Salesperson recommendation	0
	Total	71

Q7 - Other motivation to purchase:

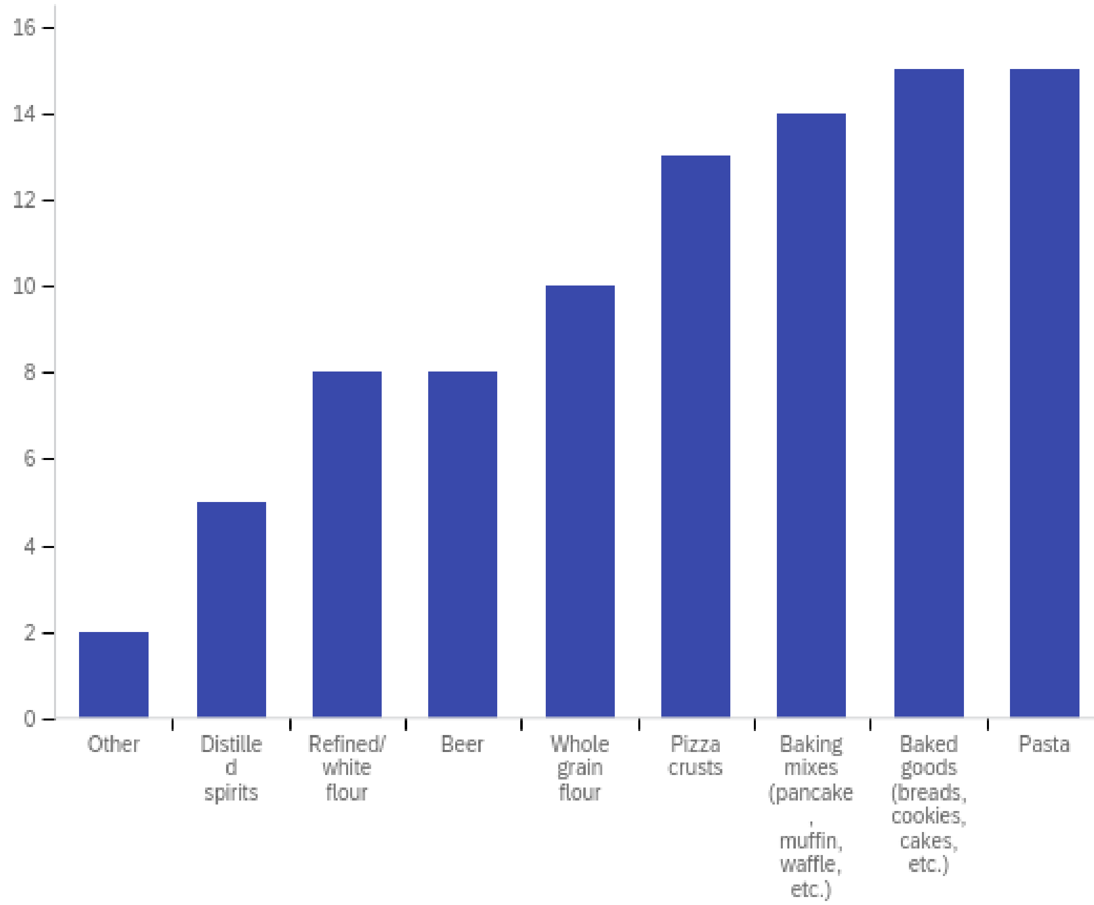
Other motivation to purchase:
Food plot for wildlife.
Health benefits and time of year it's grown.
FFA

Q8 - What information on a product label is important to you when you purchase food? Check all that apply.



#	Answer	Count
1	Nutrition	13
2	Brand You Recognize	3
3	Organic	6
4	Local	12
5	Non-GMO	4
6	Good for the Environment	13
7	Product of Regenerative Agriculture	8
8	Gluten Free	1
9	Environmentally Friendly Packaging	7
10	Vegan	1
	Total	68

Q9 - Which other products made with Kernza® would you be interested in trying? Check all boxes that apply.

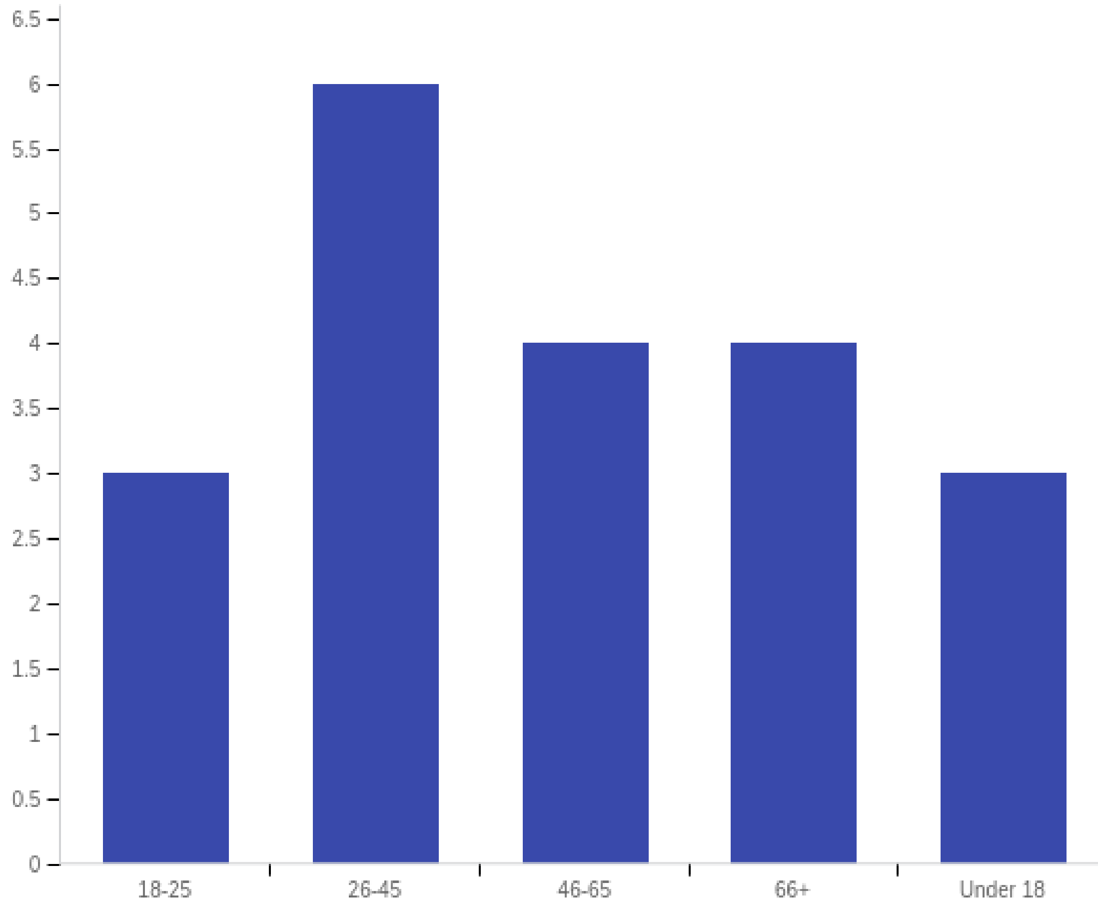


#	Answer	Count
1	Baked goods (breads, cookies, cakes, etc.)	15
2	Pasta	15
3	Whole grain flour	10
4	Refined/white flour	8
5	Baking mixes (pancake, muffin, waffle, etc.)	14
6	Pizza crusts	13
7	Beer	8
8	Distilled spirits	5
9	Other	2
	Total	90

Q10 - What other product made with Kernza® would you be interested in trying?

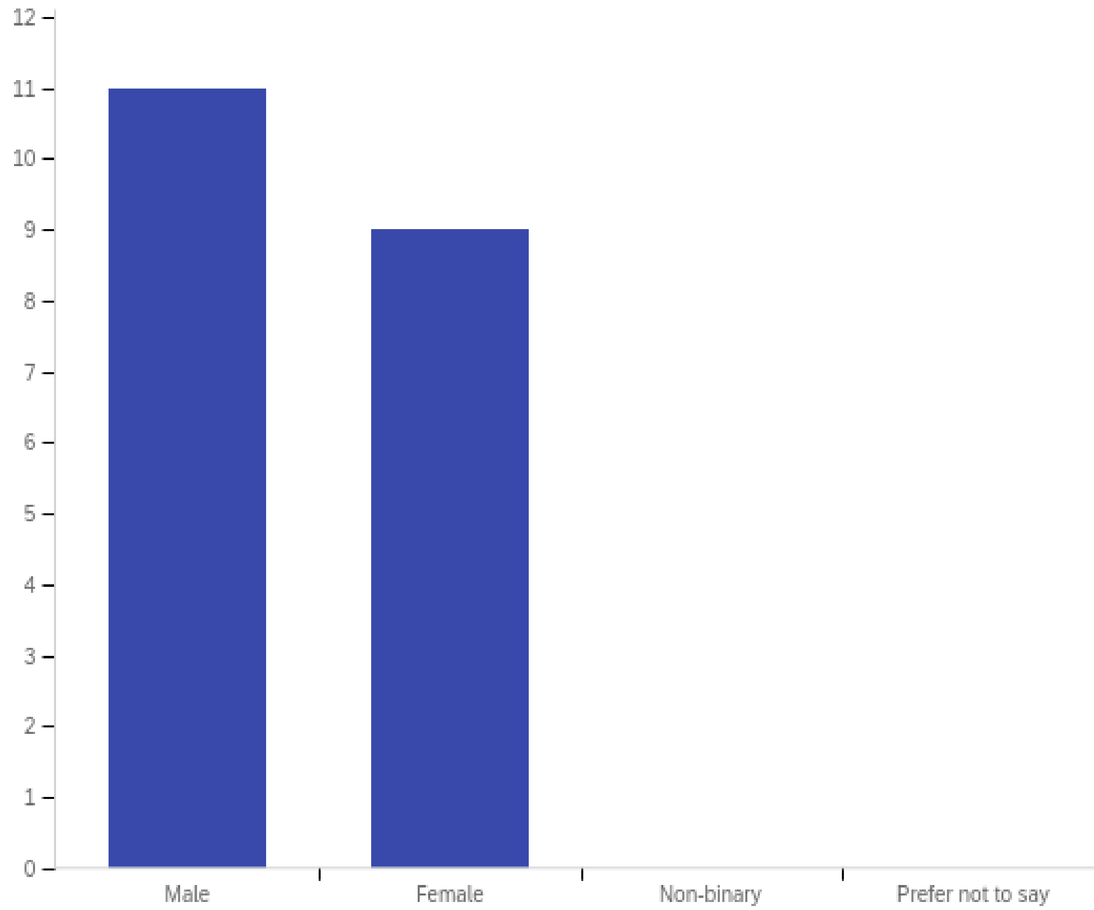
What other product made with Kernza® would you be interested in trying?
Ready-to-eat breakfast cereal

Q11 - What is your age?



#	Answer	%	Count
1	18-25	15.00%	3
2	26-45	30.00%	6
3	46-65	20.00%	4
4	66+	20.00%	4
5	Under 18	15.00%	3
	Total	100%	20

Q12 - Gender:



#	Answer	%	Count
4	Male	55.00%	11
5	Female	45.00%	9
6	Non-binary	0.00%	0
7	Prefer not to say	0.00%	0
	Total	100%	20

APPENDIX H

Fields of Innovation Innovator Profile:
Artisan Naan Bakery

FOI INNOVATOR PROFILE

ARTISAN NAAN BAKERY

ST. CLOUD, MN | ARTISANNAAN.COM

Q: What is your involvement with AURI?

A: AURI introduced Artisan Naan Bakery to Kernza® perennial grain by asking us to collaborate on a pilot project utilizing Kernza in our Naan, which was a great success.

Q: What innovative pathway are you blazing?

A: Baking bread with Kernza has enabled the bakery to expand and diversify our fresh bread products. We've also helped Kernza gain acceptance as a grain used for baking bread.

Q: What are the challenges presented and opportunities offered?

