# Exploring New Methods and Technologies for Wheat End-use Quality Testing and Benchmarking for the U of M Breeding Program

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## Research Questions

Breeding programs such as the spring wheat breeding program at the University of Minnesota's Department of Agronomy and Plant Genetics need to continually evaluate their germplasm, leading to the daunting task of determining parameters indicative of end-use quality of hundreds of samples. The overall goal of this project was to reduce the work load of this daunting task by determining rapid and effective means to screen the numerous wheat varieties produced at the early stages of the breeding process.

Specifically, our objectives were to develop regression models based on parameters (Maximum Peak Time [MPT], Aggregation Energy [AE] and Torque Maximum [MT]) obtained from the GlutoPeak Tester (i.e., gluten aggregation kinetics) and Solvent Retention Capacities (SRC) (in water (WSRC), 5% lactic acid (LASRC), 5% sodium carbonate (SCSRC), and 50% sucrose (SuSRC); which are indicative of polymer swelling due to gluten development, damaged starch, or arabinoxylan interactions, respectively) for predicting the Farinograph and Mixograph water absorption, as well as Bread volume of wheat varieties. The wheat varieties used consisted of wheat lines developed by the University of Minnesota wheat breeding program harvested from two locations, Saint Paul and Crookston.

We also evaluated a range of other parameters for potential correlations with Farinograph and Mixograph water absorption, including protein solubility, protein secondary structure distribution, accessible and total thiols, as well as pasting properties. Most of these other parameters however, were found not to be rapid processes. This report will thus concentrate on parameters from the GPT and Solvent Retention capacities.

## Results

■ Two of the GlutoPeak parameters (MPT and MT) were not significantly different for samples in the different locations, but one parameter, i.e. aggregation energy, was lower for samples from Saint Paul. This indicates that Saint Paul as a growing location produces wheat with lower gluten strength. The range of values is listed in Table 1

■ Samples from Saint Paul did not significantly differ from those grown in Crookston in Farinograph parameters (Table 1)

■ Polynomial regression models from GlutoPeak and SRC parameters to predict conventional flour and dough testing parameters were developed. Tables 2 and 3 shows the coefficients of determination ($R^2$) of the models developed for wheat varieties from the different locations. The models can be seen in Table 4. These regression models will be used to calculate the Farinograph and Mixograph water absorption of wheat varieties by just running them on the GPT and determining their SRCs.

■ GlutoPeak and SRC parameters successfully predicted the Farinograph and Mixograph water absorption of samples from the different locations (Tables 2 and 3). The regression models developed to predict the Mixograph and Farinograph water absorption of wheat varieties from SRC parameters had $R^2$ as high as 95.4% for Crookston and 96% for Saint Paul respectively. Higher $R^2$ values were also obtained for models for predicting Mixograph and Farinograph water absorption from the GPT Parameters.

■ These results indicate the potential of using GlutoPeak and SRC as alternatives to Farinograph or the Mixograph for the rapid and effective screening of large numbers of wheat samples. Response surface plots were also generated to show the relation amongst these parameters (Figure 1)

The project also screened over 1000 samples from the University of Minnesota Wheat Breeding Program for end use quality testing using the GPT.

## Application and Use

Information generated from this study is important in confirming the use of the GPT and SRC methods as a rapid and effective tool for screening large numbers of wheat samples from the University of Minnesota Wheat Breeding Program. These two methods will thus be adopted as screening methods for the wheat breeding program.

## Materials and Methods

20 wheat lines were grown in St. Paul or Crookston, Minnesota. Samples were milled on a Quadrumat Junior (Brabender, 880102.001, Duisburg, Germany), and the refined flours assessed in duplicate by the following methods:

- Gluten aggregation kinetics by GlutoPeak (Brabender 10-20-000, South Hackensack, New Jersey, USA)
- Dough mixing properties by Farinograph-AT (Brabender 810162, Duisburg, Germany)
- Solvent Retention Capacity (AACC method 56-11)
- Dough Extensibility by Kieffer Rig (Texture Analyser TA-XT2i, Hamilton, Massachusetts, USA)
- Protein conformation by Fourier Transformed Infrared Spectroscopy (FTIR) (Bruker Optics Tensor37, Billerica, Massachusetts, USA)

- Protein solubility in sodium phosphate buffer, sodium phosphate buffer containing 8M urea, and sodium phosphate buffer containing 8M urea and 0.01M dithiothreitol (Marengo et al. 2015)
- Readily accessible and SDS-Accessible thiols following the method of Iametti et al. (2006)
- Pasting properties on a Micro-Visco-Amylo-Graph (Brabender 803222, Duisburg, Germany)
- Solvent Retention Capacity

In addition, samples grown in Crookston were also evaluated at the USDA-ARS laboratory in Fargo, North Dakota, for dough and bread characteristics.

