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20 September 2024

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**THE CHAIRMAN**

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# SORGHUM TRUST REPORT

## PROJECT TITLE: ANNUAL ANALYSES ON SORGHUM CULTIVAR TRIAL SAMPLES FOR PROCESSING APPLICATIONS – 2022/23 SEASON


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## PART 1: CONTINUATION OF CULTIVAR EVALUATIONS AND REFINEMENT OF DEHULLING INDEX CALIBRATION MODEL ON THE FOSS NIT INSTRUMENT

### 1.1 BACKGROUND AND MOTIVATION FOR THE PROJECT WORK

Since the 2013/14 season, sorghum cultivars were analysed for a period of eight seasons to build a database of sorghum quality results which now has more than 400 samples' data collected. The main reason why it took so many years to arrive at a dataset of sufficient size to do statistically significant data modelling is that only a small number of sorghum cultivars is being tested every year compared to larger crops like maize.

### 1.2 MOTIVATION AND CONTINUATION OF WORK:

One of the objectives during the previous season's (2021/22) work was also to test the validity of the first FOSS NIT calibration for the Dehulling Index (DI) that was uploaded in the 2017/18 season. The initial calibration of the NIT gave poor correlations with the first validation. Statistical results have shown that the sorghum dataset contain many outlier values, which indicated that there might probably be either interaction effects between the measurements, or another factor affects the calibration sensitivity. One of those factors is the variability of sorghum in terms of morphological characteristics, especially size and colour.

Sorghum is a variable crop and local variation (growing conditions etc) can vary greatly within a cultivar causing variations in grain kernel size. Dehulling properties on the Barley Pearler are strongly influenced by the size of the grains and therefore confounds (complicate) the prediction models for sorghum dehulling as it is related to kernel hardness. Therefore, to be able to better compare results between cultivars instead of trying to distinguish between results that were influenced by grain size and those that were not, the grain size was standardised for all calibration work since 2017/18.

The biochemical basis for hardness in sorghum is similar to maize. Hardness in both grains is determined by the strength of the sulphur cross-links in the prolamin proteins. The amount of those cross-links will determine if a hard endosperm structure will be present or not. In the case of maize, the large size of the kernels and the relative thin pericarp do not interfere with the development of calibration models using NIT spectral scans. In the case of sorghum, with its very small seeds and thick pericarps, the sensitivity of the scan becomes problematic in the sense that the spectral detector may not be able to "see" the differences between proteins that are cross-linked and those that are not due to the "noise effect" from the thick pericarp.

There are ways to mitigate this problem and to refine the NIT calibration which will allow direct measurement of sorghum Dehulling Index on the NIT. These are:

- Replace scanning of whole sorghum with scanning of milled sorghum samples instead

- Classify the dataset samples according to sorghum colour and tannin content – this is only possible to do if the dataset is large enough
- Understanding interactions between the results of the quality tests.

The SAGL has kept retention samples of all the sorghum cultivars analysed for the past five years. These samples were milled and scanned again on the NIT to produce a set of spectra from the milled material. The modelling and calibration of the FOSS NIT were done again using these values. It is envisaged that the milling of the samples will reduce the interference from the sorghum morphological structure to the NIT spectra. The scans were sent to FOSS for the calibration and feedback is awaited.

Along with the refinement of the Dehulling Index model, 44 cultivars from the 2022/23 season were analysed again for the parameters listed in section 1.3.

## 1.3 MATERIALS AND METHODS

### 1.3.1 BARLEY PEARLER (BP) TESTS FOR DEHULLING

Whole sorghum >3.55 and <4 mm (round hole sieve) was dehulled after conditioning to 14 % moisture. Samples of 150 grams each were dehulled for 70 seconds on the laboratory BP with a 0.25 kW Bauer 220 V motor. Dehulling efficiency was measured by the mass % of three fractions namely “Bran” (fine bran < 2.38 mm round hole sieve), “BP Grits” (coarse bran and small broken or half-kernel endosperm pieces < 1.8 mm slotted sieve but > 2.38 mm round hole sieve) and “BP Dehulled Kernels” (dehulled sorghum > 1.8 mm slotted sieve).

*Note that due to the different actions of a slotted sieve to remove half-kernels or broken kernels and a round hole sieve to remove bran, sieve sizes do not follow in a chronological order as is usually the case when only round hole sieves are used in a single set. Half-kernels may fall through a 1.8 mm slotted sieve but will stay above a 2.38 mm round hole sieve.*

Yield of fractions were calculated as weight percentages of the total sample weight and expressed on a 14 % moisture basis.

The Dehulling Index for sorghum was calculated as follows:

DI = (% unbroken dehulled sorghum - (% grits+% bran)) + 20.

The % of each fraction was calculated as the mass % of the total whole sample before dehulling. To compensate for dehulling losses on the BP, the total amount of whole sample was calculated as the sum of the as is weight of all three fractions.

The constant value of 20 was added to the formula to prevent negative DI values obtained from very soft sorghums. It is at this stage a test value which can be adjusted in future if necessary.

At the beginning of the research work the Dehulling Index was calculated on unsieved and unconditioned sorghum. Since it was shown in previous projects that sorghum size distribution as well as moisture content had a significant effect on the dehulling properties, the standardisation of sorghum size by sieving was implemented. To ensure that size effects were similar for all samples and removing the effect of moisture variation by conditioning of all samples to 14 % moisture before dehulling, dehulling results are produced that are a better reflection of actual kernel hardness.

The new definitions in use are as follows:

**Dehulling Index DI** – calculated on Barley Pearler dehulling results for unsieved and unconditioned sorghum

**Sorghum Hardness Index SHI** – calculated on Barley Pearler dehulling results for sieved sorghum and conditioned to 14 % moisture.

### 1.3.2 Image Analyses (kernel size distribution, length, width, roundness) of whole kernels:

Sorghum kernels were photographed on a Panasonic Lumix digital camera (DNC-LX3) Photos were analysed afterwards using Digimizer version 4.0.0.0 software supplied by Medcalc (www.digimizer.com) to measure the sorghum kernels' size. Photos of all the samples are stored in a database and are available on request. The following size parameters were measured:

- Maximum length (indicated as "Length")
- Width (indicated as "width," calculated at a 90 % angle from the maximum length of an object)
- Aspect Ratio or "Roundness" (% Width/Length or W/L %)
- Kernel Volume:Surface Area ratio calculated as a percentage – by using the formulas for the calculation of the volume and surface of an ellipsoid, the calculated volume to surface ratio for individual sorghum kernels can be obtained from the image analysis data. Smaller kernels will have a lower volume to surface area ratio.

### 1.3.3 Hunter Lab colour:

The colour of the dehulled samples was determined with the Hunterlab Color-Flex 45/0 spectrophotometer on 10°/D65 according to SAGL Industry accepted method 004. The spectrophotometers operate in the Hunter L, a, b scale where:

- L measures lightness and varies from 100 for perfect white to zero for black, approximately as the eye would evaluate it.
- The chromaticity dimensions (“a” and “b”) give understandable designations of colour as follows:

  “a” measures redness when positive, grey when zero, and greenness when negative.

  “b” measures yellowness when positive, grey when zero, and blueness when negative.

A colour of a control sample was determined before every batch of samples. All samples for colour were milled on a 0.5 mm screen on the Retch mill to ensure even distribution of the colour throughout the samples.

### 1.3.4 Dehulled Sorghum particle size (PSI):

The sieving test is used to classify the fractions obtained from the Barley Pearler. Two sieve sizes are used namely a 2.38 mm round hole sieve and a 1.8 mm slotted sieve.

### 1.3.5 Whole Sorghum Particle size (sieving classification):

To compare the general size distribution of sorghum, sieve tests using round hole sieves were done. The sizes of the sieves were:

>4 mm

>3.55 mm and <4 mm

>3.15 mm and <3.55 mm

<3.15 mm

The samples collected >3.55 mm and <4 mm were used for the Barley Pearler Dehulling tests to ensure that Dehulling data reflected sorghum hardness characteristics and not sorghum size effects.

### 1.3.6 Near Infrared Transmittance (NIT):

<u>Milled sorghum samples:</u>

Cultivar samples collected over five production seasons were scanned and infrared spectra collected. These samples were milled first on a Retch mill on the 500 µm screen. After milling, the samples were scanned using the meal and flour sample cup holder on the Infratech FOSS machine. Scans were collected and sent along with the collected dehulling data to FOSS in Europe for fitting of the new model, which will be an on-line download onto the FOSS machine through Mosaic software.

Whole sorghum samples:

The existing NIT calibrations for whole sorghum is also used for providing some of the analytical results namely the % Protein, % Starch, Test Weight and 1000 kernel mass. The SAGL has developed a new % Starch calibration during the 2017/18 season for the Foss instruments.

### 1.3.7 Chemical composition (reference methods):

Oven Moisture, wet chemistry starch and wet chemistry protein analyses were done on 22 samples.

The moisture content was determined on milled grain using the ICC Standard 110/1 (latest edition), air oven moisture method at 130 °C for 2 hours. Single determinations were conducted and a control sample was analysed with every set of samples. Moisture content results were used to calculate % starch and % protein as dry base results.

Determination of Starch was according to the SAGL In-house method 019, a polarimetric method based on the modified Ewers method. The starch content is released from the sample by boiling in dilute hydrochloric acid. The starch solution in the filtrate is determined by measuring the angle of polarisation or optical rotation of the filtrate with a polarimeter. The acid also helps to break down the endosperm tissue, ensuring complete release of the starch granules from the protein matrix. Substances, which may interfere with the measurement, are removed by filtration. This method is applicable to cereals, flour, milling products (e.g. rolled oats, semolina), potatoes and other starch containing products. The samples were analysed in duplicate with a control sample included in every batch of samples.

