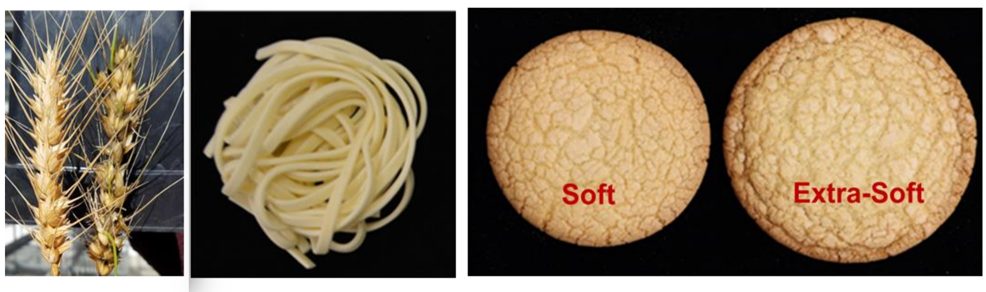
SOFT WHEAT QUALITY LABORATORY

70TH ANNUAL RESEARCH REVIEW
2024 REPORT



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USDA - AGRICULTURAL RESEARCH SERVICE

CORN, SOYBEAN AND WHEAT QUALITY RESEARCH UNIT

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SOFT WHEAT QUALITY LABORATORY

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http://ars.usda.gov/Main/Docs.htm?docid=3032

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Agricultural Research Service Vision and Mission

The ARS vision is to lead America towards a better future through agricultural research and information.

ARS conducts research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination to:

- ensure high-quality, safe food, and other agricultural products;
- assess the nutritional needs of Americans;
- sustain a competitive agricultural economy;
- enhance the natural resource base and the environment;
- provide economic opportunities for rural citizens, communities and society as a whole; and
- provide the infrastructure necessary to create and maintain a diversified workplace

National Program 306: Product Quality and New Uses

Vision

Research is focused on developing knowledge and enabling commercially viable technologies to (1) measure and maintain/enhance post-harvest product quality, (2) harvest and process agricultural materials, and (3) create new value-added products.

Mission

Enhance the marketability of agricultural products, increase the availability of healthful foods, develop value-added food and nonfood products, and enable commercially preferred technologies for post-harvest processing.

Current Action Plan 2020-2024

ARS National Program 306 (NP 306), Product Quality and New Uses, including biorefining, has the goal of enhancing economic viability and competitiveness of U.S. agriculture by improving quality and marketability of harvested foods and agricultural feedstocks to meet consumer needs, develop environmentally friendly and efficient processing concepts, and expand domestic and global market opportunities in biorefining in association with the bioeconomy.

Component 1:Foods

Problem Statement 1.A: Define, Measure, and Preserve/Enhance/Reduce Attributes that Impact Quality and Marketability.
Problem Statement 1.B: New Bioactive Ingredients and Health-promoting Foods.
Problem Statement 1.C: New and Improved Food Processing and Packaging Technologies.

SOFT WHEAT QUALITY LABORATORY

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
Corn, Soybean and Wheat Quality Research Unit
1680 Madison Ave., Wooster, Ohio

MISSION

- Improve END-USE QUALITY and VALUE of soft wheat produced in the eastern U.S. for the domestic milling and baking industries and for export trade, through contribution to the development of wheat varieties of superior quality.
- Lead SCIENTIFIC RESEARCH on END-USE QUALITY traits of soft wheat and their genetic connections and develop efficient and reliable test methods for estimation of the milling and baking qualities of wheat.
- Contribute to the improvement in HUMAN NUTRITION and HEALTH, in collaboration with wheat foods processors and eastern U.S. wheat breeding programs, through identifying and deploying traits for greater food quality and nutrition.

BACKGROUND

Wheat is the world's largest crop used for direct human consumption. Eastern U.S. soft winter wheat accounts for around 20 percent of total U.S. wheat production and is grown primarily in 23 states in the eastern region served by the USDA-ARS Soft Wheat Quality Laboratory (SWQL), Wooster, Ohio. Since the 1930s, the SWQL has conducted the end-use quality evaluation of soft wheat breeding lines and scientific research on wheat quality through long-established coordinated research with state land-grant universities and private breeding programs in the eastern U.S. for the purpose of improving the milling and baking quality of soft wheat produced in the region. It is one of the few laboratories in the world that develops methods for testing the quality of soft wheat, the major wheat type grown in the eastern U.S.

The SWQL evaluates 3,000 to 5,000 breeding lines and varieties submitted by ten to fourteen public and private breeding programs in fourteen eastern states annually for end-use quality potentials for the development of wheat varieties possessing desirable quality. The SWQL also plays a pivotal role in the end-use quality evaluation of wheat breeding lines and varieties under the uniform regional variety testing programs, state variety performance testing programs and Wheat Quality Council project in cooperation with eastern soft wheat breeders, the Wheat Quality Council and regional milling and baking companies.

Since its establishment, the SWQL has enjoyed strong, continuous support from the regional milling and baking industries and, in return, has made significant contributions to the overall improvement in the quality of soft wheat that is produced in the region. Undoubtedly, the solid cooperation from wheat breeding programs and milling and baking industries has been, and will continue to be, essential for the prosperity of the SWQL.

The SWQL critically evaluates nearly all wheat cultivars marketed from Missouri to the Atlantic seaboard. It also develops and publishes new methods and conducts research in the areas of milling and baking quality and extended uses. Research findings are shared with breeders, millers and food processors through the annual SWQL Research Review, annual Soft Wheat Quality Council Meeting, publications in refereed journals and presentations at international conferences. Our website makes SWQL data, protocols, cultivar descriptions and research news publicly available.

CURRENT FUNDING & STAFF

The SWQL currently operates with $1,313,544 in FY24. We are very grateful to all the stakeholders of the SWQL, including the wheat milling and baking industries, public and private breeding programs, academic institutions, wheat seed companies and wheat growers and growers' associations for their extensive efforts to secure funding and their continuous strong support of the SWQL. The SWQL has secured extramural research fundings through research agreements with Washington State University for the FFAR-funded project, Mondelez International and the Rural Development Administration of Korea for a total amount of $111,563.

Current base funding supports two scientists, a support scientist, and five full-time and two part-time technicians. In addition, a research scientist, who initially joined the lab as a post-doctoral research associate in 2014, continues to work for the SWQL. Three full-time and one part-time technical support staff members have been responsible for the quality evaluation of breeding lines and varieties. One support scientist, two full-time and one part-time technicians, and a research scientist have worked with two scientists to conduct research projects.

NEW IN 2023-24

We organized a joint meeting of the 69th SWQL Annual Research Review, Soft Wheat Quality Council and CGA Cincinnati Section on March 14, 2023, in Wooster, Ohio. The meeting was attended by 59 stakeholders from wheat breeding programs, universities, state wheat growers' associations, foundation seed programs and milling and baking industries. Three SWQL presenters shared the accomplishments and progress on pre-harvest sprouting resistance genetics, tortilla making quality of eastern U.S. soft wheat, high molecular weight glutenin subunit profiles for making noodles and polyphenol oxidase and noodle color. We had an open discussion on 'Increasing the Profitability of Eastern Soft Wheat'in which ten panel members participated, including Ohio wheat growers, an Ohio Corn & Wheat Association staff member, and university and USDA wheat researchers, as well as many attendees. One invited speaker talked about high-throughput genomics and phenomics for the joint improvement of grain quality and agronomic characteristics in small grains. The SWQL also organized a pre-meeting lab tour and tortilla, noodle and cracker making test demonstrations in the afternoon on March 13, 2023, for about 25 participants.

The SWQL technical staff have successfully completed the quality evaluation of the remaining 2022 crop wheat breeding lines and started working on the 2023 crop samples, despite many challenges and incidents including storm-related electrical power loss for a few days, and flooding in labs and soaked equipment from a burst water pipe. We are grateful to the SWQL staff for their efforts put forth to accomplish these tasks on time.

Dr. Byung-Kee Baik continues to serve as Director of the SWQL and Research Leader of the Corn, Soybean and Wheat Quality Research Unit (of which the SWQL is a part). Dr. Bryan Penning is a Research Geneticist and manages the research program that focuses on the molecular genetics of wheat quality and pre-harvest sprouting resistance. Dr. Fengyun Ma, a Research Scientist, investigates the quality requirements of soft red winter wheat (SRW) for making tortillas and noodles and partial-waxy wheat for making noodles and tortillas, and develops germplasms carrying early maturing, extra soft kernel texture and reduced discoloration potential traits. Dr. Taehyun Ji is a Food Technologist and is responsible primarily for the daily operation of wheat quality evaluation, the maintenance and repair of laboratory equipment, and the research projects that focus on an experimental cracker baking method and a paste flow distance testing method as an alternative to the Falling Number test to improve their efficiency and acceptability. Tom Donelson works on the rapid and reliable pre-harvest sprouting assessment methods and the Wheat Quality Council project. Amy Bugaj, Tony Karcher and Paul Nemes are Physical Science Technicians who primarily work on the milling and baking quality evaluation of wheat breeding lines and Wheat Quality Council entries. Dee Marty, a Biological Science Technician, assists in conducting research on SRW wheat quality for making noodles and works with Drs. Baik and Ma. Dr. Minwoo Lee and Cindy Hampton are Biological Science Technicians who work for Dr. Penning on molecular and statistical genetics research projects including isolation of genetic material for testing, developing markers, growing and evaluating lines for pre-harvest sprouting resistance and other flour quality traits. Dr. MN Arguello-Blanco works on the development of pre-harvest sprouting resistant germplasms.

The USDA-ARS has provided funding for the purchase of a particle size analyzer, which is used to determine flour particle size distribution, an essential quality trait for soft wheat. The SWQL has also acquired three centrifuges, two Udy Cyclone Sample mills, and a ViscoQuick for the determination of hot paste viscosity. Both the particle size analyzer and the centrifuges have been successfully installed and are in operation.

Thus far, the SWQL has received approximately 3,415 breeding lines and varieties grown in the 2023 crop year from nine private and public breeding programs, two regional Wheat Quality Council projects, and three state variety testing programs, as well as eight regional uniform testing programs, for quality evaluation. The end-use quality evaluation for the variety testing program samples from the states of Illinois, South Carolina, Ohio and Virginia, and from five uniform regional nurseries, has been completed and the summarized test results were distributed.

For the 2023 crop Soft Wheat Quality Council (SWQC) project, two breeding programs and one seed company participated and contributed a total of 18 entries (including five check varieties). All the entries were grown in two grow-out locations in Wooster, Ohio, and Lanexa, Virginia. The entries were evaluated for end-use quality potentials by nine cooperators from regional wheat breeding, milling and baking companies, as well as wheat quality testing laboratories. Wheat grain was cleaned, tested for grain characteristics, milled and sent out to collaborators for processing and baking quality evaluation. Based on the quality evaluation data obtained from the SWQL and collaborators, the WQC project report for the 2023 crop was prepared and posted on the WQC website (http://www.wheatqualitycouncil.org/).

Under the five-year project plan, we have conducted research projects including: 1) Development of simple and fast methods for the estimation of wheat grain pre-harvest sprouting (PHS); 2) Improved cracker baking test; 3) Suitability of eastern SW wheat for making tortillas and noodles and the required wheat quality characteristics; 4) Development of partial and full waxy wheat germplasms; and 5) Identification of the genes for pre-harvest sprouting resistance and development of the markers. In addition, the SWQL is working on the development of early maturing wheat germplasms suitable for the wheat-soybean double cropping system and PHS resistant germplasms in collaboration with Dr. Clay Sneller, a wheat breeder with The Ohio State University (OSU). We also initiated the development of germplasms carrying both partial-waxy traits and zero polyphenol oxidase activity giving little-to-no discoloration to the products.

HMW-GS profiles of eastern U.S. soft winter wheat appropriate for making noodles and tortillas have been identified, which will be helpful to breeding programs in screening breeding lines carrying the protein characteristics suitable for making each product. We are currently evaluating the quality potentials of the partial-waxy wheat germplasms for making tortillas and noodles.

We have completed the development of extra-soft soft red winter wheat germplasms presumed to further improve soft wheat quality for making cakes and cookies and released two extra-soft wheat germplasms of different parental backgrounds. The grain and flour characteristics and performance of the extra-soft wheat germplasms for making cookies and cakes are currently under investigation. In collaboration with

OSU faculty members, we have continued investigating the relationships between protein characteristics and properties of doughs developed under limited water systems, as for making crackers, noodles and tortillas. Dr. Baik and Tom Donelson have organized and carried out a full-scale collaborative study on an experimental cake baking method in collaboration with the Cereals and Grains Association (CGA) Soft Wheat and Flour Products Technical Committee to have it approved as an AACCI Approved Method.

We published the "2023 Annual Research Review Report" and "Milling and Baking Test Results for Eastern Soft Wheats Harvested in 2022." Dr. Baik was the corresponding author of two refereed journal articles and a co-author of three refereed journal articles published in 2023. Drs. Baik and Ma were the authors of three poster presentations at the 2023 Cereals and Grains Association Meeting in Schamburg, Illinois. The SWQL successfully released two extra-soft soft red winter wheat germplasms, which carry additional softness-conferring *Pin* genes on chromosome 5A, and thus have significantly lower kernel hardness than the typical soft red winter wheat. The extra-soft soft red winter wheat germplasms exhibited lower single kernel characterization system kernel hardness by about 17 than their parents and lines carrying no *Pin* genes on chromosome 5A.

Dr. Penning was the lead and corresponding author of two refereed Journal articles published late in 2023, and senior and corresponding author of one article currently in review. Dr. Penning made one oral presentation to the Soft Wheat Quality Lab Research Review in 2023.

SWQL Research Projects

The SWQL research team, composed of a supervisory research molecular biologist/lead scientist, a molecular geneticist, a research scientist, a support scientist and six technicians, has continued to work on a number of research projects including quality evaluation method development, identification of the biochemical characteristics of wheat grain related to noodles and tortilla making quality, and genetics of pre-harvest sprouting resistance and milling and baking quality. Following the SWQL five-year project plan, we have continued research on 1) Development of simple and fast methods for the estimation of wheat grain PHS; 2) Improved cracker baking test; 3) Suitability of eastern SW wheat for making tortillas and noodles and the required wheat quality characteristics; 4) Development of partial and full waxy wheat germplasms; 5) Partial waxy wheat quality potentials for making tortillas and noodles; and 6) Identification of the genes for pre-harvest sprouting resistance and development of the markers.

We have continued our cooperative research with Dr. Emmanuel Chatzakis in the FST at OSU to investigate the roles of protein content and composition in gluten development during dough mixing and sheeting under limited water conditions. We also collaborate with Dr. Clay Sneller in the Department of Horticulture and Crop Science at OSU in the identification of grain traits affecting the food product quality and extended uses of eastern soft wheat, identification of chromosomal locations of PHS resistance genes, and development of PHS resistant germplasms.

We have released two extra-soft soft red winter wheat germplasms, SWQL11-146-4 and SWQL11-156-5, which were developed by introgression of the additional softness conferring genes on chromosome 5A to elite soft red winter wheat cultivars. We are currently evaluating the extra-soft wheat germplasms for grain and flour characteristics, milling properties, and cookie and cake baking quality.

For the development of early heading and maturing wheat germplasms, five advanced elite eastern soft wheat breeding lines have been crossed with a donor parent exhibiting two weeks earlier heading than the typical eastern U.S. wheat to introduce early heading traits. The obtained F1s have been backcrossed three times with each recurrent parent of the elite eastern soft wheat lines, which yielded lines exhibiting earlier heading by 10 to 14 days than the parents of the eastern soft wheat lines. We also initiated the development of germplasms carrying both zero-polyphenol oxidase activity and partial waxy traits. Those germplasms would be uniquely desirable for making noodles with appropriate textural properties and little-to-no discoloration. One full-waxy germplasm on ‘Kristy’ background has been crossed with a donor parent carrying null alleles at PPO-A1 and PPO-D1. The obtained F1s will be backcrossed with the recurrent parent of the full-waxy germplasm and screened for both partial-waxy and zero PPO characteristics.

The results from the research projects “HMW-GS composition of eastern U.S. soft winter wheat desirable for making hot press tortillas,” “An Easy-to-Use Experimental Baking Method for Chemically Leavened Crackers,” and “Polyphenol oxidase (PPO) activity of eastern U.S. soft winter wheat and its influence on white salted noodle discoloration” were shared with the international audience at the Cereals and Grains Association (C&G Assoc., Formerly AACCI) Annual Meeting in Schaumburg, Illinois in October 2023.

Our progress on the selected research projects is described below.