A: Our commitment to selling and distributing fresh bread processed by hand has created a challenge in finding skilled specialty bakers and getting our products to market in a timely manner.

FUN FACT: *Artisan Naan Bakery is the first Minnesota bread bakery to place Kernza® perennial grain bread on grocery store shelves.*

Q: Do you or have you collaborated with other small businesses?

A: From the start, we have purchased whole milk from Stony Creek Dairy in Melrose, MN and extra virgin sunflower oil from Smude Sunflower Oil in Pierz, MN. Every naan and pita pocket has at least one of those liquids in it.

Q: How can AURI's readers and supporters purchase your products and connect with your business?

A: We're a small batch specialty bakery in St. Cloud, MN. Our signature item is our fabulous, fresh, and delicious naan. We also bake fresh and delicious pita pockets. For a complete listing of our products, visit artisannaan.com.

| STAY CONNECTED |

Follow Artisan Naan Bakery and hashtags online.

Facebook.com/ArtisanNaanBakery

@artisannaan

#kernza #perennialgrain #smallbatch #naanbread

artisan naan bakery

| FIELDS OF INNOVATION (FOI) |

AURI Connects: Fields of Innovation is a platform focused on bringing together Minnesota's regional ag and food value chains to build capacity and successfully commercialize new and emerging crops.

AURI.ORG

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

APPENDIX I

Fields of Innovation Innovator Profile:
Beaver Island Brewing

FOI INNOVATOR PROFILE

BEAVER ISLAND BREWING

ST. CLOUD, MN | BEAVERISLANDBREW.COM

Q: What is your involvement with AURI?

A: We were excited to work with AURI on producing a beer made from Kernza® perennial grain. The Kernza added a nice nutty profile to the beer and it has been a success in our tap room. It was great working with AURI on this project.

Q: How did you start your business?

A: I started out home brewing in the mid-nineties and was able to turn my passion into a career at a local brew pub in 1996. After working in a few more breweries, an opportunity came along to join my current partners Matt Studer and Nick Barth, and Beaver Island Brewing was born.

Q: What is the biggest challenge in your business/industry?

A: COVID has thrown a curve ball to all parts of our business. And a major drought causing a U.S. malt crop shortage was also problematic. We've also had difficulty finding qualified labor and finding time to train new staff. We've had to make adjustments in our brewhouse this year.

"We make beers that people don't just drink, they tell stories about. We're obsessed with the art of brewing and aren't afraid to work hard. At the end of the day, this is about respect—for the ingredients, for the tradition and for the vision and experience needed to turn it all into the perfect beer."

Q: Do you or have you collaborated with other small businesses?

A: We partner with Minnesota hop growers and malt producers to make truly unique local products. Beer has always been an agricultural product and it's great to tell our customers the ingredients we sourced were produced locally.

Q: How can AURI's readers and supporters purchase your products and connect with your business?

A: Our tap room is located at 216 6th Ave. S. in St. Cloud, MN. You can also find us online at beaverislandbrew.com, as well as on Facebook, Twitter and Instagram. We always encourage people to support their local breweries because it benefits all of us.

| STAY CONNECTED |

Follow Beaver Island Brewing online.

Facebook.com/BeaverIslandBrew

@beaverislandbrew

@beaverislandSTC

BEAVER ISLAND BREWING CO.
ST. CLOUD, MINN

| FIELDS OF INNOVATION (FOI) |

AURI Connects: Fields of Innovation is a platform focused on bringing together Minnesota's regional ag and food value chains to build capacity and successfully commercialize new and emerging crops.

AURI.ORG

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

APPENDIX J

Artisan Naan Bakery: Kernza®
Experience Timeline

TIMETOAST

Artisan Naan Bakery's Kernza® Experience

Aug 26, 2020

AURI Contacted Bakery about Potential Kernza® Pilot Project

The Agricultural Utilization Research Institute, inquired by email if the bakery would be interested in doing a pilot project baking with Kernza® perennial grain flour. And so began Artisan Naan Bakery's ongoing Kernza® experience. Photo courtesy of Carmen Fernholz.

Jan 5, 2021

Pilot Project with AURI Formally Began

Early January 2021, the Kernza® naan pilot project officially took off and took shape through videoconferences, emails, and telephone calls between the bakery and AURI. Photo courtesy of Carmen Fernholz.

Jan 5, 2021

Funding for the AURI & Artisan Naan Bakery Pilot Project

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

Jan 28, 2021

Bakery Received Kernza® Flour Samples

AURI delivered two Kernza® flour samples to the bakery. The flour was MN-Clearwater and had been milled by Swany White Flour Mills in Freeport, MN. Swany White Flour Mills has been owned by the Thelen Family since 1903.

Jan 28, 2021 Sep 20, 2021

Baked with MN-Clearwater Milled by Swany White and by Baker's Field

MN-Clearwater is the first variety of Kernza to be released for commercial production in the U.S. It was developed by the University of Minnesota Forever Green Initiative, a College of Food, Agricultural and Natural Resource Sciences (CFANS) research platform developing winter annual and perennial crops and cropping systems that protect soil and water while also providing new economic opportunities for growers, industry, and communities.

Mar 24, 2021

Received Kernza® Flour for Baking Pilot Project Naan

AURI shipped flour from Swany White to the bakery for the pilot project Kernza@ naan, which would be sold at the bakery's retail counter and at the 2021 St Cloud Area Farmers Market in downtown St Cloud, MN. Thereafter, the bakery finalized the Kernza® naan recipe; named our naan, The Marvel; and designed the required food label and a special label identifying the bakery's products made with Kernza®.

May 14, 2021

Baked the 1st Batch of Kernza® Naan with AURI

AURI visited the bakery and baked the 1st batch of Kernza® Naan with Gwen. We also baked amazing Kernza@ Pizzas for lunch. Yum! Yes, we hand-tossed each naan and naan pizza crust.

May 29, 2021

The Marvel and Marvelous Pizza Crust Debuted at the Farmers Market

We debuted a Kernza® naan, The Marvel, and a Kernza® par-baked Naan Pizza Crust, the Marvelous Naan Pizza Crust, at our local farmers market in St Cloud, MN. It was a sell-out!

May 29, 2021 Aug 21, 2021

Farmers Market

The bakery sold our Kernza® breads, The Marvel Naan and the Marvelous Naan Pizza Crust, for the duration of our 2021 farmers market season.

Jun 15, 2021 Aug 9, 2021

Geared Up for Wholesaling Kernza® Naan

Based on the positive reception from farmers market customers, the bakery prepared for wholesaling our new naan to 4 long-term customers, The Wedge, Eastside, and both Seward Co-Ops, Minneapolis, MN. Preparations included buying MN-Clearwater flour through Baker's Field Flour and Bread, making arrangements with our buyers, and finalizing the retail labels. AURI analyzed our recipe and provided a Nutrition Facts label.

Jul 1, 2021

Expanded our Web Presence and Launched Kernza® Social Media Campaign

The bakery expanded our web presence. We deployed a new website. We engaged a Marketing Director to handle our social media presence; and to map out a specific social media campaign for our Kernza® products. In September, the bakery added Instagram.

Jul 8, 2021

Kernza® Field Day at A-Frame Farm, Madison, MN

Gwen Williams attended the Kernza® Field Day at A-Frame Farm in Madison, MN. She met and conversed with many people, notably, grower and President of Perennial Promise Growers Cooperative, Carmen Fernholz; growers from Sustain-a-Grain in Kansas, Brandon Kaufman and Peter Miller; Tessa Peters, The Land Institute; and Connie Carlson, UMN Forever Green Initiative. Photo courtesy of Karl Hakanson.

Jul 8, 2021

Food Matters at the Kernza® Field Day in Madison, MN

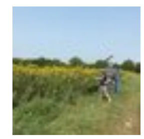
Gwen brought samples of our Kernza® Naan to the Madison Field Day. Gwen had the pleasure of meeting Beth Dooley and tasting her wonderful Kernza@ pilaf. Gwen especially enjoyed meeting and talking with Jill Holter, who had created fantastic grilled pizza recipes for our Naan back in 2017! Photo courtesy of Karl Hakanson.

Jul 17, 2021

ROCORI Community Plot Day hosted by ROCORI FFA, in Cold Spring, MN

AURI brought our Kernza® Naan to this educational Kernza® field day open to the public. Our Kernza® Naan was one of many delicious Kernza® food samples attendees enjoyed. The field day was held at the 16-acre Kernza@ plot planted by ROCORI FFA and Ag students. The day featured presentations by AURI and the Stearns County Soil & Water Conservation District, among others.

Aug 6, 2021



Educational Visit to The Land Institute

The bakery sent an envoy to The Land Institute in Salina, KS, to take one of their public Friday tours in order to learn more about perennial crop research in general and Kernza® in particular. The delegation consisted of the bakery's Marketing Director and her daughter, the bakery's Teen Food Ambassador. Photo courtesy of Julia Williams.

Aug 10, 2021

The Marvel Naan Delivered to Minneapolis Grocery Shelves

The bakery's delivery driver Dave brought The Marvel naan, made with Kernza® perennial grain, to four Minneapolis locations. The Marvel hit the shelves at Seward Community Co-op Franklin store, Seward Community Co-op Friendship store, Eastside Food Co-op, and The Wedge Community Co-op.

Sep 1, 2021 Nov 10, 2021

Geared Up for Wholesaling Kernza® Pita

The bakery prepared for wholesaling a new Kernza® pita, starting with a select group of Lunds & Byerlys stores. Preparations included buying more Kernza® flour, finalizing our pita recipe and handling / baking method, making arrangements with our buyer, and finalizing the retail labels. AURI analyzed our final recipe and provided a Nutrition Facts label.

Sep 8, 2021 Dec 30, 2022

Baking with C5 Flour from Sustain-a-Grain

The bakery bought Kernza® C5 flour from Sustain-a-Grain in Kansas, where The Land Institute is located. "C5" stands for "Cycle 5," the variety obtained through five breeding cycles at The Land Institute.

Nov 12, 2021

Perennial Grain Pockets (Kernza® Pita) Delivered to Select Lunds & Byerlys Stores

The bakery officially released our 2nd Kernza® flatbread, our Perennial Grain Pockets, or Kernza® Pita. This fresh whole grain pita launched at 5 select Lunds & Byerlys locations in Eagan, Highland Park, Maple Grove, Ridgedale, and St Louis Park.

Jan 1, 2022

Perennial Grain Pockets Sold at 3 More Lunds & Byerlys Stores

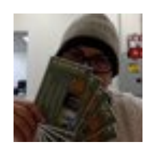
Lunds & Byerlys France Ave Edina, 50th Street Edina, and Northeast Minneapolis stores started carrying our Kernza® Pita, bringing the number of stores selling this pita to 8.

Feb 1, 2022

AURI Published a Fields of Innovation Innovator Profile on Artisan Naan Bakery

The bakery was honored that AURI selected Artisan Naan Bakery for their 2022 AURI Connects: Fields of Innovation Innovator Profiles. The profile discusses the bakery's work with AURI and the emerging grain Kernza®.

Mar 8, 2022



Bakery Distributed Mad Agriculture's Selling Aids for Grocers

At the bakery's request, Mad Agriculture, a non-profit that works to advance regenerative agriculture, delivered assistance to the bakery and the grocers selling our Kernza® breads. This assistance by Mad Agriculture came in the form of composing a 4x6 Kernza® Postcard for display in grocery store settings and a basic Kernza® Fact Sheet. Mad Agriculture represents the Perennial Promise Growers' Cooperative.

Mar 10, 2022

The Marvel Naan Sold at 5th Minneapolis Food Co-Op

Long-term customer, Linden Hills Co-Op in Minneapolis, MN, started carrying our Kernza® Naan.

APPENDIX K

Product Specification Sheet: Stone Ground Whole Grain Kernza® Flour (Swany White Mills)

Swany White Flour Mills
206 2nd St. SE
Freeport, MN 56331
320-836-2174

PRODUCT SPECIFICATION

Stone Ground Whole Grain Kernza® Flour

Definition: A food grade flour, milled from whole grain Intermediate Wheatgrass, MN Clearwater variety Kernza® Perennial Grain. Product is unenriched, unbleached and unbromated.