Protein % was determined by the AACCI 46-30.01 (Latest Edition) method.

### 1.3.8 Physical parameters:

Kern Test weight (kg/hl) and 1000 kernel mass were measured on all the samples.

### 1.3.9 Scope of the project:

The budget included a total of 44 cultivar trial samples that were analysed for the 2022/23 season. A total of 104 cultivar trial samples were received at SAGL. The 44 samples were randomly selected from the larger sample set. Samples were provided by participating breeders and from cultivar trials. The list of cultivars tested for this report and the respective suppliers are shown in Appendix A. Number and description of samples tested in this project are given in Tables 1 and 2. Due to the budget adjustments, only 22 samples (50 %) could be analysed for some of the more costly tests.

### 1.3.10 Current status of prediction models for sorghum:

Since the 2013/2014 season, work has been undertaken on the following models:

- Calibration of the FOSS NIT to predict sorghum Dehulling Index and Sorghum Hardness Index – this model is now being refined by means of expanding the calibration to include >300 samples of sorghum collected over 5 seasons. The samples were scanned during 2022/2023 as milled samples (500 µm sieve on the Retch mill) to reduce the interference of sorghum kernel size variation on the sensitivity of the scans. An existing model on the FOSS for Dehulling index is in use, but it measures whole sorghum. It was found that sample accuracy for the whole sorghum calibration model is not what it should be, possibly because of sorghum's large variation in particle size and the additional effects of the naturally occurring thick pericarp.

- Predicting sorghum Dehulling Index by means of a multiple regression and principal component analyses (PCA) approach using chemical and physical parameters as independent variables – this model is showing good potential but could not be updated using the 2022-2023 results due to the budget cuts. Only 22 samples from the 2022-2023 season could be analysed for all the independent variables needed for the model, not enough samples to make a useful contribution to the improvement of the existing prediction model. However, the data will be kept on record at SAGL and will be combined with any future work on similar samples from future seasons to update the model.

- Predicting sorghum SDU values by using a shorter (4 day) malting method instead of the current 6-day method – in the previous report (for the 2021-2022 season) a promising model was developed using malted cultivar samples selected from that group. However, due to the budget cuts, no additional work could be done on this specific model using 2022-2023 samples. The model remains unchanged until additional information becomes available.

- The use of the Rapid Visco Analyser (RVA) to replace the wet chemistry SDU titration method for sorghum malt – this model has commercial potential as a rapid replacement for the existing wet-chem method for measuring SDU values. It will provide an answer within 24 hours compared to three days for the wet chemistry method, and at a significantly reduced cost. Due to the budget cuts, it was decided to focus the 2022-2023 work on this RVA model to validate the method and to increase the robustness of the regression fit. The results of the updated model are presented and discussed in this report. Table 1 shows the number of samples tested for each analytical test. Table 2 shows the number of samples collected from each season for inclusion in the new Sorghum Hardness and Dehulling Index model by using milled samples instead of whole kernel samples.

**Table 1 Number of samples tested using each method**

| ANALYTICAL TEST | NUMBER OF SAMPLES |
|---|---|
| Barley Pearler Dehulling | 44 |
| Image Analysis | 44 |
| Hunter Lab | 44 |
| Sorghum size (sieving classification) | 44 |
| NIT (for protein, starch, moisture, test weight) | 44 |
| NIT for new Dehulling Index scans (cumulative number of samples from various seasons) | 336 |
| Chemical Composition (protein, starch, moisture) | 22 |
| Physical parameters (Kern test weight, 100 kernel mass) | 22 |

**Table 2 Number of five season's cumulative samples tested for the updated Dehulling Index calibration model**

| SEASON | SAMPLE COUNT |
|---|---|
| 2017-2018 | 66 |
| 2018-2019 | 90 |
| 2019-2020 | 80 |
| 2020-2021 | 49 |
| 2021-2022 | 47 |
| Total | 332* |

***** Four samples could not be scanned due to insect damage

## 1.4 Results and Discussion

### 1.4.1 NIT parameters

NIT measurements for Protein, Starch and Test weight are shown for ranked 2022-2023 cultivar samples in Figures 1-3.

