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Kernza® Perennial Grain

Value-Added Uses for Malting, Brewing, and Distilling

October 2024

This report compiles selected research that was issued in fulfillment of ENRTF-LCCMR projects "Accelerating perennial crop production to prevent nitrate leaching" (M.L. 2019) and "Long-Term Nitrate Mitigation by Maintaining Profitable Kernza Production" (2021-384, M.L. 2021) for the Stearns County Soil and Water Conservation District (SCSWCD).

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Executive Summary

This report is a compilation of research developed as part of a wider efforts, supported by the Stearns County Soil and Water Conservation District (SCSWCD), focused on developing sustainable supply chains for Kernza® perennial grain, an emerging small grain crop being developed by The Land Institute in collaboration with the University of Minnesota and other research partners. Kernza is notable for its positive environmental benefits, providing deep-rooted, continuous living cover that can preserve soil health and water quality. Wider adoption of the crop by farmers requires the development of viable end markets.

Technical and commercialization staff at the Agricultural Utilization Research Institute (AURI) engaged in multiple activities supporting the goal of market development. This work included the identification and development of value-added uses for the crop, assessment and optimization of processing and handling methods, and engagement with private sector businesses and external research partners to build stronger commercialization and supply chain networks for Kernza.

As part of its focus on technical assistance, along with product and process development, AURI partnered with multiple businesses and external partners to assess potential value-added uses by testing and demonstrating food and non-food uses for Kernza. Market development in the beverage industry was a focus, with pilot projects on malting, brewing, distillation, and flaking all providing promising results and a foundation for future product development by Minnesota businesses.

Acknowledgments

AURI gratefully acknowledges the Stearns County Soil and Water Conservation District for its leadership of the projects that supported the work covered in this report.

Funding for these projects was provided by the Minnesota Environment and Natural Resources Trust Fund 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. Currently 40% of net Minnesota State Lottery proceeds are dedicated to growing the Trust Fund and ensuring benefits for Minnesota's environment and natural resources.

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Kernza® Perennial Grain Overview

Kernza perennial grain is one of the first commercially available perennial grains in the United States. Producers harvest Kernza from intermediate wheatgrass (Thinopyrum intermedium). The cultivar is a relative of annual wheat and yields various products and potential co-products and also provides environmental benefits. Intermediate wheatgrass is being domesticated by Kansas-based The Land Institute and other research partners including the University of Minnesota as a multi-use grain for livestock forage and human food.

As a perennial crop with a root system that can extend 10 feet or more beneath the soil surface, Kernza provides positive ecosystem services, drawing carbon from the air to build organic matter in the soil, providing soil structure and stability to prevent erosion, capturing nutrient runoff and protecting water quality, and improving water holding capacity. In addition to these direct benefits, it can create improvements off-farm by positively impacting water quality and soil conservation and increasing biodiversity. The crop may also provide an important food source and habitat for beneficial insects and pollinator species, as well as a food and shelter resource for wildlife.

In-Hull (L) and dehulled (R) Kernza perennial grain, AURI.

Developing value-added uses

As markets are still emerging for Kernza, developing and assessing new value-added uses has remained a key area of activity for establishing a mature supply chain. Without continued development and refinement of Kernza-based products, sustainable supply chain expansion will be limited, and wider grower adoption, due to a lack of market opportunity, will be stymied. While multiple Kernza-based products (Kernza.org, 2024) and publications (The Land Institute, 2024) have been developed and released over the past several years, the volume of information on Kernza and its uses remains limited relative to other small grain crops.

Processing at all levels (primary, secondary, and tertiary) will play a key role in the future success of Kernza's market development. AURI focused a notable part of its activity over the past three years on these vital supply chain areas, pursuing pilot research aimed at developing information for processors and building connections in the vital intermediate stages of the Kernza value chain.

As part of its market development activities, AURI provided multiple companies and research partners in Minnesota and surrounding states with Kernza samples and technical information. The technical and material assistance enabled activities including ingredient assessment, product formulation, and evaluation of processing methods, as well as the development of pilot projects and new Kernza product launches in coordination with AURI.

As part of this work, AURI's commercialization and technical teams identified several value-added uses for heightened focus and effort, most notably in alcoholic beverages. Brewers and distillers have been early adopters of the grain in Minnesota and around the United States. Development and dissemination of information on the use of Kernza in malted ingredients and fermented beverages is aimed at reducing barriers to wider adoption, potentially streamlining the development of market-ready products by Minnesota businesses.

Brewing

Over the past several years, AURI has partnered with multiple Minnesota brewers and researchers to assess the use of Kernza in brewing. This work, including multiple pilot projects and lab assessments, demonstrated that Kernza is a viable option to utilize in beer production and holds notable potential as a brewing ingredient. (AURI, 2022) AURI pilot brewing partners report that the addition of Kernza yielded appealing attributes. Brewing pilot projects in Minnesota have made

use of both malted and unmalted Kernza, producing beers in a variety of styles including cream ale, farmhouse/saison, brown ale, hazy IPA, and pilsner.

In addition to brewing pilots with Minnesota brewers, AURI also connected with the Montana State University Malt Quality Lab to perform micromalting and analytical work on Kernza in 2020. Data from this work was included in a "Brewing with Kernza" informational guide, which can be found in Appendix A.

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

Kernza Malt Comparison Data, Montana State University (2020)

Following this work, AURI partnered with the Rahr Technical Center (RTC) in Shakopee, Minnesota to pursue pilot malting and brewing trials in 2021. A report with the results of these trials can be found in Appendix B. This work laid the foundation for further research on malting, brewing, and distilling by AURI and project partners including RTC over the past several years.

Kernza® Hazy Ale brewed by RTC, AURI (2021)

Distilling

Around the United States, a handful of pioneering distilleries have begun producing Kernza-based products, opening wider interest in the grain as an ingredient in whiskey. Early adopters highlighted the grain's flavor profile as a "major selling point." Distillers reported a "genuinely unique" flavor profile that, while holding some similarities to rye and wheat, also carries a "subtle nuttiness," along with "sweet and floral" notes. Most distillers working with the grain have used it in blends with other grains due to Kernza's relatively high price point (Brooks, 2023).

AURI partnered with RTC to perform distilling trials and prepare a report on their findings. (See Appendix C.) These trials included preparing a batch of malted Kernza and developing a malted Kernza American Whiskey. This whiskey was produced using 51% Kernza malt and 49% Rahr Distillers malt. A batch of whiskey using 100% Rahr Distiller's Malt was also produced for comparative purposes. As part of the trials, data was collected on the malting, mash, fermentation, distillation, and accelerated aging processes. Initial tasting notes were also compiled during the

aging process, with Rahr noting that the Kernza Whiskey had a “very sweet flavor with a unique spiciness.”

Following the completion of aging, a tasting analysis of the final product was conducted. Tasting notes from this review can be found in Appendix D.

Rahr Technical Center Distillation Lab, Rahr Corporation (2023)

Malting

The RTC and AURI pursued malting pilot work throughout the course of this project. This work developed new information on processing, assessing the production of specialty ingredients, and providing malted grain for use in further project development work by AURI and external collaborators. Analytical data on the pale malt that was produced for use in these product trials was compiled into a malt information sheet, offering additional guidance to brewers and distillers about Kernza malt and its potential utility as an ingredient. (See Appendix E)

While the RTC has successfully produced multiple batches of Kernza malt, its report on the malt process associated with the whiskey development trials noted that “working with Kernza in the

malthouse and the brewhouse requires patience and adaptability" to manage the small kernel size appropriately (Rahr Technical Center, 2023). Kernza kernels can be broken during the dehulling process, which negatively impacts germination rates and may lead to the production of under-modified malt. Kernza producers seeking to sell grain to maltsters will need to take care to limit seed damage during cleaning. Separation and removal of broken kernels can also improve results during malting but may require special equipment. During the whiskey development trials, an indent separator was used to remove broken seeds prior to malting.

Kernza Specialty Malts, Rahr Corporation (2023)

In addition to pale malt production, AURI also partnered with RTC to develop and assess the use of Kernza in specialty malts. This work moves beyond the production of pale malt to explore the use of Kernza in malts that are kilned to produce darker colors and different flavor profiles for use in the brewing and distilling industries. Two types of specialty malt, Vienna and Munich, were successfully produced as part of the pilot. A wort produced with the Munich malt was formally analyzed by a trained sensory panel. Panelists were impressed, with RTC reporting that the flavor and aroma of the wort "stand apart from any other worts ever tasted by this panel." Comparative descriptors used by panelists included sweet, spiced, fruity, nutty, and bready. RTC described the overall results of the trials as "very encouraging," noting that the "very unique and prominent attributes" that were observed should "increase the appeal and justification for malted Kernza as a specialty ingredient in brewing." RTC also noted that "there must certainly be more flavor and aroma to be unlocked with even higher color malts," and that the trials could serve as a foundation for further incremental work on darker malts (Rahr Technical Center, 2024). For a full report on this work and its results, see Appendix F.

