PROJECT REPORT No. 301

DEVELOPMENT AND VALIDATION OF ON-FARM SAMPLING PROTOCOLS FOR COLLECTION OF MARKETING (QUALITY) SAMPLES AT HARVEST

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by

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This is the final report of a 6-month project which started in July 2003 with a grant of £19,799 from HGCA (Project No. 2761).

Contents

Abstract

The aim of this project was to develop a limited set of protocols for sampling grain to measure quality characteristics. The protocols were tested to establish the variance attached to each quality measurement to enable users to understand the probability of a sample proving to represent a grain lot for parameters measured.

Protocols laying out sampling instructions for grain coming into store directly and after cleaning or high temperature drying were developed in conjunction with input from an expert panel drawn from the grain industry both in the UK and overseas.

Testing of protocols took place during the 2002 harvest at 16 farms from Kent to Aberdeenshire to try to incorporate geographic variability and differing conditions. Samples were taken to assess the variation between and within trailers (using spear sampling, pelican samplers and scoop sampling) and the impacts of cleaning and drying on sample quality. The performance of composite samples versus a series of single samples was also examined.

Results indicated significant variation between trailers but statistically insignificant variation within trailers. There were no major differences between the sampling methods although spear sampling tended to result in increased specific weight. Composite samples were adequate for quality analysis with little difference between the single and composite sample results.

Drying and cleaning resulted in reduced moisture content and fine material. However, the associated handling tended to increase specific weight and some other characteristics underwent significant change. Samples for quality assessment should therefore be taken after, rather than before, drying.

Grain is inherently variable as it comes off the field and requires careful sampling. However, single samples from each trailer provide a practical method that gives an acceptable indication of grain quality.

Background

This research submission was made at the request of HGCA in response to the Treasury funding secured to undertake a two-year programme to improve and standardise grain sampling and analysis across the UK cereals industry. The first phase of the programme is to develop and validate protocols that are suitable for collecting samples of grain on UK farms at harvest time. The second part is to train farmers in using these sampling techniques to use at or shortly after harvest to collect samples for marketing purposes

Previous practical investigations of sampling grain have suggested that the methods and equipment used may influence the sample that is collected (HGCA Project Reports No. 34 & 79). A more recent study collected data concerning the equipment and methods currently in use on farms and at commercial stores (HGCA Project Report No 118). This showed that there was little standardisation in methods. Since there is no existing experimental data on which to design a sampling scheme it is essential that this information be collected before any attempt to agree on a protocol is made. This research was aimed at developing a limited set of protocols for testing and establishing the variance attached to each of the quality measurements thus enabling users to understand the probability of a sample providing an representative value for a parcel of grain. Without this information any protocol will be fundamentally flawed, open to dispute and of little value.

The provision of a reliable and universally acceptable sampling methodology will be a major step forward in this area.

Programme of work:

i) Overall aim

To develop and deliver a reliable, validated sampling protocol acceptable to the whole industry for use on farm at or around harvest to provide representative marketing (quality) samples.

ii) Specific objectives:

To prepare and validate practical sampling protocols for farmers to use for collecting representative marketing (quality) samples at harvest in the following situations providing it is safe to do so:

1. During intake to a farm store
2. Off the (high temperature) dryer into a farm store

Constraints on the project

The project was commissioned and designed over a very short period. An essential component was to consult widely on the basic sampling requirements and the make-up of the protocols before any practical work started.

As a result the time available to do the sampling was reduced and the majority of the barley harvest was missed. Only a single set of data using oats was collected but this was of limited value because of limitations with the analytical equipment. Whilst the few results that were obtained for barley indicate that the heterogeneity is similar to wheat this cannot be confirmed and no assumptions can be made about sampling oats. The sampling that was done was under "field" conditions which meant that many factors were uncontrolled; it would be prudent to repeat some of the sampling under more controlled conditions to ensure that the variation was attributable to the factors identified within this report.

Methodology

The development of the protocols was split into two phases. The first phase was to draft protocols and circulate these widely for comment and the second phase was to test these under field conditions.

Drafting the protocol

The protocols were drafted using the expertise of the researchers and the incorporation of information from previous publications. The publications included both British and International standards (BS4510, derived from International Standard, IS950) although these are both now withdrawn. Considerable reference was made to existing "unofficial" trade protocols but the variation between these meant that no one document could be used in its entirety. The draft protocols were circulated to the expert group (Appendix 1) and then amended in the light of comments to ensure that all aspects relating to practical operation and safety were properly addressed. This resulted in final protocols that were used as the basis for the sampling experiments and these are given in full (Appendices 2 & 3).

On farm, ex-combine sampling

The purpose of the on-farm, ex-combine sampling exercise was to validate the sampling protocols and to test a variety of methods for taking the sample. In practice all grain was delivered from the combine to the store in trailers and these were used a standard delivery unit. Different sampling regimes were used to assess the degree of variation within trailers and between trailers. Samples were collected with a pelican sampler (figure 1) or scoop (a 1 litre plastic jug) for sampling a flow of grain and a grain spear to sample a heap of grain produced after a trailer had tipped. In an attempt to include differences due to geographic variation samples were taken from farms distributed over England and Scotland. A total of 16 farms were used, although whilst geographically separate, some of these were operated by the same growers. Details of the farm locations are given in Table 1:

Farm number	Commodity	Farm Location	Date of sampling
1	Wheat and barley	N. Lincolnshire	Early August 02
2	Barley	N. Lincolnshire	Early August 02
3	Wheat	Kent	Early August 02
4	Wheat	N. Lincolnshire	Mid August 02
5	Wheat	N. Lincolnshire	Mid August 02
6	Barley	Yorkshire	Mid August 02
7	Wheat	Yorkshire	Late August 02
8	Wheat	Yorkshire	Late August 02
9	Barley	Perthshire	Late September 02
10	Wheat	Perthshire	Late September 02
1A*	Wheat	N. Lincolnshire	Late August 02
1A + heap*	Wheat	N. Lincolnshire	Late August 02
2A*	Barley	N. Lincolnshire	Late August 02
3A Post drying*	Wheat	Kent	Late August 02
7A Post drying*	Wheat	Yorkshire	Early September 02
8A*	Wheat	Yorkshire	Early September 02

Table 1 List of farms, their location, cereal type, and timing of sampling

*** These farms were revisited to collect different information to the original visit and can be regarded as separate data sets.**

Figure 1 Example of “home made” pelican sampler

Assessment of samples
Almost all samples were checked for moisture content and temperature using a Protimeter GrainMaster i electrical moisture meter immediately on collection.

More detailed assessments of the properties of each sample were made using a Foss Infratec grain analyser 1241 GA-TWM. This machine measured moisture content, specific weight, protein (in the case of wheat) or nitrogen (in the case of barley) and made an assessment of hardness for wheat. As samples had to be transported to the location of the Infratec, delays of a maximum of 24 hours occurred between the collection and assessment of some samples. In these cases, samples were transported in a cool box to reduce the influence of temperature and moisture changes on the properties of the grain. In addition some samples of wheat were sent to NIAB for assessment of Hagberg falling number and a few samples were sent to a maltings for assessment of malting properties. Unfortunately, no results were ever produced by the maltings.

The level of screenings was also assessed for each sample using a single sieve. This was only a comparative test and not done using standard slotted sieves due to constraints of time. The results simply provide an indication of the variability of the level of screenings or fines that occurs between samples.

Whilst the intention was to obtain the same number of samples for each sampling method and at each farm location this was not always possible due to the sampling taking place on-farm at harvest which resulted in a variety of trailer types and tipping methods. The sampling was done under normal working conditions to ensure that the protocol was indeed practical on the farm.

Sampling was done intensively when trailers were fitted with a grain hatch with many samples being taken from each trailer to ascertain the within trailer variation, samples taken from trailers using only opening tailgates were sampled less intensively since the speed of discharge was such that fewer samples could be taken in the time. These latter samples helped to monitor between trailer variations.

The experiment also looked at:

- The comparability of the quality measurement results from individual samples taken from a trailer or series of trailers with the quality measurement results obtained from a sub-sample taken from a composite of individual samples.
- The effects of drying on the quality of the sample
- The effects of cleaning on the quality of the sample

The details of method and number of samples taken at each location is given in Table 2.

Sampling method	Trailers sampled	Pelican Number of samples	Scoop Number of samples	Spear Number of samples	Diverter sampler Number of samples
Farm 1 Barley	2	10 from each trailer	10 from each trailer		
Farm 1 Wheat	9	1 from each trailer		5 from heap from 3 trailers	
Farm 2 Barley	10	5 from first trailer 1 each from 9 trailers		5 from heap from first trailer	
Farm 2 Wheat	4	1 from each trailer			
Farm 3 Wheat	6	5 from first 4 trailers 1 from trailers 5 & 6		5 from first 4 trailer heaps 1 from trailer heaps 5 & 6	
Farm 3A Wheat					5 samples pre-drying 5 samples post-drying
Farm 4 Wheat	10	5 from each trailer			
Farm 5 Wheat	5	5 from each trailer			
Farm 6 Barley	5	1 from each trailer			
Farm 7 Wheat	6	1 from each trailer			1 from each trailer pre-cleaning 1 from each trailer post-cleaning
Farm 8 Wheat	5	1 from each trailer	1 from each trailer heap	1 from each trailer heap	
Farm 8A Wheat	6	1 from each trailer	1 from each trailer heap	1 from each trailer heap	
Farm 9 Wheat	1	20 from each trailer			20 from batch of grain post-drying
Farm 10 Wheat	1	25 from each trailer			25 from batch of grain post-drying

Table 2 Details of sampling methods used and the number of samples taken at each location,

All samples were taken as described in the sampling methodology of the protocol for each of the pieces of equipment. The moisture content of all samples were taken immediately using the Protimeter moisture meter and then the grain was placed into labelled bags for transport to the laboratory for testing in the Infratec machine. Where appropriate, composite samples were made by combining individual samples after each had had their quality characteristics measured. Sub-samples from the composites were taken after thorough mixing of the samples had taken place. Multiple samples from each composite were taken, each sample being discarded after measurement

Within trailer variation
The within trailer variation was measured on 6 occasions using between 5 and 25 sample per trailer depending on the rate at which the trailer was emptied.