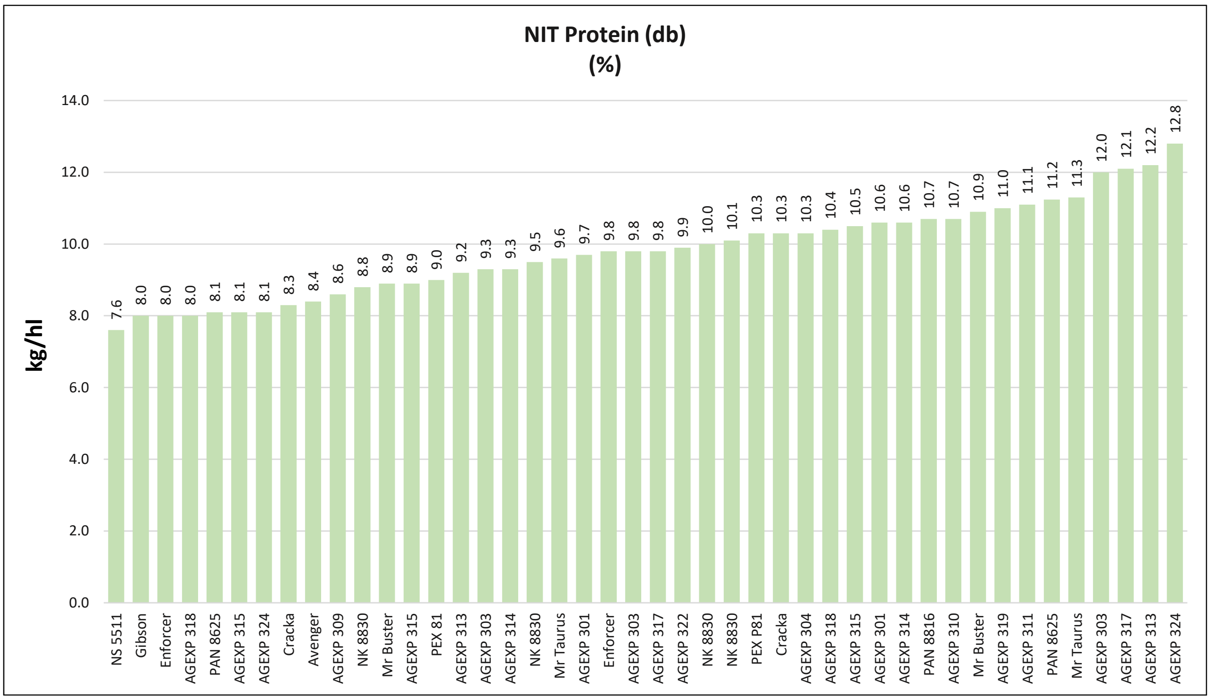



**Figure 1 Ranking of cultivars for % NIT Protein**

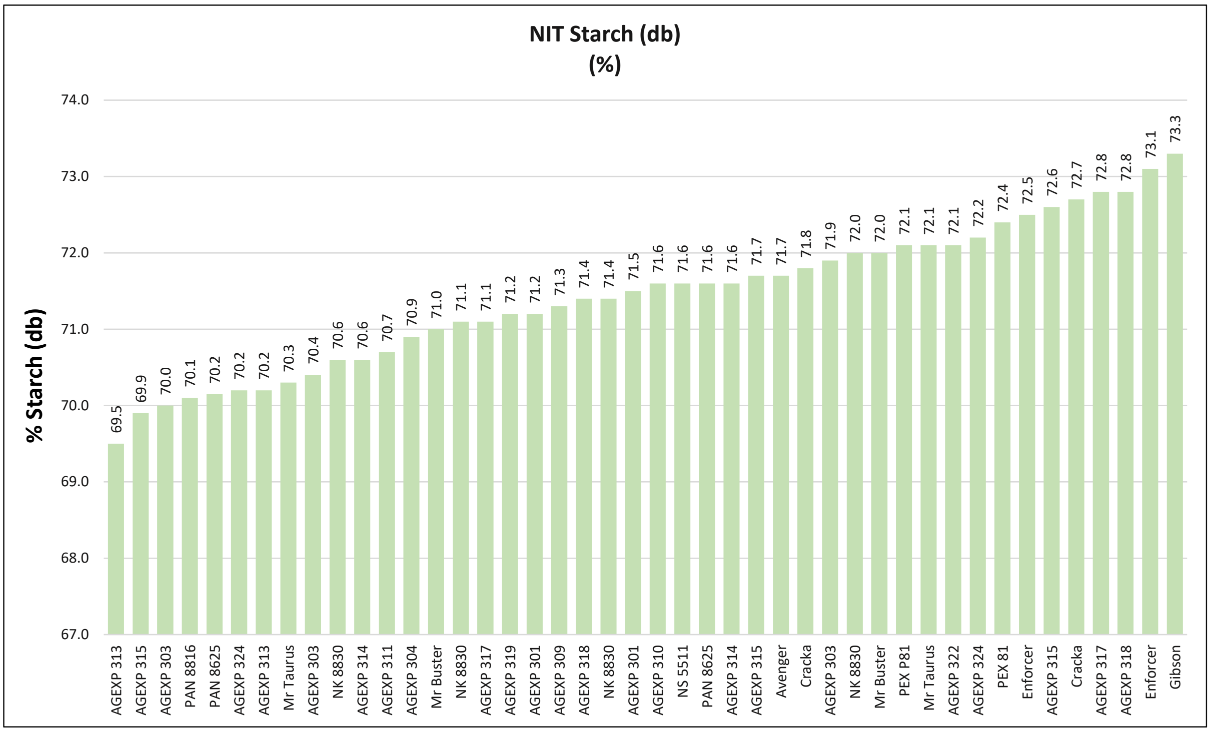


**Figure 2 Ranking of cultivars for % NIT Starch**

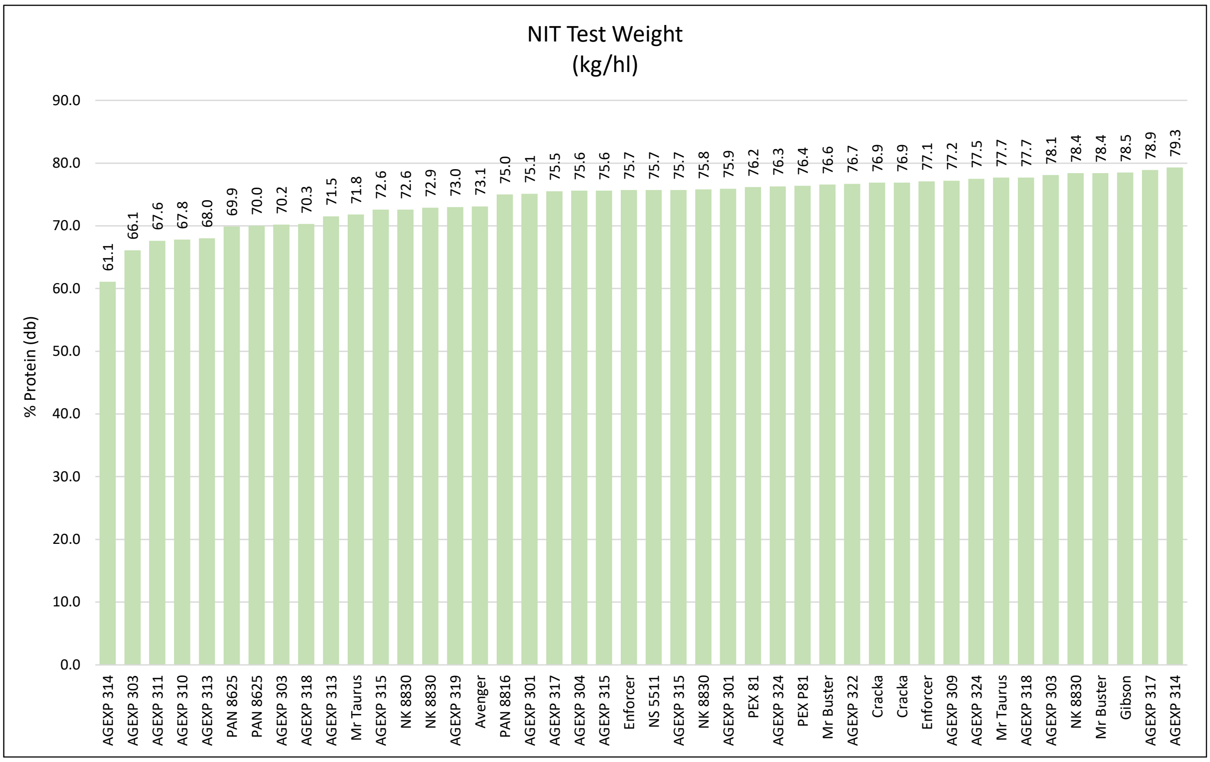



**Figure 3 Ranking of cultivars for NIT Test Weight**

### 1.4.2 DEHULLING TESTS (BARLEY PEARLER)

Barley Pearler dehulling rankings are shown in Figures 4-7.

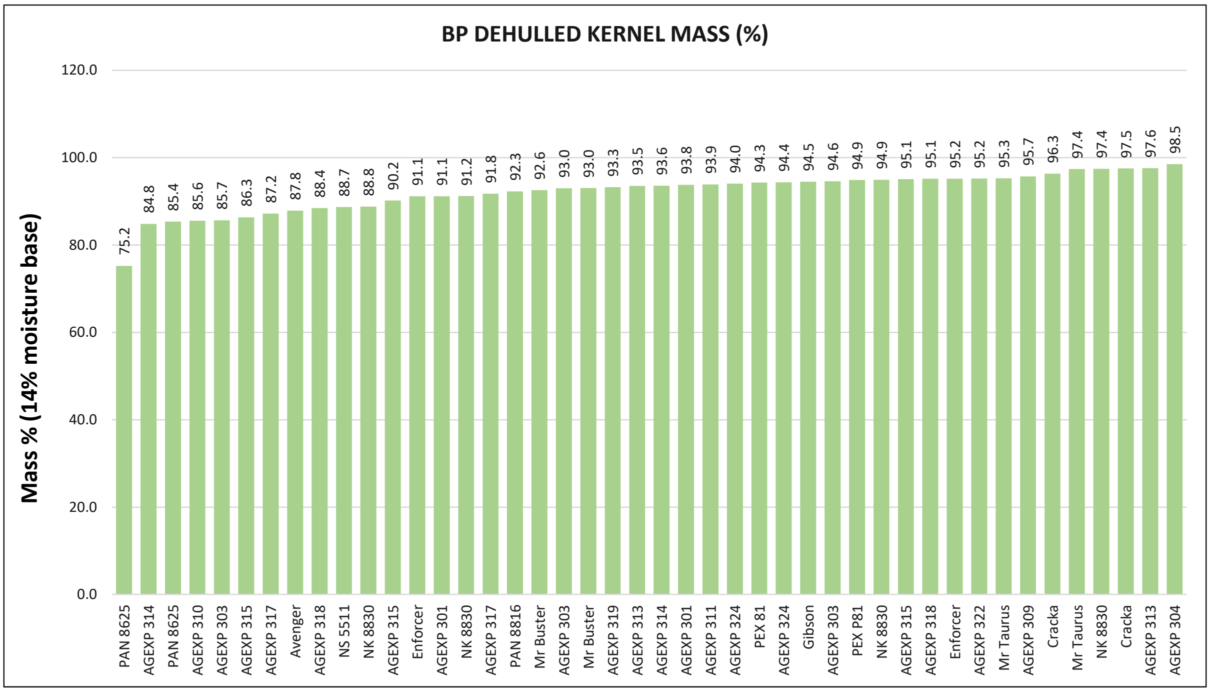
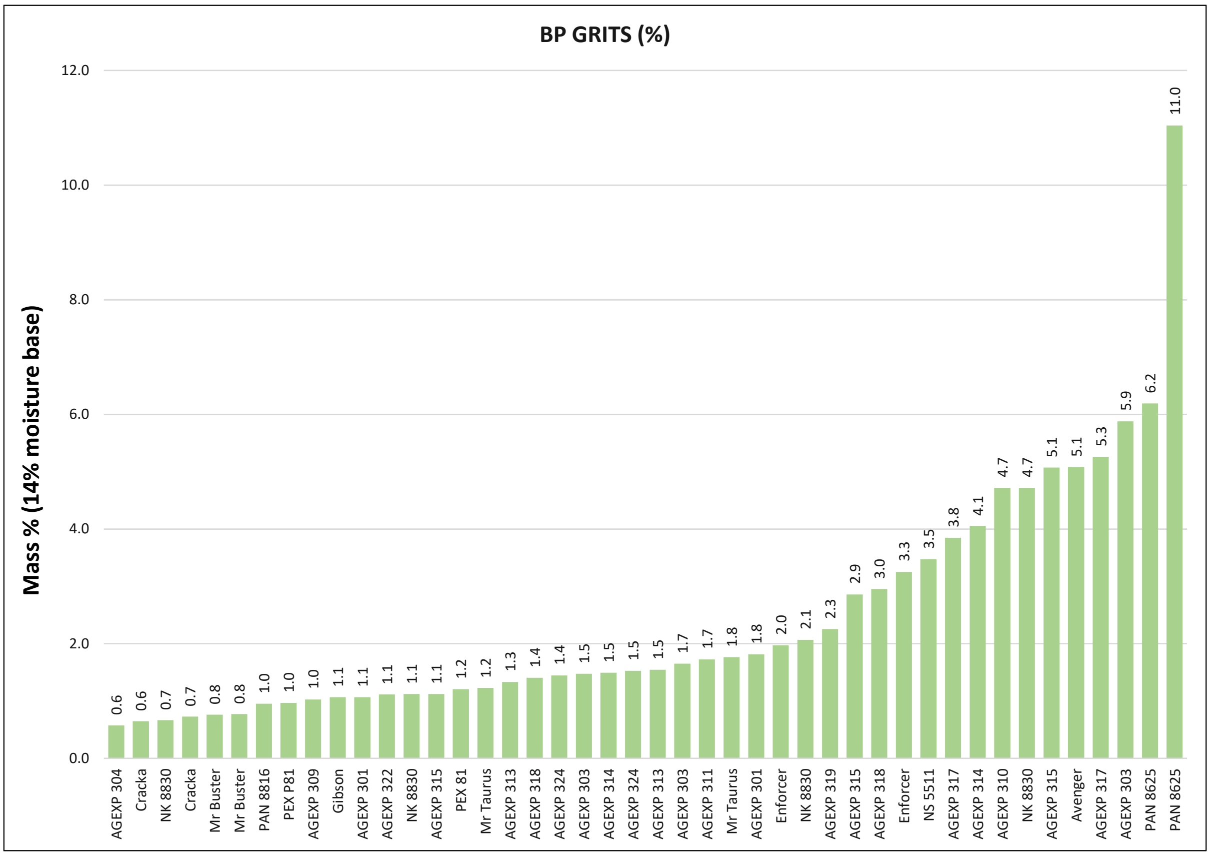
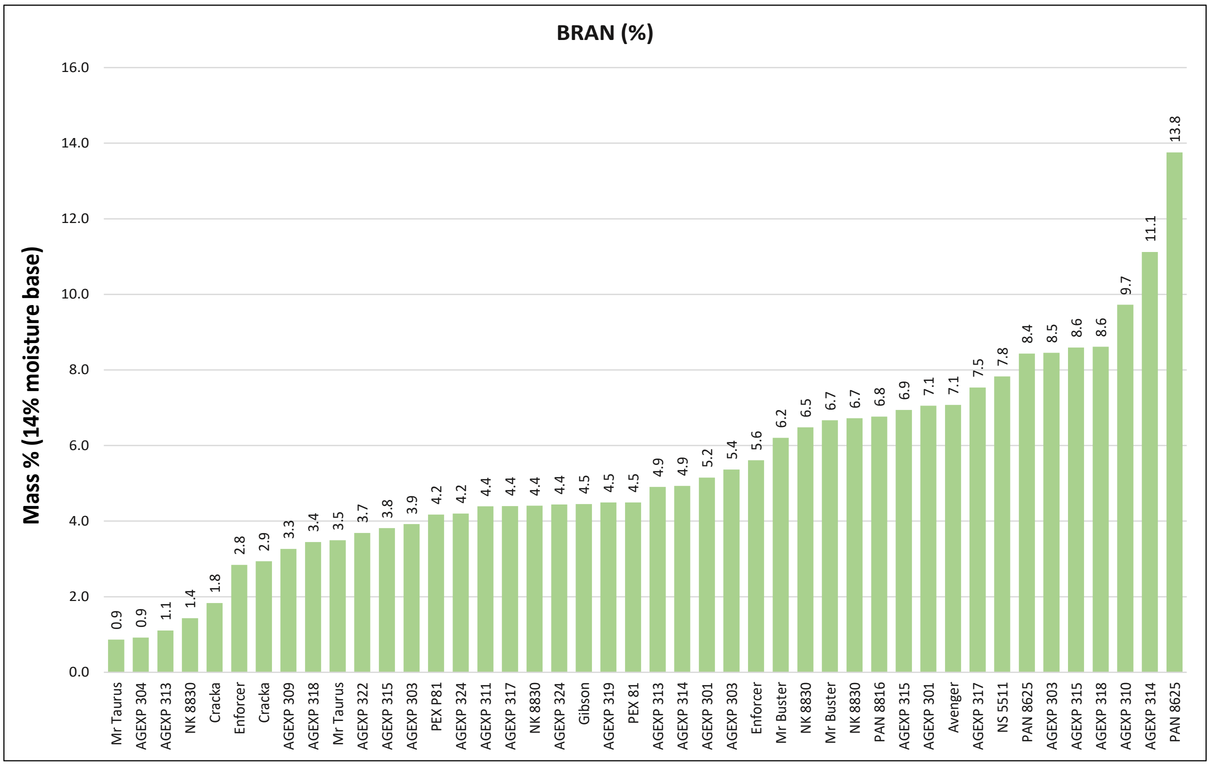



