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Wheat and Flour Quality for Varieties Tested in the 2015 OSU Wheat Variety Performance Tests

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General Information

Wheat producers are well aware of the various effects that variety, soil and crop management practices, pests and weather may have on agronomic performance of winter wheat in the southern Plains. All of those factors come together and interact to manifest a trait that is easily quantified – grain yield. Likewise, those same factors greatly influence the end-use performance of a variety, but end-use quality is not so easily quantified and may mean different things, depending on where one resides on the grain supply chain from wheat producer to consumer. When choosing a variety, producers will often consider one facet of quality— test weight, or in some cases protein content—but there is much more that determines how a crop or a single variety will perform in the mill or the bakery.

While cash price at the local elevator is not explicitly tied to milling and baking performance, the quality of wheat coming from a particular region or state can affect buyers' willingness to source product from that area. Modern millers and bakers have numerous purchasing options and are generally unwilling to settle for product that does not meet minimum industry standards. An area or region labeled as having low quality or trashy wheat could see reduced cash price relative to current KCBOT price, thus affecting the farmer's bottom line. Wheat quality is everyone's responsibility.

This report was prompted by the growing need to develop a reliable and relevant database that accounts for varietal differences in certain fundamental aspects of end-use quality, relative to expectations for hard red winter and hard white wheat. In addition to protein content, which is addressed separately in Current Report CR-2135 "Protein Content of Winter Wheat Varieties in Oklahoma 2015," the focus here is on physical attributes of the grain that lend good milling quality and on flour or dough properties, which convey acceptability for bread baking.

Procedures

Approximately 175g subsamples of wheat grain were collected from two field replicates of 45 varieties and five experimental lines in the 2015 OSU wheat variety performance tests conducted at Lahoma and Chickasha. These plots were well-fertilized and managed according to Oklahoma Cooperative Extension Service recommendations for maximum yields. Means yields for these tests were 66 bushels per acre (Lahoma) and 70 bushels per acre (Chickasha). Additional information on management practices is available in Current Report CR-2143 "2015 Oklahoma Small Grains Variety Performance Tests" on the web at www.wheat.okstate.edu. Samples were stored in plastic containers for approximately three months following harvest.

All laboratory procedures were performed in the OSU Wheat Quality Laboratory according to industry standards established by the American Association of Cereal Chemists (Table 1). Procedures reported here may be grouped into two broad categories:

i) wheat quality, or those parameters associated with the whole kernel and/or which would be especially relevant to the milling process, and
ii) flour quality, or dough testing parameters associated with straight-grade flour. Though not all-inclusive, the attributes reported here represent key indicators of milling performance and bread flour functional performance.

Interpretation of Tests

Wheat and Flour Protein

These simple tests are performed using an NIR analyzer (Figure 1), and merely determine the amount of protein present, not the kind or quality, whether in the whole kernel or in the milled product. For hard red winter or hard white wheat, a reasonable target for wheat protein is 12 percent or more,

Table 1.

Quality domain	*Test*	*Test Method*	*Test Instrument*
Wheat quality	Wheat protein	Near-infrared reflectance (NIR)	Perten Inframatic 8611
	Kernel hardness	NIR	Perten Inframatic 8611
	Kernel hardness	Single-kernel characterization system (SKCS)	Perten SKCS 4100
	Kernel weight	SKCS	Perten SKCS 4100
	Kernel diameter	SKCS	Perten SKCS 4100
	Laboratory milling yield	Straight-grade flour extraction	Brabender Quadrumat Senior Mill (modified shaker system)
Flour quality	Flour protein	NIR	Perten Inframatic 8611
	Mix time and mixing tolerance	Mixograph, 10g flour	National Manufacturing Mixograph with MixSmart software
	Gluten quality	SDS sedimentation with protein adjustment	N/A

though rarely will these varieties produce wheat protein content that exceeds 15 percent or 16 percent when averaged across multiple environments. Other hard wheat varieties may dip below 12 percent but will rarely average less than 11 percent wheat protein. This level of wheat protein may be acceptable if combined with a desirable level of protein strength. The quality (or kind) of protein determines the wheat's functionality, not the quantity, so long as certain market-class expectations for quantity are satisfied first. A range of 11.5 percent to 13.0 percent wheat protein constitutes the bulls-eye of those expectations for wheat produced in Oklahoma. About 75 percent to 80 percent of the protein present in flour is comprised of glutenin and gliadin, which interact to produce gluten when flour is mixed with water.