Country of Origin: USA (Stearns County, Minnesota)

Ingredients: Whole Grain Kernza®

Packaging/Shelf Life/Storage Conditions:

- Packaging: 50 lb. multi-walled paper bag.
- Shelf Life: 12 months from date of milling. Date code is <Lot Number> Best By: <MM/DD/YYYY>
- Storage: Dry storage at cool temperatures is recommended.

Physical Characteristics:

- Appearance: Off-white with dark specks.
- Odor and Flavor: Free of musty, bitter, rancid or other undesirable odors or flavors.
- Granulation: 33% through #35 (500 micron) and 64% through #20.
- Manufacturing of this product is in accordance with current good manufacturing practices set forth in the Federal Food, Drug and Cosmetic Act and applicable state statutes and regulations.
- The product shall be as free of all types of foreign materials as achievable through good manufacturing practices.

Chemical Attributes (based on 2020 harvest year)

- Moisture: 7.8%
- Protein: 18.5% (as is)
- Ash: 2.3% (as is)
- Falling Number: 193
- Aflaxtoxin: < 5 ppb, Vomitoxin: < 0.5 ppm

Microbiological Attributes

This product is considered not ready to eat (NRTE) and requires further processing. As a result, no microbiological guarantees are provided.

Certifications/Credentials:

Non-GMO: Yes, not 3rd party certified (see affidavit)
Kosher: None
Organic: None
Sustainability: None, refer to https://kernza.org/

Uses:

Use in applications where whole wheat flour is used including baked goods, flatbreads, pasta, and beer. Usage rate in unleavened baked goods, flatbreads and pasta up to 100% replacement of whole wheat flour. Usage rate in leavened baked goods, up to 30 % replacement of whole wheat flour is recommended. Usage rate in beer, up to 20% of the grain bill.

Allergen Statement:

- Contains wheat.
- This product contains no egg or egg products, milk or milk products, peanuts or peanut products, tree nut products (almond, Brazil nut, cashew, chestnut, hazelnut, macadamia nut, pecan, pine nuts, pistachio or walnut), soybeans or soybean products, seafood, or sulfites.

Swany White Flour Mills
206 2nd St. SE
Freeport, MN 56331
320-836-2174

Stone Ground Whole Grain Kernza® Flour

Nutritional Analysis per 100 g

Calories	368
Calories from Fat	26
Calories from Saturated Fat	4
Protein	19.21g
Carbohydrates	67.32g
Dietary Fiber	18.0g
Soluble Fiber	3.6
Total Sugars	1.68g
Added Sugars	0 g
Fat	2.93g
Saturated Fat	0.45 g
Trans Fat	0 g
Cholesterol	0 g
Vitamin D	0 mg
Calcium	120 mg
Iron	5.55mg
Potassium	480mg
Sodium	0 mg

Swany White Flour Mills
206 2nd St. SE
Freeport, MN 56331
320-836-2174

Transforming Agriculture, Perennially

1 Feb 2021

Tessa Peters
2440 E. Water Well Rd
Salina, KS 67401

To whom it may concern:

This letter is to certify that there are currently no approved Kernza® varieties that have been developed with transgenic techniques. The two approved varieties, MN-Clearwater and TLI C5 were both developed using traditional plant breeding techniques that use non-transgenic procedures.

Sincerely,

Tessa Peters
Director of Crop Stewardship
The Land Institute
Email: peters@landinstitute.org
Cell: 970-412-9489

APPENDIX L

Product Specification Sheet: Whole Grain Kernza® Flour (Swany White Mills)

Swany White Flour Mills
206 2nd St. SE
Freeport, MN 56331
320-836-2174

PRODUCT SPECIFICATION

Whole Grain Kernza® Flour

Definition: A food-grade flour, milled from whole grain Intermediate Wheatgrass, MN Clearwater variety Kernza® Perennial Grain. Product is unenriched, unbleached and unbromated.

Country of Origin: USA (Stearns County, Minnesota)

Ingredients: Whole Grain Kernza®

Packaging/Shelf Life/Storage Conditions:

- Packaging: 50 lb. multi-walled paper bag.
- Shelf Life: 12 months from date of milling. Date code is <Lot Number> Best By: <MM/DD/YYYY>
- Storage: Dry storage at cool temperatures is recommended.

Physical Characteristics:

- Appearance: Off-white with dark specks.
- Odor and Flavor: Free of musty, bitter, rancid or other undesirable odors or flavors.
- Granulation: 62% through a #35 mesh (500 Micron), 100% through a #20 mesh.
- Manufacturing of this product is in accordance with current good manufacturing practices set forth in the Federal Food, Drug and Cosmetic Act and applicable state Statutes and Regulations.
- The product shall be as free of all types of foreign materials as achievable through good manufacturing practices.

Chemical Attributes (based on 2020 harvest year)

- Moisture: 7.8%
- Protein: 18.5% (as is)
- Ash: 2.3% (as is)
- Falling Number: 193
- Aflaxtoxin: < 5 ppb, Vomitoxin: < 0.5 ppm

Microbiological Attributes

This product is considered not ready to eat (NRTE) and requires further processing. As a result, no microbiological guarantees are provided.

Certifications/Credentials:

Non-GMO: Yes, not 3rd party certified (see affidavit)
Kosher: None
Organic: None
Sustainability: None, refer to https://kernza.org/

Uses:

Use in applications where whole wheat flour is used including baked goods, flatbreads, pasta, and beer. Usage rate in unleavened baked goods, flatbreads and pasta up to 100% replacement of whole wheat flour. Usage rate in leavened baked goods, up to 30 % replacement of whole wheat flour is recommended. Usage rate in beer, up to 20% of the grain bill.

Allergen Statement:

- Contains wheat.
- This product contains no egg or egg products, milk or milk products, peanuts or peanut products, tree nut products (almond, Brazil nut, cashew, chestnut, hazelnut, macadamia nut, pecan, pine nuts, pistachio or walnut), soybeans or soybean products, seafood, or sulfites.

Swany White Flour Mills
206 2nd St. SE
Freeport, MN 56331
320-836-2174

Whole Grain Kernza® Flour

Nutritional Analysis per 100 g

Calories	368
Calories from Fat	26
Calories from Saturated Fat	4
Protein	19.21g
Carbohydrates	67.32g
Dietary Fiber	18.0g
Soluble Fiber	3.6
Total Sugars	1.68g
Added Sugars	0 g
Fat	2.93g
Saturated Fat	0.45 g
Trans Fat	0 g
Cholesterol	0 g
Vitamin D	0 mg
Calcium	120 mg
Iron	5.55mg
Potassium	480mg
Sodium	0 mg

Transforming Agriculture, Perennially

1 Feb 2021

Tessa Peters
2440 E. Water Well Rd
Salina, KS 67401

To whom it may concern:

This letter is to certify that there are currently no approved Kernza® varieties that have been developed with transgenic techniques. The two approved varieties, MN-Clearwater and TLI C5 were both developed using traditional plant breeding techniques that use non-transgenic procedures.

Sincerely,

Tessa Peters
Director of Crop Stewardship
The Land Institute
Email: peters@landinstitute.org
Cell: 970-412-9489

APPENDIX M

Sugar Extraction and Analysis: Kernza®
(Sasya LLC)

Service Provider Agreement Research Deliverable

Contents

List of Figures and Tables

Report provided to AURI under the Service Provider Agreement

This document summarizes the results of the research performed by Sasya under the Service Provider Agreement for the Agricultural Utilization Research Institute (AURI). The experimental methods used are generic methods implemented in the industry and no effort was made to optimize the methods or processes to improve the efficiency for better results. Therefore, AURI must interpret the results as a "proof-of-concept" only. Although the original schedule was disrupted due to unforeseeable causes, the final deliverable was on schedule. Sasya made reasonable effort to ensure the validity and accuracy of the methods, results and procedures.

The results presented in this document are organized according to the deliverables outlined in the Service Provider Agreement (signed on Jan-10, 2020 and amended on Jun-22, 2020). The first section is on the work performed with alfalfa (1. Reducing Antinutrients from Alfalfa, 2. Protein concentrate from alfalfa and 3. Methods to extract sugars from alfalfa). This work covers the project described under FS017IN. The second section is the work on Kernza (Sugar extraction). The results are for FS016IN and FS035IN. The second section describes the methods in much greater detail and the methods developed/implemented are consistent across all the projects.

The results and data provided reflect the good faith effort employed by Sasya. The raw data is provided in the Appendix and all calculations are described in the main text. The figures are generated using the data from the Appendix using the calculations shown in the text. Some calculations are based on the analytical data provided by AURI and Sasya has used the data as received to perform the calculations. The interpretations and inferences are subject to debate.

Kernza (FS016IN)

4. Sugar extraction from Kernza

Kernza is a domesticated variety of intermediate wheat grass. In addition to the potential use as grain, the plant biomass can also be used to extract fermentable sugars. Given the consistency of the dry straw, this section of the report presents the results from a study that evaluated the applicability of established extraction methods from dried straw. Due to the lack of information on the biomass composition or fermentable sugar extraction from Kenza, a sample of corn stover was included as a positive control. Cellulose, hemicellulose and lignin make up a major portion of biomass samples. The nature of these three components is quite different. Hemicellulose is composed of both pentose and hexose molecules, such as xylose, arabinose, mannose, and galactose, while cellulose is crystalline structure that is only composed of glucose. These constituents were measured to understand the general make-up of the biomass.

4.1. Sample preparation

Kernza straw (provided by AURI) and Corn Stover were oven dried at 60°C overnight and milled to Mesh 35 and used as the starting material for biomass extraction. As shown in Figure 11, the samples milled very cleanly leaving little residue.

Figure 11. Ground dry samples of Kernza straw (left) and corn stover (right) that were used as the starting material for quantification and extraction of fermentable sugars.

In comparison to milled corn stover, Kernza was less dense and flaky. Interestingly, milled Kernza was also more hydrophobic at alkaline pH. For carbohydrate quantification, the extraction solvent was acidified to 5.

4.2. Biomass pretreatment

Analysis procedure involved a two-step acid hydrolysis to fractionate the biomass into forms that are more easily quantified. The lignin fractionates into acid insoluble material and acid soluble material. The acid insoluble material may also include ash and protein, which must be accounted for during gravimetric analysis. The underlying principle involves hydrolyzing the polymeric carbohydrates into their monomeric forms which are readily soluble in water and can be measured using an HPLC. Acetic acid is released from the hemicellulose with xylan backbone, but not from mannan and can also be measured using an HPLC.

4.3. Biomass composition assessment

4.3.1. Solids and Ash quantification

Four aluminum boats were pre-weighed and approximately 500 mg of Kernza or Corn stover was transferred into the boats. The samples were incubated at 105°C in a convection oven for five hours (when constant weight was achieved) and re-weighed. The difference in the weight corresponded to the moisture content, allowing calculating the accurate solids content.

Four crucibles (two for Kernza and two for corn stover) were heated to 575°C for four hours and cooled in a dessicator before their weight was recorded. A pre-weighed sample of Kernza or corn stover (~500 mg) was transferred into the crucible and dried to ash over an ashing burner and transferred to 575°C for 3 h. The weight of ash measured in the duplicate samples. Using this procedure, the ash content in corn stover was ~1.5% but that in Kernza was twice that at ~3.1%.

4.3.1. Cellulose quantification

To the ~ 4 g of bone-dry plant biomass (from Section 4.3.1), 4 mL of acetic/nitric/water (8:1:1, by volume) was added in a glass sample vial with PTFE seals and placed in a water bath and 98°C for 1 h. After cooling, the volume was brought up to 10 mL with DI water. The liquid was freeze-dried overnight and the solids resuspended in 2 mL acetone, which was evaporated by incubation at 45°C. The fibers were depolymerized by adding 1 mL 50% H_2SO_4 and shaking at room temperature for 1 h followed by the addition of 1 mL of 3% anthrone and thoroughly mixed. The samples were incubated at 121°C for 1 h to release glucose and absorbance at 620 nm measured. Glucose was quantified by a standard curve using known amount of glucose which was also subjected to the exact process. Avicel was used as a positive control. Cellulose content is calculated as the $\frac{G}{W} \times D \times 100$, where G is the weight of glucose (mg) as calculated from the standard curve for each sample, W is the weight of the dried biomass in mg (shown in Appendix 5.7) and D is the dilution factor. The cellulose values were calculated in duplicate and corrected for ash (Section 5.6).