Polyphenol oxidase (PPO) activity of eastern U.S. soft winter wheat and its influence on white salted noodle discoloration

Polyphenol oxidase (PPO) activity is largely responsible for the browning and discoloration of wheat-based products and is primarily controlled by the Ppo-A1 and Ppo-D1 genes. As noodle color, especially brightness and color stability, is one of the main determinants of consumer acceptance, the determination of PPO activity and its influence on noodle discoloration is critical in screening for wheat varieties that produce bright white noodles that show little discoloration during storage. Selected eastern U.S. soft winter (ESW) wheat varieties are proven to carry the quality characteristics suitable for making Asian noodles but their PPO activity and noodle color potentials are little known. We determined the Ppo gene profile, PPO activities, and white salted noodle color and discoloration of ninety-three ESW wheat varieties grown for two years. The low PPO activity-related alleles Ppo-A1b and Ppo-D1a were observed in 20.1% and 36.6% of ESW wheat varieties, respectively, and both were observed in 7.5% of ESW wheat varieties. Grain and flour PPO activities ranged from 0.08 to1.46 $\Delta A475$/five kernels and 0.74-1.67 $\Delta A475$/g flour, respectively. The noodle lightness (L*) at 0 h and 24 h ranged from 83.6 to 86.8 and 75.3 to 81.1, respectively. Grain PPO activity exhibited a significant association with flour PPO activity ($p<0.01$) in each crop year. Grain PPO activity had a negative association with noodle L* at 24 h only ($p<0.01$), while flour PPO activity showed significant negative associations with noodle L* at 0 h and 24 h ($p<0.001$). The Ppo-A1 gene exhibited significant influences on grain and flour PPO activities, while the Ppo-D1 gene did only on flour PPO activity. Allelic variations in the Ppo-A1 gene caused significant differences in noodle L* at 0 h and 24 h, while those in the Ppo-D1 gene did only at 24 h. ESW wheat varieties carrying the Ppo-A1b and Ppo-D1a alleles mostly exhibited low grain and flour PPO activities and produced bright white noodles that showed little discoloration during storage. Increased frequencies of the Ppo-A1b and Ppo-D1a alleles in ESW wheat are expected to improve the noodle color and discoloration characteristics of ESW wheat with reduced PPO activity.

HMW-GS composition of eastern U.S. soft winter wheat desirable for making hot press tortillas

High molecular weight glutenin subunits (HMW-GSs) of wheat have a major influence on gluten strength and the quality of products requiring gluten development, including tortillas. Tortillas are expected to have a large diameter, opaque appearance, and good rollability during storage. The HMW-GS profiles desirable for making tortillas have been established for hard wheat but they are presumed to be different for soft wheat. Thirty-eight eastern U.S. soft winter (ESW) wheat cultivars of diverse HMW-GS composition and five commercial tortilla flours were analyzed for protein characteristics and tortilla-making quality to determine the influences of HMW-GSs on tortilla quality. ESW wheat cultivars exhibited large variations in protein characteristics and tortilla quality. Protein content and lactic acid solvent retention capacity of ESW wheat flours ranged from 6.6 to 10.2% and 88.9-142.7%, respectively. Tortilla diameter, opacity score, and rollability score on day 0 and day 12 ranged from 172.1 to 205.3 mm, 22.0-83.3%, 1.0-5.0 and 1.0-3.1, respectively. The Glu-1 score of ESW wheat ranged from 6.0 to

10.0 and exhibited a significant relationship with tortilla diameter ($p<0.0001$), opacity score ($p<0.01$) and rollability score on day 0 ($p<0.01$). Influences of HMW-GS alleles at the Glu-A1 locus on tortilla quality were not evident. Subunits 7*+8 at the Glu-B1 locus showed associations with a small diameter and high rollability score of fresh tortillas, while subunits 5+10 at the Glu-D1 locus showed associations with a small diameter and high opacity score. ESW wheat cultivars carrying subunits 2+121 at the Glu-D1 locus produced tortillas with the largest diameter and the lowest opacity and rollability scores, indicating that subunits 2+121 have negative influences on protein strength in the production of tortillas. ESW wheat carrying the HMW-GS profile (2*, 7*+8, 5+10) or (1, 13+16, 5+10) produced tortillas with a relatively small diameter and a relatively high opacity score and rollability score, which were most comparable to those prepared from commercial tortilla flours. Increased frequencies of the subunits 7*+8 at the Glu-B1 locus and subunits 5+10 at the Glu-D1 locus are expected to improve the tortilla-making quality of ESW wheat with enhanced gluten strength. The results suggest that HMW-GS composition would be an effective tool for quickly identifying and selecting ESW wheat breeding lines or cultivars possessing the appropriate protein characteristics for making tortillas.

An easy-to-use experimental baking method for chemically leavened crackers
The existing cracker baking methods require uncommon, expensive sheeting equipment and employ manual dough sheet cutting and docking. We identified commonly available and inexpensive dough sheeting devices and tested their performance, employed optimal dough absorption and adopted a mechanical press for cracker dough sheet cutting and docking to make the current experimental cracker baking test more efficient and easier to use. A stand mixer attachment for pasta dough sheeting (SMA) and a benchtop noodle maker (BNM) were compared to a pilot-scale dough sheeter (PDS) for cracker dough sheeting performance using three eastern U.S. soft winter (ESW) wheat flours with varying functional characteristics. SMA and BNM yielded comparable standard deviations (SDs) for the three wheat flours in dough and cracker characteristics to PDS, while higher SDs were observed for SMA than BNM in weight and thickness of cut cracker doughs and thickness and break force of baked crackers. The results achieved using SMA matched more closely with those of PDS than with those of BNM with regards to the order of the three wheat flours in the weight and thickness of cut doughs, and thickness and break force of crackers. The optimal absorption yielding about 2 to 3 cm crumbs during dough mixing and a continuous dough sheet was higher by 1 to 5% than the fixed absorption of 29% used in the existing method. Much larger differences in weight and thickness of cut cracker dough and in weight, thickness and break force of baked crackers between flours were observed with the optimal absorption compared to the fixed one. The use of a mechanical press for cracker dough cutting and docking maintained the capacity to differentiate wheat flours and their rankings in cut cracker dough and baked cracker characteristics similarly to the use of the hand cutting and docking method. The cracker baking test method employing the SMA for dough sheeting, an optimal absorption for dough mixing, and a mechanical press for cracker dough cutting and docking would make the test more efficient, reliable, and easy to use.

Genome-wide association study uncovers locations of pre-harvest sprouting resistance and milling and baking quality
The value of the winter wheat crop in the U.S. last year was ~$2.3 billion. Pre-harvest sprouting damage can reduce the soft winter wheat crop value by up to 30% in the U.S. and is a growing problem. Ideally, when improving wheat resistance to pre-harvest sprouting, other important characteristics such as agronomic traits and milling and baking quality should remain unchanged or improve to encourage adoption of the variety by farmers and acceptance for use in baked goods. A genome-wide association study uncovered ten new winter wheat chromosome locations for pre-harvest sprouting resistance under irrigated and natural rain treatments. A location on chromosome 1A explained ~25% of the variation. Multiple agronomic, milling, and baking quality traits were co-located on nine of twenty-one chromosomes and were mostly separate from the pre-harvest sprouting locations. These locations are being further investigated. The pre-harvest sprouting location on chromosome 1A does not overlap any

chromosome region affecting baking and milling quality in this population and may be useful for breeding pre-harvest sprouting resistant varieties without affecting other quality traits.

END-USE QUALITY EVALUATION OF WHEAT BREEDING LINES AND VARIETIES

Fifteen cooperators, including public and private breeding programs of the eastern soft winter wheat and the state variety testing programs, have thus far submitted over three-thousand samples harvested in the 2023 crop year for end-use quality evaluation. Analyses for approximately 40% of the samples received were completed by the end of February 2024. Milling and baking quality evaluations for the samples from three state variety performance test trials and eight uniform regional cooperative testing trials in the 2023 crop year have been completed. The samples of replicate trials for the Gulf Atlantic Wheat Nursery and Uniform Eastern Soft Red Winter Wheat Nursery, and triplicate trials for the Uniform Southern Soft Red Winter Wheat Nursery, were tested for milling and baking quality. The test results have been summarized and distributed to the breeding programs by the SWQL. We expect to complete all tests of breeding lines and varieties by the end of May 2024.

As implemented beginning with the 2013 crop year, breeding lines submitted to the SWQL for quality evaluation by the breeding programs are classified into 'Preliminary,' 'Intermediate' or 'Advanced' groups, considering breeding stage and screening requests. Grain characteristics (test weight, kernel hardness and protein content) and Quadrumat test milling properties are determined for all of the wheat breeding lines submitted to the SWQL. Intermediate and advanced group samples are further tested for flour composition (protein and moisture) and sodium carbonate and lactic acid SRCs. Only advanced group samples undergo the sugar-snap cookie baking test.

Quality evaluation data have been reported to the breeding programs along with a t-score (which is the number of standard deviations away from the check variety for each quality parameter), and a total t-score is calculated and included in the report. The total t-score is the sum of the t-scores of test weight, kernel hardness, flour yield, softness equivalence and sodium carbonate SRC, with different weights of 0.15, 0.10, 0.40, 0.15 and 0.20, respectively. Each breeding line is assigned a specific grade (A, B, C, D, or F) based on its flour yield compared to the flour yield distribution of wheat breeding lines and varieties tested in the SWQL between 2009 and 2022. The wheat breeding lines that fall in the top 15% receive a grade 'A,' in the next 20% a 'B,' in the next 30% a 'C,' in the next 20% a 'D,' and in the bottom 15% an 'F.'

The SWQL coordinates the Soft Wheat Quality Council (SWQC) in collaboration with the Wheat Quality Council. We obtained wheat grain, milled it and shipped the flour to cooperators in the domestic milling and baking industries for end-users' evaluations of flour quality and baking performance. In 2023, 18 entries for the SWQC were processed and distributed to cooperators.

Quality Characteristics of the 2023 Eastern Soft Winter Wheat Crop (Compared to the averages of the previous 14 years)

Quality Parameters	2009 - 2022	2023
Test Weight (lb/bu)	59.9	60.8
Grain Protein (%)	10.3	9.7
Kernel Hardness (SKCS)	13.6	16.0
Flour Yield (%)	68.6	68.2
Softness Equivalence (%)	58.1	55.7
Four Protein (%)	8.2	7.9
Solvent Retention Capacity (SRC, %)		
Sodium Carbonate SRC	69.6	71.7
Lactic Acid SRC	100.3	105.5
Cookie Diameter (cm)	18.7	18.9

USDA-ARS 2023 SWQL Grain and Flour Evaluations

Long-term relationships established between the SWQL, and cooperative nursery programs and the Wheat Quality Council depend on the reliable milling and baking evaluations performed in the USDA-ARS SWQL in Wooster, Ohio. The SWQL performs quality evaluations for two main collaborative projects: the Soft Wheat Quality Council and Regional Cooperative Nurseries.

2023 Crop Soft Wheat Quality Council

The SWQL coordinates and participates in the Soft Wheat Quality Council (SWQC) annual evaluation of new varieties and advanced breeding lines by milling grain, distributing flour to collaborators, performing quality trait evaluations and preparing a report that collates quality evaluations among the collaborators for presentation at the annual SWQC Meeting. Uniform milling and reliable quality trait testing, as performed in the SWQL, provide data critical for collaborators to compare the quality evaluations of the new varieties presented each year.

For the 2023 SWQC project, two breeding programs and one seed company participated, contributing 18 entries (including the checks). Entries were grown in two grow-out locations including Wooster, Ohio, and Lanexa, Virginia. The SWQL collected the grain samples, determined the grain characteristics, performed Miag milling as well as Quad experimental milling, and conducted composition analyses. Wheat flour samples were distributed to the 9 cooperators and further tested for flour compositional, biochemical, and dough rheological characteristics, and baking quality, with emphasis on SRC, cookie baking quality and cake baking quality. The test results of the entries by the SWQL and cooperators were pooled, analyzed and used to prepare the report, which is available at the WQC website (http://www.wheatqualitycouncil.org/). The chair of the Soft WQC Technical Board will lead the discussion on the quality potentials of the entries with the cooperators during the virtual Soft WQC Meeting on March 26, 2024.

Contributing Soft Wheat Breeding Programs, Test Lines and Checks

Nicholas Santantonio, Virginia Polytechnic Institute and State University

15VTK1-101
16VDH-SRW03-23
17VDH-SRW05-169
VA19FHB-36
VA19W-29
Branson*
Hilliard*

Trek Murray, Beck's Hybrids

Beck 705
Beck 720
Beck 722
Beck 724
Beck 725
Beck 727
Beck 732
Branson*
Hilliard*

Eric Olson, Michigan State University

MI16W0133

Whitetail*

*Check varieties

MILLING AND BAKING RESULTS OF 2023 CROP SWQC ENTRIES REPORTED BY COLLABORATORS AND THE SWQL

Table 1. Miag Multomat mill stream yields (%) of the WQC 2023 crop year entries by SWQL

Mill Stream	Group 1						
	15VTK1-101	16VDH-SRW03-23	17VDH-SRW05-169	VA19FHB-36	VA19W-29	Branson*	Hilliard*
1st Break	8.2	8.2	9.3	7.6	9.0	8.8	9.2
2nd Break	8.2	7.6	8.3	8.0	8.4	8.3	8.5
Grader	4.0	3.7	4.7	3.8	4.4	4.5	4.7
3rd Break	8.9	9.0	8.9	9.7	8.9	8.4	9.1
Total Break	**29.2**	**28.5**	**31.2**	**29.1**	**30.7**	**30.0**	**31.4**
1st Reduction	11.0	11.1	9.5	8.7	10.0	9.7	8.9
2nd Reduction	10.0	9.8	9.2	8.0	9.3	10.1	8.1
3rd Reduction	6.6	7.0	7.0	7.6	7.0	7.0	6.9
Duster	7.2	7.0	6.5	5.3	6.5	6.9	5.7
4th Reduction	4.4	4.7	4.7	4.9	4.4	4.6	4.3
5th Reduction	3.1	3.4	3.1	3.8	3.2	2.9	3.3
Total Reduction	42.3	43.1	39.9	38.3	40.3	41.2	37.2
Straight Grade	**71.5**	**71.6**	**71.1**	**67.3**	**71.1**	**71.3**	**68.6**
Head Shorts	7.5	7.8	6.9	8.4	6.9	7.3	8.0
Red Dog	2.7	3.1	3.3	5.3	3.2	3.1	3.6
Tail Shorts	0.7	0.9	0.6	0.8	0.6	0.6	0.8
Bran	17.6	16.7	18.1	18.2	18.2	17.7	19.0
Total Byproduct	28.5	28.4	28.9	32.7	28.9	28.7	31.4

*Check varieties.

Table 1-continued

Mill Stream	Group 2								
	Beck 705	Beck 720	Beck 722	Beck 724	Beck 725	Beck 727	Beck 732	Branson*	Hilliard*
1st Break	6.5	7.8	7.2	6.9	7.9	8.3	7.9	6.7	7.8
2nd Break	7.9	7.8	7.3	8.1	8.1	7.9	8.7	7.5	7.7
Grader	4.3	4.3	4.5	3.9	4.4	4.7	4.4	3.6	4.0
3rd Break	6.7	7.2	6.5	8.9	7.8	6.9	8.1	7.5	8.2
Total Break	**25.4**	**27.1**	**25.5**	**27.7**	**28.1**	**27.7**	**29.1**	**25.3**	**27.6**
1st Reduction	10.7	10.3	9.4	8.8	10.0	10.4	10.3	10.3	10.3
2nd Reduction	13.9	11.2	12.5	9.4	11.5	12.3	11.1	11.7	10.4
3rd Reduction	7.0	6.6	7.6	7.6	6.8	6.3	6.7	7.3	7.2
Duster	10.0	8.0	8.7	6.5	7.7	8.9	8.2	7.4	7.2
4th Reduction	4.7	4.1	5.3	4.7	4.3	3.7	4.0	4.7	4.3
5th Reduction	2.7	2.7	3.2	3.4	2.8	2.2	2.5	3.4	3.2
Total Reduction	49.0	42.9	46.7	40.3	43.2	43.8	42.8	44.8	42.7
Straight Grade	**74.4**	**70.0**	**72.1**	**68.1**	**71.4**	**71.5**	**71.9**	**70.1**	**70.3**
Head Shorts	6.2	6.4	6.1	7.4	6.6	5.8	5.9	7.1	6.2
Red Dog	1.5	1.9	2.0	3.6	1.9	1.4	1.7	2.4	2.4
Tail Shorts	0.7	0.6	0.5	0.7	0.6	0.5	0.4	0.7	0.5
Bran	17.2	21.1	19.2	20.3	19.5	20.8	20.2	19.8	20.6
Total Byproduct	25.6	30.0	27.9	31.9	28.6	28.5	28.1	29.9	29.7

*Check varieties.

Table 1-continued

Mill Stream	Group 3	
	MI16W0133	Whitetail*
1st Break	8.0	8.1
2nd Break	8.0	8.7
Grader	4.1	4.5
3rd Break	7.6	7.5
Total Break	**27.7**	**28.8**
1st Reduction	11.8	10.2
2nd Reduction	11.6	11.3
3rd Reduction	6.2	6.9
Duster	8.2	7.4
4th Reduction	4.1	4.7
5th Reduction	2.7	3.2
Total Reduction	44.6	43.6
Straight Grade	**72.3**	**72.4**
Head Shorts	5.8	5.8
Red Dog	1.7	2.1
Tail Shorts	0.6	0.6
Bran	19.5	19.1
Total Byproduct	27.7	27.6

*Check varieties.