Generally, and assuming proper mill settings, wheat shows a loss of about 1.0 to 1.5 percentage units in protein content when milled into flour, as some of the protein residing in the kernel is removed with the bran layers during flour milling. A protein loss of 2 percentage units could reflect poor flour refinement or bran separation. Wheat protein content is expressed on a 12 percent moisture basis, whereas flour protein content is expressed on a 14 percent moisture basis.

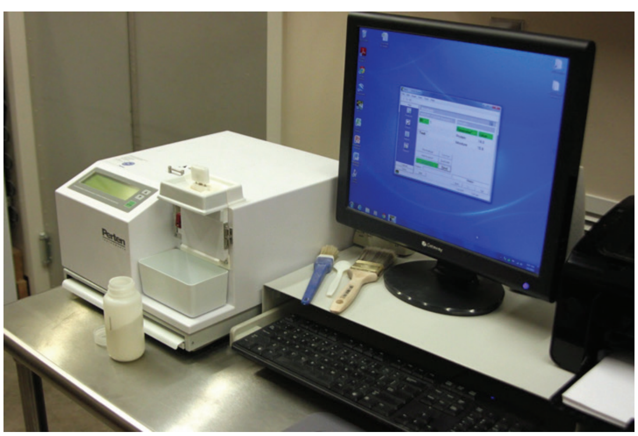

Figure 1. Perten Inframatic 8611 near infrared (NIR) analyzer.

Kernel Hardness and Size

The multitasking Single-Kernel Characterization System (SKCS) measures several physical attributes of a 300-kernel sample: hardness index or texture, diameter or size (or thickness) and weight (Figure 2). When measured by the SKCS, kernel hardness is manifested as the force required to crush a single intact kernel; softer kernels and more weathered kernels, will crush more easily, generating lower hardness index values. When measured by NIR however, kernel hardness is manifested by particle size of ground whole-wheat meal; softer kernels produce smaller particles, again generating lower hardness index values. Having both measurements provides a full-scale view of endosperm hardness, for which the hardness index value varies non-discreetly among varieties, even among hard and soft varieties within the same market class. Desirable values for kernel hardness index fall in the range from 60 to 80 within the same market class, but as with wheat protein content, millers may find bread wheat varieties slightly below or above this range that provide desirable functional characteristics in the flour. Rarely will a hard red winter or hard wheat variety grown in Oklahoma average less than 50 or greater than 100 for either measurement of hardness index.

Whether in a domestic mill or outside the USA, millers prefer high test weight, and consistent and large kernel size. These factors combined allow millers to optimize flour yields, the consummate measure of milling performance. Kernel size can be predicted using SKCS kernel diameter, in which values exceeding 2.50 mm are most desirable. This range might be unattainable in environments where kernel filling is stymied or prematurely ended by disease, drought, or many other environmental or management hazards. Because larger kernels are generally heavier kernels, SKCS kernel weight provides another reliable indicator of milling quality, in which values exceeding 30 mg are most desirable. Large or heavy kernels do not necessarily equate with high test weight. High test-weight varieties may be found which produce below-

Figure 2. Perten SKCS 4100 used to measure several physical characteristics of wheat kernels.

average kernel size but compensate for smaller size with a more spherical shape and shallow kernel crease to enable greater packing efficiency. Nonetheless, varieties with high test-weight potential and large kernel size truly represent the millers' choice.

Laboratory milling yield

Wheat quality laboratories used in wheat research programs throughout the world will employ a small-scale mill to approximate, but not duplicate, the performance on a commercial-scale mill (Figure 3). Regardless of scale, the purpose of this test is to measure the proportion of one or more flour streams produced by a unit of grain. Straight-grade flour is typically generated in a research laboratory, which does not feature the same level of refinement found in a commercial setting. Hence milling yield, or flour yield, determined in a laboratory will run eight or more percentage units lower than commercial extraction rates. The experimental mill used in the OSU Wheat Quality Laboratory will generate flour yields for hard wheat samples usually exceeding 57 percent. Of course, the break rollers on any mill are set according to the market class of the wheat feeding it. If a soft wheat sample is run through our mill set for hard wheat, the resulting flour yield will be less than 57 percent. Flour yield this low is a telltale sign of inferior millability for bread wheat applications, especially when used in combination with hardness index measurements, or even with molecular marker assays for key hardness genes. Values for flour yield exceeding 60 percent are most desirable.