Between trailer variation
The between trailer variation was measured on 11 occasions using both multiple and single samples from each trailer.

Comparison of pelican and spear sampling
The comparison of results from pelican and spear sampling was measured on 5 occasions using both multiple and single samples from each trailer.

Comparison of pelican and scoop
The comparison of results from pelican and scoop sampling was measured on 1 occasion using both multiple samples from each trailer

Comparison of single and composite samples
The comparison of results derived from single samples with results obtained from bulked samples was measured on 5 occasions.

Effects of cleaning
The effects of cleaning on quality was measured once

Effects of drying
The effects of drying on quality was measured four times

A second protocol to cover sampling grain after drying was also developed and validated. This second protocol was essentially the same as the first except for the method of sampling the grain. Grain was either sampled using the same methods as for trailers tipping into store (i.e. scoop, pelican sampler swept across the flow of grain from the conveyor or spout or spear sampling the grain after it was tipped into the bin or onto the floor) or using a diverter sampler if available where a constant stream of grain can be diverted directly into the plastic container used for holding samples allowing the regular collection of sub-samples for moisture and temperature monitoring and the production of a sample for quality testing.

Results

Residual maximum likelihood estimation (REML) using R (2002, The R Development Core Team) was used to analyse the results to account for the unbalanced incomplete nature of the data. All the data collected for samples of wheat were combined to detect differences between farms, trailers, and sampling methods. The number of samples for barley was too small for a meaningful analysis. The REML was used to detect which of the random elements of the model (farm, trailer, sampler type and sample number) best described the variance that was seen in the fixed factor (moisture, protein, hardness, specific weight or fines). The REML analysis was run with all random effects and then had effects deleted one by one. The model (i.e. random effects structure) that gave the lowest value for the Akaike's Information Criterion (AIC) indicating the best fit was selected.

The analysis showed that for moisture content, protein DM and hardness *farms* and *trailers* accounted for the significant variance in the model but there was no variation accounted for by *samples within trailers* or *sampling methods*. For specific weight, significant variance in the model was accounted for by *farms* and *sampling method* which could probably be explained by the fact that spear sampling can have a polishing effect of the grain changing its characteristics and therefore specific weight. The results for fines only showed an effect for *farms*. However, the residuals from the fines analysis were highly asymmetric and the result should therefore be treated with great caution.

A small number of samples were sent for testing of Hagberg falling number but were too few to produce a statistically meaningful result.

Within trailer variation

The overall analysis showed that there was no *statistically* significant variation within trailers. This is not to say that variation did not occur or that it could make a significant difference to individuals. To illustrate this point Table 3 below shows the "worst case scenario" with the maximum and minimum values obtained in single trailers. The results were recorded in a number of different trailers, i.e. moisture content from one trailer protein DM from another.

Quality factor	Range of values
Protein (DM)	10.0 – 12.0%
Nitrogen (DM)	1.7 – 1.8%
Moisture content	16.9- 17.9%
Hardness	30.3 - 52.7
Specific weight[1]	60.8 – 69.5 kg/hl
Fines	0.02 - 0.52%

Table 3 Greatest ranges of values recorded in single trailers . The values were not drawn from a single trailer

However, more typical results can be seen in Table 4 that contains the maximum and minimum values from 10 samples from a single trailer of barley and one of wheat.

Quality factor	Range of values (barley)	Range of values (wheat)
Protein (DM)	-	13.1 – 13.5%
Nitrogen (DM)	2.1 - 2.2%	-
Moisture content	16.6 - 17.4%	21.0 – 21.2%
Hardness	-	83.2 – 90.5
Specific weight[1]	60.5 - 62.7 kg/hl	62.5 – 65.1 kg/hl
Fines	0.05 - 0.50%	0.03 - 0.11%

Table 4 Typical variation in values using 10 samples from single trailers of wheat or barley

Between trailer variation

The overall analysis showed the variation between trailers to be statistically significant and therefore determines the minimum sample unit i.e. each trailer has to be sampled to get a good estimate of the quality of the grain. This variation is evident in Table 5 where two combines were operating in the same field but in different parts.

Trailer	Protein, DM	Moisture	Hardness	Specific weight[1]	Fines (%)
Combine 1	9.3	14.3	42.9	74.9	0.06
Combine 2	11.8	16.3	67.1	70.6	0.06

Table 5 Differences in quality parameter values recorded from two combines operating int he same field

[1] The Infratec instrument had not been calibrated for specific weight and when checked against a calibrated instrument was found to consistently under-read by about 5 units. Thus the results reported here are underestimates of the specific weight of the grain.

Comparison of pelican and spear sampling
The only statistically significant difference recorded between these two sampling methods for both wheat and barley was for specific weight with spear sampling giving a significantly higher value that the pelican sampler.

	Spear mean value, specific weight[1]	Pelican mean value, specific weight	T statistic	Probability	Degrees of freedom
Barley	62.4	61.0	-5.07	<0.0001	17
Wheat	67.7	66.4	-2.99	0.002	39

Table 6 Results from the comparison of pelican sampling versus spear sampling

Comparison of pelican and scoop
The comparison of results from pelican and scoop sampling was only done using barley and revealed no significant differences for any of the qualities that were measured (Figure 2).

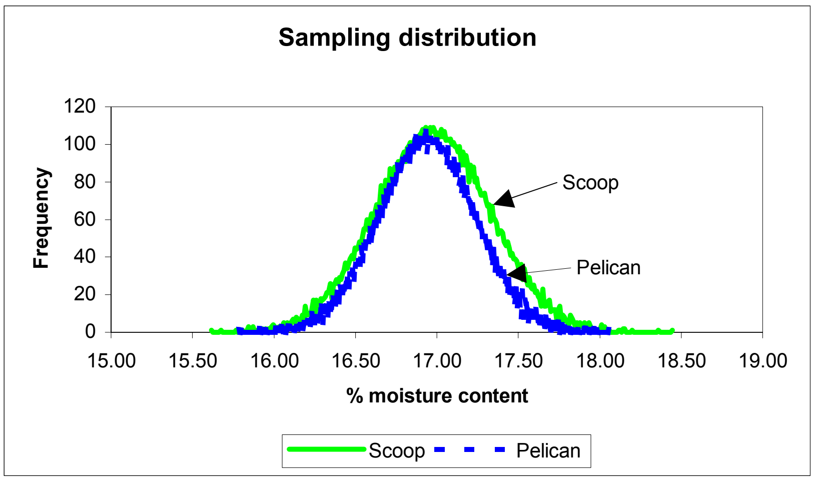


Figure 2 Comparison of range and frequency of values obtained for moisture content comparing pelican and scoop sampling

[1] The Infratec instrument had not been calibrated for specific weight and when checked against a calibrated instrument was found to consistently under-read by about 5 units. Thus the results reported here are underestimates of the specific weight of the grain

Comparison of single and composite samples

All tests were done on wheat. In general there were no significant differences between the mean result obtained from single samples and composite samples created from those individual ones (Table 7). Of the 5 comparisons examined 2 showed differences for fines, 2 showed differences for hardness and a single sample showed differences for specific weight.

Farm		Protein, DM	Moisture	Hardness	Specific weight[1]	Fines (%)
1	Single mean	10.5	13.4	37.1	74.3	0.08
	Composite mean	10.5	13.4	38.6	74.5	0.13*
2	Single mean	10.4	14.9	54.9	73.3	0.04
	Composite mean	11.2	15.1	63.5	71.7	0.06
7	Single mean	10.1	12.4	55.2	76.0	0.12
	Composite mean	10.1	12.8	60.1*	75.9	0.08
8	Single mean	12.2	19.6	68.1	70.5	0.03
	Composite mean	12.2	19.5	66.8	70.7	0.02*
8a	Single mean	13.2	18.0	64.3	66.3	0.04
1	Composite mean	13.2	17.9	62.7*	66.7*	0.03

Table 7 Comparison of quality measurement means calculated from single samples against means from composite samples for 5 farms. All samples were wheat (* shows statistically [1]significant difference see Table 8)

As has already been mentioned the measurement of the fines was problematical and no firm conclusion can be drawn from this although the extra handling and opportunity for fine material to fall out of the grain may be part of the explanation although in one case the composite sample shows a higher level and in the other a lower level of fine material. The reasons for the differences found in the specific weight are not clear although the extra handling involved in the creation of the composite may have altered the specific weight, since the composite recorded a significantly higher value than the single samples. The difference in the hardness values is not readily explicable; one difference is highly significant although this appears to be more due to the small variability than a large difference in the actual values (Table 8).

	Single samples Mean value	Composite sample Mean value	T statistic	Probability	Degrees of freedom
Farm 1 - Fines	0.08	0.13	-2.60	0.01	12
Farm 7 - Hardness	55.2	60.1	-6.07	<0.0001	13
Farm 8 - Fines	0.03	0.02	2.21	0.02	20
Farm 8A - Hardness	64.3	62.7	2.27	0.02	20
Farm 8A – Specific Weight[2]	66.3	66.7	-1.83	0.04	20

Table 8 Details of statistical differences between single sample values and those obtained from composite samples

[2] The Infratec instrument had not been calibrated for specific weight and when checked against a calibrated instrument was found to consistently under-read by about 5 units. Thus the results reported here are underestimates of the specific weight of the grain.