WHEAT GRAIN AND FLOUR CHARACTERISTICS OF 2023 CROP SWQC ENTRIES

Table 2. Grain characteristics, SKCS test parameters of the 2023 entries by USDA-ARS Soft Wheat Quality Laboratory

Group	Entry	Test Weight (lb/bu)	Grain Falling Number	Grain Protein (%, 12% mb)	SKCS Parameter		
					Kernel Hardness	Kernel Diameter (mm)	Kernel Weight (mg)
1	15VTK1-101	63.2	403	9.4	20.4	2.8	36.6
1	16VDH-SRW03-23	62.5	416	9.2	17.9	2.8	38.1
1	17VDH-SRW05-169	62.1	325	9.0	13.3	3.0	40.0
1	VA19FHB-36	63.4	380	9.2	23.2	2.8	39.5
1	VA19W-29	62.6	353	9.2	14.5	2.9	40.8
1	Branson*	61.5	339	9.4	9.5	2.8	39.9
1	Hilliard*	61.7	332	8.8	10.6	2.8	39.3
2	Beck 705	59.6	380	9.1	21.9	2.6	30.2
2	Beck 720	61.1	411	9.6	17.0	2.6	33.8
2	Beck 722	61.5	361	8.3	17.0	2.6	33.1
2	Beck 724	62.7	459	9.4	17.0	2.7	36.8
2	Beck 725	61.0	336	7.9	20.2	2.5	30.9
2	Beck 727	61.6	363	9.4	16.0	2.5	30.4
2	Beck 732	60.4	386	8.9	17.2	2.4	30.5
2	Branson*	60.2	419	9.2	25.0	2.7	34.8
2	Hilliard*	61.7	388	9.0	20.6	2.6	34.0
3	MI16W0133	58.2	329	8.7	19.6	2.7	34.6
3	Whitetail*	59.7	354	8.3	12.5	2.8	37.6

*Check varieties.

Table 3. Miag and Quadrumat Milling parameters of the 2023 entries by USDA-ARS Soft Wheat Quality Laboratory

Group	Entry	Miag Milling		Quadrumat Milling	
		Break Flour Yield (%)	Straight Grade Flour Yield (%)	Flour Yield (%)	Softness Equivalence (%)
1	15VTK1-101	29.2	71.5	56.4	69.1
1	16VDH-SRW03-23	28.5	71.6	54.0	69.0
1	17VDH-SRW05-169	31.2	71.1	59.2	69.4
1	VA19FHB-36	29.1	67.3	54.6	66.2
1	VA19W-29	30.7	71.1	57.7	68.9
1	Branson*	30.0	71.3	58.6	69.1
1	Hilliard*	31.4	68.6	59.2	67.4
2	Beck 705	25.4	74.4	55.0	70.8
2	Beck 720	27.1	70.0	59.1	68.1
2	Beck 722	25.5	72.1	55.7	69.6
2	Beck 724	27.7	68.1	56.8	66.2
2	Beck 725	28.1	71.4	60.0	69.2
2	Beck 727	27.7	71.5	60.1	69.0
2	Beck 732	29.1	71.9	60.3	69.5
2	Branson*	25.3	70.1	54.5	67.4
2	Hilliard*	27.6	70.3	57.6	68.0
3	MI16W0133	27.7	72.3	59.7	70.0
3	Whitetail*	28.8	72.4	59.6	70.4

*Check varieties.

Table 4. Flour quality parameters of the 2023 entries by USDA-ARS Soft Wheat Quality Laboratory

Group	Entry	Moisture (%)	Protein (%, 14% mb)	Flour Ash (%, 14% mb)	Starch Damage (%)
1	15VTK1-101	14.2	7.3	0.37	3.4
1	16VDH-SRW03-23	14.4	7.8	0.36	3.2
1	17VDH-SRW05-169	14.2	7.3	0.36	3.7
1	VA19FHB-36	14.2	7.6	0.37	2.8
1	VA19W-29	14.1	7.4	0.36	3.1
1	Branson*	14.1	7.8	0.35	3.2
1	Hilliard*	14.3	7.3	0.37	3.3
2	Beck 705	14.3	8.0	0.39	4.0
2	Beck 720	14.1	8.0	0.35	3.7
2	Beck 722	14.0	6.8	0.37	3.2
2	Beck 724	14.4	7.8	0.32	3.7
2	Beck 725	14.1	6.6	0.33	3.7
2	Beck 727	13.9	7.9	0.32	2.8
2	Beck 732	13.9	7.9	0.32	3.4
2	Branson*	14.0	7.8	0.34	4.1
2	Hilliard*	13.9	7.5	0.36	3.6
3	MI16W0133	14.3	7.1	0.34	3.1
3	Whitetail*	14.2	6.8	0.37	2.9

*Check varieties.

Table 5. Mean SRC test parameters and overall flour quality scores by six cooperators (n=6)[a]

Group	Entry	Solvent Retention Capacity (%)			
		Water	Sodium Carbonate	Sucrose	Lactic Acid
1	15VTK1-101	54.0 ab	71.1cd	93.9 b	111.4 bc
1	16VDH-SRW03-23	54.5 ab	73.4 b	96.2 b	102.3 d
1	17VDH-SRW05-169	53.3 b	71.9 bc	96.7 b	113.1 bc
1	VA19FHB-36	56.3 a	77.0 a	104.5 a	127.8 a
1	VA19W-29	53.6 b	72.6 bc	97.3 b	117.6 b
1	Branson*	53.0 b	69.3 d	92.9 b	108.0 cd
1	Hilliard*	54.1 ab	73.4 b	97.7 b	111.1 bc
2	Beck 705	52.8 c	70.7 d	90.8 c	102.4 g
2	Beck 720	55.4 abc	77.8 b	108.2 a	134.4 b
2	Beck 722	52.7 c	74.2 c	94.3 bc	112.6 f
2	Beck 724	57.8 a	80.6 ab	104.8 a	147.4 a
2	Beck 725	55.2 abc	74.4 c	91.3 c	108.4 fg
2	Beck 727	53.8 bc	73.5 cd	94.5 bc	125.3 cd
2	Beck 732	55.2 abc	72.6 cd	93.2 c	131.5 bc
2	Branson*	57.7 a	82.5 a	105.1 a	114.5 ef
2	Hilliard*	55.6 ab	79.0 b	101.1 ab	121.6 de
3	MI16W0133	54.4 a	77.4 a	97.1 a	100.5 a
3	Whitetail*	52.4 a	75.7 a	94.6 a	99.7 a

*Check varieties.

[a]Means with different letters within the same group are significantly different at $P<0.05$.

Table 6. Damaged starch content (n=2), flour falling number (n=2) and amylograph peak viscosity (n=1)[a]

Group	Entry	Damaged Starch Content (%)	Falling Number	Amylograph Peak Viscosity (BU)
1	15VTK1-101	4.2 a	370 a	619
1	16VDH-SRW03-23	4.2 a	360 a	570
1	17VDH-SRW05-169	4.1 a	308 b	423
1	VA19FHB-36	3.8 a	301 b	586
1	VA19W-29	3.8 a	325 b	443
1	Branson*	3.9 a	325 b	508
1	Hilliard*	3.8 a	314 b	457
2	Beck 705	4.5 a	366 b	552
2	Beck 720	4.1 a	383 ab	609
2	Beck 722	4.0 a	372 ab	542
2	Beck 724	4.5 a	406 a	695
2	Beck 725	4.3 a	310 c	417
2	Beck 727	3.7 a	379 ab	562
2	Beck 732	3.8 a	367 b	668
2	Branson*	4.7 a	371 ab	607
2	Hilliard*	4.1 a	378 ab	637
3	MI16W0133	3.8 a	315 a	310
3	Whitetail*	3.8 a	318 a	289

*Check varieties.

[a]Means with different letters within the same group are significantly different at $P<0.05$.

Table 7. Mean Alveograph test parameters by two collaborators (n=1)[a]

Group	Entry	Alveograph				
		P	L	P/L Ratio	Ie	W
1	15VTK1-101	41	61	0.67	50.1	67
1	16VDH-SRW03-23	49	45	1.09	35.8	71
1	17VDH-SRW05-169	37	57	0.65	45.5	58
1	VA19FHB-36	53	71	0.75	50.2	85
1	VA19W-29	43	61	0.7	47.3	68
1	Branson*	33	71	0.46	43.3	50
1	Hilliard*	43	57	0.75	41.8	64
2	Beck 705	29	75	0.39	38.8	41
2	Beck 720	53	63	0.84	43.9	81
2	Beck 722	34	58	0.59	44.3	52
2	Beck 724	66	40	1.65	49.6	108
2	Beck 725	31	43	0.72	39.2	46
2	Beck 727	35	73	0.48	48.5	56
2	Beck 732	43	52	0.83	54.8	72
2	Branson*	58	60	0.97	37.7	85
2	Hilliard*	55	54	1.02	44.8	85
3	MI16W0133	32	59	0.54	33.0	43
3	Whitetail*	31	65	0.48	34.2	42

*Check varieties.

[a]Means with different letters within the same group are significantly different at *P*<0.05.

Table 8. Mean farinograph test parameters by two collaborators (n=1)[a]

Group	Entry	Farinograph			
		Water Absorption	Development Time	Stability	Mixing Tolerance
1	15VTK1-101	50.0	1.3	1.3	101.0
1	16VDH-SRW03-23	53.4	1.3	0.8	107.0
1	17VDH-SRW05-169	50.2	1.3	0.8	103.0
1	VA19FHB-36	52.1	1.4	1.9	77.0
1	VA19W-29	52.7	1.4	4.8	57.0
1	Branson*	52.3	1.3	7.5	53.0
1	Hilliard*	52.8	1.4	4.4	71.0
2	Beck 705	51.5	1.6	1.0	76.0
2	Beck 720	53.2	1.4	8.5	42.0
2	Beck 722	50.2	1.2	0.8	87.0
2	Beck 724	53.7	1.5	14.4	31.0
2	Beck 725	51.1	1.3	0.6	104.0
2	Beck 727	51.4	1.4	2.5	73.0
2	Beck 732	51.8	1.3	2.1	63.0
2	Branson*	55.7	1.5	4.1	60.0
2	Hilliard*	54.3	1.5	2.2	53.0
3	MI16W0133	51.9	1.6	1.1	124.0
3	Whitetail*	50.3	1.3	0.4	121.0

*Check varieties.

[a]Means with different letters within the same group are significantly different at $P<0.05$.

Table 9. Mean (n=4) Rapid Visco-Analyzer (RVA) test parameters[a]

Group	Entry	Rapid Visco-Analyzer						
		Peak Time (min)	Peak (cP)	Trough (cP)	Break-down (cP)	Setback (cP)	Final (cP)	Pasting Temperature (°C)
1	15VTK1-101	6.3 a	2951 b	2005 a	946 a	1360 a	3365 a	84.4 a
1	16VDH-SRW03-23	6.3 a	3000 a	1998 a	1002 a	960 a	3297 a	74.5 b
1	17VDH-SRW05-169	6.4 a	2599 e	1645 a	954 a	1078 a	2723 c	84.9 a
1	VA19FHB-36	6.3 a	2990 a	1919 a	1071 a	1281 a	3200 ab	81.2 ab
1	VA19W-29	6.2 a	2623 e	1662 a	961 a	1102 a	2764 c	84.0 a
1	Branson*	6.3 a	2793 d	1793 a	1000 a	1067 a	2860 bc	83.9 a
1	Hilliard*	6.2 a	2856 c	1814 a	1042 a	1112 a	2925 bc	82.8 a
2	Beck 705	6.3 a	2845 d	1883 ab	962 a	1420 ab	3303 c	84.5 ab
2	Beck 720	6.4 a	2895 cd	2043 ab	852 a	1628 a	3671 ab	85.7 a
2	Beck 722	6.3 a	2963 b	1951 ab	1011 a	1417 ab	3368 c	84.9 ab
2	Beck 724	6.5 a	2929 cd	2177 a	752 a	1684 a	3862 a	84.9 ab
2	Beck 725	6.2 a	2701 e	1727 b	974 a	1131 b	2858 d	83.8 ab
2	Beck 727	6.4 a	2927 cd	1942 ab	984 a	1491 a	3433 bc	86.2 a
2	Beck 732	6.3 a	3193 a	2130 ab	1063 a	1548 a	3678 ab	82.2 b
2	Branson*	6.4 a	3088 ab	2076 ab	1012 a	1492 a	3568 abc	86.0 a
2	Hilliard*	6.4 a	2991 bc	2016 ab	975 a	1574 a	3590 abc	85.0 ab
3	MI16W0133	6.3a	2455 a	1541 a	914 a	1085 a	2626 a	85.4 a
3	Whitetail*	6.3 a	2118 b	1423 a	695 a	1093 a	2516 a	85.1 a

*Check varieties.

[a]Means with different letters within the same group are significantly different at $P<0.05$.

Table 10. Mean sugar-snap cookie test (AACCI Approved method 10-50D (n=4) & 10-52 (n=3)) parameters[a]

Group	Entry	Sugar-snap Cookie (10-50D) Width (mm)	Thickness (mm)	W/T Ratio (mm)	Spread Factor	Sugar-snap Cookie (10-52) Width (cm)	Top Grain Score
1	15VTK1-101	494 a	56 a	9.0 a	84 a	9.3 a	7.0 a
1	16VDH-SRW03-23	473 a	62 a	7.9 a	74 a	9.0 b	5.5 a
1	17VDH-SRW05-169	487 a	54 a	9.2 a	86 a	9.2 ab	6.0 a
1	VA19FHB-36	478 a	60 a	8.3 a	78 a	9.1 ab	5.0 a
1	VA19W-29	484 a	57 a	8.7 a	81 a	9.2 ab	6.0 a
1	Branson*	494 a	55 a	9.3 a	87 a	9.3 a	6.0 a
1	Hilliard*	492 a	55 a	9.1 a	84 a	9.1 ab	6.0 a
2	Beck 705	485 ab	57 a	8.5 a	80 a	9.2 ab	6.0 a
2	Beck 720	484 ab	57 a	8.7 a	82 a	8.9 d	6.0 a
2	Beck 722	492 ab	55 a	9.2 a	86 a	9.2 bc	6.5 a
2	Beck 724	471 ab	63 a	7.7 a	73 a	9.0 cd	5.0 a
2	Beck 725	493 ab	55 a	9.3 a	87 a	9.4 a	6.0 a
2	Beck 727	494 a	56 a	9.2 a	86 a	9.2 bc	5.5 a
2	Beck 732	489 ab	55 a	9.2 a	86 a	9.2 ab	6.5 a
2	Branson*	471 b	60 a	8.0 a	75 a	8.9 d	5.5 a
2	Hilliard*	481 ab	60 a	8.3 a	77 a	9.1 bc	5.0 a
3	MI16W0133	487 a	52 a	9.5 a	89 a	9.1 a	6.0 a
3	Whitetail*	493 a	52 a	9.7 a	90 a	9.3 a	6.0 a

*Check varieties.

[a]Means with different letters within the same group are significantly different at $P<0.05$.

Table 11. Mean (n=2) sponge cake baking test parameters[a]

Group	Entry	Sponge Cake	
		Volume (mL)	Texture Score
1	15VTK1-101	1205 ab	20.0 a
1	16VDH-SRW03-23	1129 b	19.5 a
1	17VDH-SRW05-169	1217 ab	20.5 a
1	VA19FHB-36	1235 ab	22.0 a
1	VA19W-29	1265 a	21.5 a
1	Branson*	1218 ab	21.0 a
1	Hilliard*	1261 a	22.0 a
2	Beck 705	1211 a	21.0 a
2	Beck 720	1216 a	21.0 a
2	Beck 722	1224 a	21.0 a
2	Beck 724	1122 b	21.5 a
2	Beck 725	1244 a	23.0 a
2	Beck 727	1222 a	21.5 a
2	Beck 732	1217 a	22.5 a
2	Branson*	1153 b	20.0 a
2	Hilliard*	1220 a	22.0 a
3	MI16W0133	1197 a	22.0 a
3	Whitetail*	1207 a	22.5 a

*Check varieties.

[a]Means with different letters within the same group are significantly different at P<0.

REGIONAL AND STATE PERFORMANCE NURSERIES – 2023 CROP

QUALITY CHARACTERISTICS OF REGIONAL NURSERY ENTRIES

2023 Crop Evaluations

Each year, wheat breeders submit elite breeding materials to cooperative yield trials known as regional nurseries, which are then grown throughout the target production region. Grain samples from these nurseries are evaluated each year for end-use quality by the SWQL, and this information is provided to breeders in the regional nursery reports.

Narratives describing recent quality evaluations of these uniform performance testing nurseries and data summary tables are provided below. The goal of this project is to provide consistent and complete information on the milling and baking performances of advanced breeding lines and varieties.

REGIONAL COLLABORATING NURSERIES AND COORDINATORS

GULF ATLANTIC WHEAT NURSERY 1	*Mohamed Mergoum, University of Georgia*
GULF ATLANTIC WHEAT NURSERY 2	*Rick Boyles, Clemson University*
UNIFORM EASTERN SOFT RED WINTER WHEAT NURSERY 1	*Eric Olson, Michigan State University*
UNIFORM EASTERN SOFT RED WINTER WHEAT NURSERY 2	*Nicholas Santantonio, Virginia Polytechnic Institute and State University*
UNIFORM SOUTHERN SOFT RED WINTER WHEAT NURSERY 1	*Mohamed Mergoum, University of Georgia*
UNIFORM SOUTHERN SOFT RED WINTER WHEAT NURSERY 2	*Nicholas Santantonio, Virginia Polytechnic Institute and State University*
UNIFORM SOUTHERN SOFT RED WINTER WHEAT NURSERY 3	*Rick Boyles, Clemson University*
MASON-DIXON	*Nicholas Santantonio, Virginia Polytechnic Institute and State University*

GULF ATLANTIC WHEAT NURSERY 1

Mohamed Mergoum, University of Georgia

Fifty-nine advanced breeding lines and varieties of SRW wheat were analyzed for test weight, NIR grain protein content, kernel hardness, flour yield, softness equivalence, flour protein content, sodium carbonate SRC, lactic acid SRC and sugar-snap cookie baking quality. Letter grades (A, B, C, D or F) for flour yield were assigned to each entry based on the flour yield range of wheat breeding lines and varieties the SWQL tested in 2009-2022. Those entries that fell in the top 15% range of lines and varieties for flour yield received an 'A,' in the next 20% a 'B,' in the next 30% a 'C,' in the next 20% a 'D,' and in the bottom 15% an 'F.'