## Appendix

**Table 1.** Overview of sample characteristics (n=20 per location) and their range encountered in wheat varieties grown in Crookston and Saint Paul, Minnesota. Means followed by an asterisk are significantly different (*P* < 0.05) as assessed by a paired t-test.

| Method | Parameter | Minimum | Maximum | Mean | Median | Standard deviation |
|---|---|---|---|---|---|---|
| GlutoPeak | Peak maximum time (s) | | | | | |
| | Crookston | 31 | 97 | 68 | 68 | 14 |
| | Saint Paul | 28 | 95 | 64 | 63 | 14 |
| | Maximum Torque (BU) | | | | | |
| | Crookston | 60 | 69 | 68 | 59 | 4 |
| | Saint Paul | 53 | 72 | 60 | 60 | 5 |
| | Aggregation energy (GPI) | | | | | |
| | Crookston | 1363 | 1787 | 1529* | 1494 | 121 |
| | Saint Paul | 1326 | 1725 | 1493* | 1475 | 122 |
| Farinograph | Dough development time (min) | | | | | |
| | Crookston | 2.33 | 36.24 | 11.42 | 7.32 | 10.47 |
| | Saint Paul | 1.89 | 48.32 | 12.07 | 5.75 | 14.11 |
| | Stability time (min) | | | | | |
| | Crookston | 5.2 | 39.6 | 17.2 | 18.1 | 8.2 |
| | Saint Paul | 8.5 | 53.7 | 19.8 | 16.7 | 10.8 |
| | Water absorption | | | | | |
| | Crookston | 56.1 | 65.5 | 61.8 | 61.8 | 2.3 |
| | Saint Paul | 57.6 | 65.8 | 61.0 | 60.6 | 2.3 |
| Kieffer-rig | Extensibility (mm) | | | | | |
| | Crookston | 26.7 | 60.0 | 43.1 | 45.1 | 10.5 |
| | Saint Paul | 25.3 | 59.0 | 44.4 | 46.8 | 9.6 |
| | Resistance to extension (g) | | | | | |
| | Crookston | 13.2 | 38 | 21.5 | 19.3 | 7.5 |
| | Saint Paul | 12.0 | 29.3 | 19.4 | 19.0 | 4.7 |
| Solvent retention capacity | Water | | | | | |
| | Crookston | 64.6 | 75.0 | 68.9* | 68.4 | 2.9 |
| | Saint Paul | 62.2 | 74.3 | 67.9* | 67.1 | 3.3 |
| | Lactic acid | | | | | |
| | Crookston | 110.9 | 137.0 | 124.1* | 123.9 | 6.4 |
| | Saint Paul | 101.0 | 137.0 | 115.9* | 116.8 | 7.9 |
| | 5% sodium carbonate | | | | | |
| | Crookston | 77.6 | 94.2 | 83.7* | 83.2 | 4.0 |
| | Saint Paul | 63.4 | 82.9 | 71.5* | 70.3 | 6.3 |
| | 50% sucrose | | | | | |
| | Crookston | 96.6 | 112.9 | 103.8* | 104.7 | 4.0 |
| | Saint Paul | 91.8 | 106.4 | 100.6* | 101.0 | 4.0 |
| * indicates significant differences between Crookston and Saint Paul samples | | | | | | |

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## Economic Benefit to a Typical 500 Acre Wheat Enterprise

Results generated from this research is important in the selection of not only wheat varieties with higher yields or better agronomic traits but also with the best end-use proprieties. Wheat with better end-use properties will attract a premium for the farmer, thus increasing profitability.

## Related Research

This research is my first funded research from the council and is related to earlier research done by my predecessor Koushik Seetharaman on exploring the GPT for measuring wheat gluten strength.

## Recommended Future Research

It is recommended that the GPT and Solvent Retention Capacity methods be adopted for the Rapid Screening of Wheat samples from the University of Minnesota Breeding Program. It is also recommended that regression models be developed for the other locations of the Wheat Breeding Program.

## Publications

**Predicting dough and bread-making properties of genetically diverse hard red spring wheat using the rapid high shear rate gluten peak tester. George A. Annor, James Anderson, Citra Rahardjo, Linda Dykes, Catrin Tyl** (Manuscript in preparation to be sent to the Journal of Cereal Science).