**Figure 4 Ranking of cultivars for BP dehulled kernel mass**




## Figure 5 Ranking of cultivars for BP mass % grits




## Figure 6 Ranking of cultivars for BP Mass % bran

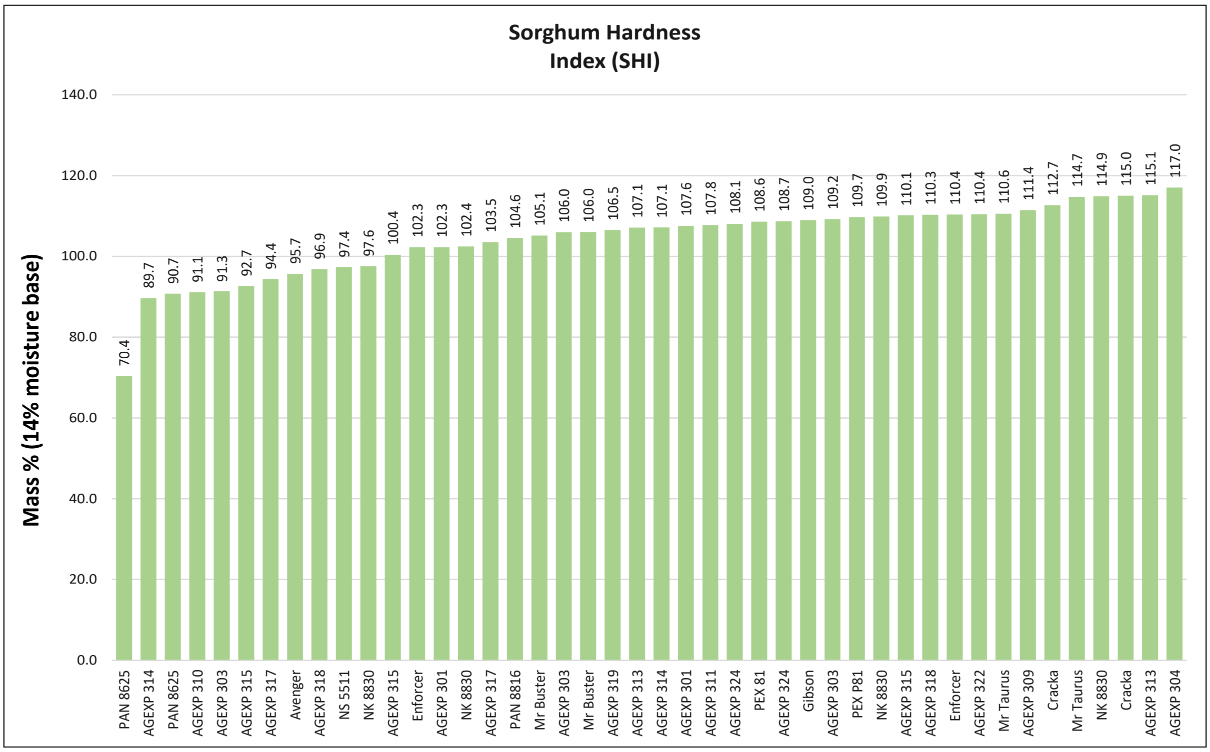



**Figure 7 Ranking of cultivars for calculated Sorghum Hardness Index (SHI) from the BP results**

### 1.4.3 Size classification

Sieve test results are shown in Figures 8-11.