Compared to the prior fourteen-year averages of the ESW varieties and lines tested by the SWQL, the entries on average exhibited lower test weights, higher grain protein contents by 0.4%, lower kernel hardness values by 1.5, lower flour yields by 1%, higher flour protein contents by 0.5%, higher sodium carbonate SRCs by 2%, higher lactic acid SRCs by 18.3%, and lower sugar-snap cookie diameters by 0.4 cm.

Kernel hardness of the entries ranged from -0.8 to 25.7 in fifty-eight entries. One entry exhibited a kernel hardness value of 32.6. Four entries exhibited flour yields of 70.7 to 71.0%, receiving a flour yield grade of 'A.' The entries exhibited wide differences in flour protein content, which ranged from 7.1 to 11.4%. Fifty-one entries exhibited lactic acid SRC values greater than 100%, of which eleven entries were higher than 130%. Thirty-nine out of fifty-nine entries exhibited sodium carbonate SRCs higher than 70% and higher than the fourteen-year average of the ESW wheat varieties and lines. Two entries exhibited sugar-snap cookie diameters equal to or greater than 19.8 cm, with a cookie diameter grade of 'A.'

Table 12. Gulf Atlantic Wheat Nursery 1 trial 2023 crop quality data

Entry	Test Weight (LB/BU)	NIR Kernel Protein (at 12%)	SKCS Kernel Hardness	SKCS Kernel Diameter (mm)	SKCS Kernel Weight (mg)	Adjusted Flour Yield (%)	Softness Equivalence (%)	Flour Protein (at 14%)	Lactic Acid SRC (%)	Sodium Carbonate SRC (%)	Cookie Diameter (cm)	Top Grade (0-9)	Adjusted Flour Yield % Grade
AGS3015	59.1	12.8	20.9	3.0	36.2	67.0	50.7	10.2	116.9	73.4	17.5	2	D
HILLIARD	58.8	10.3	12.4	2.8	35.0	66.9	60.8	8.3	126.8	74.9	18.0	2	D
PIO 26R41	57.8	9.3	13.0	2.8	36.9	68.4	62.3	7.7	119.3	72.5	18.1	3	C
PIO26R45	57.2	9.7	4.9	2.6	33.2	68.1	60.6	7.3	91.4	65.6	19.2	3	C
SS8641	58.9	11.6	14.6	2.9	36.3	67.2	53.7	9.6	124.7	67.1	18.0	2	D
FLGA111151-41	56.8	11.4	11.2	2.8	34.6	68.6	60.9	9.4	117.3	72.0	18.2	2	C
FLGA111151-55	57.7	10.5	4.4	3.0	42.8	70.7	62.2	8.5	109.0	71.1	18.7	2	A
FL14125-17	58.6	11.6	4.9	3.2	42.8	68.8	55.9	9.3	110.6	74.1	18.2	2	C
FL15020-50	57.3	10.4	15.6	2.8	35.0	67.2	58.7	8.5	128.5	71.8	18.2	2	D
FLAR160389LDH-47	60.1	10.5	5.1	2.8	33.0	69.4	61.0	8.5	135.5	70.3	18.5	3	C
FLGA11025-58	58.6	11.2	18.6	2.7	31.1	67.5	59.5	9.1	121.7	68.1	18.3	2	D
GANC12915-167-21E3	59.2	10.4	10.2	2.8	30.6	68.0	60.6	8.4	127.8	67.7	19.0	3	D
GA15036 ID-13-21E22	58.8	11.6	7.9	2.9	32.8	67.9	58.3	9.2	132.2	73.2	17.9	3	D
GA141045-9-3-2-21LE7	59.7	11.5	19.5	2.8	36.3	66.6	57.2	9.3	140.7	79.4	17.3	1	F
GA12213-10-7-21LE24	55.6	10.1	8.6	2.9	37.0	68.9	64.7	8.3	131.4	74.9	17.9	3	C
GA15340 ID-3-2-21LE29	62.0	11.2	18.2	2.9	37.4	68.3	58.1	9.4	131.7	72.4	18.2	3	C
GA12099-7-2-6-6-21LE35	58.9	9.5	11.2	2.8	36.4	66.7	62.2	7.8	121.0	76.5	18.3	3	D
X14-1110-80-12-1	57.2	9.8	8.7	2.7	35.0	66.3	61.3	8.1	121.3	71.8	18.4	4	F
X14-1217-49-11-1	58.4	10.4	14.0	2.8	36.3	66.7	63.1	8.3	123.5	76.6	18.6	4	D
X14-1147-158-14-5	54.8	9.9	11.6	2.7	34.0	65.5	60.5	8.2	134.3	75.7	18.6	3	F
X14-1031-103-4-1	54.8	10.2	1.7	2.8	36.0	65.6	62.7	8.5	128.4	74.3	18.8	2	F
X16-3013-1-12-5	61.2	10.4	21.6	2.8	32.7	68.3	56.3	8.3	113.4	71.6	18.4	4	C
X14-1110-82-1-3	55.8	9.9	10.2	2.7	33.0	67.1	53.7	7.7	119.1	69.4	18.6	4	D
LA13019SC-23-3-1-3	59.4	11.1	32.6	2.9	38.7	66.7	46.3	9.5	95.0	73.9	17.8	3	D
LA14191C-93-2-1-3	58.5	11.8	10.1	3.0	42.3	67.7	56.9	9.7	128.2	74.6	17.3	2	D
LA14272CBB-3-1-4	60.3	13.9	13.8	3.0	39.0	66.9	51.3	11.3	134.6	69.2	17.5	2	D
LA15298GBB-5-1-4	59.9	13.8	16.6	3.1	38.4	65.7	48.5	11.4	140.2	69.6	17.4	2	F
LA17006LDH042	60.0	11.5	15.2	2.9	35.4	70.2	52.6	9.3	104.0	67.2	18.8	4	B
LA18003-NDH119	60.5	11.7	5.1	2.9	38.6	68.6	56.4	9.6	129.0	65.8	18.6	4	C
UMD-21-MDW293	59.3	11.7	12.6	2.8	34.3	68.3	56.1	9.6	116.2	67.3	18.1	3	C
UMD-21-MDW314	57.2	10.8	4.2	2.6	31.2	69.3	61.2	9.1	96.8	67.1	19.4	4	C
UMD-21-MDW98	55.2	11.6	10.3	2.6	32.3	65.2	57.4	9.6	102.9	74.7	18.8	4	F
UMD-21-W299	58.4	10.8	6.7	2.7	34.1	65.0	61.5	9.2	121.1	80.4	18.0	2	F
UMD-21-MDW99	57.3	12.4	21.3	2.6	30.6	65.3	55.8	10.6	99.7	73.5	18.1	2	F
UMD-21-MDW73	56.6	11.0	17.4	2.8	35.2	63.3	51.2	9.3	133.8	71.2	17.8	3	F
NC14706-25	58.1	10.3	7.9	2.7	35.2	67.3	60.8	8.2	124.6	72.0	18.7	3	D
NC14757LDH-44	59.0	10.3	25.2	2.8	31.4	67.5	55.8	8.4	117.6	69.9	19.0	5	D
NC15305-43	60.1	10.1	14.1	2.9	34.6	66.8	59.6	8.1	101.5	70.5	18.9	4	D
NC20-21971	60.1	9.5	8.8	2.8	34.3	67.5	58.1	7.6	117.4	70.4	19.2	5	D
NC20-19797	60.3	10.0	11.3	2.8	34.9	66.6	56.7	8.1	125.7	73.1	18.8	3	D
NC15499-17	59.0	9.1	4.1	2.8	37.1	70.9	63.8	7.3	97.2	69.3	19.9	5	A
SCGA151058-2	59.9	9.6	10.7	2.7	32.8	66.9	60.1	7.6	125.2	73.7	18.7	4	D

SCGA14298-32-6	61.2	9.4	13.6	2.7	30.9	63.1	59.1	7.6	125.2	74.1	18.7	5	F
SCGA16259ID-10	59.2	10.4	9.0	2.9	39.4	67.5	61.2	8.2	116.2	78.4	18.7	4	D
SCLA19WF1222	59.0	10.9	7.1	3.0	42.2	66.5	56.4	9.1	126.9	74.9	18.1	3	F
SCLA18WF0708-4-1	57.8	10.9	8.5	2.8	33.7	68.0	55.7	8.7	125.7	67.9	18.8	3	C
SCLA18WF0705-4	61.2	10.7	10.8	2.8	39.0	66.8	54.3	9.1	134.3	70.5	18.5	3	D
TX20D5056	57.5	10.6	7.7	2.8	35.1	68.5	62.7	8.6	132.7	72.0	18.9	4	C
TX20D5075	59.2	11.3	25.7	2.6	27.9	67.0	56.2	9.4	112.3	69.5	18.1	3	D
TX20D5116	58.3	9.9	10.7	2.7	32.1	67.8	62.9	7.8	94.1	69.8	19.2	3	D
TX20D5118	58.7	10.1	15.9	2.6	29.5	69.1	59.9	8.2	94.9	65.5	19.0	3	C
TX20D5143	55.5	10.3	11.6	2.6	31.6	69.8	64.7	8.4	123.8	71.1	18.9	4	B
TX20D5145	58.6	10.9	14.7	2.8	36.6	70.7	55.4	8.9	110.4	67.9	19.2	4	A
DH17SRW136-038	56.9	10.6	9.0	2.6	27.7	68.4	58.6	8.7	90.7	62.8	19.8	4	C
17VDH-SRW02-125	60.1	11.2	19.5	2.8	31.6	66.2	57.4	9.2	129.4	74.9	18.1	4	F
18VTK10-23	59.9	9.9	18.9	2.9	35.7	67.9	61.6	8.4	118.2	76.5	18.4	4	D
VA21W-18	59.5	11.7	-0.8	3.1	43.3	71.0	55.8	9.2	103.6	65.9	18.8	4	A
VA21W-59	58.8	9.0	18.1	2.6	34.5	67.6	57.2	7.1	114.4	74.8	18.8	4	D
VA21W-112	56.4	9.0	-0.5	2.9	41.1	68.5	62.0	7.3	105.3	69.3	19.3	3	C
Average	58.5	10.7	12.1	2.8	35.2	**67.6**	58.2	8.7	118.6	**71.6**	18.5	3	
Standard Deviation	1.6	1.0	6.5	0.1	3.6	1.6	4.0	0.9	13.1	3.7	0.6	0.9	

GULF ATLANTIC WHEAT NURSERY 2

Rick Boyles, Clemson University

Fifty-nine advanced breeding lines and varieties of SRW wheat were analyzed for test weight, NIR grain protein content, kernel hardness, flour yield, softness equivalence, flour protein content, sodium carbonate SRC, lactic acid SRC and sugar-snap cookie baking quality. Letter grades (A, B, C, D or F) for flour yield were assigned to each entry based on the flour yield range of wheat breeding lines and varieties the SWQL tested in 2009-2022. Those entries that fell in the top 15% range of lines and varieties for flour yield received an ‘A,’ in the next 20% a ‘B,’ in the next 30% a ‘C,’ in the next 20% a ‘D,’ and in the bottom 15% an ‘F.’

Compared to the prior fourteen-year averages of the ESW varieties and lines tested by the SWQL, the entries on average exhibited higher test weights by 1.8 lb/bu, higher grain protein contents by 0.3%, much higher kernel hardness values by 11.3, comparable flour yields, higher flour protein contents by 0.7%, higher sodium carbonate SRCs by 3.5%, comparable lactic acid SRCs, and comparable sugar-snap cookie diameters.

Kernel hardness of the entries ranged from 4.3 to 43.5, of which thirteen entries had kernel hardness values greater than 30. Three entries exhibited kernel hardness values greater than 40. Seven entries exhibited flour yields of 70.8 to 71.5%, receiving a flour yield grade of ‘A.’ Flour protein contents of the entries ranged from 7.4 to 12.3%, with forty-eight entries exhibiting protein contents higher than the typical protein content of eastern soft wheat (8.2%). Forty-one entries exhibited lactic acid SRC values greater than 100%. Fifty-three out of fifty-nine entries exhibited sodium carbonate SRCs higher than the past fourteen-year average of the ESW wheat varieties and lines (69.6%). Two entries exhibited sugar-snap cookie diameters equal to or greater than 19.4 cm, with a cookie diameter grade of ‘A.’

Table 13. Gulf Atlantic Wheat Nursery 2 trial 2023 crop quality data

Entry	Test Weight (LB/BU)	NIR Kernel Protein (at 12%)	SKCS Kernel Hardness	SKCS Kernel Diameter (mm)	SKCS Kernel Weight (mg)	Adjusted Flour Yield (%)	Softness Equivalence (%)	Flour Protein (at 14%)	Lactic Acid SRC (%)	Sodium Carbonate SRC (%)	Cookie Diameter (cm)	Top Grade (0-9)	Adjusted Flour Yield % Grade
AGS3015	60.8	12.7	34.3	2.9	35.5	67.4	46.0	10.4	104.7	79.2	17.4	3	D
HILLIARD	62.7	10.2	26.4	2.7	34.9	68.0	55.8	8.3	112.3	73.1	18.7	4	C
PIO 26R41	60.6	9.7	28.5	2.6	33.5	69.7	57.3	8.0	111.5	73.6	18.5	5	B
PIO26R45	61.3	9.6	22.5	2.7	33.7	69.6	51.6	8.0	86.8	67.0	19.3	4	B
SS8641	62.3	11.7	25.5	2.9	38.5	67.4	50.8	9.7	122.3	71.0	18.2	3	D
FLGA111151-41	62.2	10.1	27.9	2.9	41.1	69.8	52.6	8.8	92.6	75.3	18.5	3	B
FLGA111151-55	61.6	11.4	20.4	3.1	49.3	71.1	53.2	9.4	92.0	72.9	18.5	3	A
FL14125-17	61.9	11.8	19.7	3.2	45.7	69.0	49.2	9.5	95.3	77.0	18.5	4	C
FL15020-50	59.4	10.8	24.5	2.9	40.2	67.8	51.9	9.0	109.5	74.2	18.2	4	D
FLAR160389LDH-47	62.5	10.7	19.6	2.9	37.6	69.9	54.5	8.9	115.3	72.5	18.1	4	B
FLGA11025-58	61.7	10.9	25.2	2.9	36.7	69.3	54.6	8.9	105.8	72.5	18.4	4	C
GANC12915-167-21E3	61.6	10.5	22.8	2.8	33.0	69.2	56.0	8.6	117.5	73.1	18.7	3	C
GA15036 ID-13-21E22	60.7	10.9	13.3	2.8	34.7	69.2	57.3	8.9	124.0	72.5	18.8	4	C
GA141045-9-3-2-21LE7	62.7	11.1	40.4	2.8	34.9	67.5	51.6	9.5	121.4	80.9	19.1	4	D
GA12213-10-7-21LE24	59.1	9.9	23.3	2.7	34.6	69.3	58.1	8.3	107.1	73.7	18.5	3	C
GA15340 ID-3-2-21LE29	64.4	11.2	31.6	3.0	39.9	69.8	52.1	9.6	98.1	73.5	18.2	3	B
GA12099-7-2-6-6-21LE35	61.6	9.0	20.3	2.7	36.6	67.3	59.3	7.4	90.1	75.6	18.6	4	D
X14-1110-80-12-1	61.0	9.9	24.1	2.7	34.9	68.1	53.7	8.2	109.8	72.8	18.7	4	C
X14-1217-49-11-1	62.4	9.3	29.4	2.7	34.7	68.5	56.1	7.7	112.8	75.3	18.7	4	C
X14-1147-158-14-5	59.1	10.3	26.5	2.5	29.2	67.9	55.5	8.4	111.3	73.2	18.5	4	D
X14-1031-103-4-1	57.5	11.0	22.9	2.5	29.6	67.4	56.5	9.0	105.5	71.8	18.6	3	D
X16-3013-1-12-5	64.2	10.2	37.3	2.8	32.2	69.6	51.1	8.6	100.6	73.4	18.1	3	B
X14-1110-82-1-3	59.8	9.6	24.2	2.8	34.3	67.6	49.5	7.7	111.3	69.7	18.3	3	D
LA13019SC-23-3-1-3	60.6	11.7	43.5	2.8	36.7	65.9	43.2	9.6	111.3	79.4	17.8	3	F
LA14191C-93-2-1-3	61.7	11.6	20.3	3.0	45.5	67.6	49.4	10.0	105.1	75.7	17.4	2	D
LA14272CBB-3-1-4	61.4	14.9	24.7	3.1	43.5	66.7	45.9	12.3	113.9	73.6	17.2	2	D
LA15298GBB-5-1-4	60.8	14.6	24.4	3.1	39.6	65.8	44.3	12.2	128.3	74.6	17.3	2	F
LA17006LDH042	63.4	10.6	22.9	3.0	38.7	71.5	50.0	9.0	91.8	71.6	18.7	4	A
LA18003-NDH119	61.6	10.6	7.4	2.9	44.7	70.3	54.3	8.4	111.2	69.4	19.0	4	B
UMD-21-MDW293	61.7	12.8	24.3	2.9	36.9	68.7	49.3	10.7	108.5	72.2	18.1	3	C
UMD-21-MDW314	60.3	10.3	16.9	2.6	31.7	71.2	54.3	8.6	83.1	68.8	19.0	5	A
UMD-21-MDW98	60.0	9.7	20.8	2.6	33.4	68.1	52.4	8.3	90.2	75.4	19.0	4	C
UMD-21-W299	61.6	9.9	21.7	2.5	30.7	67.6	57.8	8.4	99.9	77.0	18.2	3	D
UMD-21-MDW99	62.2	10.6	29.9	2.6	32.1	67.8	50.4	9.0	86.8	72.0	18.7	5	D
UMD-21-MDW73	60.1	10.2	31.1	2.7	32.8	65.9	49.5	8.7	114.1	71.3	18.6	4	F
NC14706-25	62.0	10.4	23.8	2.7	34.6	67.9	56.3	8.3	113.0	73.1	18.4	3	D
NC14757LDH-44	61.4	9.6	34.8	2.8	31.9	69.6	52.7	8.2	106.5	72.6	18.8	4	B
NC15305-43	62.6	10.6	28.9	2.8	31.4	68.9	54.2	8.5	91.9	72.2	18.7	4	C
NC20-21971	63.7	9.8	27.9	2.8	33.7	68.0	51.8	8.2	109.6	72.1	18.6	5	C
NC20-19797	63.7	10.6	30.9	2.7	32.9	67.2	50.2	8.7	117.3	73.2	18.7	4	D
NC15499-17	62.4	8.8	24.1	2.7	34.0	71.5	56.7	7.4	90.5	71.1	18.8	4	A
SCGA151058-2	64.1	10.7	29.0	2.8	32.6	67.8	52.2	8.7	114.5	73.5	18.3	3	D