Effects of cleaning

Cleaning significantly affected the values for fines and for specific weight (Table 9). Fines are expected to decrease in value through the action of cleaning and the change in specific weight is probably due to the polishing effect of the cleaning process allowing closer packing of the grain.

	Pre-cleaning Mean value	Post-cleaning Mean value	T statistic	Probability	Degrees of freedom
Specific weight[1]	75.5	76.7	-7.68	<0.0001	16
Fines	0.29	0.22	2.21	0.02	16

Table 9 Significant effects of cleaning on the quality parameters for wheat

Effects of drying

Drying was studied on both barley and wheat. For barley there were highly significant changes in moisture content, specific weight and fines but the value for nitrogen was unchanged. Wheat showed highly significant changes in moisture content, specific weight, hardness and protein (DM) but fines were left unchanged (Table 10). It would be expected that moisture content, specific weight, hardness and fines would be altered by the drying process but the highly significant change in protein measured on a dry matter basis would not be expected. It is possible that the high moisture content was outside the calibrated range of the instrument and therefore the first value for protein may be inaccurate. This problem may also have arisen since it is very difficult to take comparable measurements before and after drying since it is no longer possible to recognise specific trailers of grain. However, this is not a serious problem since the recommendation to take samples after drying will cover this particular problem. The table below shows the statistical significance of the changes along with the differences in the mean values.

	Pre-cleaning Mean value	Post-cleaning Mean value	T statistic	Probability	Degrees of freedom
Barley – Moisture	18.5	15.7	39.08	<0.0001	37
Barley –Specific weight	58.2	61.4	24.65	<0.0001	33
Barley –Fines	0.22	0.04	5.70	<0.0001	17
Wheat - Protein	13.3	12.8	6.70	<0.0001	31
Wheat - Moisture	21.1	13.7	155.10	<0.0001	25
Wheat – Hardness	86.8	71.5	39.20	<0.0001	47
Wheat – Specific weight	64.1	67.7	-7.04	<0.0001	27

Table 10 Significant differences in quality parameters for wheat and barley occurring after drying

Discussion

The main purpose of the experimental work was to investigate the reliability of the sampling methods and the sampling protocol. A number of conclusions can be drawn from these results.

Inherent variation in grain

All the results gathered indicate that there is inherent variation in the grain that comes from a field and is significant at the farm and field level and also between trailers. The variation in the quality of grain within in a single trailer was not detected to be statistically different using the methods tested here. However, there was variability and whilst not statistically significant it could be large enough to make the difference between the grain being rejected or accepted. The problem facing the grower, merchant or end-user is to get a reasonable indication of the quality of a batch of grain without expending excess time, and therefore money, in detecting these differences. The experiments here show that a single sample per trailer gives a reasonably reliable estimate of the quality of the grain within a trailer; to take more than a single sample would be impractical and may or may not improve the accuracy of the result. The key point to come out of this work is that grain is not homogeneous and therefore should not be sampled as if it is since this would more than likely result in inaccurate values being measured.

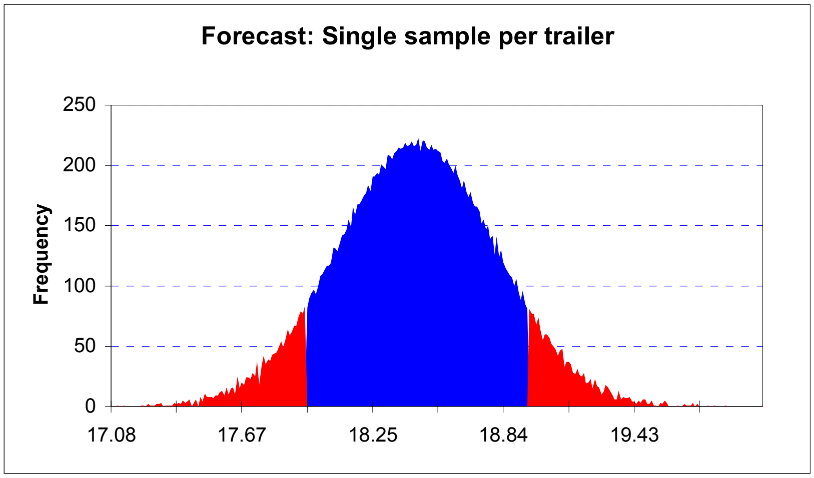
All persons involved in the grain trade should be made aware of the fact that there is a relatively large variation in grain quality and therefore sampling can only ever be indicative of the quality of the grain and never a definitive value. Specifications used for the trading of grain need to acknowledge that this variation exists and criteria should be set to include this variation.

Effect of changing sampling intensity

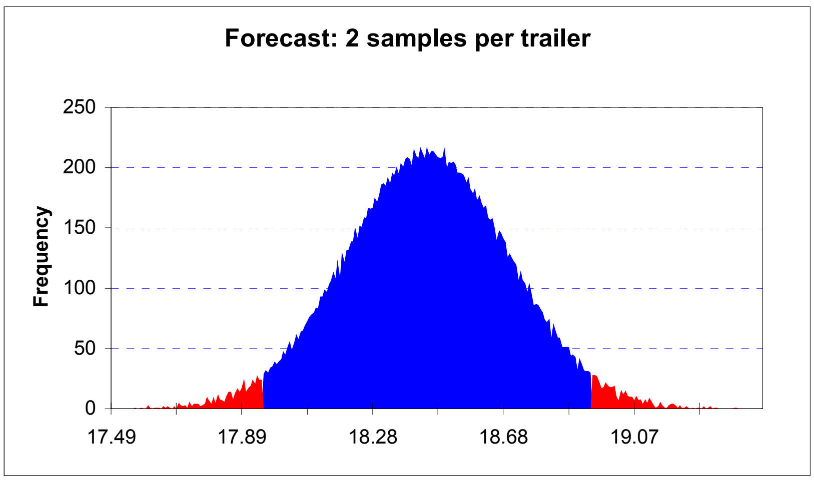
To demonstrate the effect of sampling intensity the variability of a batch of grain (wheat) was used to show the margin of error associated with taking a single sample as opposed to taking two samples from a trailer of grain. The diagrams below show the sort of level of variation that was obtained and the effects of taking one or two samples to get a measure of the moisture content for each load. The principles are the same for the other factors measured (protein, specific weight, hardness, fines).

The first diagram shows the range of values that are likely to be obtained from a series of samples of grain coming from a single field. Ten samples were taken from 4 trailers giving a total of 40 samples. The mean and standard deviation were calculated and used to produce a probability distribution curve of the range of moisture contents that may be found.

The blue area is the region that contains samples that are within the value of the mean plus or minus 0.5%, i.e. 18.45% ± 0.5%. This region contains 83.7% of the possible results, that is to say there is a probability of 83.7% that the result will lie within this area or a 14.3% chance (1 in 7 chance) that it is outside. If the tolerance is extended to 18.45% ± 0.7% then 95% of the values will fall within this range, i.e. a 5% chance (1 in 20 chance) that a value for moisture content is 0.7% more or less than the mean, i.e. it lies outside the range 19.15% - 17.75% .



The second diagram shows the impact of taking two samples. The probability of getting a value that is greater than 0.5% (1 in 20) of the mean is only 3.4% and if 0.7% is used then the probability of getting a value outside this range is reduced to 0.05% or one chance in 200.



Given the error associated with measuring moisture content (and the other parameters) it was felt taking a single sample was a simple and reasonably reliable method of estimating the qualities of the grain. It is obviously possible to get greater accuracy with more samples but it was felt that the extra time, effort and storage space for samples would make this unacceptable to the majority of growers.

Sampling methods

The different sampling methods tested did not appear to show any statistically significant differences for the important quality parameters although spear sampling did serve to increase the specific weight of a sample by the polishing effect that the extra handling had on the grain. The level of fines detected by different sampling methods varied but the fines in the samples were a continual problem and require further work to clarify the situation. No definitive statement can be made about their measurement at this stage. The use of a pelican sampler, a scoop or spear sampling appears to be equally effective and do not give significantly different results for nitrogen, protein, hardness or moisture content values. Thus it would appear possible to sample grain safely and reliably on intake from the combine whatever method is being used to tip the grain.

Single versus composite samples

The use of composite samples can save time since the measurement of the sample need not be done immediately for each trailer of grain but the samples can be taken from each trailer, placed in a container, mixed thoroughly and then sampled and the measurements recorded. This reduces the number of sample bags that have to handled and stored and the number of samples for analysis. The results indicate that for most of the measurements the results from composite samples are essentially the same as the average of individual samples. There may be some variation in the value that is obtained for fines between the single samples and the bulk. This can probably be explained by the extra handling of the grain giving greater opportunity for the fines to work their way to the bottom of the sample during handling and mixing if not done very thoroughly. The difference in the specific weight detected is probably the result of the extra handling that has taken place resulting in a polishing of the grain and therefore a higher specific weight. The one record of a difference in hardness is not easily explicable and may have been a rogue result.

Cleaning and drying

The impacts of cleaning and high temperature drying are largely as expected, with drying causing highly significant changes in specific weight, moisture content and hardness; and cleaning causing significant increases in specific weight and reductions in the level of fines. The change in protein content remains unexplained but none of these findings should be of concern since the recommendation that comes from them is that samples for quality determination should be collected after high temperature drying or cleaning, although obviously samples for the determination of moisture content need to be collected as the grain comes in from the field to determine the necessity for drying.