Mixograph Performance

An essential fixture in almost any bread wheat quality laboratory is a recording dough mixer (RDM) called the mixograph (Figure 4). Other RDMs are available and perhaps preferred in a commercial setting, such as the farinograph or alveograph, but the mixograph provides the ultimate stress test by generating quick results in usually less than 10 minutes with very little material (typically 10g flour). Much like an electrocardiogram, the mixogram (the visible output of a mixograph) translates dough development into line tracings, or a mixing curve, onto a computer screen. Now one can visualize the tolerance of a dough as it subjected to increasing stress from mixing and then overmixing. Key parts of the mixogram are i) the ascending portion of the curve, which depicts formation of gluten and development of the dough as the flour absorbs water ii) the peak of the curve that denotes optimum dough development, and ii) the descending portion where breakdown of the gluten occurs due to overmixing.

These parts are quantified as corrected mixing time (i.e., adjusted for flour protein content), mixograph tolerance score which is an overall subjective tolerance score, and two computer-generated parameters of the mixing curve, its bandwidth and its ascending and descending slope.

Mixing time (or peak time) is not a parameter that is easily interpreted as acceptable or unacceptable. In very general terms, poor mixing tolerance may be expressed as a shorter mixing time (less than 3 minutes in our laboratory) and very high tolerance may be manifested as a longer mixing time (more than 8 minutes), but longer is not necessarily better. Bread flour with short mixing time and good tolerance would have utility in lowering bakery energy costs. Consider also that bread flour that requires an excessively long mixing time could cause production problems in a mechanized commercial bakery.

Figure 3. Brabender Quadrumat Senior Mill (modified shaker system).

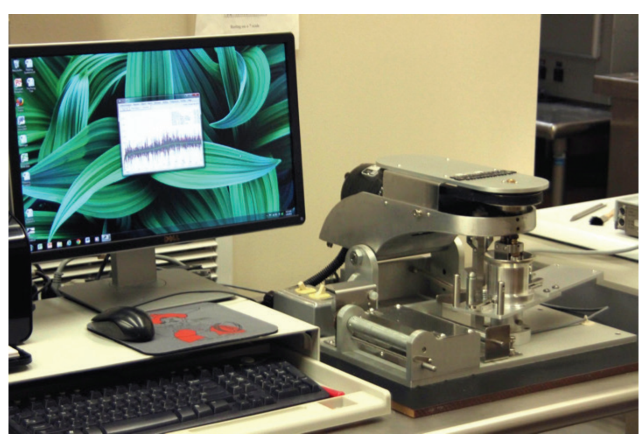

Figure 4. The mixograph is used to determine dough tolerance to mixing and overmixing.