4.3.2. Hemicellulose quantification

Hemicellulose was isolated from 4 g of dried plant biomass (from Section 4.3.1) by alkaline hydrolysis of the ester bonds. Unlike previous procedures that described using concentrated alkali which can mostly hydrolyze xylans and arabinans, a gradient elution was performed using

NaOH gradient from 0.1 M to 5 M. The lower concentration alkali can hydrolyze glucans and mannans and the analysis is expected to facilitate an accurate estimation of hemicellulose.

Hot DI water (80 mL), glacial acetic acid (0.5 mL) and 1 g of $NaClO_2$ was added to the plant biomass and heated at 70°C for 1 h. After 2 h, fresh bolus of acetic acid and $NaClO_2$ were added and the delignification continued for 5 h. The delignified plant biomass (called holocellulose) was filtered and weighed. The holocellulose was packed in a 20 mL column and 10 mL of NaOH at different concentrations (low to high) was passed through the column and the fractions pooled. Glacial acetic acid was added (15% by volume) to precipitate the polymers. The process mixture (~100 mL) was filtered through a filter paper to collect the precipitate and dried at 105°C. The weight of the resulting precipitate was determined and hemicellulose content calculated as $\frac{P}{W} \times 100$, where P is the weight of the precipitate (mg) and W is the weight of the dried biomass in mg. The values were calculated in duplicate, corrected for ash and the average value reported.

4.3.3. Biomass deconstruction

To release the carbohydrates from the biomass, 1 g of the biomass was weighed and 10 mL of 72% H_2SO_4 was added to it and thoroughly mixed for 1h at 30°C. The acid was diluted to 4% with DI water. Authentic samples of glucose, cellobiose, xylose, galactose, arabinose and mannose were also individually subjected to the same treatment to account for any sample losses during the deconstruction process. The samples were treated at 121°C for 1 h and cooled to room temperature. A 50 mL aliquot of the sample was stored at 4°C for subsequent analysis of lignin (see section 4.3.4).

4.3.4. Lignin analysis

The autoclaved solution from Section 4.3.3 was filtered to quantify acid-soluble lignin. The absorbance of the clarified filtrate was measured at 320 nm (for minimal interference any carbohydrates). The amount of acid-soluble lignin was quantified as $\frac{A_{320} \times V_f \times D}{\varepsilon \times W \times p}$, where A_{320} is the recorded absorbance at 320 nm, V_f is the volume of the filtrate, D is the dilution factor, ε is the extinction coefficient, which for corn stover is 30 L/g/cm, W is the dry weight of the biomass and p is the pathlength of the cuvette (1 cm). For the lack of better information, the same value of ε was also used for Kernza biomass.

Acid-insoluble lignin was calculated from the solids in the filter paper, which were rinsed with DI water and dried to uniform weight at 105°C. The dry solids are transferred into a muffle furnace and heated to 105°C for 10 minutes, ramping up the temperature to 250°C for 30 min and 575°C for 3 h before cooling down to room temperature in a desiccator. The weight of the dried solids was recorded. The amount of acid insoluble lignin was calculated as $\frac{W_{res} - W_{ash} - W_{prot}}{W_{dry}}$ where W_{res}

is the tared weight of all acid insolubles in the biomass, W_{ash} is the weight of ash left over and W_{prot} is the weight of protein. The exact amount of protein in Kernza straw was provided by AURI and was used in the equation to calculate insoluble lignin. Using this method, the total lignin in Kernza was 21% and in corn stover was 15.5%. The most interesting difference was that almost all the lignin in corn stover was acid insoluble. Kernza straw comprised of a substantial amount of acid soluble lignin.

4.3.5. **Quantification of structural carbohydrates**

The hydrolysis liquor from Section 4.3.3 was used to quantify glucose, cellobiose, xylose, galactose, arabinose and mannose. The sugars were measured using an enzymatic kit using colorimetric determination against a standard curve. The hydrolysis liquor (25 mL) was neutralized with $Ca(CO)_3$ to bring the pH to ~5.5 until the effervescence slowed down. The solids were removed by filtration and the clarified liquor was analyzed for sugars. Glucose was also measured by monitoring the absorption at 620 nm after anthrone treatment.

Based on the protocol and the calculations described, the composition of biomass in corn stover and Kernza straw was calculated and summarized in Table 5.

Table 5. Composition of biomass from Corn stover (used as control) and Kernza straw, on a dry matter basis. The data are the average of duplicate analysis.

	Corn Stover	**Kernza**
Cellulose	38.4%	42.1%
Hemicellulose	29.5%	32.8%
Lignin	15.5%	20.6%
Ash	1.5%	3.1%

Encouragingly, Kernza straw appears to comprise higher concentration of sugars as indicated by higher cellulose and hemicellulose content. The results conclusively demonstrate that Kernza straw contains significant amount of carbohydrates that can be extracted for use as fermentable sugars.

4.4. **Extraction of sugars from Kernza straw**

This section explores the conventional dilute acid method to extract cellulose and hemicellulose followed by their hydrolysis into fermentable sugars from Kernza. Dried, milled straw was pre-treated at different pH conditions - 3.0, 4.0, 5.0, 6.0 and 7.0 and three temperatures - 60°C, 75°C and 90°C. These conditions are relatively milder than the conventionally used conditions (pH < 2, 121°C). As a trade-off, the reaction time was extended to 6 h. The workflow of extracting sugars is shown in the schematic below (Figure 12).

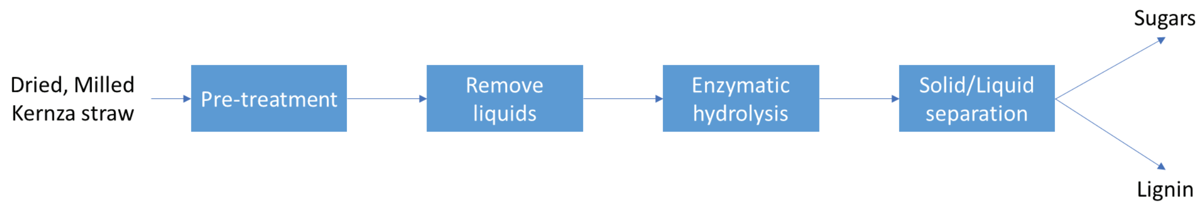


Figure 12. Schematic of the workflow for extracting sugars from Kernza straw

The pre-treated biomass samples were collected after removing the acid and subjected to enzymatic hydrolysis. The enzyme used was a cocktail of carbohydrases, comprising of arabinase, cellulase, β-glucanase, hemicellulase, and xylanase (proprietary product from Novozymes). The enzyme was previously evaluated to efficiently depolymerize cellulose and hemicellulose and was found to be resistant to inhibitors from biomass treatment (such as furfurals, etc), high temperature and low pH conditions. In a previous study, the optimal hydrolysis condition was determined to be at a pH of 5.2 and a temperature of 50°C. These conditions were employed to hydrolyze the pre-treated biomass.

After 6 h of incubation the hydrolysis reaction was stopped and solids separated from the syrup by centrifugation. The solid portion, which predominantly comprises of acid-insoluble lignin and other residue, was weighed and was used as a proxy for lignin. The syrup was filtered and sent to AURI for quantification of glucose, galactose, xylose and arabinose. The data obtained was normalized to biomass weight (dry matter) and the amount of fermentable sugar released was expressed as a percentage.

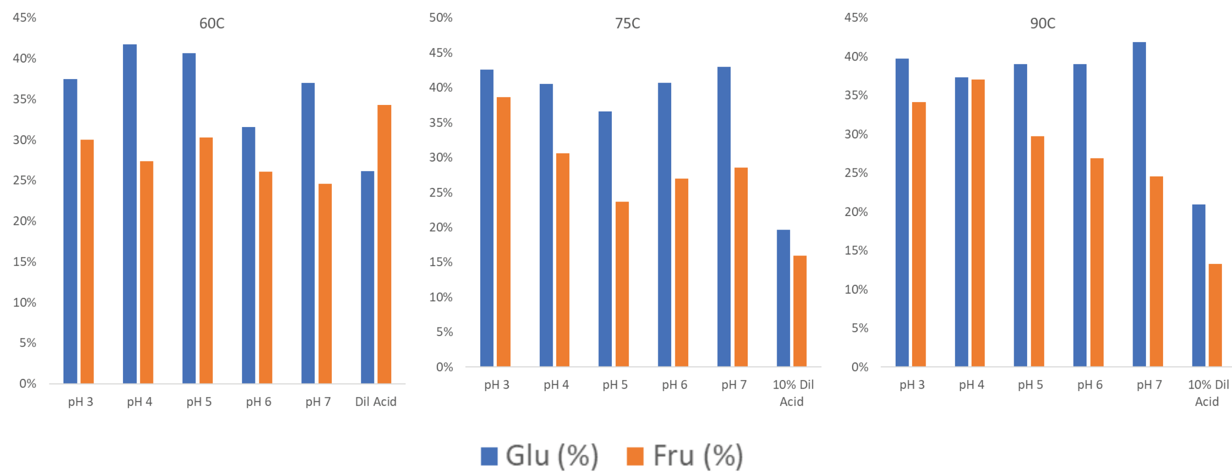


Figure 13. Extraction of hexose sugars from Kernza straw at different pH values and temperatures. Shown in the figure are Glucose (blue) and Fructose (orange) as percentage of the biomass on a dry matter basis.

Acid pretreatment appeared to have a greater impact on the deconstruction of biomass into cellulose and hemicellulose. In general, at 60°C more acidic conditions were conducive to the release of hexoses (Figure 13). Interestingly, 10% H_2SO_4 which was also used to pre-treat Kernza straw, resulted in less hexose release than at a pH of 3. The result is strongly suggestive of an optimal pH for the release of hexoses. Interestingly, the amount of hexose released was the highest at pH 4. As the pretreatment temperature increased to 75℃ and 90°C, the trend appeared to reverse, with higher pH treatment releasing more sugars. As indicated in the center panel of Figure 13, more glucose and fructose were released at pH 6 and pH 7 than at pH 3 or with dilute acid. If true, the trend has a valuable implication on process design that allows departure from the conventional conditions used in biomass pretreatment (dilute acid at a pH of 1.5 and 121°C). Overall, the dilute acid treatment followed by enzymatic hydrolysis was able to release hexoses that corresponded to ~65% of the biomass on a dry matter basis. This result alone conveys the strong promise of the applicability of Kernza straw for biofuel production.

The pretreatment condition and subsequent enzymatic hydrolysis had very different impact on the release of pentoses. Xylose and Arabinose were the major pentoses. Consistently across all pH values (3.0 to 7.0) for pretreatment, there was only a negligible amount of xylose and arabinose released (~1%) at the three temperature conditions studies. On the contrary, when 10% dilute acid was used as the pretreatment agent the amount of xylose released increased substantially to 20% at 75°C pretreatment (Figure 14). However, arabinose remained at 2%. Indeed, the large increase in xylose release was reproducible at all temperatures, with a maximum at 75°C.