Table 1: Selected AURI Kernza Trials in Minnesota		
Pilot Partner(s) (Name/Type)	**Trial Product(s)**	**Trial Notes**
Rahr Technical Center	Kernza Malt	Grain was malted and distilled into whiskey (See Appendix B)
Rahr Technical Center	Kernza Malt	Produced a pale malt (9 SRM) for use in brewing, distilling, and malted flour pilots (For analytical details on this malt, see Appendix D)
Rahr Technical Center	High Color Kernza Malt	The development and assessment of high-color specialty malts (roasted, kilned) for use in the brewing and distilling industries. (See Appendix E)
Fermented Food and Beverage Producer	Sake	Initial assessment of use as an ingredient in sake.
Modist Brewing	Saison	Development of a barrel-aged, wild-yeasted saison.
Clean River Partners, Imminent Brewing, Chapel Brewing	Beer	AURI partnered with Clean River Partners, a Northfield, Minn.-based water conservation nonprofit, to provide samples of Kernza to breweries in its region for use in product development. Imminent Brewing (Northfield, Minn.) piloted a brown ale and Chapel Brewing (Dundas, Minn.) produced a pilsner.
Craft Distillery	Bourbon	Sample provided to a Minnesota-based distillery for ingredient assessment.

Flaking

While malting Kernza may provide brewers and distillers with a unique and potentially interesting ingredient, production to date has been limited to small-scale pilots. A lack of commercial processing means that malted Kernza will remain limited in availability and high in price until wider production begins. Even once adopted by maltsters, the cost of malting coupled with Kernza's high-cost relative to other grains used in brewing and distilling, will likely lead to a product being sold at premium prices in the initial stages of commercialization. Brewers and distillers wanting to use Kernza are likely to look to clean, dehulled grain as their main option for the foreseeable future.

While unprocessed grain kernels can be a particularly useful ingredient for alcoholic beverages, they offer some challenges to end users. Milling is often required to allow enzymes and water to penetrate and efficiently convert the grain. Unmalted grains tend to be “somewhat plastic” and can be more “difficult for normal brewing roller mills” to process than malted grains, which are more “crisp and friable.” Distillers working with Kernza noted that it can be difficult to mill due to its small size (Brooks, 2023). Flaking provides a grain ingredient that may be used without milling, offering brewers and distillers an additional option when formulating products. (Hansen, 2022)

To assess Kernza’s utility as a flaked ingredient, AURI worked with the Northern Crops Institute (NCI) in Fargo, N.D. to perform Kernza flaking trials. Six samples of Kernza were flaked using a variety of heat and moisture treatments. The process included moisture tempering, warming the seeds before flaking, and moisture treatment after flaking, and was found to produce “very nice flakes,” with “low flour” levels. More details on the methodology and outcomes of these trials can be found in Appendix G.

After processing, the six sample batches of Kernza were sent to the RTC for analysis of their potential utility as a brewing ingredient. A wort analysis included the appearance, extraction, viscosity, and taste of each sample. NCI identified one sample as having “very nice flakes” and the same sample was singled out by RTC as the “clear choice for preferable flake” for use as an ingredient for brewers and distillers. More details of RTC’s analysis are included in the analytical report found in Appendix H.

Following these trials, NCI prepared additional flaked Kernza to enable further assessment of the ingredient by Minnesota-based brewers and distillers. While trials remain underway, one brewer who received a sample for assessment provided positive feedback, noting good results during the mashing and brewing process.

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Appendices

Appendix A: Brewing with Kernza® Perennial Grain (AURI, 2021)

Appendix B: Malting and Brewing with Kernza® (Rahr Technical Center, 2021)

Appendix C: Kernza® Whiskey Development (Rahr Technical Center, 2023)

Appendix D: Kernza Whiskey Evaluation Notes (AURI, 2023)

Appendix E: Kernza Malt Information Sheet (AURI, 2023)

Appendix F: Kernza Specialty Malts (Rahr Technical Center, 2024)

Appendix G: Kernza Flaking Trials (Northern Crops Institute, 2024)

Appendix H: Analytical Report - Flaked Kernza (Rahr Technical Center, 2024)

APPENDIX A

Brewing with Kernza® Perennial Grain
(AURI)

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 B

Malting and Brewing with Kernza®
Rahr Technical Center

Malting and Brewing with Kernza®

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.

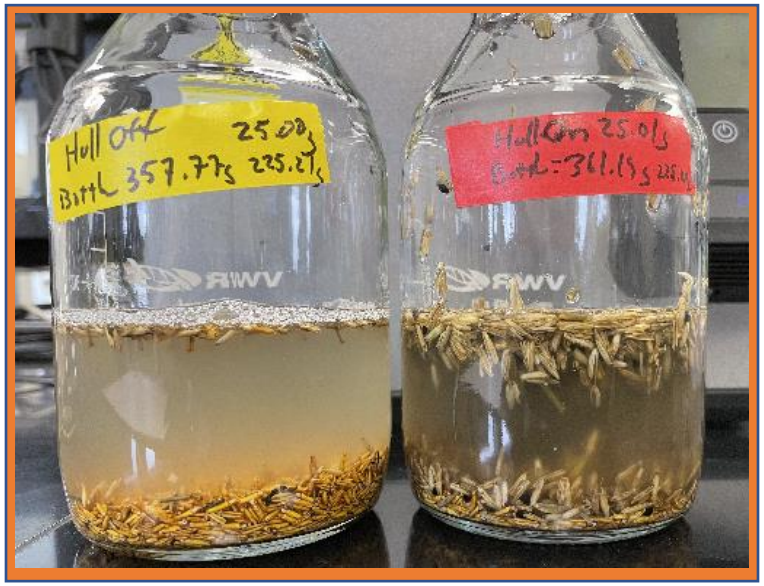
Microbiological Investigation of Micromalts

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

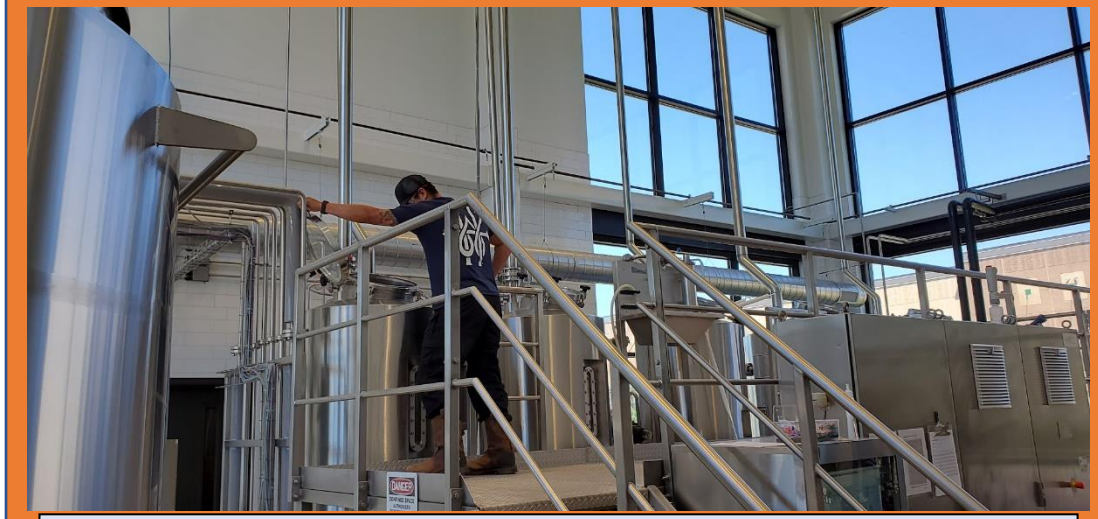
Due to the small kernel size, typical brewery roller mills cannot reach a small enough gap to thoroughly crush Kernza malt to the consistency typical of brewery grist. The Kernza pilot malt blend was nonetheless taken to the BSG Shakopee distribution center for milling and bagging to provide a minimum 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 9. 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 C

Kernza® Whiskey Development
(Rahr Technical Center)

RAHR

Kernza Whiskey

August 2023

Rahr Technical Center

Agenda

- Executive Summary
- Project Overview & Objective
- Malt Production
- Mash Production
- Distilling and Aging

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Executive Summary

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Executive Summary

AURI contracted with Rahr Technical Center, to produce a batch of malted Kernza® and a malted Kernza American Whiskey.