SCGA14298-32-6	64.3	11.0	30.5	2.6	29.9	64.7	52.9	9.1	122.1	74.3	17.8	3	F
SCGA16259ID-10	63.6	11.4	27.9	3.0	39.4	68.5	52.2	9.6	106.5	74.7	17.6	4	C
SCLA19WF1222	62.1	11.2	15.6	3.1	46.9	67.2	50.8	9.5	114.8	76.5	17.8	3	D
SCLA18WF0708-4-1	61.6	11.7	19.0	3.1	42.7	68.2	50.3	9.7	111.4	72.5	18.3	4	C
SCLA18WF0705-4	63.7	10.5	22.1	2.9	42.1	66.9	50.1	9.2	117.4	71.2	17.9	3	D
TX20D5056	60.7	9.9	17.0	2.9	36.7	70.3	59.9	7.8	112.5	70.1	19.4	5	B
TX20D5075	63.1	10.7	41.3	2.7	29.8	68.5	48.6	8.8	90.5	73.6	18.0	4	C
TX20D5116	61.9	10.9	20.0	2.8	39.1	68.1	54.8	9.0	97.8	70.8	18.8	4	C
TX20D5118	62.0	10.8	26.3	2.6	33.1	69.9	52.8	9.1	90.7	69.4	18.8	4	B
TX20D5143	58.1	9.1	18.6	2.7	34.6	71.5	61.6	7.6	109.3	72.0	19.6	4	A
TX20D5145	61.1	10.3	25.9	2.8	38.7	70.8	51.9	9.0	107.0	72.7	18.5	4	A
DH17SRW136-038	59.5	9.9	14.7	2.6	31.2	70.9	55.1	8.0	87.0	65.4	19.4	5	A
17VDH-SRW02-125	62.6	9.7	30.4	2.9	33.8	68.1	54.9	7.9	114.0	75.6	18.4	5	C
18VTK10-23	63.6	9.9	30.9	2.8	36.3	68.5	55.2	8.1	107.2	76.3	18.5	4	C
VA21W-18	61.7	13.6	15.9	3.0	41.5	69.4	51.7	11.0	99.2	70.2	18.3	4	C
VA21W-59	61.8	10.1	31.5	2.6	35.0	68.1	52.0	8.2	118.2	76.7	18.4	5	C
VA21W-112	60.3	10.6	4.3	3.1	48.0	68.6	56.2	8.8	101.1	68.8	18.7	3	C
Average	61.7	10.7	24.9	2.8	36.5	68.6	52.9	8.9	106.0	73.1	18.5	4	
Standard Deviation	1.5	1.2	7.3	0.2	4.9	1.5	3.7	1.0	10.9	2.8	0.5	0.8	

UNIFORM EASTERN SOFT RED WINTER WHEAT NURSERY 1

Eric Olson, Michigan State University

Twenty-eight advanced breeding lines and varieties were analyzed for test weight, NIR grain protein content, kernel hardness, flour yield, softness equivalence, flour protein content, sodium carbonate SRC, lactic acid SRC and sugar-snap cookie baking quality. Letter grades (A, B, C, D or F) for flour yield were assigned to each entry based on the flour yield range of wheat breeding lines and varieties the SWQL tested in 2009-2022. Those entries that fell in the top 15% range of lines and varieties for flour yield received an ‘A,’ in the next 20% a ‘B,’ in the next 30% a ‘C,’ in the next 20% a ‘D,’ and in the bottom 15% an ‘F.’

Compared to the prior fourteen-year averages of the SRW wheat varieties and lines tested by the SWQL, the entries on average exhibited higher test weights by 1.7 lb/bu, lower grain and flour protein contents by 2.0 and 1.1%, respectively, and lower flour yields by 0.6%. The average kernel hardness value was lower by 4.2 compared to the prior fourteen-year average. Only one entry, “TWR 29016,” received a flour yield grade of ‘A’ with a flour yield of 71.3%. Twenty-six out of twenty-eight entries exhibited lactic acid SRCs greater than 100%, despite their relatively low flour protein contents of 7.1% on average, indicating the presence of relatively strong protein. The average sodium carbonate SRC was higher by 2% than the prior fourteen-year average. Four entries received a cookie diameter grade of ‘A’ with a diameter ranging from 19.3 to 19.9 cm.

Table 14. Uniform Eastern Soft Red Winter Wheat Nursery 1 trial 2023 crop quality data

Entry	Test Weight (LB/BU)	NIR Kernel Protein (at 12%)	SKCS Kernel Hardness	SKCS Kernel Diameter (mm)	SKCS Kernel Weight (mg)	Adjusted Flour Yield (%)	Softness Equivalence (%)	Flour Protein (at 14%)	Lactic Acid SRC (%)	Sodium Carbonate SRC (%)	Cookie Diameter (cm)	Top Grade (0-9)	Adjusted Flour Yield % Grade
Branson	60.3	8.4	-5.0	2.5	32.7	69.0	63.6	7.2	125.1	71.9	18.4	2	C
MO080104	64.3	8.8	23.2	2.6	30.7	66.1	55.7	7.6	123.8	73.4	18.1	2	F
Hilliard	60.5	7.6	3.4	2.6	33.7	67.7	64.9	6.5	116.4	78.9	18.6	1	D
Pioneer Brand 25R46	61.6	8.3	9.1	2.4	32.4	67.5	61.0	7.1	105.6	73.9	19.2	2	D
IL17-8930	60.6	7.9	-1.7	2.8	37.1	69.8	58.0	6.7	100.3	64.7	19.9	1	B
IL18-6852	61.6	8.5	4.4	2.6	30.1	68.8	58.7	6.9	111.6	67.1	19.6	1	C
US17-IL-111-005	62.0	8.8	16.8	2.7	33.0	65.9	56.3	7.4	118.1	67.6	18.9	3	F
KWS472	61.1	7.9	0.7	2.4	31.2	67.6	63.9	6.9	115.3	72.6	19.0	1	D
KWS482	62.6	8.6	8.9	2.7	30.9	67.1	55.3	7.3	118.5	66.4	19.2	2	D
KWS490	60.9	8.0	8.0	2.4	31.0	67.4	60.9	6.7	102.4	72.5	19.2	2	D
X12-265-56-8-1	59.9	8.9	10.4	2.8	35.3	65.6	58.2	7.8	108.8	74.3	18.3	1	F
X11-0039-1-17-5	61.8	8.0	6.1	2.6	32.5	67.9	62.0	7.0	124.8	72.5	18.9	2	D
X11-0120-12-4-3	60.8	8.4	18.1	2.5	29.4	67.5	57.5	7.1	90.2	70.1	19.2	2	D
UMD-21-MDW 291	61.8	8.2	15.9	2.6	31.4	66.4	59.2	6.9	125.7	76.9	18.3	1	F
UMD-21-MDX11	61.6	8.2	19.1	2.6	29.6	67.8	60.6	6.7	107.7	73.2	18.6	4	D
UMD-21-MDX10	61.6	8.4	19.8	2.6	29.5	67.5	60.7	7.0	108.4	74.3	18.8	3	D
MI20R0013	60.9	7.7	-5.8	2.7	35.8	68.8	65.3	6.4	112.8	72.2	19.3	3	C
MI20R0096	60.3	8.0	10.8	2.8	35.4	67.7	57.6	7.0	92.7	71.2	19.0	2	D
MI20R0210	59.6	8.0	1.5	2.5	34.7	68.8	64.4	6.7	101.8	71.8	19.8	1	C
21PU-0029	61.6	8.6	6.1	2.5	30.7	68.3	60.7	7.3	125.2	68.0	18.9	2	C
21PU-0034	62.2	9.1	22.2	2.8	34.6	68.3	54.1	8.3	116.5	68.8	18.6	2	C
21PU-0038	61.6	9.2	17.3	2.8	33.7	67.9	54.1	8.4	113.8	68.2	18.9	1	D
TWR 19022	62.9	7.8	14.4	2.6	35.1	71.3	59.3	7.0	107.1	66.9	19.3	2	A
TWR 29008	62.1	8.2	16.8	2.6	34.9	67.3	57.8	7.4	104.9	74.9	18.8	1	D
TWR 29016	62.3	8.5	0.4	2.4	29.1	70.0	66.2	7.1	128.5	71.3	19.9	2	B
17VTK4-29	62.6	8.1	7.3	2.6	32.0	69.4	62.5	6.9	120.1	70.6	19.2	1	C
VA20FHB-20	63.0	7.8	6.9	2.6	34.7	68.3	59.0	6.8	119.5	71.3	19.2	2	C
VA20W-142	61.4	8.0	8.2	2.5	30.9	68.0	64.5	6.9	130.0	78.4	18.8	1	C
Average	61.6	8.3	9.4	2.6	32.6	68.0	60.1	7.1	113.4	71.6	19.0	1.8	
Standard Deviation	1.0	0.4	8.1	0.1	2.3	1.3	3.5	0.5	10.5	3.5	0.5	0.8	

UNIFORM EASTERN SOFT RED WINTER WHEAT NURSERY 2

Nicholas Santantonio, Virginia Polytechnic Institute and State University

Twenty-eight advanced breeding lines and varieties were analyzed for test weight, NIR grain protein content, kernel hardness, flour yield, softness equivalence, flour protein content, sodium carbonate SRC, lactic acid SRC and sugar-snap cookie baking quality. Letter grades (A, B, C, D or F) for flour yield were assigned to each entry based on the flour yield range of wheat breeding lines and varieties the SWQL tested in 2009-2022. Those entries that fell in the top 15% range of lines and varieties for flour yield received an ‘A,’ in the next 20% a ‘B,’ in the next 30% a ‘C,’ in the next 20% a ‘D,’ and in the bottom 15% an ‘F.’

Compared to the prior fourteen-year averages of the SRW wheat varieties and lines tested by the SWQL, the entries on average exhibited higher test weights by 1.0 lb/bu, comparable grain and flour protein contents, and lower flour yields by 0.8%. The average kernel hardness value was higher by 9.4 compared to the prior fourteen-year average. Three entries showed kernel hardness values equal to or greater than 30.0. No entry received a flour yield grade of ‘A.’ “TWR 19022” exhibited the highest flour yield of 70.3. Nineteen entries exhibited lactic acid SRCs greater than 100%, indicating the presence of relatively strong protein. Twenty-six out of twenty-eight entries exhibited higher sodium carbonate SRCs than the prior fourteen-year average of 69.6%. Two entries received a cookie diameter grade of ‘A’ with diameters of 19.7 cm.

Table 15. Uniform Eastern Soft Red Winter Wheat Nursery 2 trial 2023 crop quality data

Entry	Test Weight (LB/BU)	NIR Kernel Protein (at 12%)	SKCS Kernel Hardness	SKCS Kernel Diameter (mm)	SKCS Kernel Weight (mg)	Adjusted Flour Yield (%)	Softness Equivalence (%)	Flour Protein (at 14%)	Lactic Acid SRC (%)	Sodium Carbonate SRC (%)	Cookie Diameter (cm)	Top Grade (0-9)	Adjusted Flour Yield % Grade
MO080104	62.2	10.6	30.0	2.9	38.4	65.5	52.0	8.6	123.5	80.9	18.0	1	F
MI20R0210	59.3	9.9	14.8	2.9	44.4	69.3	56.8	7.6	89.9	73.9	19.1	3	C
21PU-0034	62.1	11.0	28.7	3.1	45.2	67.9	46.1	9.7	99.3	72.5	18.4	3	D
IL18-6852	60.7	10.3	17.5	3.0	39.5	68.4	50.9	8.0	97.9	69.9	19.0	4	C
21PU-0038	62.0	11.3	27.0	3.2	45.5	67.8	47.4	9.7	98.9	71.1	18.1	3	D
TWR 29016	62.0	10.1	23.2	2.8	39.1	68.2	55.4	8.0	111.9	75.1	18.7	4	C
TWR 19022	61.5	10.7	27.3	2.7	40.5	70.3	52.4	8.6	117.9	72.6	18.6	4	B
17VTK4-29	61.2	10.4	25.9	2.9	38.3	68.0	53.0	8.3	113.6	78.3	18.4	4	C
X11-0039-1-17-5	61.2	9.6	23.4	3.0	43.5	69.0	54.4	7.9	114.3	74.8	18.3	3	C
KWS472	60.8	9.4	17.4	2.8	41.3	68.0	58.3	7.4	106.5	74.7	19.2	3	C
Hilliard	60.8	10.6	19.5	2.9	42.3	67.0	56.2	8.2	117.2	77.0	18.5	2	D
IL17-8930	60.0	10.5	9.4	3.1	44.3	69.1	52.4	8.3	101.8	66.6	19.7	3	C
X11-0120-12-4-3	60.3	9.9	27.3	2.9	39.5	69.3	51.5	8.1	78.2	70.7	19.2	4	C
MI20R0096	60.2	9.3	21.1	3.2	46.5	69.4	53.3	7.6	79.8	71.4	19.0	4	C
US17-IL-111-005	60.2	10.3	28.1	3.0	40.9	65.9	50.4	8.3	114.4	74.1	18.7	4	F
VA20W-142	61.4	9.8	22.1	2.9	41.5	67.3	56.4	7.7	124.3	78.1	18.1	3	D
VA20FHB-20	62.9	10.1	15.7	3.0	45.8	68.4	52.7	8.1	118.2	76.9	18.7	4	C
KWS482	61.2	10.3	25.4	2.9	36.9	67.1	48.6	8.0	105.7	72.4	19.0	4	D
KWS490	56.8	10.4	28.0	2.8	39.0	65.4	49.1	8.2	99.6	82.0	18.4	3	F
UMD-21-MDX10	60.6	10.6	31.9	2.8	35.0	67.6	52.0	8.5	105.5	80.9	17.6	2	D
X12-265-56-8-1	61.0	10.5	23.4	3.1	45.0	67.0	49.9	8.9	89.7	76.0	18.2	2	D
21PU-0029	61.7	10.4	17.4	2.8	39.3	68.1	53.7	8.2	115.7	70.1	19.2	5	C
UMD-21-MDW 291	60.7	10.0	26.4	2.8	38.5	65.6	51.1	8.0	129.4	80.8	18.1	3	F
TWR 29008	60.2	10.6	33.6	2.9	44.2	66.5	47.5	8.6	105.9	81.1	18.3	3	F
Branson	59.9	10.2	11.8	2.8	42.5	67.4	57.0	8.2	124.4	73.7	18.7	4	D
Pioneer Brand 25R46	61.3	9.8	26.7	2.8	41.9	67.7	52.7	7.6	94.0	76.9	19.1	5	D
MI20R0013	60.7	9.2	11.5	3.0	45.5	69.4	57.7	7.1	104.2	74.4	19.7	5	C
UMD-21-MDX11	60.7	10.1	29.7	2.9	37.1	68.3	51.7	7.9	105.0	79.1	17.9	3	C
Average	60.9	10.2	23.0	2.9	41.5	67.8	52.5	8.2	106.7	75.2	18.6	3.4	
Standard Deviation	1.1	0.5	6.5	0.1	3.2	1.3	3.2	0.6	13.1	4.0	0.5	1.0	

UNIFORM SOUTHERN SOFT RED WINTER WHEAT NURSERY 1

Mohamed Mergoum, University of Georgia

Thirty-seven SRW wheat breeding lines and varieties were analyzed for test weight, NIR grain protein content, kernel hardness, flour yield, softness equivalence, flour protein content, sodium carbonate SRC, lactic acid SRC and sugar-snap cookie baking quality. Letter grades (A, B, C, D or F) for flour yield were assigned to each entry based on the flour yield range of wheat breeding lines and varieties the SWQL tested in 2009-2022. Those entries that fell in the top 15% range of lines and varieties for flour yield received an 'A,' in the next 20% a 'B,' in the next 30% a 'C,' in the next 20% a 'D,' and in the bottom 15% an 'F.'