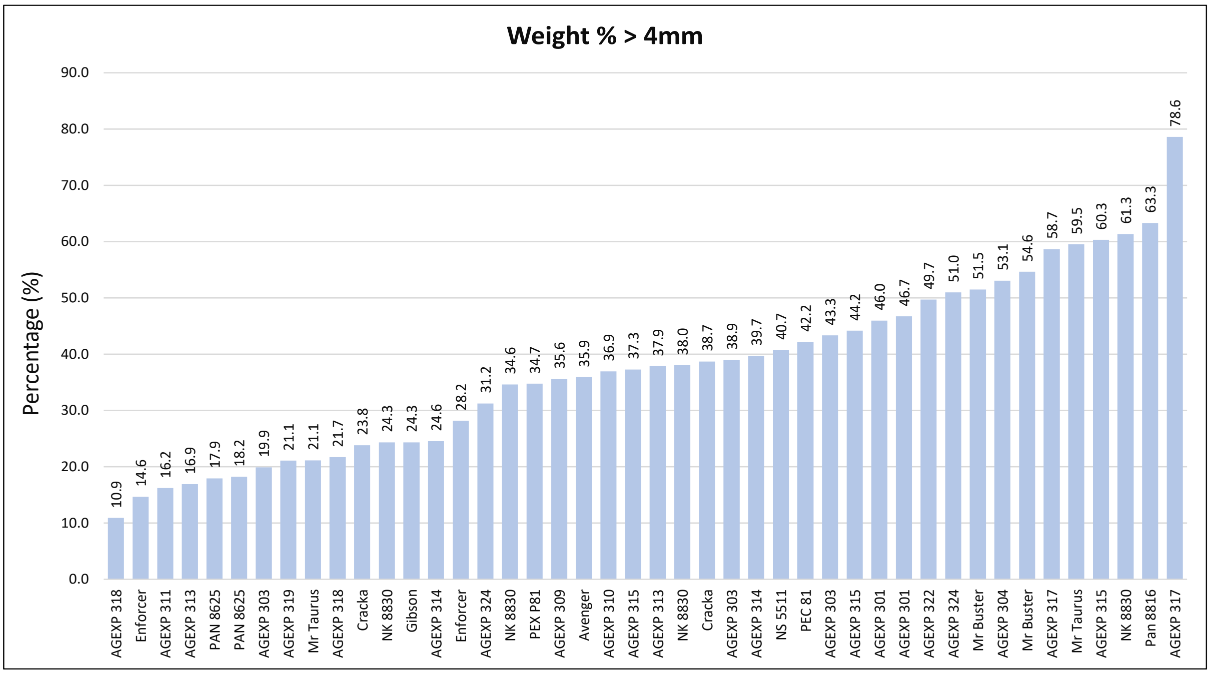



**Figure 8 Ranking of cultivars for sorghum weight % > 4 mm (round hole sieve)**

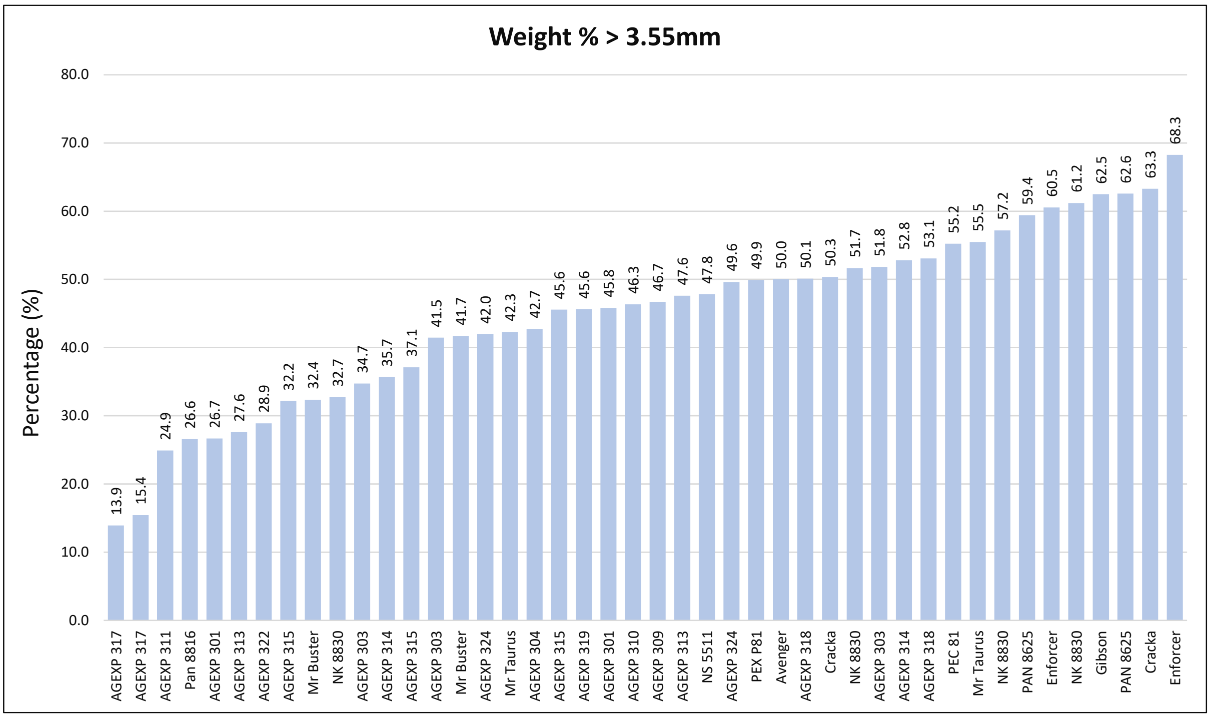



**Figure 9 Ranking of cultivars for sorghum weight % > 3.55 mm (round hole sieve)**

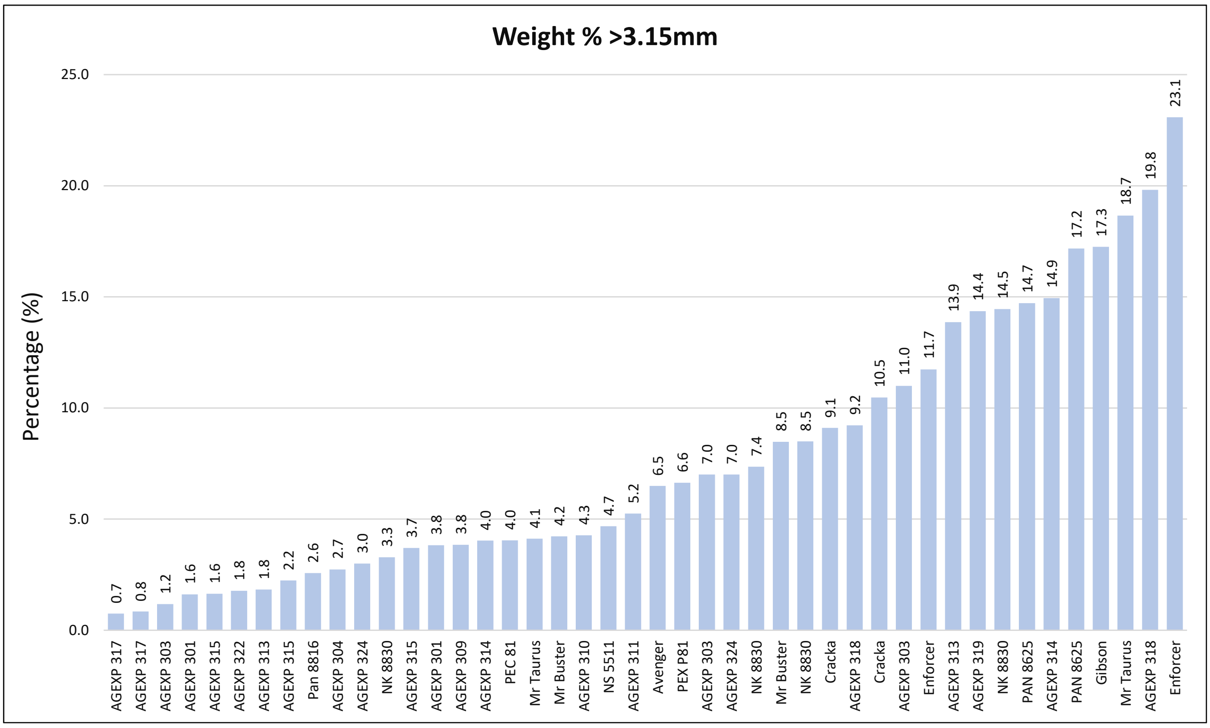



**Figure 10 Ranking of cultivars for sorghum weight % > 3.15 mm (round hole sieve)**

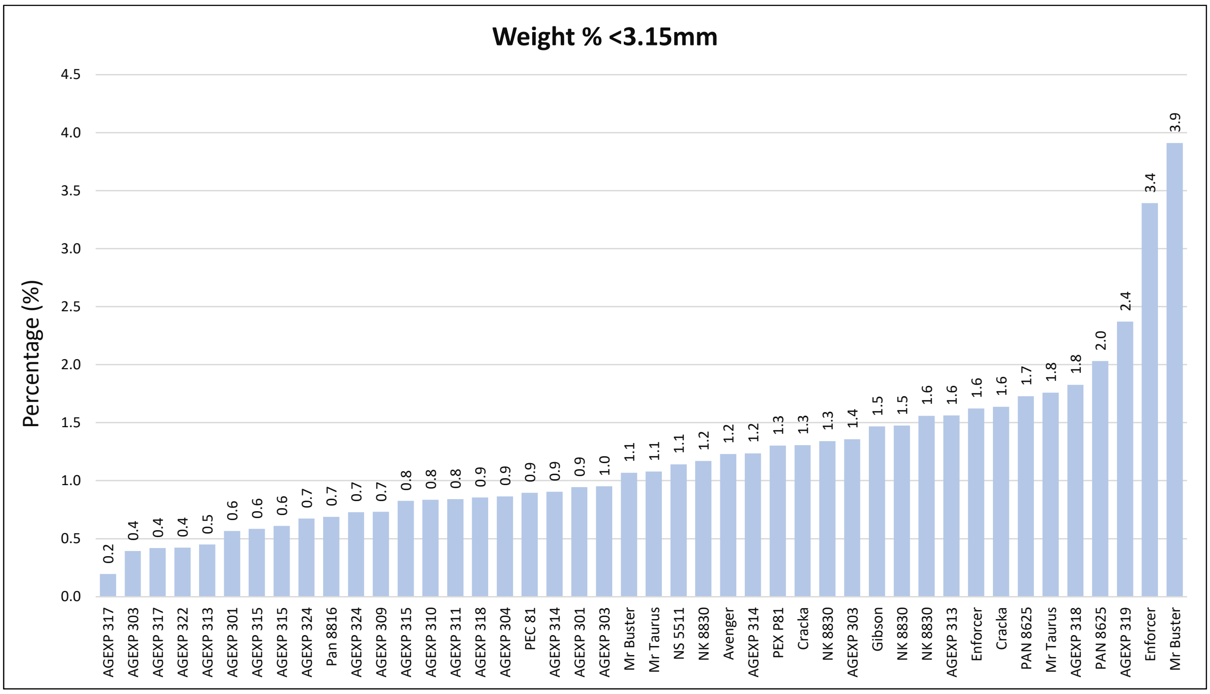



**Figure11** **Ranking of cultivars for sorghum weight % < 3.15 mm (round hole sieve)**

### 1.4.4 HUNTER LAB COLOUR TESTS

Cultivar rankings for colour determinations are shown in Figures 12, 13 and 14.