Germination testing of Kernza was done to evaluate for malting parameters and a batch of malted Kernza was produced on the pilot system. A high level of broken kernels in the dehulled grain resulted in a low germination rate and highly under-modified malt. It was determined that the use of enzymes in the mash production would assist with conversion of starch to sugars for fermentation. The need for enzymes may be a barrier for most distillers in the adoption of this malt if a high rate of broken kernels continues to be a challenge.

A mash was produced using 51% Kerzna malt and 49% Rahr Distiller's malt. As a bonus a 100% Rahr Distiller's Malt batch was also produced for comparative purposes. Enzymes were applied to both mashes to increase efficiencies. After being separated from the grain, the washes were inoculated with Fermentis SafSpirit™ M-1 and left to ferment. Though the fermentation time was extended to 12.5 days, the alcohol by volume (ABV) at 48 hours was similar to the final ABV. The ability to ferment quickly is a desired characteristic for most distillers as ferment residency time is typically as short as possible.

The wash was then processed through stripping runs and was followed by a final sprit run in which the hearts were collected. Both spirits were proofed and placed into Squarrel® Square Barrels with new American Oak staves. At the time of this report, the products have been aged for 3.5 months. An informal tasting described the Kernza whiskey as having a very sweet flavor with a unique spiciness, higher alcohol aroma and flavor. It was deemed that more aging time was needed. The product will be aged for up to 6 months in the small barrels, approximating 2 years of aging in a full-size barrel and a guided tasting will occur once the final product has been bottled.

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Project Overview & Objective

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Project Overview & Objective

Agricultural Utilization Research Institute of Minnesota (AURI) contracted with Rahr Technical Center (RTC), to produce malted Kernza® and a 51% malted Kernza American Whiskey at 1-2 different accelerated ages up to 6 months.

The final deliverables of this project were bottles of aged whiskey, a final report to address the brewing and distilling experience, challenges and other learnings, a guided tasting/final meeting of resulting product with AURI employees, and a bonus comparison of 100% barley whiskey produced on same still for informal comparison of Kernza flavor impact. A formal sensory analysis of the product by the Rahr Technical Center team fell outside the scope of this project.

The guided tasting will occur once the final product has been bottled, anticipated to occur end of 2023.

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Test Overview

- Germination testing of stored Kernza was done to evaluate for malting parameters.
- One pilot-scale malting batch of Kernza was produced, resulting in ~150 pounds of finished malt
- Utilizing the resulting Kernza malt, one 3 hL batch size mash was produced (off-grain) using 51% Kerzna Malt and 49% Rahr Distiller's Malt. A second batch was produced using 100% Rahr Distiller's Malt. Enzymes were applied to increase reduced efficiencies.
- Both washes were inoculated with Fermentis SafSpirit™ M-1 and left to ferment for approximately 12.5 days. Fermentation data was collected during this time.
- Both spirits were proofed to ~ 60% ABV and put into Squarrel® Square Barrels with 12 new American Oak staves char number three.
- Aging of resulting white spirit in small batches resulting in accelerated aging for 1-2 different time points, up to six months total time in barrels (approximate accelerated aging of 2 years)

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Malt Production

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Kernza Selection

- Four samples of Kernza were evaluated for peroxide germination prior to malting, with the results shown below. A very high number of broken kernels were observed, and it is assumed that all damage is associated with the dehulling process.

Sample	% Broken	% Germ	Total damaged
1	39	80	59
3	37	86	51
4	46	82	64
5	35	85	50

- AURI then removed more broken kernels using an indent separator at MNL in Foley, removing about 110lb of broken kernels from the 600lb of grain in barrels 3 and 5.
- The resulting lot of grain was then sent to the RTC and evaluated again.
- Approximately 37% broken kernels were recorded. Germination was 83.3% with obvious broken kernels removed. The remaining non-germinated kernels also had embryo damage that became visible when wetted for the germination energy test, so damaged kernels was closer to 55%.
- Of note, the more recent batch (pilot malted in June '23) had 1.3% obvious broken kernels with 86% germination; total damaged kernels around 15%.

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Malt Production

- Malting of Kernza was done according to similar parameters as previous trials at the Rahr Technical Center.
- As with previous pieces for brewing with Kernza malt, the grain became sticky with germination water additions. The water increased the Kernza size & shape, creating compaction of the grain bed and resulting in somewhat poor airflow and therefore some anaerobic conditions.
- Similarly, kilning required special attention to add time and stirring steps due to compaction and channeling.
- The final steep out moisture was 42.5%.

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Malt Production

	Rahr Distillers	Kernza
Color (SRM)	1.85	3.98
Moisture (%)	4.19	7.88
Fine Grind as is (%)	77.8	73.9
Total Protein (%)	12.3	26.3
Soluble Protein (%)	5.43	9.88
Soluble/Total Protein Ratio	44.1	37.6
FAN (ppm)	224	472
β-glucan (ppm)	88	29
pH	5.99	6.04
α-amylase (DU)	61.2	54.1
Diastatic Power (°Lintner)	217	259
Bushel Weight (lbs/bushel)	41.9	42.9

Grading	Rahr Distillers	Kernza
7/64	52.4	.4
6/64	34.6	.4
5/64	11.9	1.4
Thru	1.1	97.8

A high level of broken kernels resulted in low germination rate and highly under modified malt. It was determined that the use of enzymes in the mash production would assist with conversion of starch to sugars for fermentation. This is not a practice that most large-scale distilleries employ and may be a challenge in adoption of this grain. Improvements in grain-handling (especially dehulling) will ameliorate this issue, however.

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Mash Production

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Mash Test Design Summary

- Two 300 L batches of mash were produced to evaluate Malted Kernza for distilling potential. The malt bill for each mash were as follows:
  - Distillers – 100% Rahr Distillers Malt
  - Kernza – 51% Malted Kernza + 49% Rahr Distillers Malt

- Enzyme additions were made to each mash to help with saccharification and the breakdown of β-glucan. Sour Wort was also added to each mash to reach a desired mash pH.
  - 15 mL Bioglucanase GB
  - 15 mL Amylo 300
  - 1200 mL Weyermann Sour Wort

- The mashes were designed with the following set parameters:
  - Mash Parameters (1.5°F/min ramp rate)
    - 122°F – 20 minutes
    - 148°F – 180 minutes
    - 171°F – 5 minutes
  - Original Gravity: 15.15° Plato
  - Yeast: Fermentis SafSpirit™ M-1
  - Pitch Rate: 80 g/hL
  - Fermentation Temperature: 80°F

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Brewhouse Performance

	Rahr Distillers Malt	Kernza
Foundation Water pH	7.10	7.09
pH, Ramp to 2nd Rest	5.46	5.35
Starch Check	Negative	Negative
Clarity After Vorlauf (EBC)	12	12
1st Wort °Plato/pH	19.4°P / 5.40 pH	- / 5.27 pH
Last Wort °Plato/pH	4.5°P / 5.40 pH	6.34°P / 5.32 pH
Total LT Volume Pulled (L)	330	-
Lautering Time (min)	103	128
KTF °Plato/pH	16.1°P / 5.39 pH	15.5° P / 5.25 pH
KO °Plato/pH	17.3°P / 5.28 pH	16.0°P / 5.12 pH
Evaporation Rate (%)	5.0	5.0
Final Cooled Volume (L)	300	300
Fermenter Full °Plato/pH	16.09	15.31
Lautering Efficiency (%)	90.5	80.9

Kernza kernel size is much smaller than barley, increasing lautering times and reducing efficiencies.

Deep cuts with the lauter tun rakes were performed multiple times to ensure continued flow during lautering.

Flow meter was not recording correctly during Kernza lauter, so an accurate volume could not be recorded (~330 L based off recorded Kettle volume).

Due to the high viscosity of the Kernza wash, there was a significantly lower lautering efficiency, which corresponded to lower extract. The viscosity of the wash would be reduced with lower inclusion rates of Kernza.

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Cellar Performance Data - Fermenter

	Rahr Distillers	Kernza
Yeast Strain	Fermentis M-1	
Pitch Amount (g)	240 g	
Original Gravity (°Plato)	16.09	15.31
Final Gravity (°Plato)	1.01	2.31
ROH (v/v %)	6.49	7.07
RE (w/w %)	3.91	4.81
Ratio (RE/ABW)	0.60	0.86
RDF (%)	77.5	70.4

In addition to a lower extract, the Kernza was less fermentable than the distiller's malt, resulting in a higher final gravity.