Compared to the prior fourteen-year averages of the ESW varieties and lines tested by the SWQL, the entries on average exhibited comparable test weights, higher grain and flour protein contents by 0.7 to 0.8%, and lower flour yields by 1%. The average kernel hardness value of the entries was 18.3, higher by 4.7 than the prior fourteen-year average. Two entries exhibited kernel hardness values higher than 30. One entry, UMD-21-MDW107, had a kernel hardness of 66.7. Two entries exhibited flour yields equal to or greater than 70.8%, receiving a flour yield grade of 'A.' The average sodium carbonate SRC was higher by 2.9% than the prior fourteen-year average. No entries produced cookies with diameters greater than 19.3 cm; thus none received a cookie diameter grade of 'A.'

Table 16. Uniform Southern Soft Red Winter Wheat Nursery 1 trial 2023 crop quality data

Entry	Test Weight (LB/BU)	NIR Kernel Protein (at 12%)	SKCS Kernel Hardness	SKCS Kernel Diameter (mm)	SKCS Kernel Weight (mg)	Adjusted Flour Yield (%)	Softness Equivalence (%)	Flour Protein (at 14%)	Lactic Acid SRC (%)	Sodium Carbonate SRC (%)	Cookie Diameter (cm)	Top Grade (0-9)	Adjusted Flour Yield % Grade
AGS 2000	60.8	11.8	8.1	3.2	46.2	65.5	58.3	9.2	133.2	74.8	17.8	1	F
Jamestown	61.2	11.8	15.7	3.0	36.7	66.0	53.3	9.3	119.2	73.6	17.7	2	F
Hilliard	59.8	10.6	17.8	2.7	32.9	70.8	54.6	8.7	103.0	70.9	18.6	2	A
Pioneer Brand 26R41	59.2	11.6	18.8	2.6	31.4	66.1	59.3	9.5	137.0	70.9	17.8	1	F
FL15105-LDH043	60.0	13.5	23.0	2.8	29.6	64.8	49.6	11.4	121.8	69.8	17.1	0	F
FLLA16124LDH-51	60.4	10.7	35.9	2.9	35.0	67.5	44.1	9.2	120.8	75.0	17.2	1	D
GA131246LDH-86-21E2	58.6	9.6	17.3	2.8	34.4	71.0	60.9	7.7	102.8	69.0	19.0	4	A
GA17634DH-08-21E36	60.7	10.7	9.6	2.9	42.8	68.1	56.4	8.9	104.1	75.8	18.1	2	C
GA15490 ID-19-5-21LE2	59.4	10.4	14.2	2.8	34.7	67.0	57.2	8.4	119.8	74.3	18.6	2	D
GA141556-5-1-21LE22	60.6	10.5	18.9	2.7	31.8	68.1	57.8	8.6	128.0	75.5	18.0	1	C
KWS397	56.1	9.6	14.4	2.8	35.1	67.5	57.7	7.7	113.1	70.1	19.0	4	D
KWS477	59.6	9.8	15.6	2.7	37.7	67.0	56.1	8.0	112.7	74.3	18.1	2	D
KWS495	58.2	10.2	9.9	2.7	32.9	66.9	57.3	8.2	112.3	71.7	18.4	3	D
LA14234CBW-31	60.4	10.7	15.0	2.8	34.3	68.4	57.8	8.6	104.0	65.1	18.9	3	C
LA14272CBW-15-1-2													
NC14711-12	60.2	12.0	23.5	2.6	31.2	66.7	54.9	9.7	129.3	72.4	18.0	2	D
NC15V25-20	60.9	11.8	29.4	2.5	28.5	63.8	56.2	9.3	137.0	76.4	17.9	2	F
NC16VT30-7-47	60.8	12.7	28.8	2.6	29.7	67.7	50.6	10.5	131.4	67.8	18.3	2	D
SCLA19WF2110	60.1	10.3	18.8	2.8	37.0	66.3	58.5	8.3	139.2	77.5	17.9	1	F
SCGA141638-8-4	61.4	11.1	14.5	3.0	38.5	69.9	51.1	9.1	102.2	68.3	18.7	3	B
SCLA18WF0304-13	62.0	10.8	13.5	3.0	41.2	68.1	54.3	9.0	134.4	71.9	18.1	3	C
TN 2301	59.5	10.3	12.6	2.7	35.0	66.7	59.4	8.3	134.8	72.6	18.7	3	D
TN 2302	57.3	10.2	13.7	2.6	29.7	68.5	63.2	8.3	124.9	72.2	18.7	3	C
TWR 29012	60.0	10.6	13.2	2.5	32.0	68.1	61.0	8.5	127.2	70.2	18.8	2	C
TWR 29036	55.7	11.3	24.9	2.6	29.2	66.3	61.3	9.6	106.8	72.2	18.5	4	F
TWR 29005	59.5	10.9	11.2	2.6	32.7	67.7	59.5	8.7	123.5	71.2	18.4	2	D
TWR 29014	59.6	9.4	9.4	2.6	32.6	68.5	63.0	7.5	118.1	69.9	19.2	2	C
TX18D3212	59.4	10.4	17.4	2.7	32.4	68.1	60.0	8.3	117.5	71.8	18.0	3	C
TX2017DDH193	61.0	11.1	9.1	2.9	40.7	70.0	55.7	9.2	124.8	69.5	17.8	2	B
AR09485-10-1	61.4	12.3	19.9	3.0	39.2	69.4	52.9	10.2	123.2	68.3	18.0	3	C
18VDH-FHB-MAS07-164-01	59.2	10.2	19.1	2.8	34.4	66.8	58.4	8.2	116.5	71.8	18.9	2	D
VA20W-135	60.4	9.5	19.9	2.8	34.3	66.3	61.5	7.8	131.1	77.2	18.0	1	F
17VDH-SRW05-169	58.9	8.8	6.6	2.7	34.2	69.8	64.8	7.1	115.4	72.5	19.3	3	B
18VDH-FHB-MAS07-173-03	58.3	10.1	19.4	2.9	37.1	68.9	53.3	8.3	107.6	70.6	19.1	3	C
UMD-21-MDW104	59.0	10.5	18.9	2.7	31.3	66.2	55.8	8.4	133.1	71.1	18.3	2	F
UMD-21-MDW107	59.7	12.3	66.7	2.9	35.5	66.7	36.6	10.7	145.9	96.3	15.4	0	D
UMD-21-MDW314	58.4	12.3	13.9	2.5	29.6	68.4	57.2	10.1	114.1	69.3	18.0	1	C
Average	59.7	10.8	18.3	2.8	34.5	67.6	56.4	8.8	121.4	72.5	18.2	2.1	
Standard Deviation	1.4	1.0	10.4	0.2	4.1	1.6	5.4	0.9	11.7	4.9	0.7	1.0	

UNIFORM SOUTHERN SOFT RED WINTER WHEAT NURSERY 2

Nicholas Santantonio, Virginia Polytechnic Institute and State University

Thirty-seven advanced breeding lines and varieties were analyzed for test weight, grain protein content, kernel hardness, flour yield, softness equivalence, flour protein content, sodium carbonate SRC, lactic acid SRC and sugar-snap cookie baking quality. Letter grades (A, B, C, D or F) for flour yield were assigned to each entry based on the flour yield range of wheat breeding lines and varieties the SWQL tested in 2009-2022. Those entries that fell in the top 15% range of lines and varieties for flour yield received an 'A,' in the next 20% a 'B,' in the next 30% a 'C,' in the next 20% a 'D,' and in the bottom 15% an 'F.'

Compared to the prior fourteen-year averages of the ESW varieties and lines tested by the SWQL, the entries exhibited higher test weights and kernel hardness values, but comparable flour yields. The average kernel hardness value of the entries was 21.3, higher by 7.7 than the prior fourteen-year average. The average softness equivalence of the entries was lower by 5.2% than the prior fourteen-year average. Two entries showed kernel hardness values greater than 30. 'UMD-21-MDW107' exhibited a kernel hardness value of 74.4, indicative of hard wheat. Three entries exhibited flour yields ranging from 70.6 to 72.8%, receiving the flour yield grade 'A.' The sodium carbonate SRCs of the entries ranged from 70.1 to 109.1% and were all higher than the prior fourteen-year average. 'UMD-21-MDW107' exhibited the highest sodium carbonate SRC of 109.1%. The average lactic acid SRC of the entries was higher than the prior fourteen-year average. The highest lactic acid SRC was observed with 'UMD-21-MDW107.' Three entries produced cookies with diameters ranging from 19.5 to 19.7 cm, receiving the cookie diameter grade 'A.' The cookie diameters ranged from 18.1 to 19.7 cm in thirty-six entries. One hard wheat entry, 'UMD-21-MDW107,' produced a cookie with a diameter of 15.7 cm.

Table 17. Uniform Southern Soft Red Winter Wheat Nursery 2 trial 2023 crop quality data

Entry	Test Weight (LB/BU)	NIR Kernel Protein (at 12%)	SKCS Kernel Hardness	SKCS Kernel Diameter (mm)	SKCS Kernel Weight (mg)	Adjusted Flour Yield (%)	Softness Equivalence (%)	Flour Protein (at 14%)	Lactic Acid SRC (%)	Sodium Carbonate SRC (%)	Cookie Diameter (cm)	Top Grade (0-9)	Adjusted Flour Yield % Grade
AR09485-10-1	62.2	10.0	20.9	3.3	48.5	72.8	59.1	8.2	113.6	73.7	18.7	4	A
SCGA141638-8-4	62.2	10.3	28.3	3.1	45.0	69.5	47.8	8.5	101.8	76.9	18.4	4	B
NC14711-12	60.9	10.0	23.0	2.9	39.9	66.9	53.2	7.9	109.6	77.8	19.3	4	D
GA131246LDH-86-21E2	61.4	9.5	21.5	3.0	41.5	71.5	58.0	7.7	87.5	73.1	19.3	5	A
GA17634DH-08-21E36	61.2	9.8	21.4	2.9	44.6	68.7	55.0	8.2	100.3	78.8	18.6	3	C
TN 2302	61.0	8.6	15.9	2.9	42.3	69.6	57.4	7.1	103.8	75.1	18.8	5	B
Hilliard	60.1	9.1	15.9	2.7	38.6	67.2	58.7	7.1	110.1	75.7	19.1	4	D
TWR 29036	60.2	8.9	12.9	2.9	41.2	68.7	58.0	6.9	93.7	70.4	19.7	5	C
TN 2301	60.5	9.2	20.0	2.8	38.4	67.3	56.8	7.0	120.9	77.3	19.3	5	D
Pioneer Brand 26R41	60.1	9.1	17.9	2.8	42.4	68.5	57.9	7.3	112.0	76.0	18.7	5	C
LA14234CBW-31	61.7	9.7	22.2	2.8	40.0	68.5	55.1	7.8	94.3	70.9	19.0	4	C
SCLA19WF2110	61.9	9.2	22.9	2.9	43.6	66.0	52.9	7.5	121.1	78.2	18.6	4	F
LA14272CBW-15-1-2	61.8	9.6	21.3	3.1	44.9	68.2	51.6	8.1	123.6	74.3	18.7	4	C
AGS 2000	62.3	9.4	14.4	3.0	47.2	69.6	52.3	8.1	102.1	75.4	19.2	5	B
17VDH-SRW05-169	58.9	8.5	2.0	2.8	38.5	70.3	62.2	6.8	102.2	74.4	19.6	4	B
18VDH-FHB-MAS07-164-01	61.5	9.2	24.6	2.9	37.7	67.4	54.5	7.3	103.6	76.1	19.0	5	D
TX18D3212	61.0	8.9	18.1	3.0	41.1	68.3	58.0	7.2	98.5	73.9	18.8	5	C
NC15V25-20	61.7	8.6	25.8	2.7	34.0	65.3	56.8	6.8	113.6	77.3	19.1	5	F
SCLA18WF0304-13	63.0	9.3	19.2	3.0	42.9	67.6	52.5	7.6	127.9	78.1	18.7	4	D
KWS477	61.5	8.6	20.3	2.7	40.3	69.0	53.2	7.1	95.4	75.1	19.4	4	C
Jamestown	61.8	9.7	17.6	2.9	36.7	66.5	54.4	7.7	118.3	75.4	18.9	5	F
VA20W-135	61.6	9.4	19.9	2.9	39.3	66.8	59.4	7.1	130.3	76.4	18.9	4	D
KWS495	60.2	9.6	14.2	2.9	41.7	67.8	52.5	7.5	99.2	71.0	18.9	5	D
FLLA16124LDH-51	62.4	9.1	36.4	2.9	39.8	68.2	44.9	7.4	112.4	79.2	18.1	4	C
GA15490 ID-19-5-21LE2	62.2	9.5	20.1	2.8	38.0	67.1	52.7	7.6	100.5	72.6	19.1	5	D
18VDH-FHB-MAS07-173-03	60.8	10.2	24.3	3.1	46.3	68.2	46.7	8.4	114.1	74.5	18.8	5	C
GA141556-5-1-21LE22	62.5	9.9	26.7	2.8	36.8	67.8	51.5	8.1	114.9	75.7	18.3	4	D
KWS397	60.1	9.1	16.3	3.0	44.1	68.3	54.2	7.1	102.3	70.3	19.5	5	C
UMD-21-MDW107	62.1	10.5	74.4	3.0	39.5	65.0	34.0	9.3	140.2	109.1	15.7	0	F
UMD-21-MDW314	59.5	9.8	11.1	2.8	38.0	70.6	55.1	8.0	89.1	70.1	19.4	5	A
NC16VT30-7-47	61.5	10.3	17.1	3.0	42.3	70.0	51.5	8.5	107.2	70.7	19.1	4	B
FL15105-LDH043	62.4	10.6	23.5	3.0	36.6	66.9	50.0	8.4	99.5	73.1	19.1	4	D
UMD-21-MDW104	61.1	9.9	28.5	2.8	35.7	67.3	51.0	8.2	131.8	76.0	19.0	5	D
TWR 29005	58.7	9.6	20.9	2.6	35.1	68.3	55.9	7.5	115.4	80.1	18.8	5	C
TWR 29014	61.1	9.3	13.7	2.7	37.0	68.7	60.1	7.1	116.1	74.6	18.8	5	C
TX2017DDH193	63.5	10.7	19.7	3.1	48.7	69.3	51.2	8.6	118.8	74.1	18.8	4	C
TWR 29012	61.0	9.3	13.9	2.7	39.1	68.3	59.9	7.2	117.8	74.5	18.7	4	C
Average	61.3	9.5	21.3	2.9	40.7	68.3	53.9	7.7	109.8	75.8	18.9	4.4	
Standard Deviation	1.1	0.6	10.7	0.1	3.7	1.6	5.1	0.6	12.3	6.2	0.6	0.9	

UNIFORM SOUTHERN SOFT RED WINTER WHEAT NURSERY 3

Rick Boyles, Clemson University

Thirty-seven advanced breeding lines and varieties were analyzed for test weight, grain protein content, kernel hardness, flour yield, softness equivalence, flour protein content, sodium carbonate SRC, lactic acid SRC and sugar-snap cookie baking quality. Letter grades (A, B, C, D or F) for flour yield were assigned to each entry based on the flour yield range of wheat breeding lines and varieties the SWQL tested in 2009-2022. Those entries that fell in the top 15% range of lines and varieties for flour yield received an 'A,' in the next 20% a 'B,' in the next 30% a 'C,' in the next 20% a 'D,' and in the bottom 15% an 'F.'

Compared to the prior fourteen-year averages of the ESW varieties and lines tested by the SWQL, the entries exhibited higher test weights by 2.1 lb/bu, kernel hardness values by 12.7 and flour yields by 0.6%, but lower softness equivalence values by 6.3%. Six entries showed kernel hardness values ranging from 31.4 to 70.3. 'UMD-21-MDW107' exhibited a kernel hardness of 70.3, indicative of hard wheat. The entries exhibited grain and flour protein contents higher than the prior fourteen-year averages by 0.4 and 0.8% respectively. There were five entries with flour yields ranging from 71.4 to 71.9%, receiving the flour yield grade 'A.' The average lactic acid SRC of the entries was higher by 7.4% than the prior fourteen-year average, likely due to the higher protein contents of this year's entries. Thirty-six out of thirty-seven entries exhibited higher sodium carbonate SRCs than the prior fourteen-year average of 69.6%. The cookie diameter of the entries ranged from 15.5 to 19.3 cm, and none received a cookie diameter grade of 'A.' The smallest cookie was obtained from 'UMD-21-MDW107,' which exhibited the highest kernel hardness.