Recommendations

A number of recommendations for further work are made.

Barley:

Constraints at the start of this project meant that it was impossible to start the work until after the majority of the English barley crop had been harvested. Therefore, only limited data were collected. It is recommended that work be done to confirm that the protocols are applicable to barley and that the investigation should concentrate on malting barley.

Assessment of screenings:

An arbitrary method of testing for screening/fine material had to be used during this project. It is recommended that more work be done using industry standard methods to confirm the validation of the Protocols. This work should include both wheat and barley but assessments on malting barley should be done using both a simple field assessment and standard testing by the IOB method.

Falling number:

A small number of tests of the falling number of some samples were done during this project. These seemed to indicate that the samples were sufficiently representative to give results that were satisfactory and fell within the margin of error of the falling number test method. However, the small number of samples did not allow proper statistical confirmation. It is recommended that a further series of samples are collected and tested for falling number so that a full validation of the protocol can be made.

Drying:

On-floor drying:

A large proportion of UK grain is dried and stored on-floor. This work concentrated on sampling such grain as it entered the store and did not consider changes that might occur during the slow drying process. It is recommended that tests be done at on-floor drying stores so that grain is sampled according to the protocol as it enters the store and the grain is re-sampled in a similar manner as the store is emptied. This will allow the effects of slow drying on the quality of the grain as shown by the sampling method to be assessed.

High temperature drying:

The results obtained during this project confirmed that passing grain through a high-temperature drier had an effect of quality and that it was therefore more appropriate to collect quality assessment samples after drying. However, it also indicated that drying could have some unexpected affects on quality. It is recommended that further work be done to investigate these unexpected effects (changes in protein and specific weight).

Acknowledgements

The authors of this report wish to acknowledge the valuable assistance given by many sectors of the grain industry with the development of the protocols. We also wish to thank the farmers who allowed us to work on their farms at an extremely busy time of the year.

We also wish to thank Foss Instruments for the loan of the Infratec and the training given in its use. We would also thank Protimeter for the loan of a moisture meter, moisture probe and a temperature probe.

Appendix 1

Expert Group details

Name	Position	Company
Hurburgh, Charles	Researcher	Iowa State University
Colville, David	NFU Cereals Committee member	W R Colville & Son
Allison, Sandy	Farmer	Allison & Sons
Attridge, Stuart	Trader	Harlow Ag Merchants
Badger, Nick	Trader	Banks Cargill
Baxter, Denise	Researcher	BRi
Booth, Philip	Grain buyer	Bradshaws of Driffield
Cragg, Andrew	Farmer and Cereals R & D member	Brooker farms
Errington, John	Farmer	Herne Manor Farm
Hanger, Mark	Lab manager	Glencore
Knight, Chris	Head of Agriculture	CCFRA
Lacey, Graham	Trader	Centaur Grain
Lamont, Archie	Trader	Grainfax
Lockey, Nicky	Lab manager	Banks Cargill
Norfolk, Mike	Maltster (commercial)	Muntons Plc
Norman, Keith	Technical Director	Velcourt
Patrick, Nigel	Commercial director	NRM
Prevett, Chris	Chief crops officer	Rural Payments Agency
Salmon, Sue	Head of Cereals	CCFRA
Seed, Debbie	Grain Services Assistant Manager	Bedfordia Farms
Stokoe, John	Independent merchant	
Streatfield, Robert	Independent consultant	CS Commodity Solutions
Vernon, Stewart	Cereals R & D member	Coatsay Moor Farm
Wildey, Ken	Researcher	CSL
Paul Ibbott	Chief arable advisor	NFU England
Randall Warin	Trade policy manager	GAFTA
Andrew Williams		H&SE, Stoneleigh
Meurig Raymond	Farmer and HGCA board member	
Ward, Simon	Trader	Centaur Grain
Poole, Richard	Trader	Centaur Grain
Mcgarel, Alex	Policy officer, Seeds and Cereals department	UFU
Murrell, Ivor	Director	MAGB
Damian Testa	Trade policy manager	Nabim

Appendix 2

Sampling protocol
- ex trailer

The aim of taking a sample or series of samples is to give a fair representation of a batch or bulk to allow assessment of quality, value and storage potential. Sampling grain going into store is not a substitute for sampling during storage.

1. Equipment
Keep equipment clean and only use for sampling and storing grain samples.

1.1. Samplers

- Pelican sampler
- 1litre plastic jug
- A sampling spear (a to collect about 750g grain from one or several insertions). Preferably use a multi-aperture spear that can be opened and closed by the operator to collect from several depths at each insertion.

1.2. Containers

- 10 litre or larger plastic drums, boxes or tubs with lids.
- Sample bags of about 1kg capacity – which can be effectively sealed and labelled.

Establish a system to relate samples to specific bins of grain or sections of a bulk store. Number bins and paint bay numbers on the walls of floor stores. Indicates these numbers on the site plan.

2. Collecting samples
Collect a sample of about 1kg from the tailgate as trailers tip in the store. If trailer tips through a hatch in the tailgate, a jug or pelican can be used. If the whole tailgate is opened, only use the pelican. It may be safer to collect a sample from the tipped heap with a sample spear.

2.1. Technical details
Sweep a plastic jug or pelican sampler across the flow of grain from the trailer, so as to cut the stream of grain. Remove the jug or pelican as soon as full. Sample in a consistent manner. Avoid the first or last parts of the load.

Sample the grain after tipping by inserting the spear and removing a sample(s), from at least three positions.

Empty the jug, pelican or spear into a plastic container. Check for moisture content and temperature of some grain from each individual sample first, if this container is being used to build up a composite sample. Blend composite samples thoroughly before sub-sampling.

2.2. Testing
Measure the moisture content of each sample to give guidance on intake moisture and the need for drying.

If the meter uses a large, un-ground sample, tip the grain back into the main sample after testing. Measure the temperature of the grain to indicate the need for in-store cooling.

3. Frequency of sampling
3.1. Storage potential
Assess samples from sufficient incoming loads for moisture and temperature to allow proper decisions to be made about drying and cooling. This may mean testing every load as moistures will often change during the day.

3.2. Commercial sample
Produce one composite sample to represent each bin or each identified section or bay within a bulk store.

Start a new composite sample whenever moving to a new part of the store or taking grain from a different field.

Make up at least one composite sample for each 50 tonnes of grain irrespective of bin or bay size.

Samples best representing commercial value are made up from sub-samples taken as every trailer enters the store. Sub-sampling frequency depends upon the intake variability.

4. Sample handling
Label the container holding the composite sample clearly outside and inside. Make sure that the sample can be related to an identifiable batch of grain in the store (bin or section of a store). Make sure that the labels correspond to the site plan. .

Close the container with a lid that will prevent rodent access, stop contamination by dust or other grain and minimise moisture loss.

If grain in the store is moved, amend the site plan and ensure that the sample label still corresponds to the correct batch of grain. Moving the grain may also present an ideal time to re-sample and produce new composite samples.

Store the containers in the grain store under the same conditions as the grain they represent.

4.1. Sample storage

Samples with a moisture content of >14.5% may deteriorate long-term storage; those with high moisture contents will go mouldy. Dry those with moisture content >14% by spreading thinly on a tray in a warm dry room for 24 – 48 hours and label as “dried”. Alternatively, samples of wet grain analysis without delay.

5. Extracting commercial samples

Mix the composite sample thoroughly before extracting any samples for buyers

After mixing, tip the grain onto a clean plastic sheet and divide up using a clean board into halves, quarters and eights, until the correct amount is obtained for the buyer’s sample.

Carefully remove all the buyer’s sample (about 1kg) from the sheet, including all the fine material and transfer to a plastic bag.

Seal and label the bag.

It is worth measuring the moisture of this sample as, by doing so, as comparison between the farm and merchant’s moisture meter will be obtained.

6. Labelling

Label information for composite samples should include::

- Date of collection
- Variety
- Moisture content(s)
- Location of grain represented by the sample: e.g. Bin 3, or Shed 1, left bay 2.

Labels on buyer’s samples should include:

- Farm address and any other identity codes
- Quality scheme membership Number (attach an assurance scheme identity sticker to the sample bag)
- Location of grain represented by the sample (it must be possible for the buyer to be able to identify the location of the batch of grain covered by the sample. In some cases this may differ from the farm office address)
- Date of harvest
- Tonnes represented by sample
- Variety
- Moisture content

7. Safety

There are risks associated with the collection of samples. Assess the risks involved with specific tasks and locations, and take steps to minimise them.

Specific risks include:

- working near moving equipment
- conveying equipment – augers and elevators – **must be guarded**
- being engulfed by grain – **never stand or walk on moving grain**
- grain dust – **wear a dust mask**
- grain pits - **must be covered with a protective grill**

When handling treated grain, personal protective clothing must be worn, e.g. gloves and masks.

Working at the back of trailers during tipping can be dangerous because of the risk of being hit by the swinging tailgate or by being engulfed by grain. Only approach the rear of the trailer if it safe to do so. Always ensure that the trailer driver knows the sampler is present, especially when the trailer has a hydraulic tailgate.

Appendix 3

Sampling protocol

- ex-high-temperature drier

The aim of taking a sample or series of samples is to give a fair representation of a batch or bulk to allow assessment of quality, value and storage potential. Sampling grain going into store is not a substitute for sampling during storage.

1. Equipment
Keep equipment clean and only use for sampling and storing grain samples.

1.1. Samplers

- Pelican sampler
- 1litre plastic jug
- A sampling spear (a to collect about 750g grain from one or several insertions). Preferably use a multi-aperture spear that can be opened and closed by the operator to collect from several depths at each insertion.
- Diverter sampler inserted permanently into drier input and output flows.