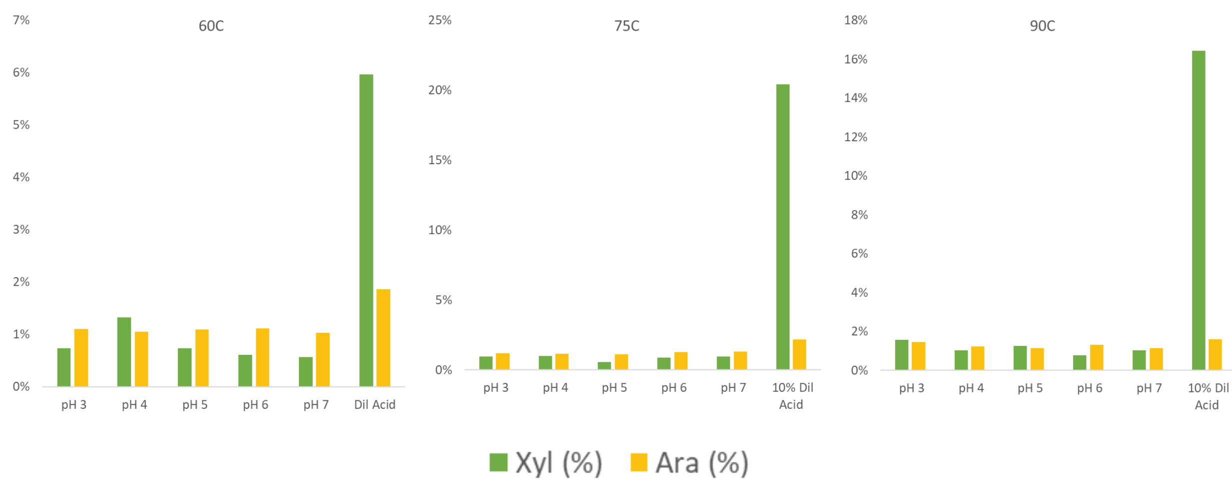


Figure 14. Extraction of pentose sugars from Kernza straw at different pH values and temperatures. Shown in the figure are Xylose (green) and Arabinose (yellow) as percentage of the biomass on a dry matter basis.

An important message from this result is that higher temperature is not necessarily required to depolymerize hemicellulose and xylan. As demonstrated with Kernza straw, pretreatment at an intermediate temperature of 75°C yielded higher xylose titer than pretreatment at 60°C or 90°C. The result is in agreement with the higher acetate concentration detected in the samples from dilute acid pretreatment. Acetals are produced as a result of hydrolysis of hemicellulose and not cellulose, higher xylose yields should be accompanied by higher acetate titers.

The result is clearly indicative of a requirement of stringent pretreatment conditions to deconstruct hemicellulose from Kernza straw. The recalcitrant nature of hemicellulose in corn stover and switchgrass is widely reported and appears to hold true for Kernza straw. Given that the amount of arabinose content in biomass is typically very low, there is very little effort into optimizing the release of this sugar.

4.5. Conclusions

The main conclusion from the study is that Kernza is very amenable to extracting cellulosic sugars to provide feedstock for the biofuel industry. Given the significantly different pretreatment conditions required for the release of hexoses and pentoses from the straw, a one-pot, two-stage pretreatment process to deconstruct Kernza straw into monomeric sugars might be suitable. The first stage of the proposed process would comprise of moderate reaction conditions to deconstruct biomass into cellulose followed by a second stage harsh acidic conditions for hemicellulose.

5.6. Solids and Ash Quantification for Kernza

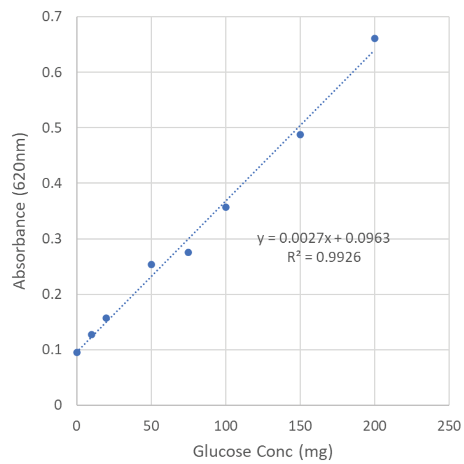
Quantification of solids in Kernza and Corn Stover samples

Boat	Init Wt (g)	Final Wt (g)	Final Wt (g)	Moisture
K1	4.35	4.05	4.06	6.90%
K2	4.62	4.28	4.3	7.36%
C1	4.89	4.41	4.4	9.82%
C2	4.12	3.7	3.68	10.19%

Quantification of ash in Kernza and Corn Stover samples

Crucible	Weight (g)	Final Wt (g)	Final Wt (g)	Ash
K1	64.1569	67.1280	65.1623	3.10%
K2	65.8506	68.8375	66.8775	3.05%
C1	66.1334	67.6351	66.596	1.49%
C2	65.9796	67.4738	66.4945	1.52%

5.7. Glucose released and cellulose calculation



Boat	Solids (g)♦	Glu (mg)	Dilution	Cellulose
K1	4.055	86.71842	20	42.77%
K2	4.29	83.322	20	38.84%
C1	4.405	80.00761	20	36.33%
C2	3.69	72.54624	20	39.32%

♦ Calculated from data in Section 5.6

5.8. Hemicellulose determination

Boat	Dry Solids (g)	P (mg)	Hemicellulose
K1	3.975	14.5715	36.66%
K2	4.055	10.9192	26.93%
C1	4.157	12.0416	28.97%
C2	4.054	11.8161	29.15%

5.9. Lignin quantification

Acid-soluble lignin

Sample	A320	Vf (L)	W	Soluble lignin
K1	0.388	0.06	0.244	3.18%
K2	0.402	0.06	0.254	3.17%
C1	0.118	0.06	0.422	0.56%
C2	0.131	0.06	0.512	0.51%

Acid-insoluble lignin

Crucible	Wbio	Wdry	Wash (calc)	Wres	% prot (from AURI)	Wpro (calc)	Insoluble lignin
K1	1.0321	0.9609	0.0295	0.2770	7.98%	0.0767	17.77%
K2	1.1002	1.0192	0.0313	0.2860	7.87%	0.0802	17.12%
C1	1.0442	0.9417	0.0289	0.2185	5.12%	0.0482	15.01%
C2	1.0875	0.9766	0.0300	0.2272	5.25%	0.0513	14.94%

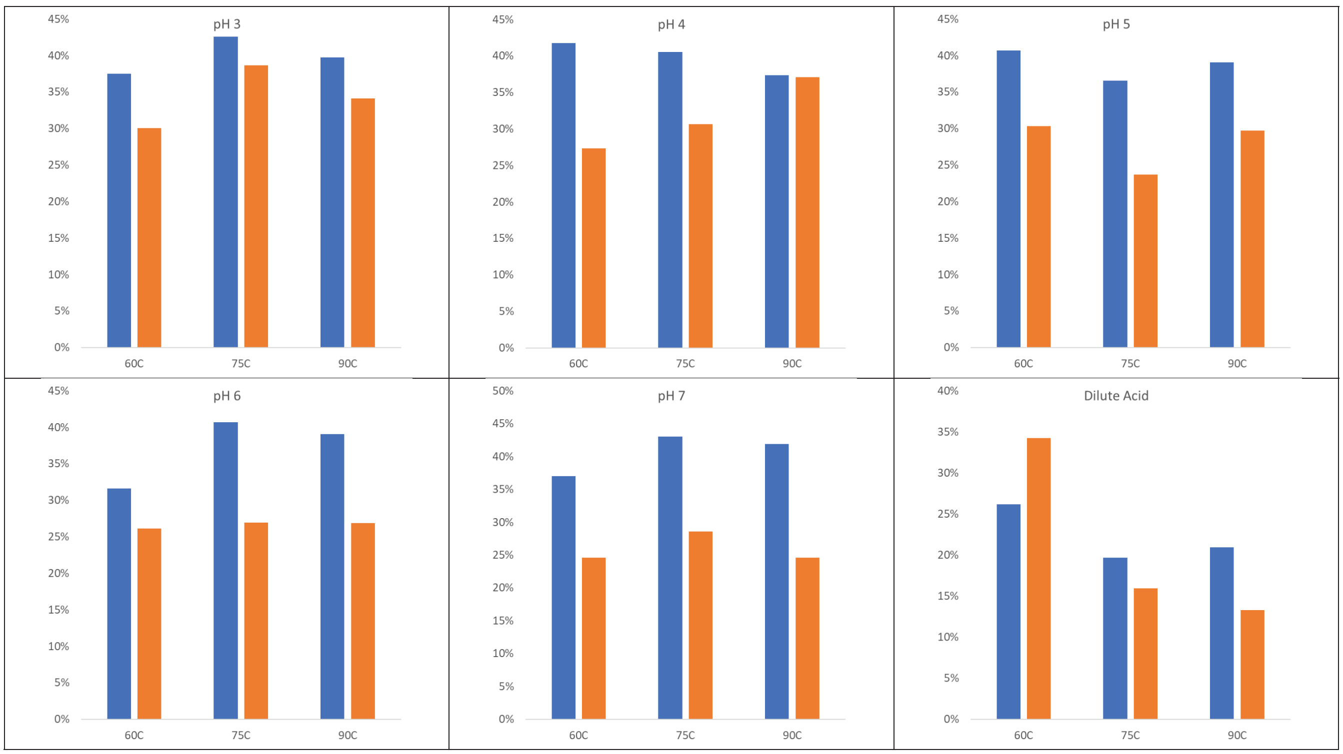
5.10. Sugar recovery

Sugar	Absorption	Measured Conc (g/L)	Actual Conc (g/L)	Recovery
Glucose	0.241	4.98	5.01	99.4%
Cellobiose	0.118	5.01	4.99	100.4%
Galactose	0.321	5.06	5.03	100.6%
Xylose	0.224	4.97	5.01	99.2%
Arabinose	0.13	5.01	4.99	100.4%
Mannose	0.0921	4.93	4.96	99.4%