Table 18. Uniform Southern Soft Red Winter Wheat Nursery 3 trial 2023 crop quality data

Entry	Test Weight (LB/BU)	NIR Kernel Protein (at 12%)	SKCS Kernel Hardness	SKCS Kernel Diameter (mm)	SKCS Kernel Weight (mg)	Adjusted Flour Yield (%)	Softness Equivalence (%)	Flour Protein (at 14%)	Lactic Acid SRC (%)	Sodium Carbonate SRC (%)	Cookie Diameter (cm)	Top Grade (0-9)	Adjusted Flour Yield % Grade
AGS 2000	62.4	11.6	20.6	3.0	46.3	71.4	48.2	9.9	99.0	74.6	18.1	3	A
Jamestown	62.7	12.4	24.3	3.0	38.2	66.9	49.6	10.1	113.7	77.0	17.3	3	D
Hilliard													
Pioneer Brand 26R41	61.6	10.5	31.4	2.7	35.0	69.7	53.5	8.8	113.6	75.1	17.7	3	B
FL15105-LDH043	62.2	13.0	26.0	3.0	36.0	66.9	46.6	10.8	111.5	75.0	17.4	3	D
FLLA16124LDH-51	62.4	11.2	38.7	3.0	41.7	68.7	41.8	9.7	113.4	77.2	16.7	2	C
GA131246LDH-86-21E2	61.0	11.0	24.3	2.9	38.2	71.9	54.9	9.0	94.0	71.6	18.8	3	A
GA17634DH-08-21E36	61.8	11.5	20.0	3.0	47.2	68.4	50.4	9.9	96.0	78.7	17.8	3	C
GA15490 ID-19-5-21LE2	62.8	10.3	21.5	2.7	35.3	68.9	51.8	8.7	108.6	71.8	18.7	3	C
GA141556-5-1-21LE22	63.6	10.5	32.4	2.7	33.8	69.6	50.7	9.0	110.1	74.8	17.9	2	B
KWS397	57.2	9.3	19.6	2.7	33.0	69.3	57.3	7.7	100.8	71.4	19.3	3	C
KWS477	62.0	9.6	28.6	2.7	37.5	69.7	52.4	8.0	95.7	74.0	18.4	4	B
KWS495	61.6	10.3	20.4	2.8	35.6	69.8	51.1	8.4	98.6	70.9	18.8	3	B
LA14234CBW-31	62.8	11.5	22.1	2.8	37.1	69.7	54.3	9.2	87.1	69.1	19.0	4	B
LA14272CBW-15-1-2	60.9	12.4	19.9	3.1	44.8	68.4	48.8	10.3	128.1	74.0	17.6	2	C
NC14711-12	62.6	11.3	32.1	2.7	34.4	68.2	50.1	9.6	123.0	75.1	18.1	3	C
NC15V25-20	63.2	10.3	37.1	2.5	28.3	66.7	53.3	8.5	96.9	76.9	18.6	4	D
NC16VT30-7-47	63.7	11.1	25.4	2.9	38.7	70.4	48.6	9.5	105.3	70.8	18.2	5	B
SCLA19WF2110	61.8	10.2	29.2	2.9	39.1	66.7	52.5	9.0	90.2	78.4	17.7	3	D
SCGA141638-8-4	63.1	11.8	28.7	3.1	43.5	70.1	44.9	10.2	98.3	74.2	18.0	4	B
SCLA18WF0304-13	64.1	11.1	24.7	3.0	41.0	69.2	50.9	10.0	123.9	77.8	17.0	2	C
TN 2301	62.6	10.8	23.9	2.7	36.5	67.3	53.7	8.7	108.6	73.7	18.2	4	D
TN 2302	62.1	10.0	24.6	2.8	37.9	70.1	55.2	8.4	124.3	73.8	18.7	3	B
TWR 29012	61.8	9.8	18.8	2.6	34.7	69.2	59.9	7.9	118.8	71.3	19.2	4	C
TWR 29036	60.8	9.5	17.6	2.8	36.6	70.6	58.7	7.9	119.1	69.1	19.2	3	B
TWR 29005	61.5	9.8	25.3	2.6	33.0	70.0	56.1	7.7	98.2	70.3	19.2	4	B
TWR 29014	61.8	9.3	20.2	2.6	33.4	69.6	60.3	7.5	100.3	70.3	19.3	5	B
TX18D3212	61.9	10.9	26.5	2.9	37.6	68.7	54.2	9.0	100.2	70.3	18.4	5	C
TX2017DDH193	63.7	11.6	21.0	3.1	46.8	70.1	48.8	9.9	113.2	72.2	18.4	3	B
AR09485-10-1	62.9	12.4	23.5	3.2	45.2	70.6	50.2	10.2	109.6	70.8	18.4	3	A
18VDH-FHB-MAS07-164-01	61.8	9.9	28.4	2.8	36.7	68.0	53.3	8.4	106.0	75.4	19.1	5	C
VA20W-135	63.7	9.2	29.2	2.9	35.9	67.7	57.1	7.7	121.1	74.9	18.1	5	D
17VDH-SRW05-169	61.0	9.9	14.1	2.7	35.6	71.6	58.9	8.1	102.8	70.1	18.9	4	A
18VDH-FHB-MAS07-173-03	60.0	10.6	28.4	2.9	38.7	69.6	49.2	8.6	107.5	72.3	18.7	4	B
UMD-21-MDW104	62.4	10.6	27.0	2.8	36.3	67.4	49.9	9.1	118.8	72.6	18.3	5	D
UMD-21-MDW107	62.5	11.2	70.3	3.0	36.6	67.0	35.0	10.3	133.9	98.7	15.5	4	D
UMD-21-MDW314	59.9	10.2	20.7	2.6	32.5	71.8	52.8	8.7	85.4	68.6	19.3	4	A
Average	62.0	10.7	26.3	2.8	37.7	69.2	51.8	9.0	107.7	74.0	18.3	4	
Standard Deviation	1.3	1.0	9.2	0.2	4.4	1.5	5.0	0.9	11.9	5.1	0.8	0.9	

MASON-DIXON REGIONAL NURSERY

Nicholas Santantonio, Virginia Polytechnic Institute and State University

Sixty-seven advanced breeding lines and varieties were analyzed for test weight, grain protein content, kernel hardness, flour yield, softness equivalence, flour protein content, sodium carbonate SRC, lactic acid SRC and sugar-snap cookie baking quality. Letter grades (A, B, C, D or F) for flour yield were assigned to each entry based on the flour yield range of wheat breeding lines and varieties the SWQL tested in 2009-2022. Those entries that fell in the top 15% range of lines and varieties for flour yield received an 'A,' in the next 20% a 'B,' in the next 30% a 'C,' in the next 20% a 'D,' and in the bottom 15% an 'F.'

The averages for grain and flour protein contents and sugar-snap cookie diameter of the 76 entries were not evidently different from the prior fourteen-year averages of the ESW varieties and lines tested by the SWQL. The average kernel hardness of the entries was higher by 9.6 than the prior fourteen-year average, which led to a lower average softness equivalence by 5.1%. Only one entry received a flour yield grade of 'A,' with flour yield of 72.0%. The entries exhibited a higher average lactic acid SRC value than the prior fourteen-year average by 13.2%. The entries exhibited unusually high sodium carbonate SRCs. The sodium carbonate SRCs ranged from 70.9 to 78.0%, which were all higher than the fourteen-year average of 69.6%. Only two entries produced sugar-snap cookies with diameters ranging from 19.5 to 19.8 cm, receiving a cookie diameter grade of 'A.'

Table 19. Mason-Dixon Regional Nursery trial 2023 crop quality data

Entry	Test Weight (LB/BU)	NIR Kernel Protein (at 12%)	SKCS Kernel Hardness	SKCS Kernel Diameter (mm)	SKCS Kernel Weight (mg)	Adjusted Flour Yield (%)	Softness Equivalence (%)	Flour Protein (at 14%)	Lactic Acid SRC (%)	Sodium Carbonate SRC (%)	Cookie Diameter (cm)	Top Grade (0-9)	Adjusted Flour Yield % Grade
MD19-16-463-12	61.6	10.2	18.5	3.1	50.9	69.1	52.3	8.3	117.8	76.5	18.0	3	C
17VDH-SRW03-204	61.8	10.6	20.4	2.9	42.0	67.5	52.8	8.5	123.2	78.2	17.8	3	D
18VTK12-111	60.8	10.9	38.7	2.8	37.7	65.1	42.4	9.1	115.8	80.5	17.6	2	F
X14-1031-103-4-1	57.9	9.8	16.9	2.7	36.5	67.1	56.2	8.0	119.1	76.4	19.1	2	D
X14-1031-104-7-3	59.0	9.3	19.1	2.9	38.6	67.4	59.1	7.3	107.8	72.8	19.5	5	D
MD19-1-9-34	60.6	9.6	25.8	2.9	41.0	68.9	53.4	7.6	103.3	75.4	19.3	4	C
MD19-16-463-4	60.5	10.5	23.7	2.7	37.7	67.7	51.2	8.4	104.4	77.4	18.3	3	D
MD19-195-4	61.6	10.5	38.6	3.0	38.3	66.2	46.9	8.5	114.4	88.5	17.3	3	F
18VTK10-77	61.0	9.7	23.6	2.8	36.1	66.7	54.5	7.8	133.1	80.3	18.4	4	D
X14-1209-140-12-1	61.2	10.4	29.0	2.8	37.6	67.4	52.9	8.0	114.2	78.2	18.5	4	D
MD19-1-9-37	62.0	9.3	12.9	3.0	47.8	69.1	53.9	7.7	119.6	78.2	18.9	5	C
17VTK18-13	61.2	9.9	12.6	3.1	43.1	68.9	52.1	7.6	99.2	73.8	19.0	4	C
X14-1107-95-18-5	61.7	9.6	31.8	2.9	41.3	68.0	51.0	8.2	103.2	80.0	18.4	3	C
VA21W-39	61.5	9.7	19.1	3.0	44.6	67.6	56.6	7.9	95.8	73.4	19.1	4	D
MD19-195-2	61.7	10.3	28.6	2.9	35.1	68.5	48.9	8.4	110.0	76.5	18.5	3	C
X14-1209-141-18-3	61.4	10.2	28.4	2.8	36.6	67.2	51.2	8.2	111.4	78.7	18.5	3	D
MD19-1-9-30	60.2	10.4	17.3	2.8	40.2	67.7	55.5	8.1	113.3	78.0	18.6	4	D
X15-1079-130-7-5	60.8	10.1	35.0	2.9	40.0	67.1	50.1	8.3	104.2	83.4	17.9	4	D
MD-21-MDW105	59.8	9.9	22.0	2.7	38.1	68.1	53.6	8.2	126.0	78.7	18.1	4	C
X14-1206-52-2-1	60.0	10.0	30.2	2.7	37.6	66.5	51.2	8.1	117.2	83.0	18.2	4	F
X14-1217-49-11-1	62.2	10.8	30.2	2.9	39.1	67.3	53.8	8.9	132.1	82.6	18.0	2	D
VA21FHB-8	60.8	11.7	22.5	3.0	39.4	67.1	48.1	9.4	106.2	79.4	18.1	2	D
MD19-4-98-27	60.8	10.2	24.6	2.7	37.4	69.6	54.2	8.4	120.0	76.9	18.7	5	B
VA21W-76	60.8	9.5	15.5	3.0	45.9	68.1	60.3	7.2	94.0	84.6	18.2	4	C
VA20FHB-21	61.9	9.9	26.4	2.9	44.1	65.5	51.4	7.7	129.8	83.8	18.1	4	F
18VTK10-110	61.2	10.2	33.6	2.7	35.9	67.5	51.5	8.0	122.0	80.5	18.1	4	D
Hilliard	60.7	10.3	16.2	2.7	38.6	67.8	57.1	7.9	119.8	79.4	18.5	3	D
X14-1205-147-16-1	61.6	9.9	22.8	2.7	37.0	66.8	56.2	8.0	142.7	78.0	18.6	3	D
19VT1FHB_DH-241	60.8	10.6	23.0	2.8	38.1	66.6	52.6	8.6	119.0	79.9	18.4	2	D
MD19-15-447-4	60.5	9.4	19.7	2.9	40.4	69.8	55.0	7.4	94.5	71.3	19.2	3	B
Shirley	59.5	10.0	17.9	2.8	41.2	69.3	51.9	7.8	82.2	78.5	18.8	4	C
Pioneer 26R59	61.4	10.0	18.5	2.8	41.4	69.6	56.1	7.6	103.5	75.8	19.0	5	B
18VTK15-27	58.7	10.0	8.6	3.0	44.2	69.1	57.4	7.7	125.8	73.1	19.0	3	C
VA21W-60	61.9	10.5	31.2	2.9	40.6	67.5	49.0	8.6	128.4	80.0	18.1	4	D
MD19-195-16	61.5	9.8	22.8	2.8	35.2	70.4	56.0	7.7	94.6	75.5	18.7	4	B
MD19-1-9-28	60.7	9.9	13.2	2.8	43.3	68.3	55.8	7.8	108.7	75.7	18.9	4	C
MD19-4-98-19	60.5	10.1	24.5	2.9	42.8	69.2	53.2	8.6	110.9	76.0	18.3	3	C
18VTK18-112	61.9	10.2	26.0	3.1	44.3	68.7	48.7	8.2	129.1	76.2	17.7	3	C
18VTK12-60	60.2	10.1	33.1	2.8	36.2	66.7	49.6	8.2	112.5	81.3	18.0	3	D
X15-1091-98-18-3	60.2	10.6	18.0	2.9	42.4	67.5	51.8	8.4	110.8	77.9	18.5	4	D
16VT07-5-4-3	62.3	10.8	23.1	2.8	37.3	72.0	53.4	8.8	100.8	70.9	18.7	5	A
MD19-1-9-5	62.0	11.1	27.0	2.9	36.6	67.1	52.5	9.0	127.4	80.0	18.1	4	D
X15-1118-27-1-3	61.9	11.0	27.0	3.1	43.5	68.0	49.0	9.1	102.3	85.2	18.0	4	C

ARS20W231	58.0	9.8	23.2	3.0	40.7	64.7	51.1	7.6	124.8	80.9	18.0	3	F
X14-1008-92-13-3	61.1	10.0	15.2	2.9	42.3	68.5	55.3	8.0	107.9	72.9	18.8	4	C
X16-3013-1-12-5	61.7	10.2	28.6	2.9	38.4	68.4	51.8	8.1	108.6	79.3	18.3	4	C
18VTK6-3	61.6	10.4	29.6	2.8	36.3	67.5	51.3	8.6	116.2	77.7	18.4	4	D
X14-1205-147-13-5	62.0	10.1	20.9	2.7	38.2	67.0	56.5	8.0	143.2	75.6	18.5	4	D
ARS20W012	60.2	10.6	32.4	2.9	36.1	64.3	53.8	8.4	109.5	78.7	18.5	4	F
X14-1107-95-19-5	62.0	10.4	27.3	3.0	44.5	67.8	52.1	8.5	115.1	77.2	18.4	4	D
X14-1110-80-12-1	61.4	10.5	29.4	3.1	46.8	66.9	47.3	8.5	108.7	80.4	18.0	3	D
X14-1027-131-19-5	60.6	10.2	24.2	2.9	40.8	65.5	53.5	7.8	122.3	78.9	18.7	4	F
L11541	61.5	9.8	26.2	2.8	35.1	70.0	54.1	8.0	115.3	74.2	18.8	5	B
MD19-195-13	61.2	9.9	20.0	3.0	40.3	67.5	54.2	7.3	105.5	76.7	18.6	4	D
X14-1147-158-14-5	58.3	9.5	15.4	3.0	44.3	67.1	52.4	7.5	119.9	77.1	18.6	4	D
MD-16-W58	58.6	10.0	20.2	2.7	39.5	67.6	50.7	7.7	97.3	78.7	18.8	5	D
ARS20W039	62.5	11.1	32.5	3.0	47.1	69.7	48.7	9.2	106.3	81.3	17.7	3	B
MD19-195-10	60.1	10.9	10.1	3.0	43.9	68.4	55.9	8.3	134.3	76.0	18.6	3	C
MD19-4-98-3	62.2	10.0	20.3	2.9	39.4	69.5	55.6	8.2	125.5	74.2	18.9	5	B
VA21W-126	60.5	9.5	10.3	3.0	42.4	69.4	51.0	7.1	84.8	73.8	19.8	5	C
X14-1147-137-4-1	60.4	9.1	19.1	2.9	40.8	65.4	56.0	7.3	108.1	80.0	19.0	5	F
18VTK10-188	60.5	9.1	23.5	2.8	38.1	67.8	57.7	7.3	119.9	78.8	18.8	5	D
18VTK5-95	61.3	9.2	23.4	2.9	37.7	67.1	58.0	7.6	124.0	79.8	18.7	5	D
VA20FHB-18	61.5	9.4	24.3	2.9	42.5	65.1	53.7	7.3	124.4	78.8	18.6	5	F
MD19-19-555-3	62.0	9.7	28.5	3.1	41.7	70.2	50.9	8.0	97.6	77.0	18.1	3	B
MD19-15-423-1	62.0	10.3	18.5	3.0	42.7	68.3	53.5	8.5	99.9	74.9	18.7	5	C
X15-1091-49-2-3	61.0	9.9	10.5	2.8	42.0	68.0	56.4	7.8	117.1	74.0	19.3	5	C
Average	60.9	10.1	23.2	2.9	40.4	67.8	53.0	8.1	113.5	78.0	18.5	4	
Standard Deviation	1.1	0.5	6.9	0.1	3.4	1.4	3.2	0.5	12.6	3.3	0.5	0.9	

MATERIALS AND METHODS

QUADRUMAT MILLING TESTS – BREEDER SAMPLES

The Soft Wheat Quality Laboratory evaluates thousands of breeder wheat samples yearly. Table 20 summarizes the traits tested and reported to breeders by the SWQL. The SWQL milling methods are described below.