1.2. Containers

- 10 litre or larger plastic drums, boxes or tubs with lids.
- Sample bags of about 1kg capacity – which can be effectively sealed and labelled.

Establish a system to relate samples to specific bins of grain or sections of a bulk store. Number bins and paint bay numbers on the walls of floor stores. Indicates these numbers on the site plan.

2. Collecting samples
Sample collection site depends upon facilities. Options include drier outflow, conveyor discharge or point of grain discharge into bin or floor store. Use samples collected as grain enters drier to assess drier performance. The best and safest option is a permanent diverter sampler in the drier flow..

2.1. Technical details
Sweep a plastic jug or pelican sampler across the flow of grain from either conveyor or spout, so as to cut the stream of grain. Remove the jug or pelican as soon as full. Sample in a consistent manner.

Sample the grain after tipping by inserting the spear and removing a sample(s), from at least three positions.

Empty the jug, pelican or spear into a plastic container. Check for moisture content and temperature of some grain from each individual sample first, if this container is being used to build up a composite sample. Blend composite samples thoroughly before sub-sampling.

If using a diverter sampler, allow the grain to fall directly into a plastic container. Collect sub-samples at regular intervals and measure moisture content and temperature.

3. Frequency of sampling
Sampling frequency depends on drier type, whether batch or continuous flow.

3.1. Storage potential:
Measure temperature and moisture content of samples regularly. Base sampling frequency on grain moisture content before drying. Sample grain several times if moisture content varies within the bulk pre-drying.

3.2. Commercial sample:
The best samples to represent commercial value compromise many sub-samples taken at relatively short intervals as grain is discharged from the drier.

For batch driers, collect several samples (at least1/t of grain in the drier) as the dried batch is discharged.

Combine samples from several batches into a single composite sample, provided the grain represented by the sample is stored in an identified section of the store.

Produce one composite sample to represent each bin or each identified section or bay within a bulk store.

Start a new composite sample whenever moving to a new part of the store or taking grain from a different field.

Make up at least one composite for each 50 tonnes of grain irrespective of bin or bay size.

4. Sample handling
Label the container holding the composite sample clearly outside and inside. Make sure that the sample can be related to an identifiable batch of grain in the store (bin or section of a store). Make sure that the labels correspond to the site plan. .

Close the container with a lid that will prevent rodent access, stop contamination by dust or other grain and minimise moisture loss.

If grain in the store is moved, amend the site plan and ensure that the sample label still corresponds to the correct batch of grain. Moving the grain may also present an ideal time to re-sample and produce new composite samples.

Store the containers in the grain store under the same conditions as the grain they represent.

5. Extracting commercial samples

Mix the composite sample thoroughly before extracting any samples for buyers

After mixing, tip the grain onto a clean plastic sheet and divide up using a clean board into halves, quarters and eights, until the correct amount is obtained for the buyer's sample.

Carefully remove all the buyer's sample (about 1kg) from the sheet, including all the fine material and transfer to a plastic bag.

Seal and label the bag.

It is worth measuring the moisture of this sample as, by doing so, as comparison between the farm and merchant's moisture meter will be obtained

6. Labelling

Label information for composite samples should include::

- Date of collection
- Variety
- Moisture content(s)
- Location of grain represented by the sample: e.g. Bin 3, or Shed 1, left bay 2.

Labels on buyer's samples should include:

- Farm address and any other identity codes
- Quality scheme membership Number (attach an assurance scheme identity sticker to the sample bag)
- Location of grain represented by the sample (it must be possible for the buyer to be able to identify the location of the batch of grain covered by the sample. In some cases this may differ from the farm office address)
- Date of harvest
- Tonnes represented by sample
- Variety
- Moisture content

7. Safety

There are risks associated with the collection of samples. Assess the risks involved with specific tasks and locations, and take steps to minimise them.

Specific risks include:

- working near moving equipment
- conveying equipment – augers and elevators – **must be guarded**
- being engulfed by grain – **never stand or walk on moving grain**
- drier exhaust fumes
- grain dust – **wear a dust mask**

When handling treated grain, personal protective clothing must be worn, e.g. gloves and masks.

Appendix 4

Results from farm sampling

Farm1 barley		Regina					
Instrument	Application	Sample_ID	Nitr.DM	Moisture	Volume we	Protimeter	Fines (%)
12411675	WB210241	1/1/1	1.7622	16.7249	59.9773	15.8	0.07
12411675	WB210241	1/1/2	1.7472	16.697	59.9416	16.2	0.06
12411675	WB210241	1/1/3	1.7771	16.8466	60.4235	16.2	0.10
12411675	WB210241	1/1/4	1.7488	16.8281	60.0487	16.1	0.08
12411675	WB210241	1/1/5	1.8232	16.9042	60.1379	16.2	0.06
12411675	WB210241	1/1/6	1.7777	16.6765	60.0487	16.3	0.08
12411675	WB210241	1/1/7	1.7665	17.1752	60.4056	16.3	0.16
12411675	WB210241	1/1/8	1.7373	16.7048	60.1915	16.3	0.30
12411675	WB210241	1/1/9	1.7282	17.5414	59.6025	16.3	0.95
12411675	WB210241	1/1/10	1.765	17.2902	59.2634	16.5	0.56
12411675	WB210241	1/1/11	1.8433	17.389	59.7631	15.9	0.06
12411675	WB210241	1/1/12	1.7607	16.6865	60.1736	16.0	0.05
12411675	WB210241	1/1/13	1.7861	16.8397	60.0665	15.9	0.06
12411675	WB210241	1/1/14	1.8013	16.5102	60.0487	16.0	0.05
12411675	WB210241	1/1/15	1.7481	16.6207	60.1736	15.8	0.07
12411675	WB210241	1/1/16	1.7259	17.0224	59.9773	16.0	0.08
12411675	WB210241	1/1/17	1.8248	17.3818	59.9416	16.2	0.07
12411675	WB210241	1/1/18	1.7596	17.5186	59.8345	16.0	0.19
12411675	WB210241	1/1/19	1.7554	17.0143	59.0671	16.2	0.59
12411675	WB210241	1/1/20	1.7616	16.7601	60.0844	16.4	1.42
12411675	WB210241	1/2/1	1.7081	16.8989	60.2093	15.7	0.09
12411675	WB210241	1/2/2	1.6646	16.6117	59.6204	15.7	0.10
12411675	WB210241	1/2/3	1.6746	16.7253	59.2813	15.6	0.07
12411675	WB210241	1/2/4	1.7021	16.6255	59.3884	15.7	0.06
12411675	WB210241	1/2/5	1.709	16.596	59.6561	15.8	0.07
12411675	WB210241	1/2/6	1.7222	16.9139	59.7631	15.7	0.11
12411675	WB210241	1/2/7	1.6527	16.269	59.8881	15.0	0.05
12411675	WB210241	1/2/8	1.7485	16.7253	59.7988	15.7	0.10
12411675	WB210241	1/2/9	1.6753	17.0435	59.2991	15.9	0.13
12411675	WB210241	1/2/10	1.7143	16.7168	59.6204	16.1	0.09
12411675	WB210241	1/2/11	1.6322	16.3476	59.9238	15.8	0.08
12411675	WB210241	1/2/12	1.6326	16.2684	59.6025	15.8	0.08
12411675	WB210241	1/2/13	1.6929	16.4644	59.8345	15.8	0.07
12411675	WB210241	1/2/14	1.6965	16.5622	59.7275	15.7	0.10
12411675	WB210241	1/2/15	1.7241	16.4464	59.9773	15.8	0.09
12411675	WB210241	1/2/16	1.6716	16.5715	59.8345	15.9	0.11
12411675	WB210241	1/2/17	1.6468	16.4314	60.0844	15.7	0.05
12411675	WB210241	1/2/18	1.7529	17.0934	59.8881	16.0	0.07
12411675	WB210241	1/2/19	1.6974	16.4646	60.1915	16.2	0.07
12411675	WB210241	1/2/20	1.6815	16.6964	60.0844	15.8	0.08

Farm 1 Wheat Consort

Application	Sample_ID	ProtDM	Moisture	Hardness	Volume we	Protimeter	Fines (%)
WH10106(	1A/1/1	10.3476	13.9551	31.8666	74.9785	13.5	0.07
WH10106(	1A/2/1	10.4745	13.5965	35.3254	75.1857	13.7	0.06
WH10106(	1A/3/1	10.318	13.4637	32.4797	74.9095	13.3	0.09
WH10106(	1A/4/1	10.3369	13.3627	37.3767	74.5125	13	0.13
WH10106(	1A/5/1	10.5708	13.2716	42.5596	73.9601	12.8	0.08
WH10106(	1A/6/1	10.6741	13.1736	40.0838	74.2708	12.6	0.08
WH10106(	1A/7/1	10.649	13.2329	36.8557	73.2697	12.7	0.07
WH10106(	1A/8/1	10.723	13.1589	39.2567	74.478	12.9	0.02
WH10106(	1A/9/1	10.6545	13.3622	38.191	73.5286	12.8	0.12
WH10106(	1A/C/1	10.4662	13.3597	39.4602	74.5125		0.16
WH10106(	1A/C/2	10.5012	13.36	39.4535	74.5988		0.1
WH10106(	1A/C/3	10.5864	13.474	37.6925	74.7369		0.17
WH10106(	1A/C/4	10.4956	13.4259	37.6814	74.0464		0.11
WH10106(	1A/C/5	10.5743	13.3915	38.596	74.6506		0.1