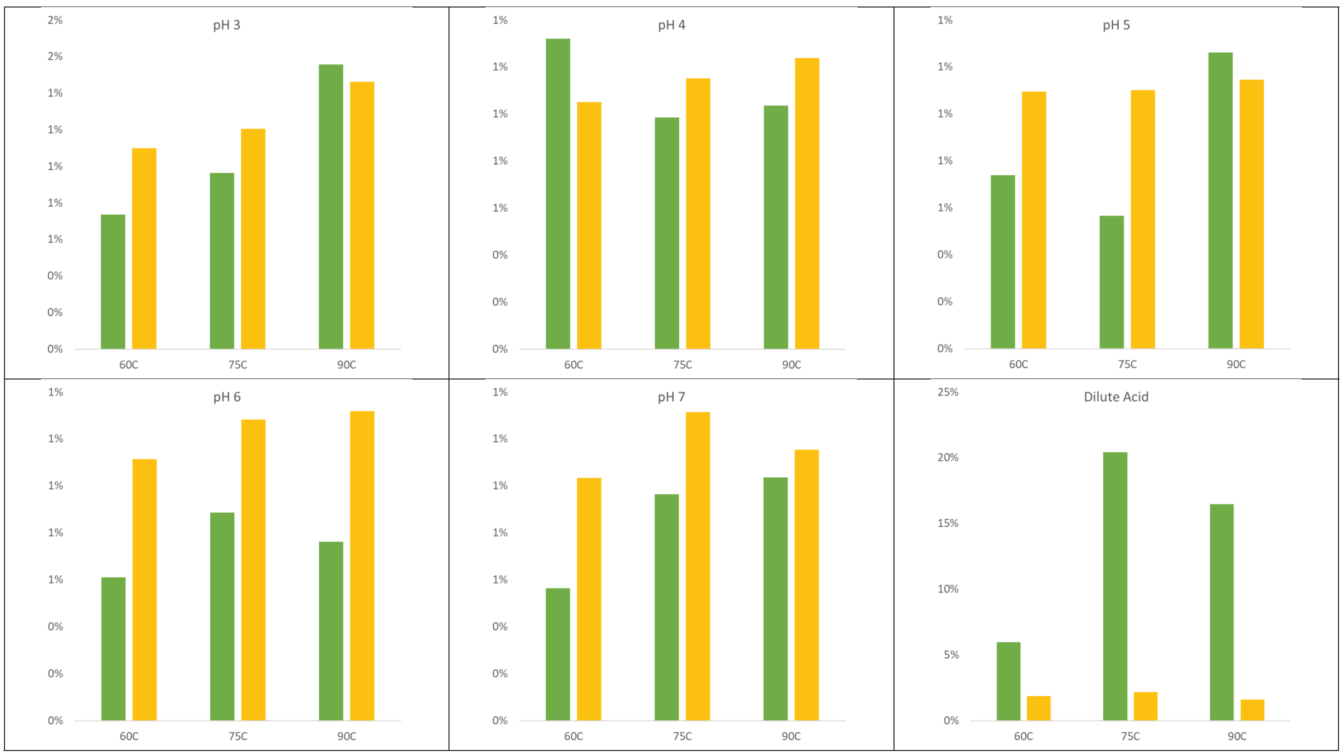
5.11. Raw data for sugars from Kernza

Pretreatment conditions							
pH	**Temp**	**Init biomass (g)**	**Glu (g/L)**	**Fru (g/L)**	**Xyl (g/L)**	**Ara (g/L)**	**Acetate (g/L)**
pH 3	60	5.99	11.33	9.08	0.22	0.33	0.08
pH 3	75	5.97	12.59	11.44	0.28	0.36	0.11
pH 3	90	6	12.00	10.30	0.47	0.44	0.20
pH 4	60	5.99	12.59	8.25	0.40	0.32	0.10
pH 4	75	6.01	12.09	9.13	0.29	0.34	0.10
pH 4	90	6.01	11.13	11.05	0.31	0.37	0.16
pH 5	60	5.96	12.03	8.96	0.22	0.32	0.07
pH 5	75	5.99	10.86	7.03	0.17	0.33	0.08
pH 5	90	5.99	11.60	8.83	0.37	0.34	0.19
pH 6	60	5.98	9.36	7.73	0.18	0.33	0.16
pH 6	75	5.99	12.24	8.11	0.27	0.39	0.12
pH 6	90	5.92	11.46	7.88	0.22	0.39	0.22
pH 7	60	6.02	11.06	7.35	0.17	0.31	0.27
pH 7	75	6.01	13.01	8.64	0.29	0.40	0.17
pH 7	90	5.97	12.38	7.26	0.31	0.34	0.27
10 % H2SO4	60	6	7.90	10.34	1.80	0.56	1.46
10 % H2SO4	75	6.01	5.95	4.81	6.17	0.66	2.09
10 % H2SO4	90	5.99	6.32	4.01	4.96	0.48	2.00

5.12. Hexoses released from Kernza Straw



5.13. Pentoses released from Kernza straw



6. References used to develop the methods

1. Sluiter A, Hames B, Ruiz R, Scarlata C, Sluiter J, Templeton D, Crocker D (2008) Determination of structural carbohydrates and lignin in biomass, laboratory analytical procedure (LAP). Technical report NREL/TP-510-42618

2. Silvio Vas Jr. (2016) Analytical Techniques and Methods for Biomass. Springer International Publishing, Switzerland.

3. Handbook of Wood Chemistry and Wood Composites, edited by Roger M. Rowell, Taylor & Francis Group, 2012

APPENDIX N

Brewing with Kernza® Perennial Grain
(AURI Info sheet)

Brewing with Kernza®
Perennial Grain

Agricultural Utilization Research Institute

Brewing Overview

Kernza® perennial grain (Kernza) is a new type of perennial intermediate wheatgrass that is under development in Minnesota for its environmental benefits. According to University of Minnesota researchers, Kernza has an extensive root system that helps protect soil from erosion, improves soil health, and reduces nitrogen leaching, protecting water resources from nitrate contamination. As a close relative of wheat, Kernza has many potential applications in the food and beverage industry.

Comparison of Brewing Characteristics

Type of Grain		2-row Barley Base Malt	Kernza Malted Hulled*	Unmalted Hulled Kernza*	Malted White Wheat	Unmalted White Wheat
Moisture	%	5.23	3.53	4.30	5.00	12.0
Total Protein	%	11.5	18.0	17.9	11.5	10.0
Alpha Amylase	D.U.	65.0	15	8	48	-
Germination Energy	%	>95**	NA	65	NA	>95**
Germination Capacity	%	>95**	NA	75	NA	>95**
Extract (FG Dry Basis	%	81.0	79.9	69.9	83.0	76.0
Color	°SRM	2.2	3.3	1.8	2.5	2
Turbidity	NTU	8.7	N/A	3.0	-	-
pH	-	5.8	6.0	6.3	-	-
Soluble Protein	%	4.7	8.9	4.6	4.7	-
S/T Ratio	-	41.0	49.4	25.7	41.0	-
ß-Glucan	mg/L	96	67	176	-	-
Free Amino Nitrogen (FAN)	mg/L	169	174	45	-	-
Diastatic Power	°L	129	104	108	160	-

*- Source: Data represents initial lab scale testing results at Montana State Malting Labs

** Montana State Lab does not recommend malting grain that does not have Germination Energy and Germination Capacity over 95%.

Malt test results based on one sample of MN Clearwater, numbers may vary slightly, sample to sample

Brewing with Kernza®
Perennial Grain

Agricultural Utilization Research Institute

Comparison of Brewing Characteristics

- Compared to wheat, Kernza yields less extract on a fine ground basis
- S/T Ratio: Soluble Protein to Total Protein Ratio
    - Malted Kernza: Indicates thinner and lighter-bodied beer
    - Unmalted Kernza: indicates fuller-bodied beer with good head retention and foam stability
- FAN level, Free Amino Nitrogen, of malted Kernza suggests higher percentage usage will not negatively impact yeast growth or result in need for added yeast nutrients in the wort
- Low turbidity of unmalted Kernza suggests a clear, bright finished beer appearance
- Both the malted and unmalted Kernza made beers with low SRMs, Standard Reference Methods, suggest that Kernza usage in higher percentages (>50 percent) won't darken the final product

Challenges

- Grain size: Seed is approximately 80% smaller than conventional wheat, potentially leading to difficulties in milling and malting Kernza traditionally. Genetic modifications are currently under exploration at the University of MN and the Land Institute to increase Kernza grain size
- Processing: The addition of ß-glucans in unmalted Kernza and elevated protein levels in malted Kernza may lead to stuck sparges during brewing. Addition of rice hulls during the mash step could mitigate the frequency of these occurrences
- Supply: Low grain supply may impact availability of Kernza for brewing purposes

Typical Usage

- Suggested beer styles for Kernza use:
    - American Wheat Beer
    - German Hefeweizen
    - German Dunkelweizen
    - German Weizenbock
    - Belgian Witbier
- Typical usage levels- Small batch testing has suggested usage of 15-20% of Kernza to have no perceived negative effects. Specific brewing conditions and finished product sensory preferences may result in usage levels outside of this suggested range.
- For example, a 500-gallon batch of a traditional mild American wheat beer would use around 950 pounds of grain, 20% of which would be wheat. If Kernza were substituted in this recipe, the 500 gallon batch would require around 200lb of Kernza grain.

- Sensory Profile Impacts
    - Addition of Kernza at 15% added a slight sour-like acidity to the beer
    - Beer made with 15% Kernza had less lingering sweetness than a standard, malty beer
    - Inclusion of Kernza at 15% was shown to have a slight dampening effect on the perceived carbonation of the beer
    - Imminent Brewing out of Northfield, MN has used milled Kernza in a German Alt beer at 20% with success, noting a slightly lighter color and a pleasant nuttiness addition
    - Overall, the addition of Kernza at lower levels does not seem to negatively impact the sensory characteristic of beer and may add a unique flavor profile.

References

The Land Institute, 2020, https://landinstitute.org/our-work/perennial-crops/kernza/ • Interviews with Dr. George Annor from the University of Minnesota Food Science Department 2020 • Interview with Imminent Brewing 2020

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

APPENDIX O

Kernza® Perennial Grain as a Cereal Grain
(AURI Info Sheet)

Kernza® Perennial Grain as a Cereal Grain

Agricultural Utilization Research Institute

Introduction

Kernza® perennial grain (Kernza) is a new domesticated grain introduced by The Land Institute that is now being developed for commercial use in Minnesota. It originates from a forage grass called intermediate wheatgrass (*Thinopyrum intermedium*) and is a relative of wheat. In 2019, the University of Minnesota released its first named Kernza® variety: MN-Clearwater.

As a close relative of wheat, Kernza has application opportunities in the food industry. It contains a higher protein and dietary fiber content versus wheat but lacks in some gluten components that limit its functionality in some applications. Besides the potential for food applications, Kernza also provides environmental benefits. According to University of Minnesota Researchers, its deep roots can protect soil from erosion, improve soil health, and reduce nitrogen leaching, protecting water resources from nitrate contamination.

Nutritional Comparison to Wheat

Kernza contains more protein, dietary fiber and bioactive compounds such as carotenoids versus wheat but certain characteristics limit its use as a stand-alone flour. Although Kernza contains gluten, it is deficient in one of the gluten components (high molecular weight glutenin).

***Values in table based on 100g sample**

Types of Grain		Kernza Whole Grain[a]	White Wheat Berries[b]	Kernza Refined Flour[a]	All Purpose White Flour[c]
Moisture	%	8.6	13.75	8.1	11.9
Ash	%	2.4	N/A	0.6	0.47
Calories	-	368	318	368	364
Protein	g	19.2	9.24	17.5	10.3
Carbohydrates	g	67.3	73.7	73.2	76.3
Dietary Fiber	g	18.0	10.3	4.3	2.7
Soluble Fiber	g	3.6	N/A	1.0	0.9
Sugar	g	1.7	1.1	N/A	0.3
Total Fat	g	2.9	2.3	1.2	1.0
Sat Fat	g	0.5	0.4	0.3	0.2
Mono Fat	g	0.5	0.3	0.1	0.1
Poly Fat	g	1.9	1.6	0.7	0.4
Trans Fat	g	0	0	0	0
Cholesterol	mg	0	0.10	0	0
Calcium	mg	120.0	25.0	50.0	15.0
Iron	mg	5.5	2.6	3.7	1.2
Potassium	mg	480.0	N/A	140.0	107.0
Sodium	mg	0	13.0	0	2.0

Characteristics

- Kernels are 80% smaller than Hard Red Wheat (breeding efforts are underway at the UMN and The Land Institute to increase kernel size)
- Hull/Kernel weight Ratio: 25-35% Hull to 65-75% Kernel
- Amber/Mahogany color

Bakers Field toasted the grain to assist in milling the product, which led to an enhanced flavor and a more consistent particle size for the flour.

—Steve Horton- Bakers Field Flour and Bread

a: *Source: Results are directional only, data represents analysis of one sample of Clearwater Variety, MVTL, New Ulm, MN*
b: *ESHA Database: Star of the West Milling Company*
c: *ESHA Database: USDA Composition Data*

Kernza® Perennial Grain as a Cereal Grain

Agricultural Utilization Research Institute

Suggested Application Opportunities

Whole Grain
Granola or other cereal
Pilaf style side dish
Brewing (malted or unmalted)
Puffed or Sprouted

Flour	
Bread and Flatbreads	Pretzels
Biscuits	Pasta
Pancake/Waffle Mix	Crackers
Cupcakes	Brewing

Processing and Grain Stability

- On average 30-50% of the harvested material will be dehulled usable grain
- Inconsistent grain sizes could lead to inefficient dehulling and/or the need to regularly modify processing settings
- Mold/Mycotoxins: Kernza can be tested using existing methods for molds and mycotoxins
- Food Grade Storage and Handling: Kernza does not present any unique challenges for food grade storage and handling
- Higher fat content increases overall rancidity potential, but higher antioxidant content may offer protective effect
- Kernza showed reduced levels of peroxide formation during storage versus Hard Red Wheat which points to an increased resistance to oxidative rancidity
- Microbiological Spoilage: Kernza does not require special preventative measures
- Whole grain Kernza is stable when stored under typical grain storage conditions, though once hulled, the grain may benefit from refrigerated storage to help extend its shelf life

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1. The Land Institute, 2020, https://landinstitute.org/our-work/perennial-crops/kernza/
2. *"Kernza in Southern Minnesota: Assessing Local Viability of Intermediate Wheatgrass"* Erik Muckey, January 2019, University of Minnesota Extension
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Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

APPENDIX P

Kernza® Perennial Grain in Baking Applications
(AURI Info Sheet)

Kernza® Perennial Grain in Baking Applications

Agricultural Utilization Research Institute

Introduction

Kernza® perennial grain (Kernza) is a new domesticated grain introduced by The Land Institute that is now being developed for commercial use in Minnesota. It originates from a forage grass called intermediate wheatgrass (*Thinopyrum intermedium*) and is a close relative of wheat. In 2019, the University of Minnesota released its first named Kernza variety: MN-Clearwater. Besides the potential for food applications, Kernza also provides environmental benefits. According to University of Minnesota researchers, Its deep roots can protect soil from erosion, improve soil health, and reduce nitrogen leaching, protecting water resources from nitrate contamination.