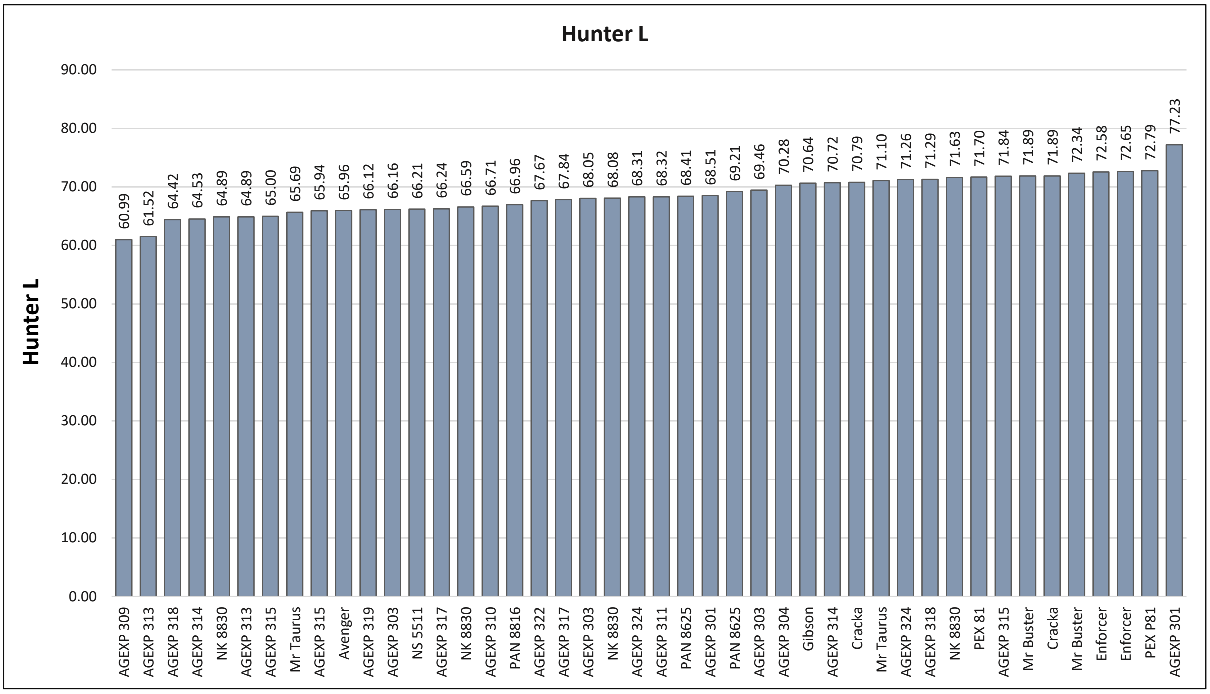



**Figure 12** **Ranking of cultivars for Hunter L (Lightness index)**

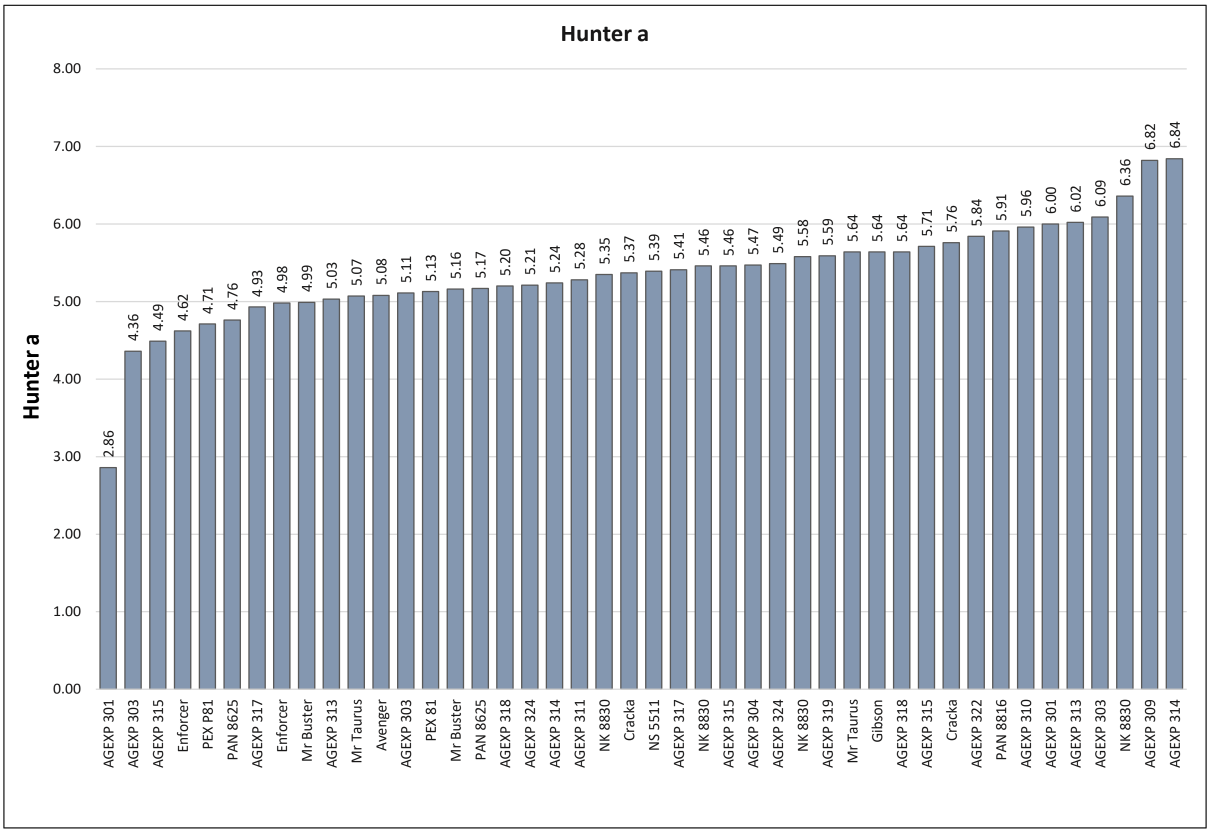



**Figure 13** **Ranking of cultivars for Hunter a (Red/green)**

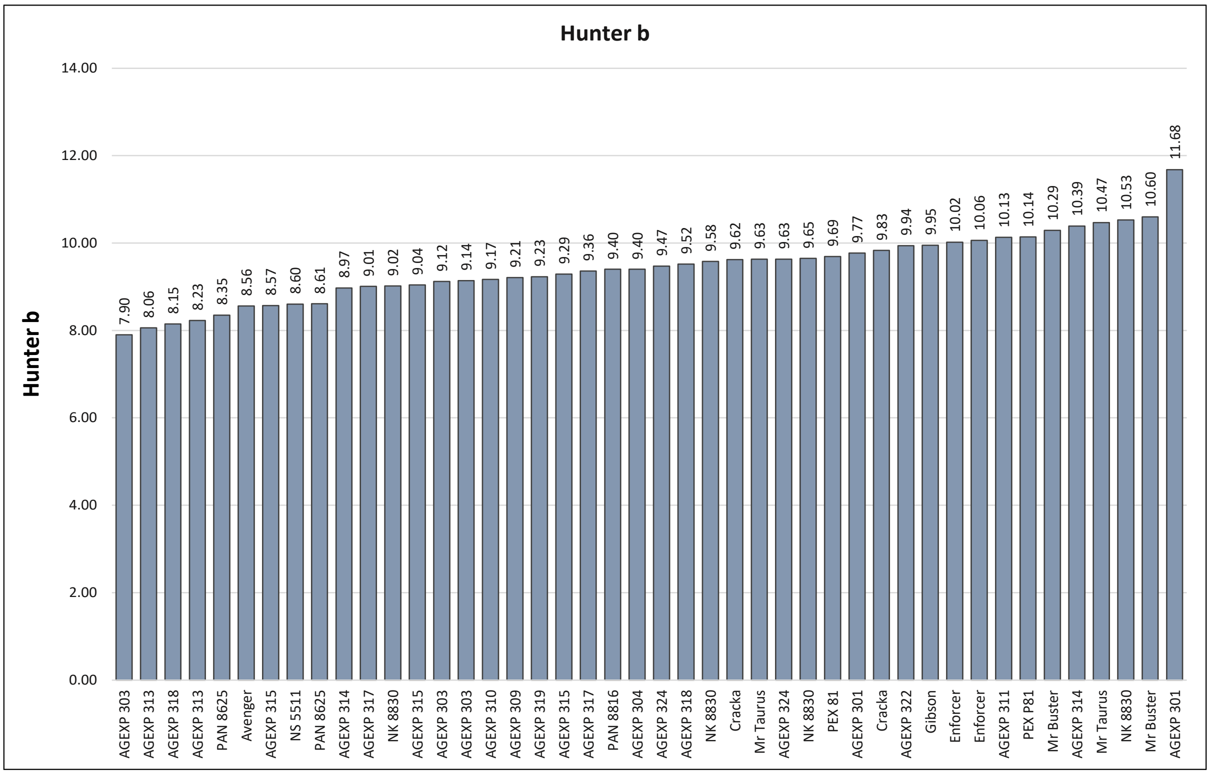



**Figure 14 Ranking of cultivars for Hunter b (yellow/blue)**

### 1.4.5 CHEMICAL COMPOSITION (REFERENCE TESTS)

Cultivar rankings for the protein and starch reference tests are shown in Figures 15 and 16.