Yellow cells are composite sample values

Samples from heap

Application	Sample_ID	ProtDM	Moisture	Hardness	Volume weight
WH10106(	1A/H/1	10.4951	13.3131	39.8566	73.9774
WH10106(	1A/H/2	10.757	13.3199	43.1439	73.8738
WH10106(	1A/H/3	10.5218	13.3299	42.1618	73.425
WH10106(	1A/H/4	10.6545	13.3168	42.3223	74.1845
WH10106(	1A/H/5	10.7853	13.2914	45.8984	73.5113

(In black and white version, read ‘shaded’ for ‘yellow’)

Farm 2 Barley Opal

Sample_ID	Nitr.DM	Moisture	Volume we	Protimeter	Fines (%)
2/1/1	2.0513	17.7625	61.1552	16.4	0.20
2/1/2	2.0397	16.8665	61.8156	16.2	0.09
2/1/3	2.0552	17.29	60.3164	16.7	0.06
2/1/4	2.0029	16.9002	61.887	16.3	0.15
2/1/5	2.1889	17.93	59.3884	17.4	0.40
2/1/6	2.0257	17.0344	62.4402	17.7	0.25
2/1/7	2.0546	17.1279	62.3688	16.7	0.20
2/1/8	2.0984	17.0545	62.7079	16.6	0.15
2/1/9	2.051	17.8076	62.3688	17.0	0.51
2/1/10	2.0697	16.9524	62.4759	16.8	0.33
2/2/2	2.1399	16.899	61.8156	16.7	0.26
2/2/3	2.1027	17.3583	60.4949	16.6	0.15
2/2/4	2.1321	16.6441	61.6371	16.6	0.05
2/2/5	2.0864	17.4025	60.7626	16.7	0.21
2/2/6	2.1335	17.0302	62.3688	16.6	0.16
2/2/7	2.1324	17.0721	62.1547	16.7	0.38
2/2/8	2.1	17.0805	62.226	16.7	0.29
2/2/9	2.1255	17.3688	62.5651	16.9	0.50
2/2/10	2.1452	16.8187	62.7258	16.8	0.37

Farm 2 Wheat	Savannah						
Application	Sample_ID	ProtDM	Moisture	Hardness	Volume we	Protimeter	Fines (%)
WH101060	2A/1/1	9.2898	14.2998	42.8603	74.9095	14.1	0.06
WH101060	2A/2/1	11.8469	16.2747	67.1267	70.6459	16.7	0.06
WH101060	2A/3/1	11.8396	15.048	71.0497	70.6804	15.9	0.04
WH101060	2A/4/1	9.5971	14.4784	48.0899	74.7196	14.2	0.03
WH101060	2A/1/1A	9.3386	14.3309	45.438	75.4619		
WH101060	2A/C/1	11.1633	15.1144	63.4057	72.6482		0.12
WH101060	2A/C/2	11.0238	15.0818	61.4848	72.0959		0.05
WH101060	2A/C/3	11.177	15.0845	64.0462	71.4227		0.05
WH101060	2A/C/4	11.284	15.0921	65.1906	70.2834		0.06
WH101060	2A/C/5	11.1221	15.0439	63.2135	72.2167		

Yellow cells are composite values

(In black and white version, read ‘shaded’ for ‘yellow’)

eat Charger

Instrument	Application	Sample_ID	ProtDM	Moisture	Hardness	ume weight	Protimeter	Fines (%)
12411675	WH101060	3/1/1	11.8212	18.5961	52.9745	66.5377	18.7	0.14
12411675	WH101060	3/1/2	11.8789	18.4648	55.0770	67.1936	18.7	0.04
12411675	WH101060	3/1/3	12.3504	18.6021	59.0756	66.6930	18.6	0.58
12411675	WH101060	3/1/4	12.7072	18.9235	58.6743	64.4318	18.7	0.04
12411675	WH101060	3/1/5	12.8680	18.8072	57.8443	65.9508	19.0	0.06
12411675	WH101060	3/1/6	12.8405	18.8615	56.7873	67.0383	18.8	0.11
12411675	WH101060	3/1/7	12.8070	18.9224	59.7500	67.1764	18.9	0.09
12411675	WH101060	3/1/8	12.8101	18.8994	57.8689	67.3145	18.3	0.07
12411675	WH101060	3/1/9	12.2716	18.6927	52.0758	67.3835	18.7	0.08
12411675	WH101060	3/1/10	12.6462	19.0344	59.5837	66.8484	19.5	0.06
12411675	WH101060	3/1/10	12.9844	18.7271	54.9760	60.5825		
12411675	WH101060	3/2/1	13.1111	18.8204	53.6169	60.8242	19.0	0.44
12411675	WH101060	3/2/2	12.4168	18.4742	56.3781	67.7805	18.4	
12411675	WH101060	3/2/3	12.4923	16.8133	52.8521	69.5239	18.5	0.14
12411675	WH101060	3/2/4	12.4472	18.5998	56.6466	66.9692	18.5	0.01
12411675	WH101060	3/2/5	12.2276	18.6497	51.7847	63.7759	18.7	0.12
12411675	WH101060	3/2/6	12.3576	18.5151	55.4942	68.2293	18.7	0.11
12411675	WH101060	3/2/7	12.8242	18.5699	57.3412	67.9877	18.4	0.07
12411675	WH101060	3/2/8	12.8273	18.5537	59.3171	68.0740	18.6	0.10
12411675	WH101060	3/2/9	12.6174	18.5322	57.6622	68.1948	18.6	0.10
12411675	WH101060	3/2/10	12.5668	18.7377	52.9529	67.8841	18.9	0.05
12411675	WH101060	3/3/1	12.2204	18.3453	50.2056	67.2800	18.1	0.07
12411675	WH101060	3/3/2	12.4449	18.4581	53.0238	65.0532	18.3	0.02
12411675	WH101060	3/3/3	12.3461	18.4351	55.2916	66.4514	18.4	0.02
12411675	WH101060	3/3/4	11.5256	18.1721	44.3203	67.3835	17.8	0.13
12411675	WH101060	3/3/5	11.8203	18.2815	46.7327	67.2800	18.7	0.10
12411675	WH101060	3/3/6	11.9839	18.3935	51.4429	67.2800	18.3	0.07
12411675	WH101060	3/3/7	12.1171	18.3721	50.8281	67.5734	19.2	0.08
12411675	WH101060	3/3/8	12.0972	18.3751	51.1371	68.4192	18.7	0.08
12411675	WH101060	3/3/9	12.2587	18.3674	52.4408	68.1603	18.2	0.09
12411675	WH101060	3/3/10	12.0160	18.4121	50.1453	68.4019	18.1	0.07
12411675	WH101060	3/3/8	12.3237	18.4563	51.5760	68.2293	18.1	0.52
12411675	WH101060	3/4/1	10.0519	18.2825	30.2817	65.4675	17.8	0.06
12411675	WH101060	3/4/2	11.9571	18.0819	51.0113	68.1430	18.3	0.03
12411675	WH101060	3/4/3	12.0142	18.0816	52.6922	68.7299	18.3	0.26
12411675	WH101060	3/4/4	10.7728	18.2633	37.0879	67.3317	17.8	0.23
12411675	WH101060	3/4/5	10.4772	18.2073	35.7284	65.9335	18.0	0.16
12411675	WH101060	3/4/6	11.2322	18.2017	42.8633	68.2984	17.8	0.25
12411675	WH101060	3/4/7	10.9382	18.2714	39.6547	67.5216	18.4	0.24
12411675	WH101060	3/4/8	10.4958	18.2196	34.5473	67.4353	18.0	0.19
12411675	WH101060	3/4/9	10.8520	18.1780	37.1240	67.6942	18.3	0.19
12411675	WH101060	3/4/10	11.1403	18.4267	41.8035	67.1419		

Farm 3a Wheat Claire pre and post drying

Sample_ID	ProtDM	Moisture	Hardness	Volume we
3A/PDC/1	12.5438	16.8533	55.8563	69.4549
3A/PDC/2	12.5058	16.8043	56.6455	68.5228
3A/PDC/3	12.5405	16.9065	56.8474	68.2638
3A/PDC/4	12.3938	16.8164	53.2451	68.3847
3A/PDC/5	12.5763	16.8913	56.6584	68.8335
3A/ADC/1	12.7369	14.4213	46.0622	69.9209
3A/ADC/2	12.7739	14.5871	45.5199	69.6793
3A/ADC/3	12.818	14.4192	45.6441	69.2823
3A/ADC/4	12.4768	14.4236	45.1876	69.2132
3A/ADC/5	12.5272	14.5646	44.7745	69.7311
3A/H/1	12.4382	14.6844	44.9415	70.456
3A/H/2	12.5776	14.4888	46.6519	70.3697
3A/H/3	12.4544	14.7457	50.7845	70.8013
3A/H/4	12.4706	14.3862	47.9214	70.5424
3A/H/5	12.4005	14.4993	47.1359	70.9911
3A/C/1	12.4802	14.4546	47.5698	70.059