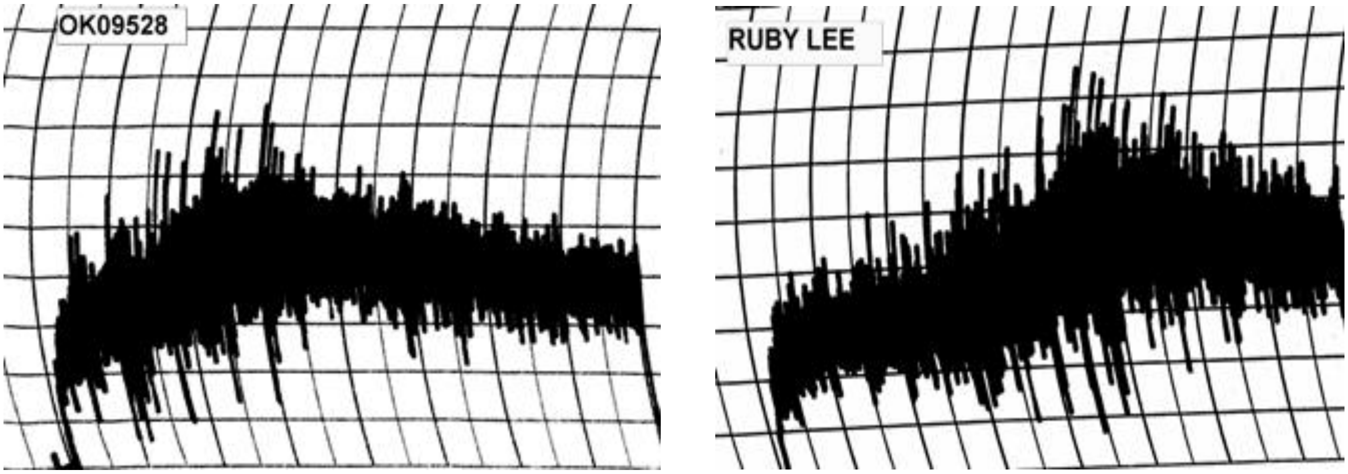

Figure 5. Mixograms provided by the USDA-ARS Hard Winter Wheat Quality Laboratory, Manhattan, KS. Mixing tolerance ratings on a 0 to 6 scale are 2 (left) and 5 (right).

Mixograph tolerance score is often rated on a scale of 0 (very poor tolerance) to 6 (very high tolerance). Poor tolerance is manifested as a curve with a sharp peak, followed by a rapid descent and narrowing of the band. Excellent tolerance can be seen in a curve with a gradual peak and descent with little narrowing of the band. The angle of ascent and descent is used to compute a mixogram stability value in which lower values (<10) indicate greater stability and thus tolerance. Bandwidth can be measured at some point on the curve following the peak, where higher values (more than10 mm at two minutes past the peak) indicate greater tolerance.

It is important not to overemphasize dough strength over all else. Producing pan bread from hard winter wheat flour is more about balance than about brute strength – in other words bakers need a sufficiently strong dough to handle the stress of commercial processing, certainly to contain the fermentation gases, yet pliable enough to rise during baking. Some of this balance may be achieved by blending different grain sources from the same market class with varying dough strength, or by blending two or more market classes.

Figure 6. A sedimentation test is used to determine the quantity and quality of gluten.

SDS Sedimentation

This simple laboratory test utilizes the water-absorptive capacity of certain gluten proteins, in the presence of sodium dodecyl sulfate, to predict gluten strength and to some extent loaf volume (Figure 6). Sedimentation values reflect both the quantity and quality of gluten; thus in the OSU WQL an adjustment is made for flour protein content so that the amount of water absorbed primarily reflects gluten quality. Higher values (more than 7 mL) are more desirable.

Brief Interpretation of Results

With the addition of a foliar fungicide and the lack of significant drought stress during grain filling at each location, most varieties were expected to approach their potential grain size and quality in 2015. However, waterlogged conditions and delayed harvest negatively impacted test weight as already reported (CR-2143). Overall, wheat protein in these two trials averaged 12.2 percent and kernel weight came in slightly under 30 mg, though the latter varied widely among varieties from 24 mg to 35 mg. Flour yield also varied widely from 52 percent to 65 percent, though kernel weight and flour yield were not correlated (r=0.21, P>0.05).

Varietal differences were highly noticeable for dough strength. Individual subsamples covered the complete scale for mixograph tolerance score. Mean tolerance scores were not associated with wheat or flour protein content (r<0.05, P>0.05), underscoring the importance of avoiding the use of grain protein quantity to predict protein quality. The range of quality attributes observed, and the relatively low experimental error associated with each attribute (with exception of mixogram stability value), signified 2015 as a very good year to evaluate varietal differences in quality attributes at these sites.

TAM 114 had the distinction of clearly having the greatest dough strength among all varieties, though its mixing time was long and milling attributes were about average. TAM 114 was one of three varieties that excelled in dough strength at a below-average level of wheat or flour protein. The other two were Iba and T158. Everest exhibited above-average milling attributes, but below-average dough strength. Varieties that demonstrated consistently good milling and dough attributes across the board, irrespective of protein content, were Bentley, Ruby Lee, Oakley CL, SY Monument and Winterhawk. Winterhawk also stood out in the 2014 tests. On the other hand, varieties such as LCS Wizard, NF 101, Pete and WB-Redhawk exhibited mostly undesirable milling and dough attributes.

Table 2. Wheat and flour quality parameters for hard winter wheat varieties included in the 2015 Oklahoma Wheat Variety Performance Tests at Lahoma and Chickasha, OK. Shaded values fall outside the target for a performance attribute. Except for hardness and mixing time, the top 25 percent of observations within a performance attribute are signified in boldface.