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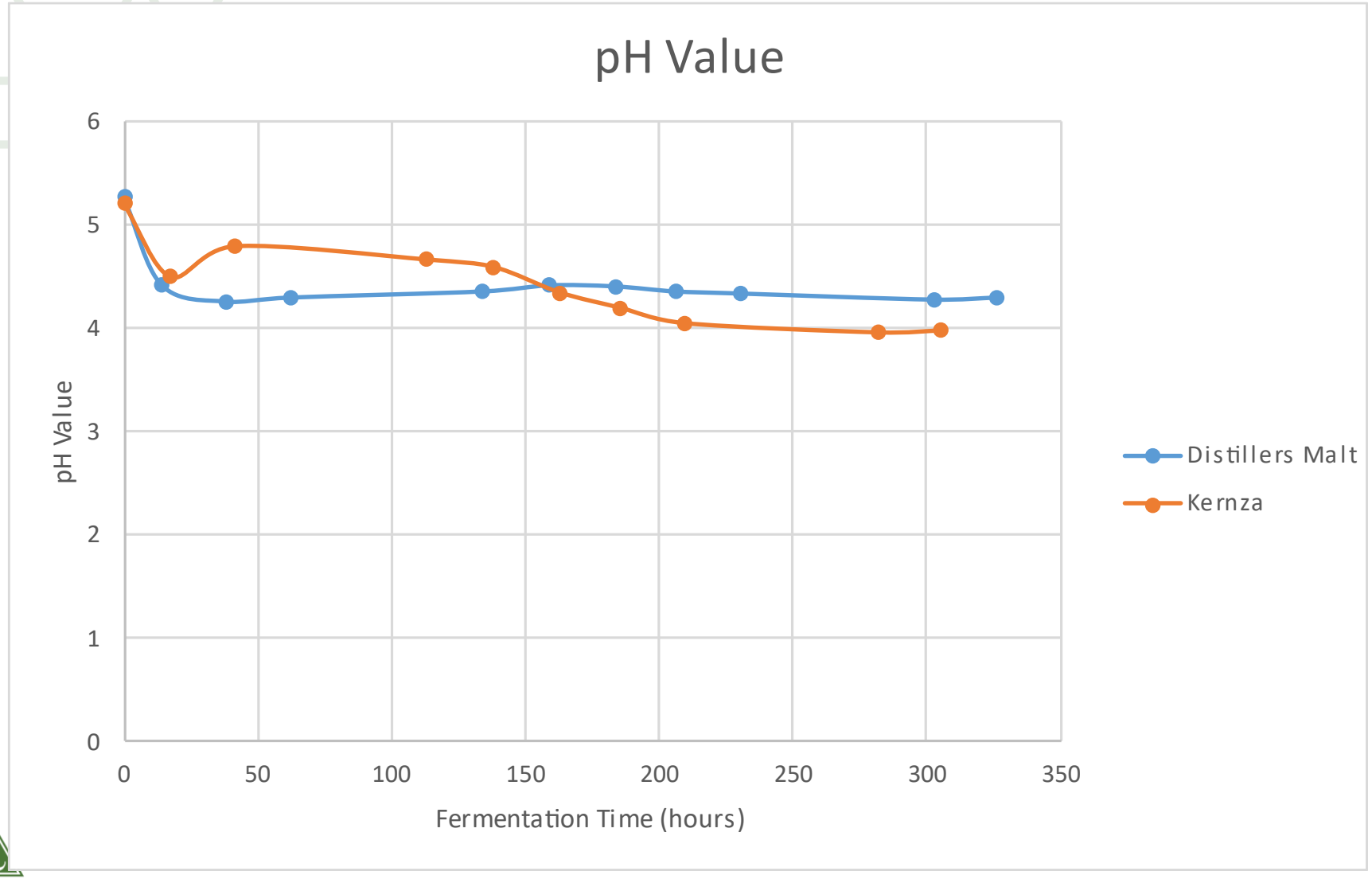
Fermentation Trends - pH



The pH of the Kernza wash was higher than the Distiller's from about 14 hours to about 158 hours, after which it decreased to below that of the Distiller's wash.

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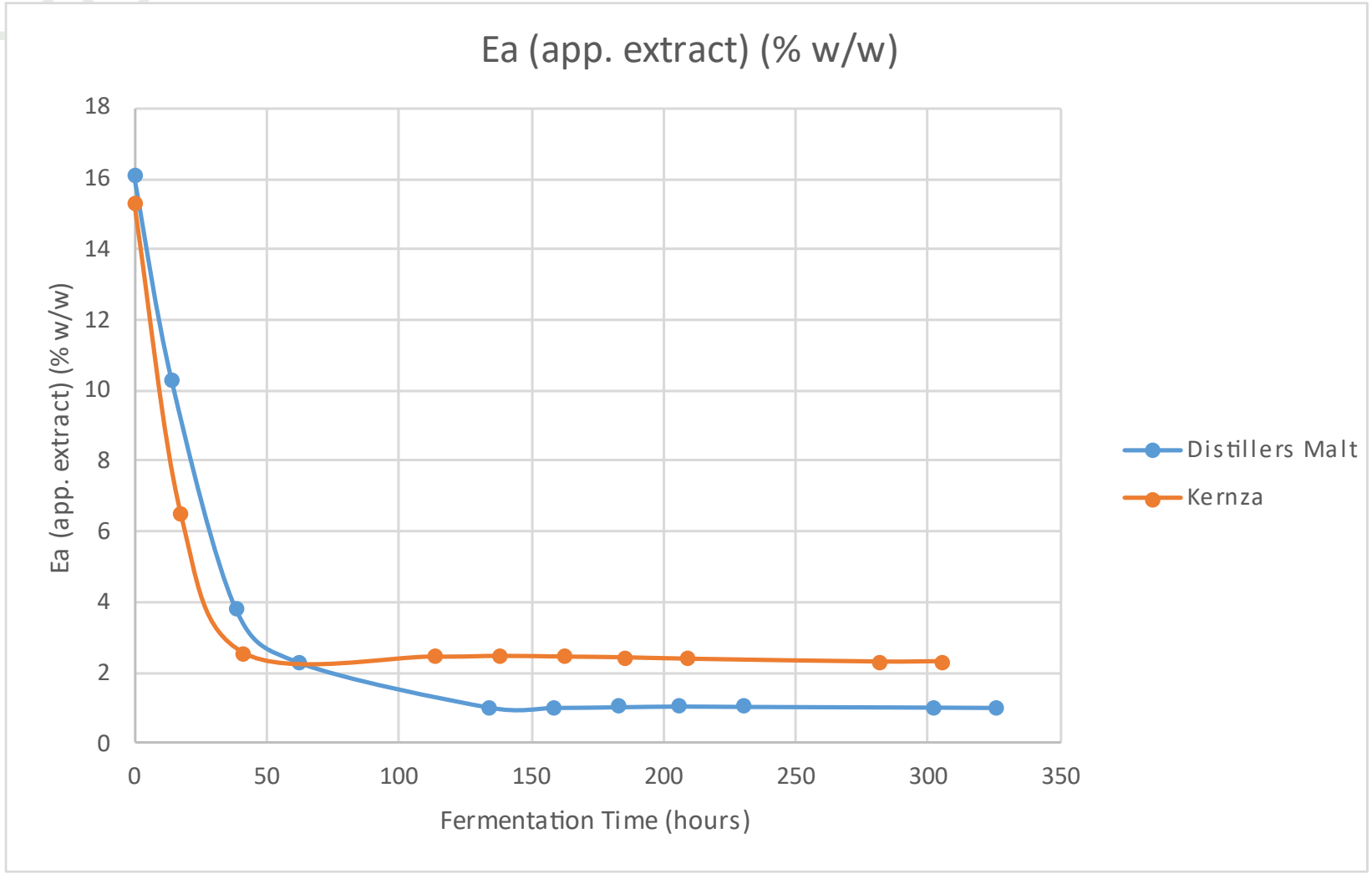
Fermentation Trends – Apparent Extract (°Plato)



The Kernza was less fermentable than the distiller's malt, resulting in a higher final gravity. This could be overcome with an adjusted ratio of Kernza to Distiller's malt.