As a close relative of wheat, Kernza has application opportunities in the food industry. It contains a higher protein and dietary fiber content versus wheat but lacks in some gluten components that limit its functionality in some applications. To overcome the gluten component deficiency, there are several additives or dough conditioners that can be utilized to help improve functional properties. Kernza can also be blended with wheat flour to improve baking (or baked good) quality.

Comparison with Traditional Wheat

***Values in table based on 100g sample**

Grain Types		Kernza Refined Flour[a]	All Purpose White Flour[b]
Moisture	%	8.1	11.9
Ash	%	0.6	0.5
Calories	-	368	364
Protein	g	17.5	10.3
Carbohydrates	g	73.2	76.3
Dietary Fiber	g	4.3	2.7
Soluble Fiber	g	1.0	0.9
Sugar	g	N/A	0.3
Total Fat	g	1.2	1.0
Sat Fat	g	0.3	0.2
Mono Fat	g	0.1	0.1
Poly Fat	g	0.7	0.4
Trans Fat	g	0	0
Cholesterol	mg	0	0
Calcium	mg	50	15.0
Iron	mg	3.7	1.17
Potassium	mg	140	107.0
Sodium	mg	0	2.0

a *Source: Results are directional only, data represents analysis of one sample of Clearwater Variety, MVTL, New Ulm, MN*
b ESHA Database USDA Composition Data

Baking Properties

- Whole Grain Flour: Kernza berries have a higher bran-to-endosperm ratio which can lead to reduced loaf volume and increased crumb firmness when using whole grain flour

- Refined Flour: Removal of the bran through refining processes can lead to dough that has increased stickiness

Handling and Special Considerations

- With the proper storage conditions (maintaining low humidity and a temperature-controlled environment) flour from Kernza would be considered shelf stable

- Toasting the grain prior to milling may improve flour particle size consistency and help to highlight

Kernza® Perennial Grain in Baking Applications

Agricultural Utilization Research Institute

Challenges and Opportunities

- Glutenin: Kernza contains significantly less glutenin (a functional component of gluten) which limits the dough's ability to form viscoelastic networks required for certain baking applications
- Starch Content: Kernza dough contains less starch, leading to a reduced loaf volume and a weaker crumb structure when compared to conventional wheat dough
- Dough Conditioners: the addition of several dough conditioners, such as vital wheat gluten, ascorbic acid, transglutaminase, xylanase, and alpha amylase, can improve the overall quality of the food products made from Kernza dough
- Blending: Baked goods made from Kernza would benefit from the addition of wheat flour to make up for the lack of gluten proteins and starches
- Dietary Fiber: Kernza flour could be used as a fiber source in flour blends due to its higher dietary fiber content
- Sourdough fermentation was found to highlight the earthy notes in Kernza's flavor profile
- Kernza works well in flatbread applications combined with wheat flour, at a Kernza inclusion rate of about 10 to 15%

Baking Applications

- Bread & Sourdough
- Flatbreads such as Focaccia and Pizza Crust
- Pretzels
- Biscuits
- Muffins
- Cupcakes
- Cookies
- Scones
- Pancake/Waffle Mix
- Crackers
- Pasta

"I prefer the flour in non-yeasted applications, particularly products like pound cake, because the flavor of the grain resembles graham and works well with sweet applications. It reflects the flavor of the Earth quite well where conventional flour does not."

—Beth Dooley- Cookbook Author and Minneapolis Chef

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3. *"Evaluation of the Chemical and Functional Stability of Intermediate Wheatgrass (Thinopyrum intermedium) over Storage and in Response to Steam Treatment" Amy Mathiowetz, December 2018, University of Minnesota*
4. *Interviews with Steve Horton from Bakers Field Flour and Bread 2020*
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APPENDIX Q

Kernza® Perennial Grain: Cleaning & Dehulling Process
(AURI Info Sheet)

Kernza® Perennial Grain: Cleaning & Dehulling Process

auri
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There are several processing steps which need to take place to clean and prepare Kernza for end users. AURI worked with equipment manufacturers and current cleaners/processors to identify the steps and equipment necessary to clean Kernza and remove/separate hulls to achieve a product for milling or to be supplied directly to end users. The identified processing steps are outlined in the diagram.

Inconsistencies in grain size and characteristics between various grain lots is currently a significant factor when processing Kernza. As a result, AURI recommends building flexibility into cleaning and processing equipment setups. The University of Minnesota and others are working to improve seed genetics, which will likely impact grain characteristics such as percentage of free threshed grain in the combine and size of individual grain kernels. Therefore, post-harvest dehulling and cleaning of Kernza grain are processes which are likely to change with time.

- As indicated on page 2, current expectations are for 30-50% of the harvested material to be dehulled usable grain

Kernza from Combine

These steps can be done in conjunction with an air screener or fanning mill type setup

Test Grain for: Moisture, Molds and Mycotoxins

Vomitoxin and Aflatoxin among the common issues

Removal of Dockage via Shaker Table/ Screens or Indent

3/32” x 1/2” slotted screen; 14mm indent

Option 1: Dehuller discharge recycled to aspiration and separation until all grain is dehulled

Option 2: Dehuller discharge sent to separate aspirator and gravity table for increased process efficiency

Removal of Hulls (Aspiration)

Removes hulls and additional dockage

Hulls to be used as feed, fuel or bedding

Grain in-hull and hulled grain

Dehulling (Impact Huller)

1,000—1,500 RPM
Stone impact surface works best

Removal of Hulls (Aspiration)

Grain in-hull and hulled grain

Gravity Table Separation

Grain in-hull

Dehulled Grain

Grain in-hull

Grain Separation: Indent Separation or Slotted Screen

Separation of hulled grain from in-hull grain
8mm indent (length grader) or 3/64” x 3/8” slotted screen

Ddehulled Kernza Grain

Color Sorting

If ergot is an issue, grain will need to be run through a color sorter

Cleaned, Dehulled Kernza Grain

Kernza® Perennial Grain: Cleaning & Dehulling Process

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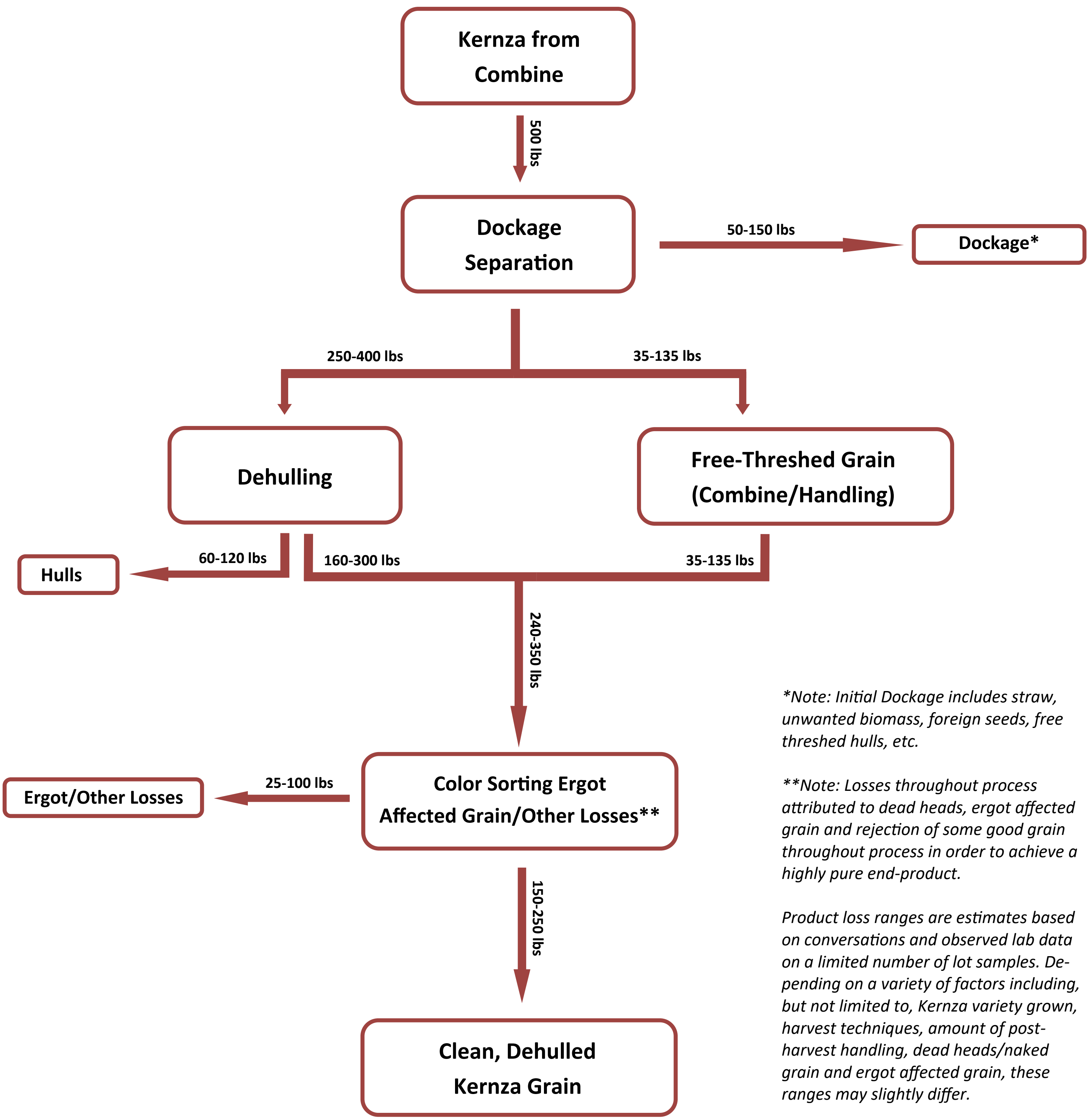
Identified Ranges of Product Weights and Losses Throughout Cleaning and Processing Steps – One Acre Example



**Note: Initial Dockage includes straw, unwanted biomass, foreign seeds, free threshed hulls, etc.*

***Note: Losses throughout process attributed to dead heads, ergot affected grain and rejection of some good grain throughout process in order to achieve a highly pure end-product.*

Product loss ranges are estimates based on conversations and observed lab data on a limited number of lot samples. Depending on a variety of factors including, but not limited to, Kernza variety grown, harvest techniques, amount of post-harvest handling, dead heads/naked grain and ergot affected grain, these ranges may slightly differ.

Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR).

APPENDIX R

Kernza®: Valuation, Pricing and
Market Segmentation

Kernza®: Demand, Valuation and Market Segmentation

Report Prepared By:

- Dillon McBrady- Graduate Student, University of Minnesota Carlson School of Management
- Matthew Leiphon- Project Manager, AURI

Emerging Demand

"Food is a product of supply and demand, so try to figure out where the supplies are fresh, the suppliers are creative, and the demanders are informed."[i] If there isn't demand for a new product, then most likely there won't be a product sold. By starting with a demand analysis, one can see where the market is in Minnesota and if the supply chain should even exist to meet that demand. In the early stages of Kernza's product life cycle, the supply chain was not able to keep up with the initial demand, with Cascadian Farms cereal being hampered by low crop turnout[ii] and breweries considering themselves "lucky to get as much as we did" due to low initial grain availability.[iii] While production has increased, and growers and other key stakeholders are working to ensure more steady and reliable availability, building awareness of the crop to drive demand will be an important ongoing activity to match production to markets.