Table 20. Milling and baking measurements and calculations for evaluation of breeder samples

TRAIT	SYMBOL	DESCRIPTION / CALCULATION
Whole Grain Protein	WPRO	Percent protein of whole, untempered grain measured on DA7200 near infrared (NIR) analyzer
Whole Grain Hardness	Hard	Scale of 1-120, soft to hard. Whole, untempered grain measured using Single Kernel Characterization System
Grain Weight	GW	Weight of tempered, whole grain sample
Bran	Bran	Weight of milled product retained by 40-mesh* screen (over 40)
Midds	Midds	Weight of milled product retained by 94-mesh* screen (over 94)
Break Flour	BkFl	Weight of milled product passing through 94-mesh* screen (Grain weight – (bran + midds))
Percent Bran, MIdds, Break Flour	%	Expressed as percent of grain weight (Bran Weight/GW) x 100
Total Flour	Flour	Break Flour + Midds
Flour Yield	FY	(Total Flour/GW) x 100
Softness Equivalence	SE	(BkFl/Total Flour) x 100
Flour Moisture	FMOIST	Percent moisture of wheat flour estimated by Unity NIR
Flour Protein	FPRO	% protein of wheat flour by Unity NIR
Cookie Diameter	Cookie Dia	Total diameter of 2 baked cookies (cm)
Cookie Top Grain	Cookie TopG	0-9 visual scale (0 worst, 9 best)
Solvent Retention Capacity Tests	SRC	Percentage of solvent retained by a flour/solvent slurry after centrifugation and draining
Lactic Acid Sodium Carbonate Sucrose Water	LA SC SU WA	((residue wt/ flour wt)-1) x (86/(100 - %FMOIST)) x 100 flour wt = weight of dry flour residue wt = weight of drained, saturated flour

* Mesh size is the number of openings in the SSBC screen per linear inch; smaller particles pass through higher mesh number.

MODIFIED QUADRUMAT MILLING METHOD

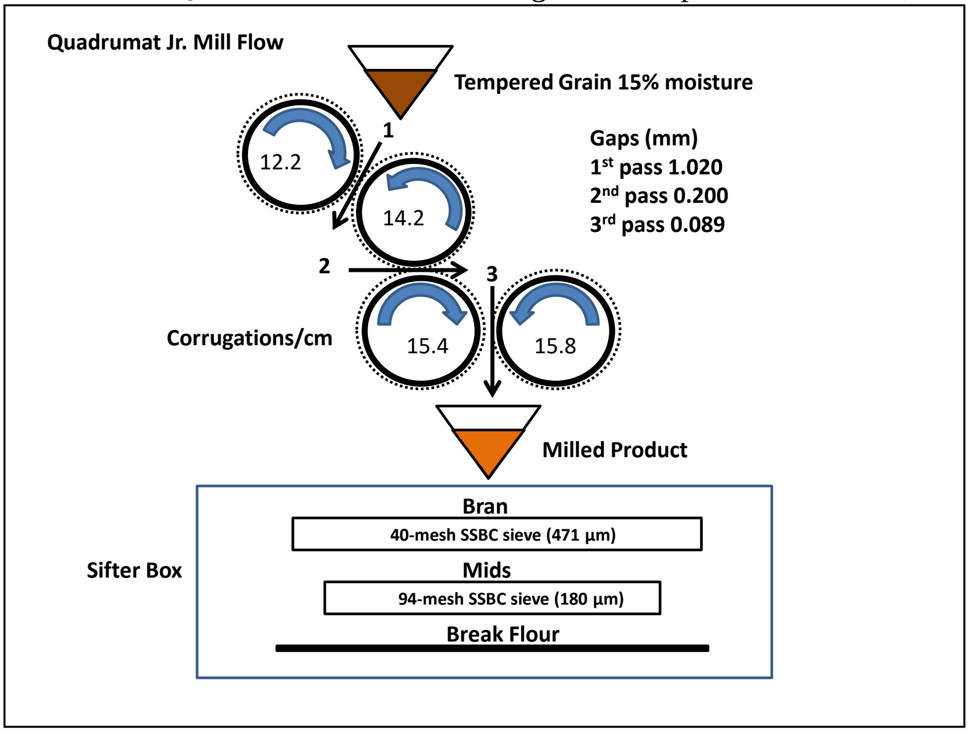
Tempering: Prior to milling, wheat grain is estimated for moisture content using a Perten NIR DA7200 whole grain analyzer and tempered to 15% moisture. Grain samples are tempered in glass jars by adding distilled water, sealing with silicon-free, screw-top lids and tumbling on a chain driven roller/conveyor (Lewco) until the water is absorbed, about 30 minutes. Tempered grain samples are kept sealed at room temperature for at least 24 hours prior to milling to allow moisture equilibration throughout the kernel. For the ***preliminary*** group samples, *tempered grain* is fed into the Quadrumat break roll unit and passed through three sets of milling rolls, each with increasing corrugations per centimeter and decreasing gaps to decrease particle size sequentially from grain to flour.

Milled product is sifted on a Great Western sifter box through sequential 40- and 94-mesh stainless steel bolting cloth (SSBC) screens, with 471 and 180 micron openings, respectively, to separate the milled product into three fractions: bran, midds and break flour. Bran is recovered above the 40-mesh screen, midds above the 94-mesh screen, and break flour passes through the 94-mesh screen. For ease of handling and accuracy, the bran and midds fractions are weighed as an indirect method for calculating flour yield (grain sample weight less bran as a percent of total grain weight) and softness equivalence (break flour as a percent of total flour).

For the ***intermediate*** group and ***advanced*** group grain samples, middlings are further passed through the Quadrumat reduction roll unit to obtain shorts and reduction flour. The milled fraction is sifted on an 84-mesh screen (213 micron openings) to yield shorts and reduction flour. Break and reduction flours are combined, blended to produce straight grade flour and used for composition, SRCs and cookie baking tests. Bran yield, break flour yield and total flour yield are determined the same ways as described for the preliminary group samples. All samples are milled under controlled temperature and humidity (19-21^{o}C and RH 58-62%). Mill temperature is equilibrated to 33 ± 1.0^{o}C by running the mill empty prior to sample milling.

Bran yield (%) is the percentage of bran retained by a 40-mesh SSBC screen (471 micron opening size) over the grain weight. Break Flour Yield (%) is the percentage by weight of the flour sifted through a 94-mesh SSBC screen (180 micron) over the grain weight. Midds (%) is the percentage middling stock (retained by the 94-mesch screen) over the grain weight. Potential Flour Yield (%) is the percentage by weight of the sum of break flour and middling stock over the grain weight.

Figure 1. Brabender Quadrumat break roll milling unit – adapted from Gaines, et al, 2000.



BREEDING SAMPLES

The SWQL treats samples as ***preliminary, intermediate*** or ***advanced*** group samples. The difference in treatment for each test type is summarized in Table 21.

Preliminary group testing is used for screening early generation selections, *intermediate* testing is used for intermediate generation samples and *advanced* testing is for advanced breeding lines. Milling scores produced for all three sample treatments are determined in the same way. *Intermediate* and *advanced* group testing add SRC and flour protein determinations, and *advanced* group testing includes sugar-snap cookie baking.

Preliminary group testing involves grain characteristics (TW, Grain NIR for protein and kernel hardness) and milling properties for breeders to screen early generation lines. Grain is milled using the Quadrumat break roll unit to obtain bran, middling and break flour. Flour yield and softness equivalence are calculated based on the equations described below in **Soft Wheat Quality Laboratory Testing Methods for Quality Traits** and summarized in Table 22. No further tests are performed using the break flour.

Intermediate and ***advanced*** group samples are milled using both the break and reduction roll units to produce break and reduction flours. The blend of break flour and reduction flour (straight grade flour) is used for flour quality tests. Grain characteristics and milling properties (TW, Grain NIR for protein and kernel hardness, flour yield and softness equivalence) are determined as for the preliminary groups. In addition, straight grade flour is tested for protein content and solvent retention capacity (SRC) of sodium carbonate and lactic acid. For ***advanced*** group samples, the straight grade flour is used for the sugar-snap cookie baking test.

Table 21. Differential processing of *Preliminary*, *Intermediate* and *Advanced* testing at SWQL

PROCEDURE	***Preliminary***	***Intermediate***	***Advanced***
Sample Size	80 g		200 g
Test weight	Whole grain		
Milling Method	Break Roll Unit Milling	Break and Reduction Roll Units Milling	
Flour Yield	Midds+Flour/Grain x 100		
Softness Equivalence	(Break Flour/Total Flour) x 100		
Kernel Hardness	Single Kernel Characterization System (SKCS)		
Whole Grain Protein & Moisture	DA7200 NIR		
Flour Test	NO	Straight Grade Flour (blend of break and reduction flours)	
Flour Moisture/Protein Content	NO	YES – Unity NIR	
Solvent Retention Capacity Tests (SRC)	NO	YES	
Sucrose	NO		YES upon request (5-g test)
Lactic Acid	NO	YES (1-g test)	
Water	NO		YES upon request (1-g test)
Sodium Carbonate	NO	YES (1-g test)	
Sugar-snap Cookie Diameter	NO		YES
Sugar-snap Cookie Top Grain	NO		YES

SOFT WHEAT QUALITY LABORATORY TESTING METHODS FOR QUALITY TRAITS

Traits included in the SWQL evaluation of breeding samples, the method used, the purpose of the measurement and measurement units are summarized in Table 31, below. Complete descriptions of the individual SWQL methods follow below.

Table 22. Traits measured at SWQL: methods, purpose and units

TRAIT	METHOD	INDICATES	UNITS
Test Weight	Modified AACC Method 55-10	Grain size, condition, packing efficiency	Estimated Pounds/bushel
Hardness (SKCS)	Perten Single Kernel Characterization System (SKCS) AACC Method 55-31.01	Grain hardness <40 is considered soft wheat	0-120
Whole Grain Protein & Moisture	Near Infra Red (NIR) Perten DA7200	Whole grain Protein & Moisture content	0-100 Percent
Falling Number	Perten Falling Number Tester AACC Method 56-81.03	Pre-harvest sprout damage	seconds
Flour Yield	midds + break flour as % of initial grain weight	Flour recovery	Percent
Softness Equivalence	Break flour weight as % of total flour weight (Finney, 1986)	Estimates grain hardness, flour particle size	Percent
Flour Ash	AACC Method 08-01	Inorganic residue after combustion	Percent
Flour Moisture	NIR Unity Spectra-Star	Flour moisture	Percent
Flour Protein		Flour protein content	Percent
Solvent Retention Capacity Profile (SRC)	AACC Method 56-11.02	Solvent affinity	Percent
	Lactic Acid	Gluten strength	
	Sodium Carbonate	Damaged starch	
	Sucrose	Pentosan Content (Arabinoxylans)	
	Water	Overall water affinity	
Sugar-snap Cookie Diameter	Baking Quality of Cookie Flour, Intermediate Method AACC Method 10-52	Cookie spread	Centimeters
Sugar-snap Cookie Top Grain		Visual quality cookie surface	1-10 higher is better

Grain Moisture, Hardness and Protein

Grain moisture and protein are estimated using the NIR DA7200 Analyzer (Perten Instruments). Adjustment of calibrations was performed in Wooster, Ohio, for grain moisture and protein using values produced on the oven moistures (AACC Method 44-01.01) and nitrogen combustion analysis Rapid NIII Nitrogen Analyzer (Elementar), respectively.

Definitions:

Grain is the cleaned whole grain.

Break flour (BkFl) is the flour passing through the 94 mesh screen after a single pass through the Quadrumat break roll unit. Break flour has the finest particle size. Break flour weight is approximated by subtracting the weight of bran and midds from the tempered grain weight.

Midds (middlings) is the particles/grits passing through the 40 mesh screen but retained by the 94 mesh screen after a single pass through the Quadrumat break roll unit.
Bran is the pieces of wheat grain outer layers retained by the 40 mesh screen after a single pass through the Quadrumat break roll unit.

Reduction flour is the flour passing through an 84 mesh screen after a second, reduction milling of the midds (from break roll unit) through the Quadrumat reduction roll unit.

Straight Grade Flour is a blend of break flour and reduction flour.

Flour Yield

Flour yield (FY) is calculated as the percent total flour weight (break flour + midds) of the tempered grain weight (GW) from a single pass through the Quadrumat break roll unit. For calculation of flour yield, the difference between the grain weight (GW) and the bran weight (Bran) is used to estimate total flour (midds + break flour).

FY = ((GW-Bran)/GW) x 100

The formula is equivalent to: **(Total Flour/GW) x 100**

Softness Equivalence

Softness Equivalence (SE) is the percentage break flour (BkFl) passing through 94-mesh screen, of the total flour weight (break flour + midds). SE approximates grain softness and particle size of flour produced from a single pass through the Quadrumat break roll unit (*C.W. Brabender Instruments, Inc.*) and is analogous to break flour in a large-scale mill (Finney, 1986). Total flour weight is calculated by subtracting bran weight (remaining over the 40-mesh screen) from initial grain weight. Subtracting the weight of the midds (remaining over the 94-mesh screen) from the total flour gives the weight for break flour.

SE = {(GW – (Bran + Midds))/(GW - Bran)} x 100

This formula is equivalent to: **(BkFl/Total flour) x 100**

Flour Moisture and Protein

Flour moisture and protein are estimated using the SpectraStar NIR analyzer (Unity Scientific), calibrated yearly for protein by nitrogen combustion analysis using a combustion nitrogen analyzer (Leco) and for moisture by the oven drying method (AACC method 44-01.01). Units are recorded in percent moisture or protein converted from nitrogen x 5.7 and expressed on a 14% moisture basis.

Solvent Retention Capacity

Solvent Retention Capacity (SRC) assays are performed as described in AACC Method 56-11.02, *Solvent Retention Capacity Profile*. The profile of SRCs in the four solvents (sucrose, lactic acid, sodium carbonate and water) is used to predict milling and baking quality. In general, lower SRCs are preferred for water, sodium carbonate and sucrose solvents (Kweon, Slade, & Levine, 2011).

Breeder samples processed by intermediate and advanced group testing use *straight grade flour* (blend of break and reduction flours) for SRC tests.

With the exception of sucrose, SRCs are performed using 1 gram of flour in glass test tubes with rubber stoppers. Sucrose SRCs are performed with 5 grams of flour in 50 mL disposable screw top centrifuge tubes, because the highly viscous sucrose solution impedes even distribution of solution in 1 gram flour tests, reducing the reliability of the small scale test.

The following descriptions of the biochemistry and correlations of SRCs with milling and baking traits were published in the Soft Wheat Quality Laboratory Annual Report 2011 (Souza, Kweon, & Sturbaum, 2011).

Water SRC is a global measure of the water affinity of the macro-polymers (starch, arabinoxylans, gluten, and gliadins). Lower water values are desired for cookies, cakes, and crackers, with target values below 51% on small experimental mills and 54% on commercial or long-flow experimental mills.

Sucrose SRC values are related to the content of arabinoxylans (also known as pentosans), which can strongly affect water absorption in baked products. Sucrose SRC is a good predictor of cookie quality and shows a negative correlation with wire-cut cookie diameter ($r = -0.66$, $p<0.0001$). The cross hydration of gliadins by sucrose also causes sucrose SRC values to be correlated to flour protein ($r = 0.52$) and lactic acid SRC ($r = 0.62$). The 95% target value can be exceeded in flour of high lactic acid SRC.

Sodium carbonate SRC takes advantage of the very alkaline solution to ionize the ends of starch polymers increasing the water binding capacity of the molecule. Sodium carbonate SRC increases as starch damage due to milling increases.

Lactic acid SRC predicts gluten strength of flour. Typical values are below 85% for “weak” protein soft wheat varieties and above 110% for “strong” protein soft wheat varieties. Lactic acid SRC results correlate to the SDS-sedimentation test. The lactic acid SRC is also correlated to flour protein concentration and dependent on genotypes and growing conditions.

Cookie Bakes (Sugar-Snap Cookies)

Two sugar-snap cookies are baked in the SWQL bake laboratory for each sample as described in AACC Method 10-52, *Baking Quality of Cookie Flour*. Cookies are baked exclusively for advanced group samples using straight grade flour (blend of break and reduction flours). Diameter of the two cookies is measured and recorded electronically using a Mitutoyo Absolute Digimatic Caliper. Cookies are graded visually for surface appearance and color, from worst to best on a scale of 1 to 10.

Falling Number

The falling number test (AACC Method 56-81B) is performed using the Perten Falling Number instrument. A glass tube filled with a suspension of whole grain meal or milled flour is heated in a boiling water jacket to produce gelatinized starch. Immediately after heating, a weighted plunger is released into the suspension, and the travel time of the plunger is measured in seconds (falling number) as it falls from the top to bottom of the glass tube. The higher the viscosity of whole grain meal or flour paste in the glass tube, the longer the travel time of the plunger. The enzyme α-amylase, produced when grain sprouts, hydrolyzes starch molecules and lowers the viscosity of gelatinized starch, resulting in decreased travel time of the plunger (falling number). Alpha-amylase can be measured directly using a kit from Megazyme, International (AACC Method 22-02-01, *Measurement of alpha-Amylase in Plant and Microbial Materials Using the Ceralpha Method*). The SWQL uses a modified micro method of the Megazyme assay.

Flour Ash

Flour Ash is measured according to the AACC method 08-01 and detects residual inorganic materials after combustion. Since inorganic materials are higher in bran than in endosperm, flour ash is an indirect indicator of residual bran in the flour.

Materials and Methods References

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