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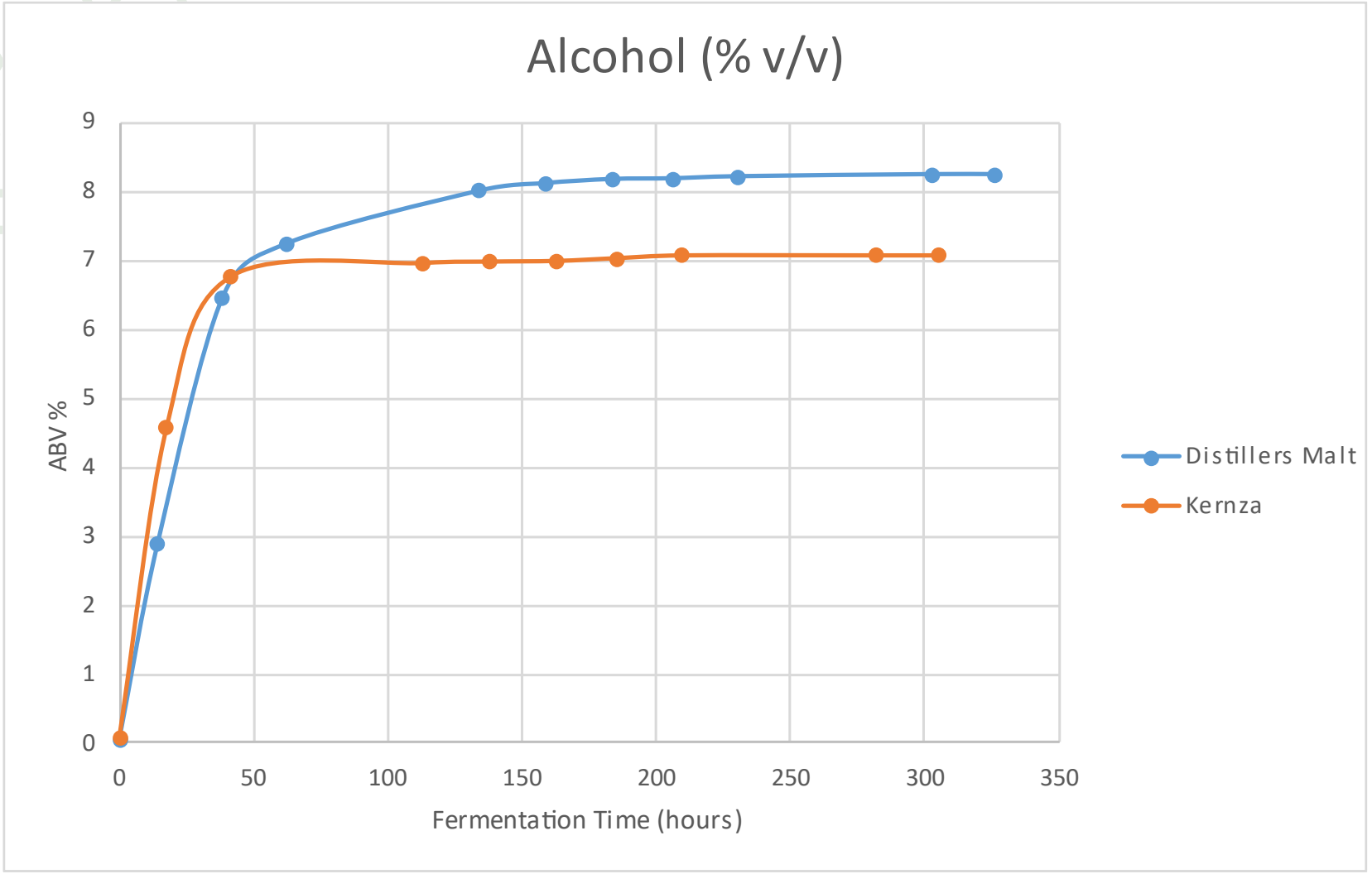
Fermentation Trends - %ABV



An extended fermentation time was employed but the ABV% of the Kernza wash did not increase much between 48 and 110 hours. This indicates that a shorter fermentation may be utilized in the future, a positive aspect for most distilleries.

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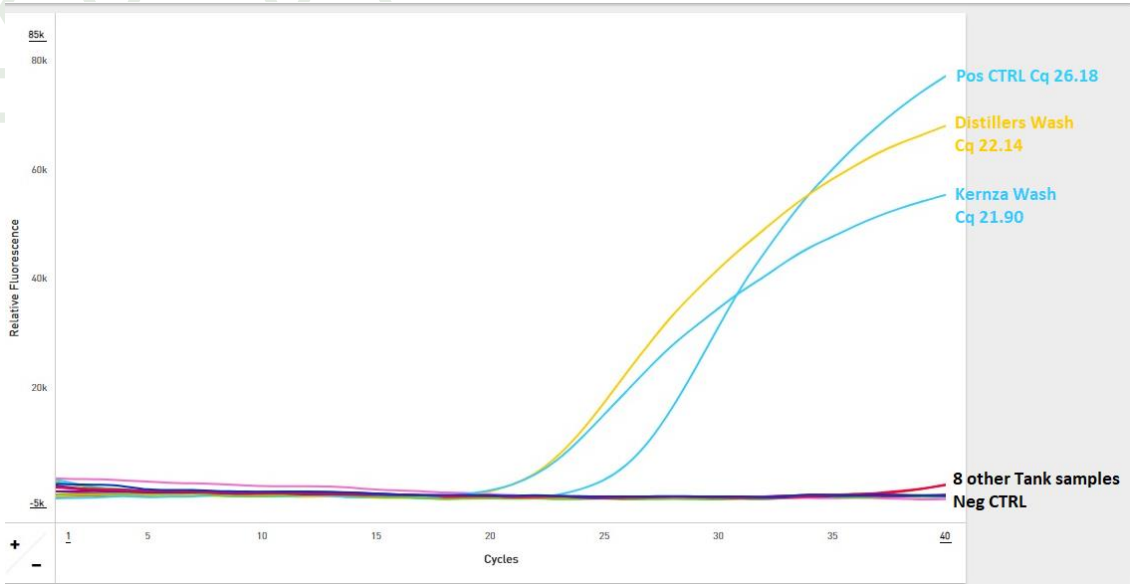
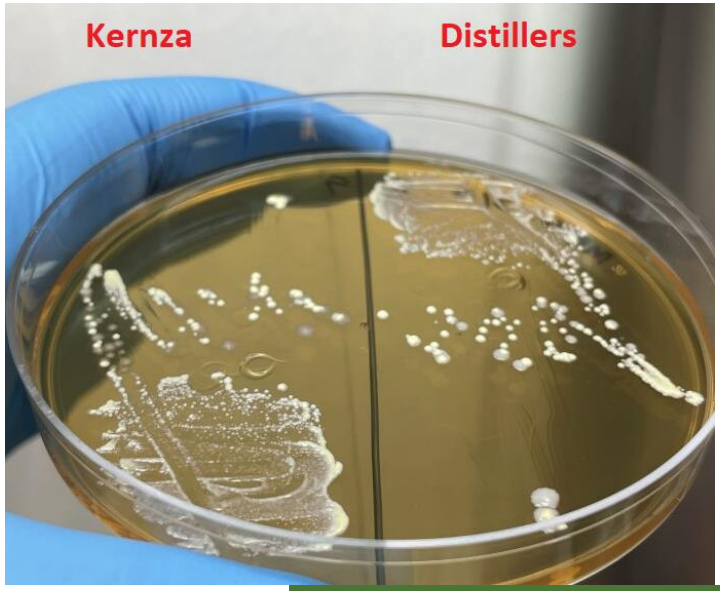
Lactic Acid Bacteria



As a curiosity, the presence of lactic acid bacteria (LAB) was tested for.

The presence of LAB was verified in both the Distillers and Kernza washes by PCR analysis using a Pika *Lactobacillaceae* test kit. Samples were obtained during fermentation from the fermenters.

Two distinct colony morphologies were isolated from both washes



- Samples of each colony type from both washes were sent to Azenta for 16S sequencing and identification
- Both washes had a combination of *Levilactobacillus brevis* and *Lactiplantibacillus plantarum*
- The presence of these may be due to a short boil being insufficient to achieve reduction of LAB load from the grain, or due to contamination, either from the yeast or brewery sources.
- Overall, the presence of these are not of great concern.

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Distillation and Aging

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Initial Distillation

The distillation process was performed on two different stills at the Rahr Technical Center.

The initial stripping runs for each spirit type was performed on a 200L still with a maximum operating capacity of 170L. The stripping runs are done to separate the water, yeast, and any sediment from the wash before primary distillation.

Due to the batch size two stripping runs were done for each spirit. FermCap® S was added as an anti-foam agent to aid in transfer and reduce loss.

The total volume produced from the stripping runs of the 100% Distillers spirit and the 51% Kernza spirit was 37 and 35 liters of ~ 33% ABV spirit, respectively.