Farm 4 Wheat Savannah

Sample_ID	ProtDM	Moisture	Hardness	Volume we	Fines (%)
4/1/1	9.4247	17.1013	44.0857	72.9589	0.11
4/1/2	9.4295	17.0459	44.9483	72.9244	0.12
4/1/3	9.3634	17.1651	41.5594	72.8899	0.18
4/1/4	9.1282	17.2549	41.5754	72.1131	0.13
4/1/5	9.2604	17.1483	43.3469	72.8899	0.23
4/4/1	9.6382	16.5948	50.0901	72.8554	0.05
4/4/2	9.6413	16.5217	48.7683	72.5101	0.07
4/4/3	9.5845	16.7693	50.7672	72.8726	0.10
4/4/4	9.4847	16.7023	46.1648	73.0453	0.06
4/4/5	9.7319	16.8451	49.5328	72.9762	0.12
4/2/1	9.2253	17.2477	41.9138	72.8036	0.06
4/2/2	9.3277	17.3075	42.7682	72.7173	0.07
4/2/3	9.7228	17.0721	44.4546	73.0453	0.07
4/2/4	9.6905	17.0475	47.0277	73.6149	0.17
4/2/5	9.6778	16.985	42.6136	72.9417	0.12
4/3/1	9.2018	16.986	44.6848	73.4768	0.10
4/3/2	9.1191	17.0074	43.7927	73.1143	0.07
4/3/3	9.2893	17.0693	44.8925	72.9589	0.07
4/3/4	9.3909	17.0339	47.4523	73.0625	0.07
4/3/5	9.1232	17.3666	45.6764	73.4078	0.07
4/5/1	9.3012	16.9971	42.9356	73.0107	0.07
4/5/2	8.9357	17.0797	42.3656	73.0798	0.05
4/5/3	8.8844	17.1708	42.2259	73.5804	0.07
4/5/4	8.8582	17.184	44.1778	72.7173	0.37
4/5/5	9.2081	17.0335	47.3038	72.7	0.17
4/6/1	9.5557	16.9221	47.3633	73.6839	0.10
4/6/2	9.4176	16.9424	42.718	73.6494	0.06
4/6/3	9.3789	16.8448	45.7463	73.4078	0.05
4/6/4	9.6369	16.8743	50.8171	73.6149	0.08
4/6/5	9.6092	17.0725	47.5853	73.3387	0.11
4/7/1	9.3348	16.9025	45.3982	73.8393	0.01
4/7/2	8.7993	16.966	40.5545	72.2685	0.09
4/7/3	9.0282	16.978	41.0022	72.9762	0.09
4/7/4	9.2483	17.0457	44.0746	73.0107	0.08
4/7/5	9.1075	17.048	45.1023	72.8036	0.09
4/8/1	9.2501	17.1362	40.4641	74.0464	0.14
4/8/2	9.3566	17.2066	48.9186	73.753	0.09
4/8/3	9.6125	16.7633	48.7404	73.7702	0.04
4/8/5	9.8157	16.4992	51.0591	73.6149	0.05
4/9/1	9.5581	16.6032	50.3552	73.5631	0.06
4/9/2	9.8801	16.3957	50.3124	73.8738	0.09
4/9/3	9.7775	16.4692	50.84	73.9601	0.11
4/9/4	9.9064	16.386	50.773	74.0464	0.10
4/9/3	9.757	16.58	51.1504	74.2536	0.19
4/9/5	9.808	16.7667	45.195	73.822	0.11
4/10/1	9.768	16.1993	52.0311	73.6149	0.12
4/10/2	10.0606	16.501	52.7528	73.4941	0.21
4/10/3	9.7803	16.4432	51.4707	73.3387	0.16
4/10/4	9.9049	16.2464	52.5918	73.3905	0.10
4/10/5	10.0927	16.4092	55.0477	73.6839	

Farm 5 wheat

Instrument	Application	Sample_ID	ProtDM	Moisture	Hardness	Volume we	Protimeter	Fines (%)
12411675	WH101060	5/1/1	12.2771	16.1829	67.3325	72.5274	16.1	0.12
12411675	WH101060	5/1/2	12.1523	16.1293	64.1076	72.8726	15.9	0.10
12411675	WH101060	5/1/3	12.1516	16.2024	69.1799	73.3905	16.0	0.08
12411675	WH101060	5/1/4	12.1716	16.2571	68.0094	73.6321	15.8	0.08
12411675	WH101060	5/1/5	12.2273	16.2969	67.0051	73.5459	16.1	0.10
12411675	WH101060	5/2/1	10.8361	15.8451	56.3569	72.3375	15.2	0.10
12411675	WH101060	5/2/2	11.0316	15.7864	56.4032	72.4929	15.1	0.10
12411675	WH101060	5/2/3	10.9062	15.9727	58.3064	72.8209	15.1	0.09
12411675	WH101060	5/2/4	11.4026	16.0531	62.5934	73.2869	15.8	0.11
12411675	WH101060	5/2/5	11.47	15.9329	62.5352	72.9417	15.6	0.10
12411675	WH101060	5/3/1	12.2799	15.5689	67.0944	72.7346	14.8	0.07
12411675	WH101060	5/3/2	11.9887	15.6374	65.1149	72.7	15.0	0.16
12411675	WH101060	5/3/3	12.0336	15.8545	67.5735	74.0464	15.5	0.05
12411675	WH101060	5/3/4	11.9541	15.669	65.8546	73.2351	15.1	0.05
12411675	WH101060	5/3/5	12.1852	15.5886	66.8555	72.7	15.5	0.13

Farm 6 barley

Instrument	Application	Sample_ID	Nitr.DM	Moisture	Volume we	Protimeter	Fines (%)
12411675	EO210240	6/2/1	1.3913	16.7056	66.438	16.6	0.16
12411675	EO210240	6/3/1	1.2893	15.7645	67.4017	16.2	0.17
12411675	EO210240	6/4/1	1.6243	16.9923	65.4742	15.5	0.20
12411675	EO210240	6/5/1	1.6113	16.1197	66.0989	16.5	0.31
12411675	EO210240	6/6/1	1.3655	15.1302	67.0091	16.2	0.23

Farm 7 Wheat Savannah

Pre-drying

Sample_ID	ProtDM	Moisture	Hardness	Volume we	Protimeter	Fines (%)
7/1/1	10.5633	16.6462	54.4652	74.7714	16.7	0.21
7/2/1	10.0779	15.7916	50.7916	75.6	15.5	0.29
7/3/1	10.077	15.6163	52.7449	75.8243	15.5	0.34
7/4/1	10.3506	15.4204	50.7358	75.4446	16.2	0.25
7/5/1	9.997	14.8612	51.8572	75.0131	15.0	0.18
7/6/1	9.2837	14.9208	42.9346	75.6345	14.9	0.34
7/7/1	9.4773	15.1817	45.2756	75.5309	14.5	0.29
7/8/1	9.8264	14.6304	47.0299	75.6345	14.3	0.31
7/9/1	10.0808	14.8989	52.6354	75.6863	14.7	0.38

Post-drying

Sample_ID	ProtDM	Moisture	Hardness	Volume we	Protimeter	Fines
7/PD/1	10.1142	12.6951	54.9972	75.1512	12.6	0.19
7/PD/2	10.188	12.2785	53.1895	75.9107	12.3	0.16
7/PD/3	10.1358	11.2966	55.0787	75.9797	12.1	0.08
7/PD/4	10.17	11.6438	56.4639	75.4446	12.1	0.06
7/PD/5	9.9132	12.9548	53.7376	76.4112	12.6	0.16
7/PD/6	10.0002	12.5415	53.9904	76.2041	12.8	0.1
7/PD/7	9.9854	12.816	56.9494	75.8589	13	0.08
7/PD/8	9.9633	12.689	54.0645	76.5321	12.8	0.08
7/PD/9	10.0156	12.7542	57.0483	76.5838	12.7	0.12
7/PD/10	10.0199	12.529	56.5067	76.3077	12.3	0.12
drying composite						
7/PD/C1	10.0612	12.8666	60.2034	75.8934		0.07
7/PD/C2	10.1261	12.8866	62.0109	76.1005		0.11
7/PD/C3	10.0202	12.8139	60.7121	76.1696		0.08
7/PD/C4	10.1018	12.7948	59.51	75.8589		0.07
7/PD/C5	10.1488	12.7353	57.9215	75.669		0.08

Farm 8 Wheat Molucca

Instrument	Application	Sample_ID	ProtDM	Moisture	Hardness	Volume we	Protimeter	Fines (%)
12411675	WH10106C	8/1/1	12.3731	20.5282	71.5966	67.5389	19.8	0.02
12411675	WH10106C	8/1/2	12.12	20.3947	71.2343	68.4882	20.5	0.03
12411675	WH10106C	8/2/1	12.2141	19.992	70.3229	68.9716	19.7	0.04
12411675	WH10106C	8/2/2	12.0202	19.9389	72.2939	70.0936	19.9	0.03
12411675	WH10106C	8/3/1	12.5565	19.6557	69.9797	70.1971	19	0.01
12411675	WH10106C	8/3/2	12.2905	19.5548	69.4347	71.3882	19.3	0.03
12411675	WH10106C	8/4/1	12.1882	19.2253	66.991	71.2328	18.7	0.02
12411675	WH10106C	8/4/2	12.214	19.4877	65.3202	70.9566	19.3	0.02
12411675	WH10106C	8/5/1	12.1874	19.0261	66.0181	71.3364	18.7	0.01
12411675	WH10106C	8/5/2	11.9648	19.063	64.4355	72.3203	18.8	0.04
12411675	WH10106C	8/6/1	12.2695	18.9266	66.3556	71.6816	18.5	0.05
12411675	WH10106C	8/6/2	12.1838	19.0234	63.545	72.0786	18.4	0.02
12411675	WH10106C	8/C1/1	12.3306	19.5065	68.3557	70.784		0.02
12411675	WH10106C	8/C1/2	12.3602	19.2908	69.8499	70.5251		0.02
12411675	WH10106C	8/C1/3	12.2792	19.7428	66.5924	70.5596		0.02
12411675	WH10106C	8/C1/4	12.3151	19.609	67.8042	70.1971		0.01
12411675	WH10106C	8/C1/5	12.0849	19.7835	67.783	69.4549		0.01
12411675	WH10106C	8/C2/1	12.2554	19.4298	64.4788	71.0084		0.02
12411675	WH10106C	8/C2/2	12.2173	19.4199	66.0637	71.0775		0.03
12411675	WH10106C	8/C2/3	12.1794	19.3862	67.1659	70.2662		0.02
12411675	WH10106C	8/C2/4	12.0004	19.5872	64.4973	71.7507		0.01
12411675	WH10106C	8/C2/5	12.029	19.3528	65.4611	71.4572		0.01