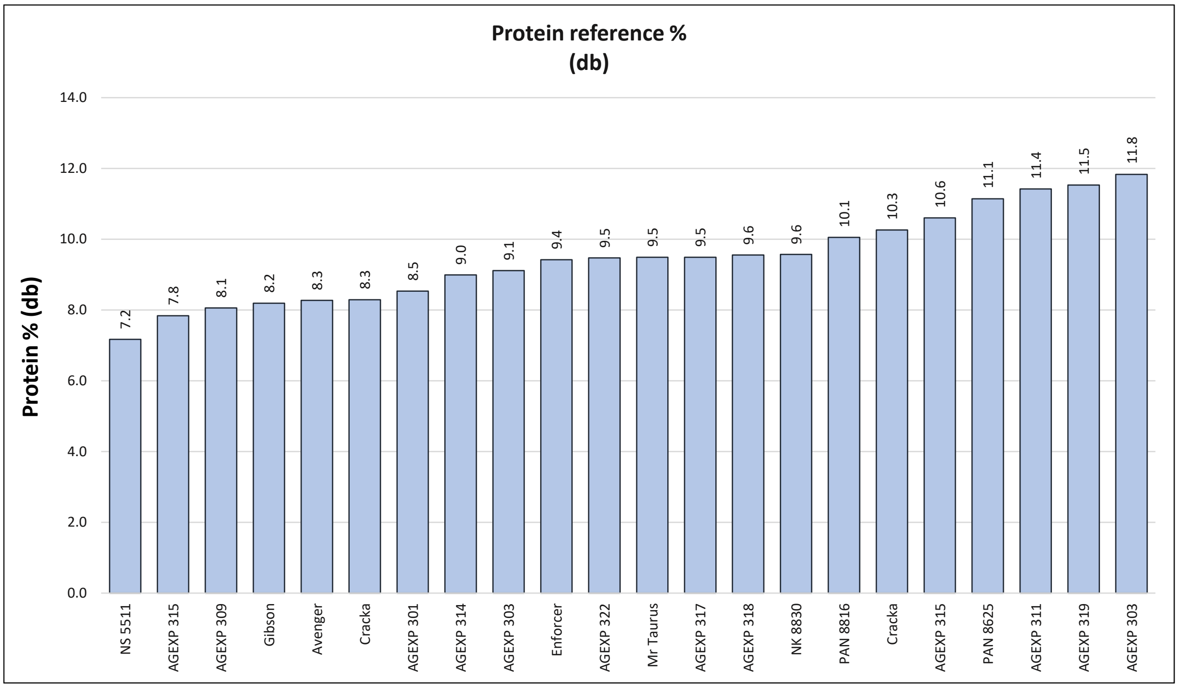



**Figure 15** **Ranking of cultivars for protein (% dry base)**

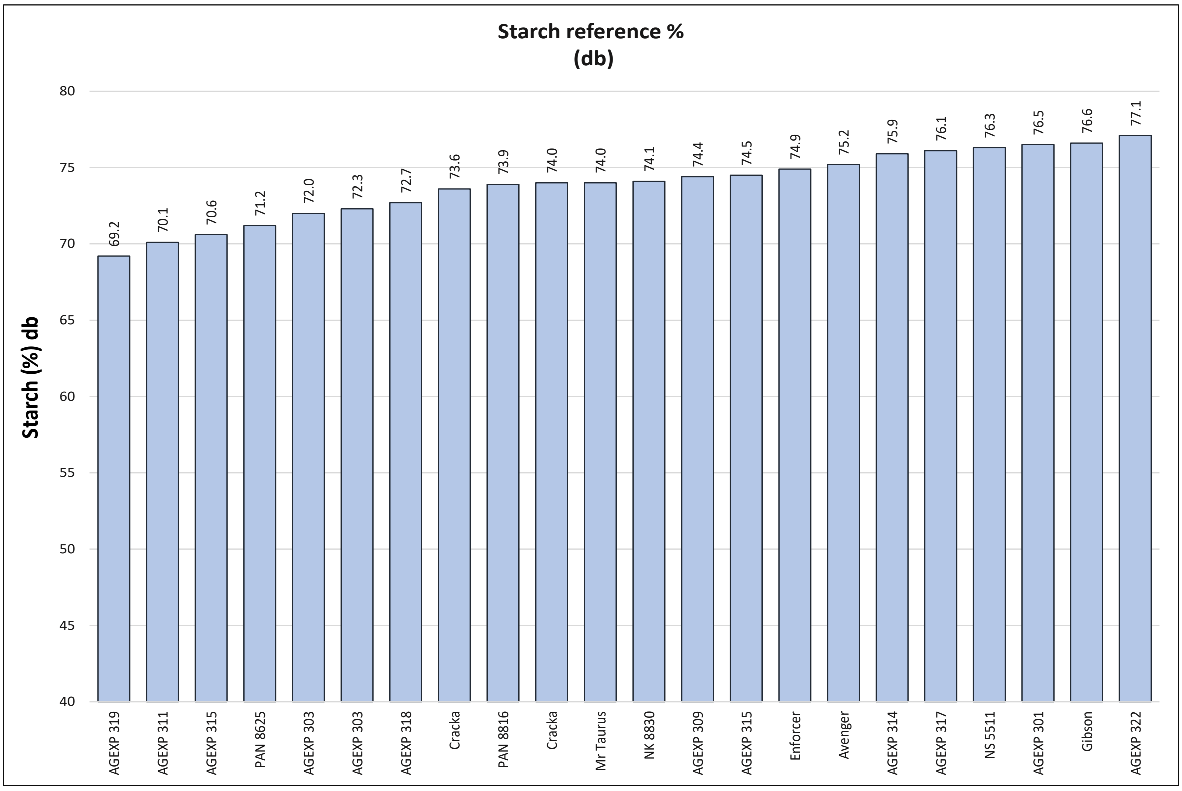



**FIGURE 16** **Ranking of cultivars for starch (% dry base)**

## 1.4.6 PHYSICAL TESTS

Cultivar rankings for Test Weight and 1000 kernel mass are shown in Figures 17 and 18.

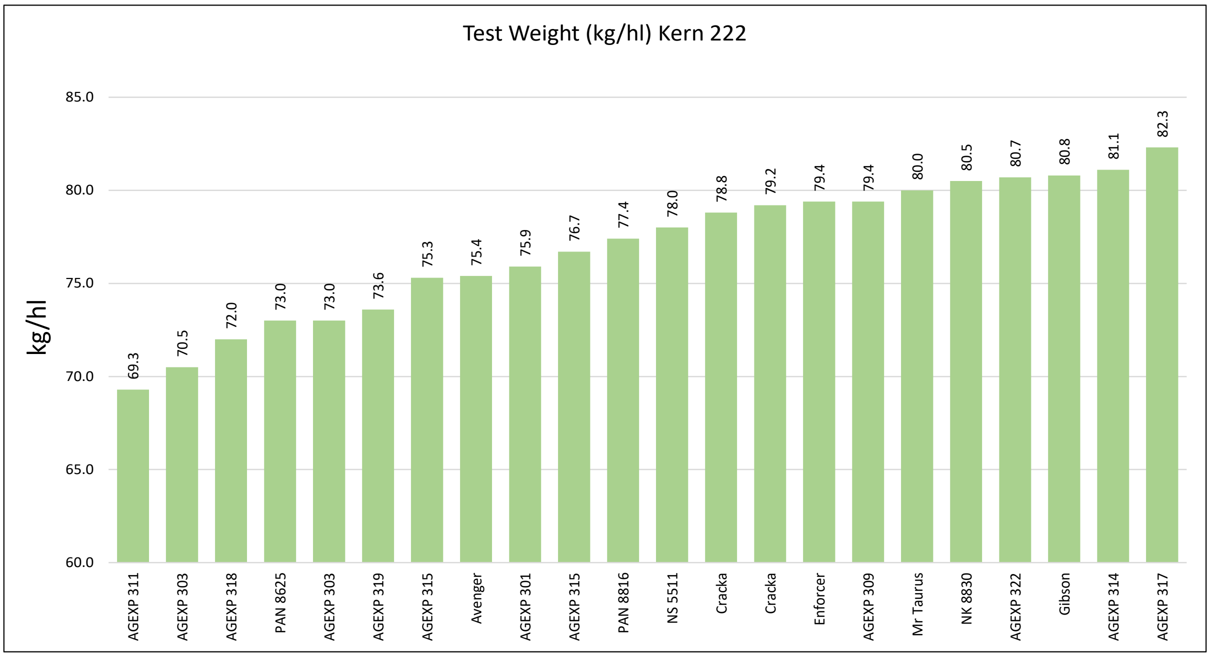



**Figure 17 Ranking of cultivars for Kern 222 Test Weight (kg/hl)**

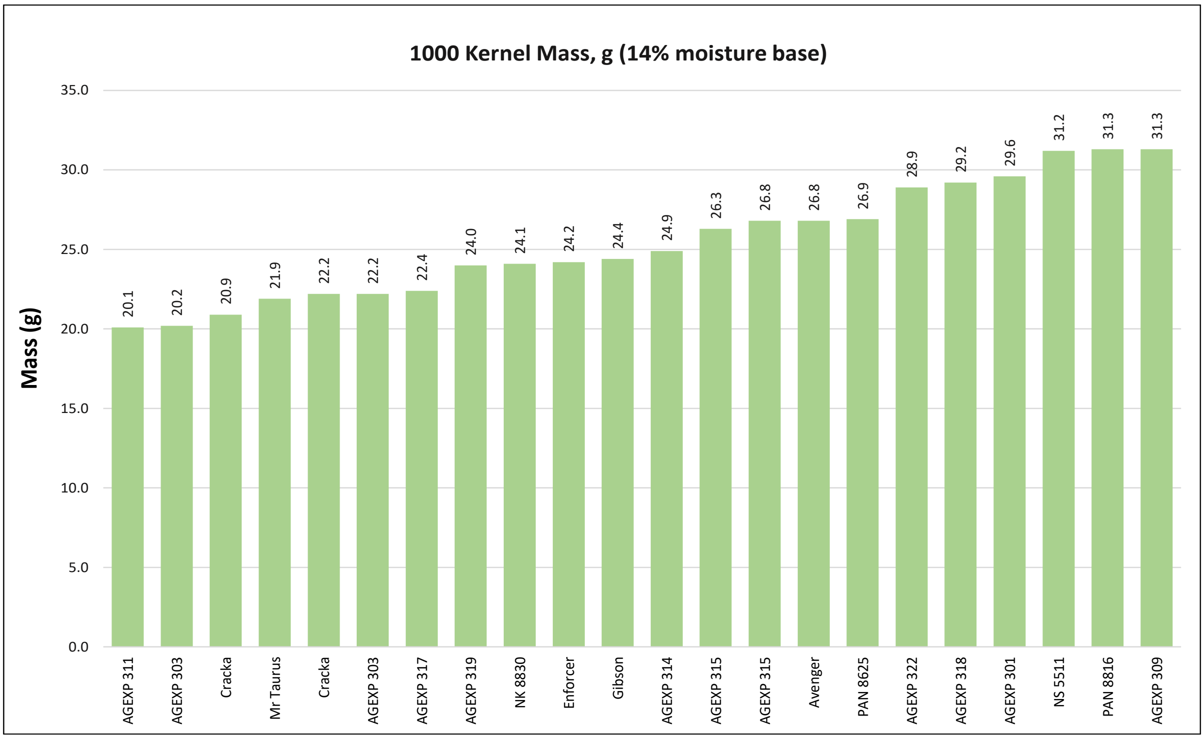



**Figure 18 Ranking of cultivars for 1000 kernel mass (14% moisture base)**

### 1.4.7 Image Analysis

Image Analysis results are given in Figures 19 – 22.