	Rahr Distillers	Kernza
Stripping Run Charge	170 L + 7ml FermCap® S	
Stripping Run	37 liters @ 33.22 ABV	35 Liters @ 33.75 ABV

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Primary Distillation

The resulting spirit runs were further distilled to increase the ABV%. These were performed on an 8 gallon still (shown on the left in the photo).

The heads are the initial cuts containing a high percentage of low boiling point volatiles. The tails are the final cuts that contain low alcohol and high levels of fusel alcohols. Both the heads and the tails were discarded.

The heart cuts are the most desirable portion of the spirit. These were collected when the boiler head reached 193°F until the temperature hit 207°F.

	Rahr Distillers	Kernza
Spirit Run Hearts	80.23% ABV	80.69 % ABV

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Barreling and Aging

Both spirits were proofed from ~80%ABV to ~ 60% ABV and put into Squarrel® Square Barrels with 12 new American Oak staves char number three on April 21, 2023.

The spirits will reside in the small barrels for up to six months total time, approximating 2 years of aging in a full-size barrel.

	Rahr Distillers	Kernza Straight
Squarrel Square Barrels	59.95 % ABV	60% ABV

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Initial Tasting Impressions

Initial tasting of the product was done on August 3rd, 3.5 months from the time the product began aging, approximately equal to 14 months non-accelerated aging.

The Kernza whiskey was described as having a very sweet flavor with a unique spiciness, higher alcohol aroma and flavor. More aging time was deemed necessary, and a 100 mL sample was retained for future comparison purposes.

From a sensory standpoint, the 100% Distiller's product had a more woody and traditional whiskey flavor at this timepoint and was preferred by the majority of the sensory panelists.

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Project Summary

Working with Kernza in the malthouse and the brewhouse requires patience and adaptability to manage the small grains appropriately.

When comparing a 51% malted Kernza whiskey to a 100% distiller's malt whiskey, the residual sugars in the mash was much higher. The lower extract may be mitigated at least in part by decreasing the number of broken kernels prior to malting, allowing for more complete germination and thus a greater conversion into fermentable sugars.

It should be noted that in a distillery where fermenting on-grain is done, the challenges with lautering would not present an issue, increasing the valuable extract for fermentation.

From a sensory perspective, at 3.5 months aging the flavor of the whiskey still had a higher alcohol aroma/flavor to it indicating that further aging was necessary to achieve a desirable product.

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Thank You

TechnicalServices@rahr.com

Rahr Technical Center

APPENDIX D

Kernza® Whiskey Evaluation Notes
(AURI)

Kernza Whiskey Evaluation at Rahr Technical Center

March 27, 2024

AURI Evaluation Panel

- **Alexandra Ostlund**
- **Michael Stutelberg**
- **Lolly Occhino**

Background, Production Notes

- Kernza Whiskey produced during trials is analogous to a scotch, using all malted grain. An American Single Malt Scotch is all malted Barley. Could call this product Malted Kernza Whiskey, it is comprised of 51 % Malted Kernza plus 49 % Distiller's Malt.
- The Kernza grain used had embryo damage from de-hulling. As a result, germination rate was low- 86%. Rahr needed to add enzymes to the mash to make the malt available for fermentation.
- Mash time was long- 205 minutes. Typical is 60 to 90.
- 86% germination rate on Kernza Malt
- A little less was extracted for the Kernza test vs the Control, slightly less alcohol.
- The whiskey was proofed from 80 % down to 60 % and aged in new American Oak "squarrels" for 8 months, then proofed down again to 50%.

Tasting Notes

Kernza Whiskey Sample:

- Slight citrus, toasty and "warm" notes
- Similar flavors to a Stroopwafel
- Sweet characteristics, spice, cinnamon/caramel
- Some fruit
- Very pleasant, aged well, more complex spice versus Control

Control Whiskey Sample:

- Note that this sample hasn't been proofed down to 50 % yet, it is at 60 % but it is barrel aged
- Aroma is like banana cream

Collated notes from Alexandra O., Lolly O.

APPENDIX E

Kernza® Malt Information Sheet
(AURI)

Kernza® Perennial Grain

Malt Info Sheet

Agricultural Utilization Research Institute

Grain Type

- Kernza® Perennial Grain (intermediate wheatgrass- *Thinopyrum intermedium*)

Grain Source

- Minnesota (Perennial Promise Grower's Cooperative)

Grain Cultivar

- MN-Clearwater (World's first commercial food-grade intermediate wheatgrass grain cultivar. Developed by the University of Minnesota and released for production in 2019.)

Malting Location

- Rahr Technical Center- Shakopee, Minn.
- May 2023

Malt Data Analysis (Rahr)

Bushel Weight (lbs)	42.3
Alpha Amylase (DU)	51.9
Beta Glucan (ppm)	50
Color (SRM)	9.72
NTU	11
Diastatic Power (DP Units)	217
DON	0.1
Extract % (Dry Basis)	75.4

FAN (ppm)	492
Moisture (%)	4.7
pH	6.08
S/T Ratio (%)	57.5
Soluble Protein % (dry basis)	12.3
Total Protein % (dry basis)	21.39
Viscosity (cP)	1.84

For More Information Contact:

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ENVIRONMENT AND NATURAL RESOURCES TRUST FUND

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APPENDIX F

Kernza® Specialty Malts
(Rahr Technical Center)

RAHR

Kernza Specialty Malt

August 2024

Rahr Technical Center

Agenda

- Executive Summary
- Grain Quality
- Malting Process
- Malt Quality
- Sensory

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Executive Summary

The scope of this project was to explore the deeper flavor and aroma potential of malted Kernza. Based on the learnings from previous Kernza maltings, the goal was to push the malting process to develop a high-color specialty malt that would boast a bolder flavor. This goal stemmed from two premises. First, the malted Kernza already showed some unique flavor and aroma characteristics that were displayed in the malted Kernza hazy IPA as well as in the malted Kernza whiskey. Second, a malt with a bolder flavor could be used at a lower inclusion rate in a grist bill, thereby potentially providing a better value to prospective users.

Preliminary grain testing was done to evaluate the germination and kernel integrity of dehulled Kernza. Next, the Kernza was pilot malted using steep and germination conditions optimized and extrapolated from previous RTC pilot maltings of Kernza with a goal of reaching the kiln with high moisture and modification to facilitate extensive color formation. Kilning varied from typical base-malt type regime by inclusion of a “stew” step conducive to proteolysis and Maillard reactions, and then high-temperature curing added the finishing touches for color formation. Unfortunately (but also ultimately beneficially), the first attempt failed in the kiln as a technical malfunction caused the kilning to be carried out without the air recirculation for the stew step. A second attempt was successful, and the result was two malts from the same lot of grain produced with very similar modification but different kiln regimes. This allows for very useful comparisons of what might be considered Vienna- and Munich-type Kernza malts.

Malt quality analysis and descriptive sensory analysis were applied to evaluate the final products. Some exceptional, unique flavor and aroma attributes were described in the sensory panel, and overall, the panelists gave extremely positive reviews.

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Preliminary Grain Quality

- Broken kernels
  - 2% measured
  - minimum estimate due to difficulty in distinction
    - Embryo damage is not always apparent in raw grain
      - more visible once hydrated
- Germinative Energy
  - 69% average
    - Very low, even compared to past Kernza (85-93 in the past)
    - Not much visible embryo damage—other causes of poor germination
  - This result aligns with other reports of this lot (per Matthew Leiphon commentary)

GE	Day 1	Day 2	Day 3	Total
Dish A	29	27	10	66
Dish B	33	28	11	72

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Malting Process

Piece 1 (Vienna)

- Steep
  - 300 pounds raw Kernza
  - Double immersion
    - 6 hrs immersion, 6 hrs air rest, 4 hrs immersion, 2 hrs couch
  - Steep-out moisture 42.2%
- Germination
  - 4 days at 68, 70, 72, and 74°F, respectively
  - 1.0 gal water additions at 20,30, 40, 50, 60, 70, 80, and 90 hrs
  - Germ-out (on-kiln) moisture = 48.0%
- Kiln
  1. 160°F, 20 hrs, no recirculation
  2. 195°F, 5 hrs, no recirculation

L to R: raw, Vienna, Munich

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Malting Process

Piece 2 (Light Munich)

- Steep
  - 350 pounds raw Kernza
  - Single immersion + spray steep
    - 6 hrs immersion
    - 12 hrs spray steep
      - 5-min short bursts, hourly
      - 2x 45-min long bursts
  - Steep-out moisture 41.0%
- Germination
  - 4 days at 68, 70, 72, and 74°F, respectively
  - 1.0 gal water additions at 20,30, 40, 50, 60, 70, 80, and 90 hrs
  - Germ-out (on-kiln) moisture = 46.6%