Yellow cells are composite values

(In black and white version, read ‘shaded’ for ‘yellow’)

Farm 8A Wheat Molucca

Instrument	Application	Sample_ID	ProtDM	Moisture	Hardness	Volume we	Protimeter	Fines (%)
12411675	WH101060	8A/1/1	12.9316	18.4837	68.4282	65.6574	17.9	0.03
12411675	WH101060	8A/1/2	13.1196	18.3005	65.0902	67.1591	17.9	0.07
12411675	WH101060	8A/2/1	13.0741	18.304	63.1681	65.9681	17.4	0.05
12411675	WH101060	8A/2/2	12.966	18.086	63.0415	66.4687	17.7	0.05
12411675	WH101060	8A/3/1	13.2615	17.96	66.4028	66.4859	17.7	0.02
12411675	WH101060	8A/3/2	13.4876	17.8967	64.8668	67.2627	17.5	0.04
12411675	WH101060	8A/4/1	13.5121	17.9091	65.8474	65.8818	17.4	0.02
12411675	WH101060	8A/4/2	12.9395	17.869	63.2578	66.9002	17.4	0.03
12411675	WH101060	8A/5/1	13.2723	17.8911	62.3777	65.433	17.2	0.03
12411675	WH101060	8A/5/2	13.0944	17.8981	61.882	66.7103	17.4	0.05
12411675	WH101060	8A/6/1	13.3828	17.7715	63.3691	65.3639	16.9	0.02
12411675	WH101060	8A/6/2	13.2395	17.7735	64.0022	66.0371	17.1	0.05
12411675	WH101060	8A/C1/1	13.302	17.9103	64.3402	66.6585		0.03
12411675	WH101060	8A/C1/2	13.2551	17.9087	61.2099	66.5377		0.04
12411675	WH101060	8A/C1/3	13.1921	17.8697	61.7677	66.3996		0.03
12411675	WH101060	8A/C1/4	13.1248	17.9781	60.9649	66.4687		0.06
12411675	WH101060	8A/C1/5	13.1571	17.949	62.2459	66.8484		0.03
12411675	WH101060	8A/C2/1	13.2057	17.921	64.8051	67.1764		0.02
12411675	WH101060	8A/C2/2	13.1863	17.9881	63.1455	66.8139		0.03
12411675	WH101060	8A/C2/3	13.1911	17.9258	63.2863	66.7794		0.04
12411675	WH101060	8A/C2/4	13.0805	17.939	62.9012	66.2788		0.01
12411675	WH101060	8A/C2/5	13.1855	17.91	62.4599	66.8484		0.02

Yellow cells are composite values
(In black and white version, read ‘shaded’ for ‘yellow’)

Farm 9 + 9a Barley Optic(?)

Sample_ID	Nitr.DM	Moisture	Volume we	Fines
9/1/1	1.8982	18.2265	57.7286	0.17
9/1/2	1.8239	18.193	58.139	0.21
9/1/3	1.8533	18.3292	57.9427	0.21
9/1/4	1.872	18.462	58.496	0.16
9/1/5	1.8579	18.6934	58.4781	0.19
9/1/6	1.8742	18.657	57.7286	0.18
9/1/7	1.8344	18.5854	57.7107	0.15
9/1/8	1.9076	18.7188	56.9254	0.24
9/1/10	1.8489	18.4513	58.0498	
9/1/11	1.8024	18.2134	58.496	0.11
9/1/12	1.8422	18.8428	58.0677	0.15
9/1/13	1.8676	18.6592	58.1569	0.15
9/1/14	1.8358	18.7141	58.4246	0.21
9/1/15	1.8918	18.7087	58.6566	0.22
9/1/16	1.8642	18.9928	58.3354	0.1
9/1/17	1.88	18.3717	58.5495	0.35
9/1/18	1.8821	18.3092	58.6388	0.24
9/1/19	1.8355	18.3678	58.3889	0.7
9/1/20	1.8808	18.6138	58.8708	0.22

Post drying

9A/1/1	1.8785	15.9155	60.6376	0.06
9A/1/2	1.8634	15.6428	60.8161	0.03
9A/1/3	1.845	15.7183	61.3694	0.03
9A/1/4	1.7915	15.5295	61.6192	0.04
9A/1/5	1.8449	15.4642	60.834	0.05
9A/1/6	1.8388	15.6364	61.0838	0.06
9A/1/7	1.8056	15.6376	61.1731	0.05
9A/1/8	1.8112	15.8152	61.5835	0.03
9A/1/9	1.8521	15.687	61.1374	0.05
9A/1/10	1.8521	16.0578	61.887	0.03
9A/1/11	1.8672	15.4514	61.7442	0.03
9A/1/12	1.7974	16.0556	61.7085	0.03
9A/1/13	1.8433	15.4682	61.4229	0.04
9A/1/14	1.862	15.4545	61.53	0.03
9A/1/15	1.895	15.6029	61.3158	0.06
9A/1/16	1.8761	15.2318	61.298	0.05
9A/1/17	1.8792	15.6514	61.5657	0.03
9A/1/18	1.8389	15.4015	61.6371	0.04
9A/1/19	1.7855	15.9967	61.4586	0.05
9A/1/20	1.8637	15.8773	61.4765	0.04

Farm 10 + 10a Wheat

Sample_ID	ProtDM	Moisture	Hardness	Volume we	Fines
10/1/1	13.23	21.1383	87.8905	63.4997	0.05
10/1/2	13.5278	21.0671	88.6649	63.8794	0.07
10/1/3	13.3898	21.1083	87.9979	63.6378	0.11
10/1/4	13.1586	21.0637	86.6975	63.7413	0.1
10/1/5	13.1564	21.1204	87.9244	63.9312	0.08
10/1/6	13.4457	21.1472	86.674	64.0348	0.06
10/1/7	13.3664	21.1242	90.5082	63.3271	0.07
10/1/8	13.242	21.0705	84.711	64.1038	0.08
10/1/9	13.2011	21.0937	85.7168	63.7068	0.07
10/1/10	13.3971	21.1081	87.1146	63.4652	0.07
10/1/11	13.2367	21.0925	86.8362	63.6205	0.07
10/1/12	13.282	21.0981	86.7309	64.3628	0.06
10/1/13	13.181	21.0628	87.7105	64.2074	0.11
10/1/14	13.2867	21.1058	89.1731	64.8806	0.07
10/1/15	13.2414	21.1335	86.0329	64.3973	0.08
10/1/16	13.2044	21.0714	86.4586	64.7425	0.08
10/1/17	13.1476	21.128	85.0799	64.2592	0.07
10/1/18	13.0718	21.0274	85.6008	64.7598	0.07
10/1/19	13.1273	21.0556	83.1649	64.2592	0.09
10/1/20	13.3547	21.1308	86.9778	64.4836	0.07
10/1/21	13.2397	21.1566	85.5748	64.5354	0.09
10/1/22	13.3192	21.1684	87.2689	65.105	0.03
10/1/23	13.1818	21.0975	87.0443	64.7943	0.08
10/1/24	13.4448	21.1595	86.479	62.5503	0.08
10/1/25	13.4138	21.1064	86.9056	64.6735	0.1
Post Drying					
10A/1/1	12.4614	13.8513	71.4932	69.9727	0.06
10A/1/2	12.5531	13.7121	70.0305	69.4031	0.06
10A/1/3	12.5427	13.6604	69.3474	56.7332	0.03
10A/1/4	12.4701	13.9311	71.4139	69.4549	0.05
10A/1/5	12.7403	13.373	72.7642	67.6942	0.06
10A/1/6	12.4741	13.791	71.2238	68.4192	0.09
10A/1/7	12.5314	14.1168	68.5198	69.99	0.06
10A/1/8	12.7558	13.4327	70.1558	67.1936	0.09
10A/1/9	12.5734	13.6525	70.1283	68.5918	0.05
10A/1/10	12.6525	13.9249	73.698	67.9704	0.07
10A/1/11	12.606	13.6219	71.4263	68.2466	0.08
10A/1/13	12.991	13.2451	71.3676	67.0555	0.05
10A/1/14	12.5287	13.8001	71.8639	67.6424	0.07
10A/1/15	12.9516	13.4195	70.7491	67.6079	0.06
10A/1/16	12.6919	13.8496	70.6102	67.1591	0.05
10A/1/17	13.1168	13.4133	73.5844	66.2788	0.06
10A/1/18	12.8628	13.7436	72.4783	68.5745	0.09
10A/1/19	13.1625	13.5396	71.2913	68.0567	0.06
10A/1/20	13.1241	13.9117	73.4146	67.5734	0.06
10A/1/21	12.961	13.4433	71.4847	67.2454	0.05
10A/1/22	12.9922	13.6946	72.2331	68.4537	0.1
10A/1/23	13.3523	13.645	71.423	67.677	0.07
10A/1/24	13.3488	14.0738	72.5352	67.4526	0.1
10A/1/25	13.1599	13.4291	71.684	68.6263	0.06
10A/1/26	13.3434	13.9999	72.3372	69.0061	0.12