Minnesota is currently leading in many ways when it comes to knowledge of Kernza. Through efforts led by the Forever Green initiative and the University of Minnesota, soil and water conservation districts, grower groups and other industry stakeholders, information about the benefits and potential of Kernza has been steadily spreading, as well as more research to develop the crop. Minnesota also has the benefit of a major CPG company creating a Kernza cereal[iv], several breweries creating Kernza beer and restaurants using Kernza in food products to raise the crop's profile. "Buzz" about Kernza is demonstrable, but measuring it is more difficult. To make a rough estimate of the "buzz" around Kernza, Google Trends was used as a measure.

Google Trends Data

Google Trends is a platform created by Google that analyzes the popularity of top search queries in Google Search across various regions and languages. The website uses graphs to compare the search volume of different queries over time. This can is useable as a preliminary analysis tool to scout interest and demand in a region for specific terms.

Using the search term "Kernza" with the filter of the past 5 years, shows Minnesota as the leader when it comes to people searching "Kernza," more than doubling queries made in the next highest state, Wisconsin. It also shows that "Kernza" as a search term peaked nationally in November 2019, with periodic spikes in interest over the next several years. The top queries over the past five years associated with Kernza include: "Kernza grain," "Kernza wheat" and "Kernza cereal."

Overall, Minnesota has been the leading state for interest in Kernza as measured by Google Trends over the past five years, and in the past 12 months. (See Figures 1 and 2) While using this data to make an exact measure of demand is impossible, the data does indicate that residents of Minnesota are seeking information on the crop and its uses at rates above those seen anywhere else in the country. As production increases and supply chains build out, this interest in and knowledge of the crop may offer market development opportunities not available in other states.

Figure 1: Google Trends with search term "Kernza", five years ending July 2022

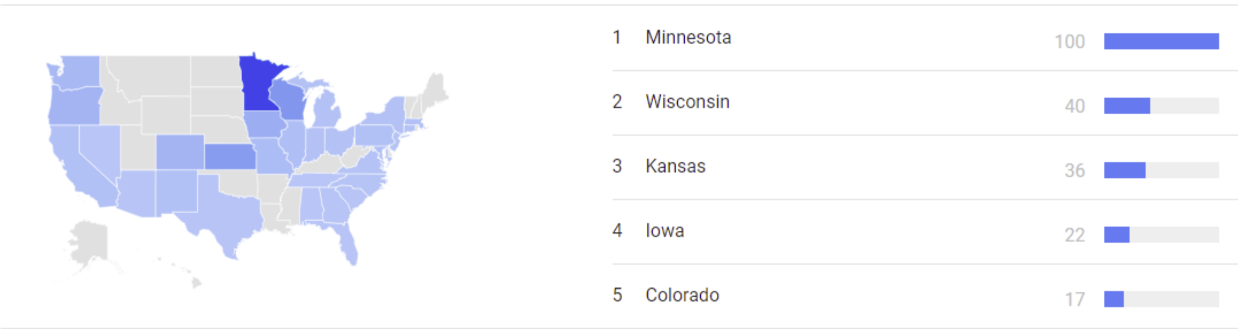
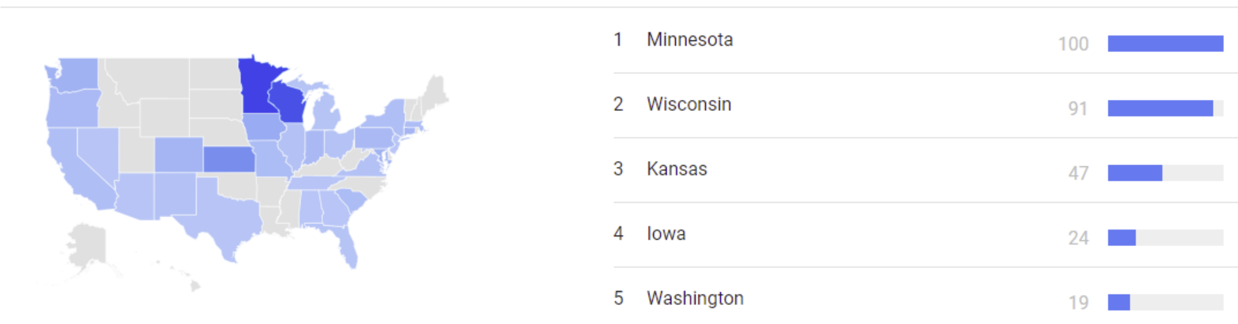


Figure 2: Google Trends data for search term "Kernza," July 2021 to July 2022



Valuation

In "The Strategy and Tactics of Pricing: A Guide to Growing More Profitability," authors Thomas T. Nagle and Georg Müller lay out several pricing strategies, including Cost-Plus, Customer-Driven and Value-Based pricing. Value-based pricing is a pricing strategy that sets prices of a product around the perceived value rather than the cost. Since Kernza® is early in its product life cycle, there is limited data around cost and customer driven pricing, however the extra value that Kernza instills can at least be applied to the value framework.

Value-Based Pricing

Value: The University of Minnesota Carlson School of Management is known for applying value-based pricing, and Professor Mark Bergen, the James D. Watkins Chair in Marketing, organized a value marketing mix used to outline the value of a product. The value is based upon customers, company, competitors and collaborators. These sections broken down further in each category. Since there is such limited data and the focus of this report is on the development of the end customer, this framework solely focuses on the customer.

Customers: The value of Kernza to customers breaks down into Elasticity/Demand, Segmentation, Buyer Behavior and Relationship. For the market data, the national percentages and per capita are used, then broken down to Minnesota and Central Minnesota populations, based on the assumption that Minnesota interests reflect roughly the general population of the United States.

Elasticity/Demand: Market data for Kernza remains limited, making it difficult to report on elasticity/demand. As a result, this section is less focused on elasticity/demand and more focused on recent pricing data. As Kernza acres increase and more grain is available for end-users, several different companies started selling Kernza whole grain and flour direct to consumers. Prices reported during 2021 amount to an average of 43 cents per ounce for whole grain and 91 cents per ounce for flour. (See Figure 3) It is worth noting that Perennial Pantry sold 14 oz bags as a kickstarter to drive awareness and funds for Kernza, which may have contributed to its decision to charge a higher price per ounce. Sprowt Labs' whole grain average of 31 cents per ounce may be closer to an actual market price.

Figure 3: Direct to Consumer Prices for Kernza Grain and Flour: 2021

Selling	Price	Quantity	Type	Ounces	Price /oz.
Perennial Pantry	$9.25	14 oz	Whole grain	14	$0.66
Perennial Pantry	$9.75	14 oz	Flour	14	$0.70
Sprowt Labs	$50	10 lbs	Whole grain	160	$0.31
Sprowt Labs	$250	50 lbs	Whole grain	800	$0.31
Columbia County Bread & Granola	$14.99	15 oz	Sprouted Flour	15	$1.00
Columbia County Bread & Granola	$50	3 lbs	Sprouted Flour	48	$1.04

Whole grain	Average	$0.43
Flour	Average	$0.91

Market Segmentation

To try to pin down the market size of potential Kernza use, segmentation of known markets is used. The Diffusion of Innovation Theory, developed by E.M. Rogers in 1962, breaks down the total population with how they adopt a new idea, product or behavior. Because Kernza is so early in its product life cycle, it is likely largely used by innovators. (See Figure 4)

Figure 4: Diffusion of Innovation Theory[v]

Segment	Description	Population Percentage
Innovators	These are people who want to be the first to try the innovation. They are venturesome and interested in new ideas. These people are very willing to take risks and are often the first to develop new ideas.	2.5%
Early Adopters	These are people who represent opinion leaders. They enjoy leadership roles and embrace change opportunities. They are already aware of the need to change and are very comfortable adopting new ideas.	13.5%
Early Majority	These people are rarely leaders, but they do adopt new ideas before the average person. That said, they typically need to see evidence that the innovation works before they are willing to adopt it.	34%
Late Majority	These people are skeptical of change and will only adopt an innovation after it has been tried by the majority.	34%
Laggards	These people are bound by tradition and very conservative. They are very skeptical of change and are the hardest group to bring on board. Strategies to appeal to this population include statistics, fear appeals and pressure from people in the other adopter groups.	16%

Based on the Diffusion of Innovation Theory, the total market size is estimated at different times of Kernza's product life cycle. A few key metrics used are the population of Minnesota, which is 5.7 million, with the population of central Minnesota being 291,000.[vi] (See Figure 5)

Figure 5: Diffusion of Innovation Market Segment Populations

Segment	Population %	Market Population-MN	Market Population-Central MN
Innovators	2.5%	142,662	7,282
Early Adopters	13.5%	770,377	39,323
Early Majority	34.0%	1,940,208	99,035
Late Majority	34.0%	1,940,208	99,035
Laggards	16.0%	913,039	46,604
Total	100.0%	5,706,494	291,278

As noted, Kernza perennial grain is currently priced at between $4.50 and $6.00 per pound, with a premium for grain with regenerative certifications. As the market matures, these prices may decline. For the purposes of this model, we expanded the low and high price range to $3.50 and $7.00 to provide coverage for market fluctuations around the current reported market prices.

While Kernza many often compare Kernza to wheat, its market potential is likely better when compared to other specialty small grains with a more limited acreage. One potential benchmark for what "success" might look like for a more mature Kernza market is rye. In 2021, Minnesota producers harvested 11,000 acres of rye, yielding 484,000 bushels of grain (21.1 million pounds). While this level of production was far above current Kernza production in the state (approximately 1,400 acres) it does provide an example of a small grain with a limited but established market. According to the United States Department of Agriculture (USDA) Economic Research Service, the total per capita "food availability" of rye in the United States in 2019 (most recent data) was 0.6 pounds. The USDA notes that the total food availability data "serve as proxies for actual consumption at the national level."[vii] At 0.6 pounds per person, annual consumption of rye pales in comparison to wheat, which had a per capita food availability of 131.1 pounds according to recent data. While there are plenty of reasons to be optimistic about the prospects of Kernza, its market segment is far more likely to resemble a crop like rye than a crop like wheat - at least in the near future. (See Figures 6 and 7)

Figure 6: Kernza Market Size Estimate: Benchmarked to Rye

	Market if consumption equal to Rye (0.6 lbs per capita per year)					
Segment	Annual Grain Consumption - Statewide (lbs)	Annual Grain Consumption- Central MN (lbs)	Low Market-Central MN ($3/lb)	High Market-Central MN ($7/lb)	Low Market-Statewide ($3/lb)	High Market-Statewide ($7/lb)
Innovators	85,597	4,369	$13,108	$30,584	$256,792	$599,182
Early Adopters	462,226	23,594	$70,781	$165,155	$1,386,678	$3,235,582
Early Majority	1,164,125	59,421	$178,262	$415,945	$3,492,374	$8,148,873
Late Majority	1,164,125	59,421	$178,262	$415,945	$3,492,374	$8,148,873
Laggards	547,823	27,963	$83,888	$195,739	$1,643,470	$3,834,764
Total	3,423,896	174,767	$524,300	$1,223,368	$10,271,689	$23,967,275

Figure 7: Acres Needed to Meet Kernza Demand if Benchmarked to Rye Consumption[viii]

Segment	Acres to Meet Demand- Central MN	Acres to Meet Demand- Statewide
Innovators	17.5	342.4
Early Adopters	94.4	1848.9
Early Majority	237.7	4656.5
Late Majority	237.7	4656.5
Laggards	111.9	2191.3
Total	699.1	13695.6

Buyer Behavior: There is an expectation that consumers will continue showing interest in the trend of regenerative agriculture,[ix] which is a central part of Kernza's marketing strategy. This may add perceived value to Kernza as a product, as other companies will want to start using more soil/carbon friendly products. One example of this is Zume, which is beginning to create sustainable packaging from the byproducts of regenerative products.[x] There is potential to not only collaborate with companies across Minnesota and the United States, but also in Central Minnesota to pursue additional pilot projects and help diversify and develop the market for Kernza-based products.

To reiterate, because the market for Kernza is so new, it is difficult to pin down potential pricing since there is little data to support projections. Despite this fact, the current high price points indicate that there is interest in the crop, and the potential to create significant value to the end consumer and develop opportunities for value creation at every step of the supply chain.

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