- Kiln
  1. 160°F, 6 hrs, 100% recirculation
  2. 145°F, 2 hrs no recirculation
  3. 150°F 4rs no recirculation
  4. 155°F 8hrs no recirculation
  5. 195°F, 5 hrs 50% recirculation

L to R: raw, Vienna, Munich

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Malting Process Observations and Learnings

- Stickiness in the grain bed was not an issue this time around
  - Much less broken material than in previous Kernza pilot maltings
  - Higher steep-out moisture reduced need for hydration compensation during germination
  - Delayed initial watering run in germination also employed to minimize surface moisture
  - Reduced water amount per run (1.0 vs 1.75 gal)
- While longer steep time (higher steep-out moisture) improves germination conditions, bridging occurs in steep vessel with increased residency.
  - Unloading steep vessel becomes difficult.
- Reduced airflow in early kilning improved the fissuring/channeling experienced in previous batches
  - Highly reduced airflow (2/3 of normal) during early free dry was noticeably better
    - Some room for improvement still for further reduction (maybe 50%)
  - Fissuring/channeling requires pausing kilning to rake the grain bed

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Malt Quality

Identity	Off-kiln date	α-amylase	diastatic power (DP)	color (SRM)	turbidity (NTU)	pH	extract (% db)	FAN (ppm)	soluble protein (%db)	total protein (%db)	S/T ratio	β-glucan	viscosity (cP)	Moisture %
Piece 1 (Vienna)	10-May-2024	41.9	106	4.62	39	6.2	74.9	219	11.74	21.77	53.9	93	1.75	8.44
Piece 2 (Munich)	19-Jul-2024	44.8	60	9.82	19.4	6.02	73.5	251	9.79	20.8	47.1	97	1.69	6.11

- Color was expected to reach higher levels as previous pieces achieved substantial color without pushing the process
  - Nevertheless, the color near 10 SRM is a new level reached
  - color reached by higher temperature kilning may have different hue expression and flavor outcomes
  - Low germination rate may have hampered modification, thereby limiting color precursor formation
- Relatively good enzyme retention for the Munich malt.
  - Production of higher color will reduce enzymes
- Lower extract and viscosity from higher color malt while having slower S/T is unexpected
  - Maybe due to some variance between the grain lots (slight TP difference also noted)

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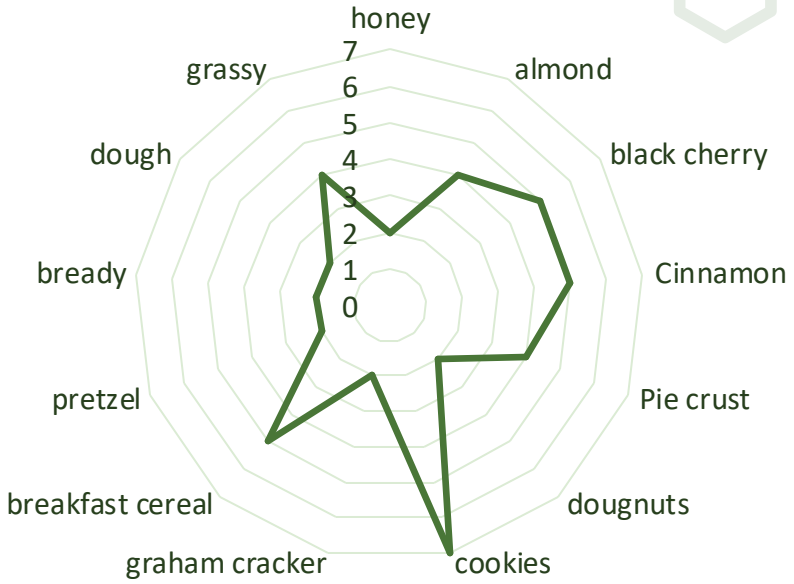
Sensory

- Congress wort was produced at an inclusion rate of 50%, cut with 2-row pale malt for practicality
- Only the second piece (Munich) was formally analyzed by the trained sensory panel
- Sensory panelists were impressed with the wort
  - Flavor and aroma attributes stand apart from any other worts ever tasted by this panel
  - Many sweet, spiced desserts were used as comparative descriptors
  - Fruity, nutty, and bready descriptors were also prominent

Kernza Munich Malt: Top Sensory Descriptors



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Sensory and Appearance Comparison

- Hot-steeps were made to compare wort colors and were also informally tasted for comp
- The paler malt (Vienna) seemed to have some of the unique, prominent attributes as the Munich but at a lower intensity
  - Key color/flavor formation probably occurred specifically at the high heat step (195°F)
    - Reasonable to expect further potential with higher modification, more stewing, and/or higher maximum temperature application
      - Also, new attributes might appear, others might fade

Vienna wort (L), Munich wort (R)

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Conclusion

Overall, the results of the high-color malting with Kernza are very encouraging. Very unique and prominent attributes increase the appeal and justification for malted Kernza as a specialty ingredient in brewing. These results should encourage others to pursue high color Kernza malts for their unique flavor potential, and there must certainly be more flavor and aroma to be unlocked with even higher color malts.

While a new level of color was reached in this trial, it was done with a cautious approach. Stewing highly modified grains can cause liquefaction inside the kernel, and while this can be risky enough with barley, grains lacking hulls are even more vulnerable to collapsing into a gooey mess. Future endeavors in making highly colored malts can use the production regime in this experiment as a baseline framework for incremental increase toward higher color.

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Thank You

Rahr Technical Center

APPENDIX G

Kernza® Flaking Trials
(Northern Crops Institute)

	AURI- Kernza Flaking			
	Project # 2455			
	Kernza dehulled seed			
	Start 1/9/24			
Date/ Time	**What**	**Warmed to temp. (F)/ time in min,**	**Moisture (%)**	**Comments**
1.9.24				
	Check Kernza seed , excellent very clean and dehulled, 50 lbs			
3-	check moisture, using tester in the pasta lab		10.37	
4p	check seed thickness 0.038-0.065", average of 10 seeds 0.0513"			
1.10.24				
10-	Sample #1			
	Temper no, seeds to moisture/ as is/ 1 lbs		10.4	good but lots of flour, dust
	Warm seeds before flaking, No- Room temp			
12p	Flake with Creason 2M roller (Flat/smooth) set to 0.006"			
1p-	Sample #2			
	Temper no, seeds to moisture/ as is/ 1 lbs		10.4	better but some fines and flour
	Warm seeds before flaking	160/12min		
	Flake with Creason 2M roller (Flat/smooth) set to 0.006"			
	Sample #3			
	Temper to Moisture, 1 lbs=0.007 lbs water		11	good flakes, fines
	Warm seeds before flaking	160/12min		
	Flake with Creason 2M roller (Flat/smooth) set to 0.006"			
	Sample #4			
	Temper to Moisture, 1 lbs=0.0182 lbs water		12	good flakes, little fines
	Warm seeds before flaking	160/12min		
	Flake with Creason 2M roller (Flat/smooth) set to 0.006"			
	Sample #5			
	Temper to Moisture, 1 lbs=0.0299 lbs water		13	good flakes, little fine
	Warm seeds before flaking	160/12min		
	Flake with Creason 2M roller (Flat/smooth) set to 0.006"			
	Sample #6			
	Temper to Moisture, 1 lbs moisture tested		16.7	Very nice flakes, low flour
	Warm seeds before flaking	160/12min		
	Flake with Creason 2M roller (Flat/smooth) set to 0.006"			
	Moisture after flaking		12.4	
	flakes measure 0.012" average thickness			
	width 0.150" average			
	length 0.275" average			
430p				

APPENDIX H

Analytical Report - Flaked Kernza®
(Rahr Technical Center)

The following report summarises the findings of the Rahr Technical Center team regarding the six (6) flaked Kernza samples received on February 5, 2024.

Flake Appearance Notes:

Generally, #1 moving toward #6, the samples have a gradient wherein the overall grain integrity is decreasing (broken bits and dust decreasing). Also, the flakes of #5 and #6 appear to have slightly darker color. These observations are somewhat visible in the photos (below) although looking directly at the grain (not though plastic) offered a better assessment. In discussion with our brewers, they have a preference for #6 based on these visible grain integrity attributes. The rationale is that generally dust and broken bits can conribute toward mashing/lautering complications.

Wort Notes:

Based on visual assessment, the worts are nearly indistinguishable. There appeared to be some slight differences in turubidity, but they were minute. Similarly, the taste of the worts did not vary by much. The brewers did not find any differences that would make them choose one over another. Others who tasted noted slight differences in the character of the sweetness and aromatic aspects, but chiefly, there was no sensory aspect of any of the worts that was concerning or outstanding.