## Appendix *continued*

**Table 2.** Regression coefficients of the quadratic models developed to predict Farinograph parameters and dough resistance to extension using GPT parameters of wheat grown in different locations.

| Property | Growing location | $R^2$ |
|---|---|---|
| Mixograph Water absorption | Crookston | 70.2 |
| | Saint Paul | ND |
| Farinograph water absorption | Crookston | 76.2 |
| | Saint Paul | 88.4 |
| Bread volume | Crookston | 22.5 |
| | Saint Paul | ND |
| ND: No Data from USDA-ARS Lab in Fargo | | |

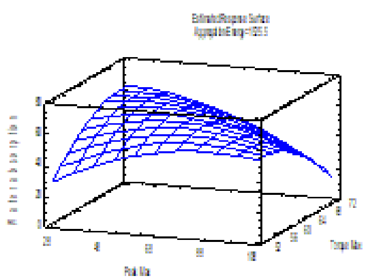
**Table 3:** Regression coefficients of the quadratic models developed to predict Farinograph and Mixograph water absorption using SRC parameters.

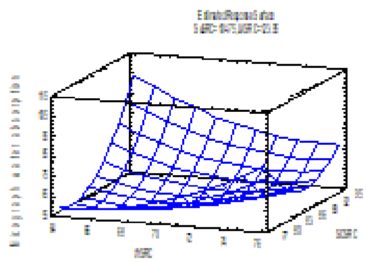
| Property | Growing location | $R^2$ |
|---|---|---|
| Mixograph Water absorption | Crookston | 95.4 |
| | Saint Paul | ND |
| Farinograph water absorption | Crookston | 62.3 |
| | Saint Paul | 96.0 |
| Bread volume | Crookston | 58.2 |
| | Saint Paul | ND |

**Table 4:** Regression models developed for parameters measured

| Parameter (Saint Paul) | Regression Model |
|---|---|
| Farinograph Water Absorption (GPT parameters) | Water absorption = -144.897 + 2.53649*Peak Max + 8.18056*Torque Max - 0.173085*Aggregation Energy - 0.00717973*Peak Max^2 - 0.0448881*Peak Max*Torque Max + 0.000702608*Peak Max*Aggregation Energy - 0.0984598*Torque Max^2 + 0.00457747*Torque Max*Aggregation Energy - 0.0000490895*Aggregation Energy^2 |
| Farinograph Water Absorption (SRC parameters) | Water absorption = -2.47576 - 5.25585*WSRC - 0.295352*SCSRC + 3.81727*SuSRC + 0.955478*LASRC + 0.168361*WSRC*SCSRC - 0.0610205*WSRC*LASRC - 0.0849779*SCSRC^2 - 0.0797823*SCSRC*SuSRC + 0.0850145*SCSRC*LASRC + 0.0228404*SuSRC^2 - 0.0269925*SuSRC*LASRC |
| Parameter (Crookston) | |
| Farinograph Water Absorption (GPT parameters) | Water absorption = 48.1725 + 2.09595*Peak Max - 5.91872*Torque Max + 0.116179*Aggregation Energy - 0.00672278*Peak Max^2 - 0.0482691*Peak Max*Torque Max + 0.00124338*Peak Max*Aggregation Energy + 0.0875026*Torque Max^2 - 0.0000716818*Aggregation Energy^2 |
| Farinograph Water Absorption (SRC parameters) | Water absorption = 80.9128 - 13.0873*WSRC + 27.6753*SC-SRC - 22.9829*SuSRC + 7.17897*LASRC + 0.406465*WSRC^2 - 0.690691*WSRC*SCSRC + 0.331109*WSRC*SuSRC - 0.153356*WSRC*LASRC + 0.334505*SCSRC^2 - 0.350984*SCSRC*SuSRC + 0.123387*SuSRC^2 + 0.0336542*SuSRC*LASRC |
| Mixograph Water Absorption (GPT parameters) | Mixograph water absorption = 21.4286 + 0.509919*Peak Max + 2.67116*Torque Max - 0.0864334*Aggregation Energy - 0.00847284*Peak Max*Torque Max - 0.0570511*Torque Max^2 + 0.00303622*Torque Max*Aggregation Energy - 0.000028361*Aggregation Energy^2 |
| Mixograph Water Absorption (SRC parameters) | Mixograph water absorption = -234.118 - 0.408056*WSRC - 7.10023*SCSRC + 15.737*SuSRC - 3.4135*LAS-RC + 0.207643*WSRC^2 - 0.258244*WSRC*SCSRC - 0.0613185*WSRC*SuSRC + 0.213963*SCSRC^2 - 0.0855518*SCSRC*LASRC - 0.16525*SuSRC^2 + 0.178365*SuSRC*LASRC - 0.0313067*LASRC^2 |

**Figure 1:** Response Surface Plots indicating relationships between some of the parameters





## References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