	Wheat quality					
Variety	*Wheat protein*	*NIR Hardness*	*SKCS Hardness*	*SKCS Kernel weight*	*SKCS Kernel diameter*	*Flour yield*
	%			*mg*	*mm*	*%*
Bentley	12.0	67	75	**32.1**	**2.78**	60.0
Billings	**12.5**	76	88	**35.1**	**2.87**	**61.4**
Centerfield	**13.0**	84	89	27.1	2.67	56.4
Deliver	12.3	67	75	30.6	2.66	60.1
Doublestop CL Plus	**12.9**	74	88	30.9	**2.76**	58.4
Duster	**12.5**	85	80	24.2	2.52	57.0
Endurance	12.4	69	76	28.7	2.63	57.6
Gallagher	12.0	80	84	**32.9**	**2.83**	60.2
Garrison	12.1	70	75	26.8	2.47	58.8
Iba	11.3	60	68	29.8	2.72	**62.0**
OK Rising	**12.5**	77	81	28.8	2.71	58.1
Pete	10.9	72	84	30.9	2.72	59.5
Ruby Lee	12.2	65	75	**31.9**	**2.80**	56.7
Everest	**12.5**	64	81	30.7	2.70	**62.5**
Hot Rod	12.1	89	103	**32.8**	**2.82**	55.1
KanMark	12.2	78	82	27.3	2.66	**62.3**
Oakley CL	**13.0**	71	90	30.8	2.68	**60.8**
1863	11.9	73	87	30.3	2.68	59.2
Greer	12.3	72	80	28.2	2.58	**61.8**
Jackpot	11.8	80	87	31.4	**2.76**	**60.3**
SY Drifter	**12.5**	76	85	28.7	2.70	**62.8**
SY Flint	**12.5**	73	85	28.4	2.68	59.6
SY Llano	12.0	81	84	28.5	2.68	59.4
SY Monument	12.2	79	90	30.4	2.70	**62.6**
SY Southwind	12.0	73	87	25.8	2.53	**63.6**
Winterhawk	12.0	62	80	30.1	2.65	59.8
WB-Cedar	12.2	70	83	**33.2**	2.71	58.3
WB-Grainfield	11.7	79	87	27.7	2.60	59.6
WB-Redhawk	11.9	76	92	29.8	**2.76**	58.1
WB4458	12.4	68	86	**33.5**	**2.85**	57.9
LCS Chrome	**12.7**	81	90	24.7	2.47	58.7
LCS Mint	11.5	72	82	27.5	2.55	58.9
LCS Pistol	**12.5**	59	61	24.9	2.51	53.3
LCS Wizard	**12.9**	80	91	25.1	2.55	59.9
T153	12.0	75	83	30.8	2.73	55.9
T154	12.1	73	81	30.5	2.71	56.9
T158	11.5	67	74	**32.3**	2.75	60.2
TAM 112	12.0	78	79	28.2	2.61	52.4
TAM 113	**12.6**	77	77	25.0	2.51	57.3
TAM 114	11.7	74	82	27.9	2.61	59.8
TAM 204	**12.6**	71	75	25.3	2.50	59.6
Avery	12.1	70	74	27.1	2.60	55.8
Brawl CL Plus	**13.0**	68	81	29.2	2.71	58.2
Byrd	12.1	68	77	25.6	2.49	59.3
NF 101	11.9	67	78	29.2	2.69	**60.8**
LCH13DH-14-91	**12.7**	63	84	**35.0**	**2.91**	**64.9**
OK1059060-2C14	**12.5**	73	79	30.0	2.70	59.0
OK10126	**12.5**	82	91	**32.1**	**2.81**	58.7
OK11D25056	**12.6**	78	93	**31.5**	2.67	60.1
OK13625	**12.9**	62	71	**32.4**	**2.81**	58.9
Mean	12.2	73	82	29.4	2.68	59.2
L.S.D. (0.05)	0.5	4	5	2.3	0.09	3.2
C.V.	2.3	2.4	4.5	3.5	1.6	4.0
Target	>11.5	≥60	≥60	≥28.0	≥2.5	≥58.0

Table 2. Wheat and flour quality parameters for hard winter wheat varieties tested in the 2015 Oklahoma Wheat Variety Performance Tests. Shaded values are below target for the respective performance attribute and bold values are in the top 25 percent of observations within a performance attribute (cont'd).