Analytical Notes:

Overall, the heated and tempered flakes look substantially different from the plain flake. Overall, #6 looks the best having the highest extract and lowest viscosity; #1 has equally low viscosity, but this comes at the cost of much lower extract, so it is not a valid advantage.

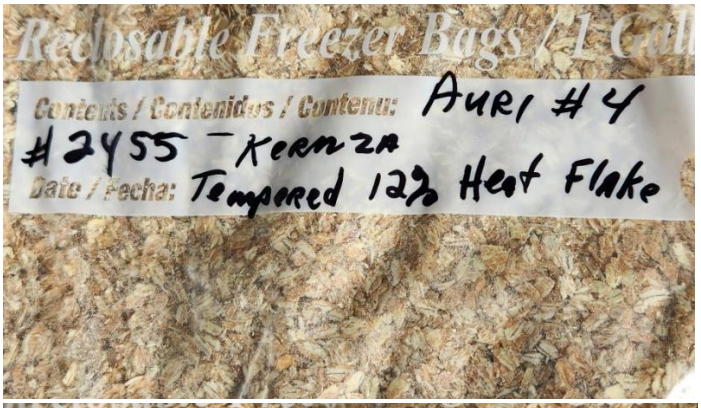
Conclusion:

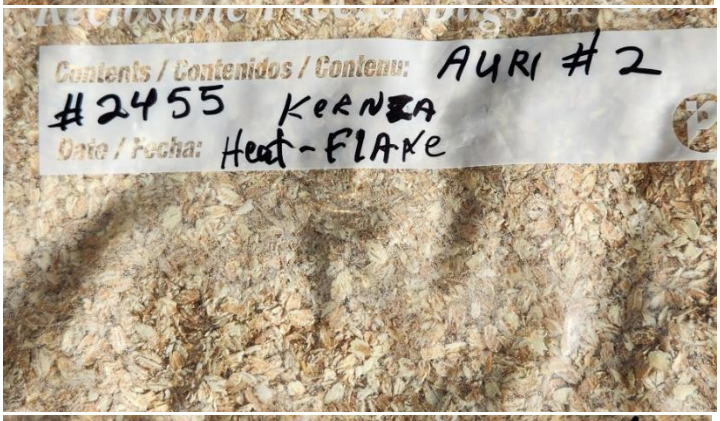
Based on the above notes #6 stands out as the clear choice for preferable flake.

Results of the Congress Wort Analysis - prepared 50% flaked Kernza and 50% standard 2-row malt.

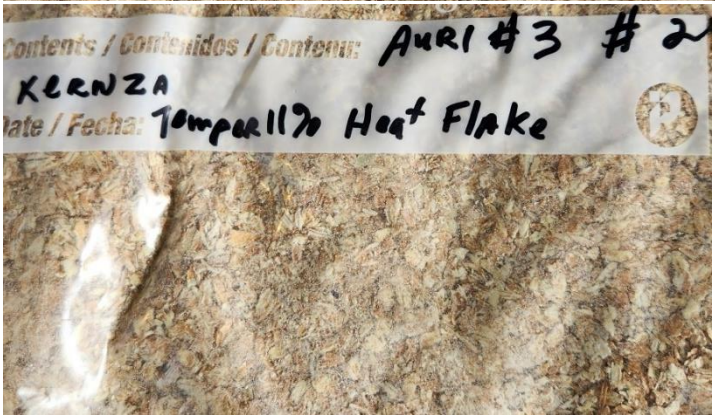
Id numeric	Id text	Extract	Moisture	Viscosity
300138	AU#1KERNZAFLAKE-2201	66.9	8.28	1.63
300139	AU#2KERNZAHEAT-FLAKE	69.8	9.19	1.66
300140	AU#3KERNZATEMPERED11	69.4	8.89	1.68
300141	AU#4KERNZATEMPERED12	69.1	9.29	1.66
300142	AU#5KERNZATEMPERED13	69.6	10.11	1.66
300143	AU#6KERNZATEMPERED16	69.9	11.85	1.63

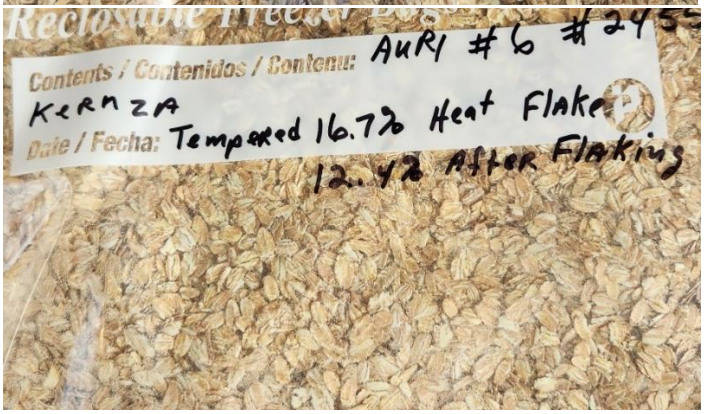

Contents / Contenidos / Contenu: AU #1
#2455 KERNZA
Date / Fecha: FLAKE


Reclosable Freezer Bags / 1 Gal
Contents / Contenidos / Contenu: AURI #4
#2455 - KERNZA
Date / Fecha: Tempered 12% Heat Flake


Contents / Contenidos / Contenu: AURI #2
#2455 KERNZA
Date / Fecha: Heat-FLAKE


Contents / Contenidos / Contenu: AURI #5
#2455 KERNZA
Date / Fecha: Temper 13% Heat FLAKE


Contents / Contenidos / Contenu: AURI #3 #2
KERNZA
Date / Fecha: Temper 11% Heat Flake


Contents / Contenidos / Contenu: AURI #6 #2455
KERNZA
Date / Fecha: Tempered 16.7% Heat Flake
12.4% After Flaking

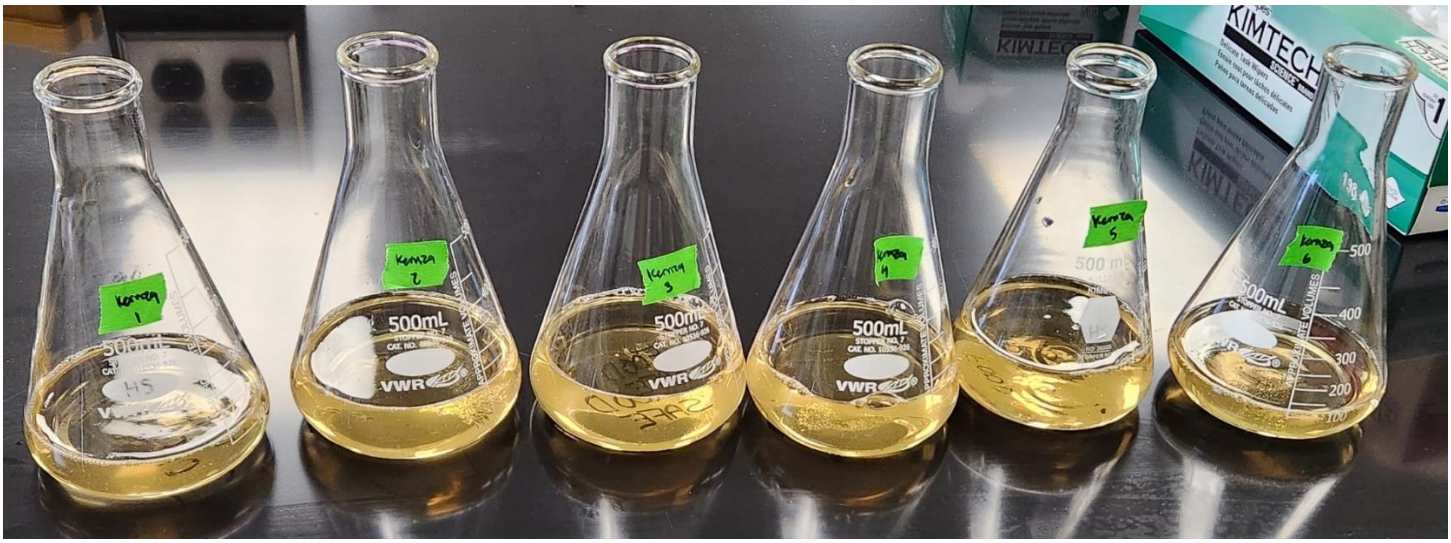


Image of the congress wort samples from left to right. AURI#1, AURI#2, AURI#3, AURI#4, AURI#4, AURI#5, AURI#6.