	Flour quality					
Variety	*Flour protein*	*Mixing time*	*Mixogram tolerance score*	*Mixogram bandwidth*	*Mixogram stability*	*SDS Sedimentation*
	%	*min*	*0-6*	*mm*		*mL*
Bentley	10.3	3.8	4.0	**19.0**	5.3	**8.8**
Billings	10.5	3.7	4.0	16.3	4.3	8.3
Centerfield	**11.2**	3.7	3.5	17.6	6.1	8.1
Deliver	10.7	4.2	4.0	16.4	5.4	8.0
Doublestop CL Plus	**11.0**	3.9	4.0	15.0	5.5	8.5
Duster	10.7	3.9	**4.5**	17.5	3.6	7.6
Endurance	10.7	3.8	4.0	17.2	4.5	7.9
Gallagher	10.3	3.9	4.0	**19.0**	4.5	7.3
Garrison	10.7	3.0	3.8	16.2	4.1	8.2
Iba	9.7	4.0	4.0	**18.3**	3.4	**8.8**
OK Rising	10.8	3.6	2.3	11.1	8.6	8.2
Pete	9.0	2.6	1.3	8.0	6.0	7.9
Ruby Lee	10.6	4.8	**4.5**	**21.0**	**2.6**	**8.8**
Everest	**11.1**	2.9	1.8	14.1	8.1	7.4
Hot Rod	10.3	4.2	**5.0**	15.2	**2.7**	7.9
KanMark	10.6	5.1	4.0	17.4	4.3	8.5
Oakley CL	**11.3**	5.1	4.0	**19.1**	6.0	8.1
1863	10.1	3.6	2.0	16.4	7.2	8.0
Greer	10.6	4.2	4.0	15.6	6.0	**8.6**
Jackpot	9.9	2.9	3.0	16.2	6.0	7.0
SY Drifter	**10.9**	5.0	4.0	17.3	4.0	8.1
SY Flint	10.7	3.4	3.8	17.3	5.6	8.0
SY Llano	10.3	4.9	**4.3**	16.8	**3.0**	8.3
SY Monument	10.4	6.4	3.5	**21.4**	**2.0**	8.5
SY Southwind	10.3	4.9	4.0	17.9	**3.3**	**8.6**
Winterhawk	10.3	4.1	4.0	15.6	**3.3**	8.5
WB-Cedar	10.4	3.8	3.0	13.9	4.1	8.1
WB-Grainfield	10.0	4.0	3.0	17.9	4.3	8.0
WB-Redhawk	10.1	3.2	1.0	10.1	7.1	6.1
WB4458	10.7	3.4	2.8	**18.0**	7.4	7.9
LCS Chrome	**10.9**	3.4	2.3	**22.1**	9.7	7.8
LCS Mint	9.8	4.3	4.0	14.3	3.7	**8.6**
LCS Pistol	**10.9**	3.2	3.0	13.5	7.2	8.0
LCS Wizard	**11.4**	2.8	2.8	17.5	9.5	7.1
T153	10.1	4.0	4.0	15.4	**2.8**	**8.6**
T154	10.4	3.3	3.5	16.4	4.5	8.3
T158	9.9	3.9	4.0	13.0	**2.8**	**8.7**
TAM 112	10.3	4.2	4.0	15.8	3.1	**8.7**
TAM 113	10.7	4.2	**5.0**	16.5	**1.9**	8.5
TAM 114	9.9	9.0	**6.0**	**18.0**	**1.3**	**9.0**
TAM 204	**11.3**	2.9	3.0	**22.7**	11.1	8.0
Avery	10.4	4.6	3.8	17.0	4.1	**8.6**
Brawl CL Plus	**11.4**	3.8	2.8	16.5	6.5	7.8
Byrd	10.3	5.6	4.0	17.6	**2.4**	**8.6**
NF 101	10.2	2.6	2.0	12.8	6.4	7.3
LCH13DH-14-91	**11.1**	3.7	3.0	**18.7**	8.9	8.2
OK1059060-2C14	10.7	3.8	4.0	17.2	6.5	8.2
OK10126	10.7	4.9	3.5	**18.9**	6.0	7.3
OK11D25056	**11.1**	5.2	4.0	16.5	3.5	7.4
OK13625	**11.1**	5.2	4.0	16.9	**3.3**	8.2
Mean	10.5	4.1	3.6	16.6	5.1	8.1
L.S.D. (0.05)	0.5	0.8	0.9	4.7	2.5	0.5
C.V.	2.8	10.9	9.1	18.8	36.4	4.1
Target	>10	≥3.0	>2.0	≥12.0	≤9.0	≥7.5

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