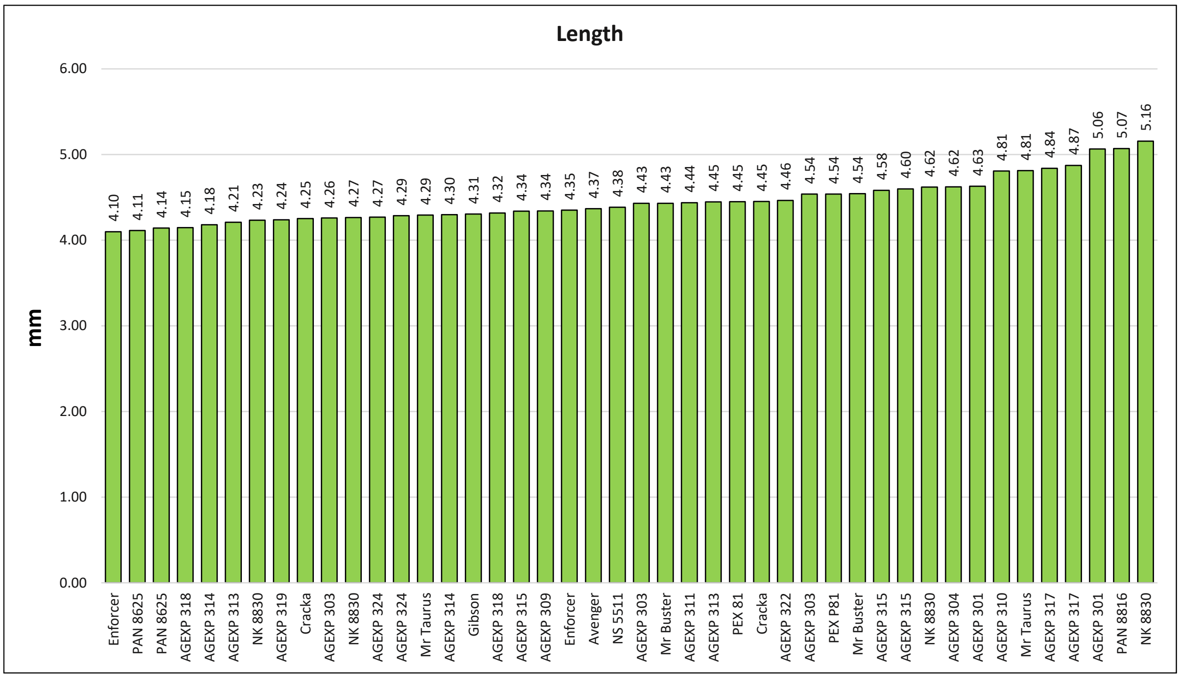



**Figure 19 Ranking of cultivars for average kernel length**

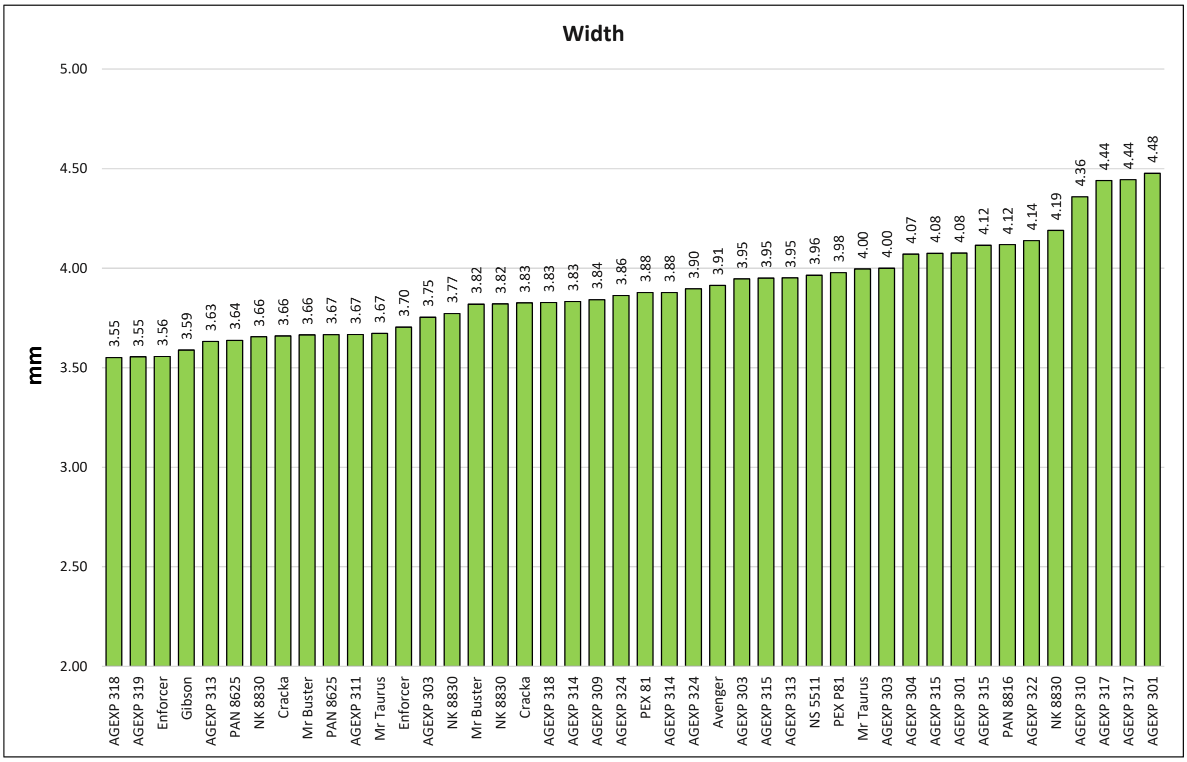



**Figure 20 Ranking of cultivars for average kernel width**

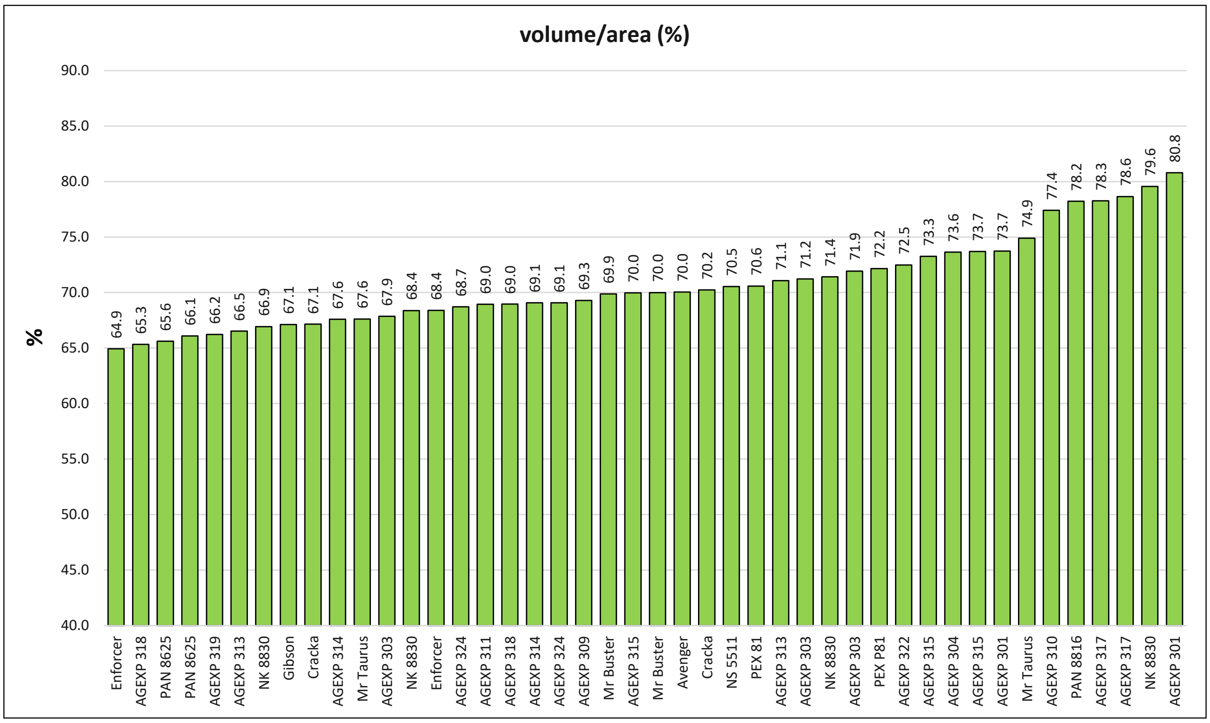



**Figure 21 Ranking of cultivars for average kernel volume/surface area percentage**

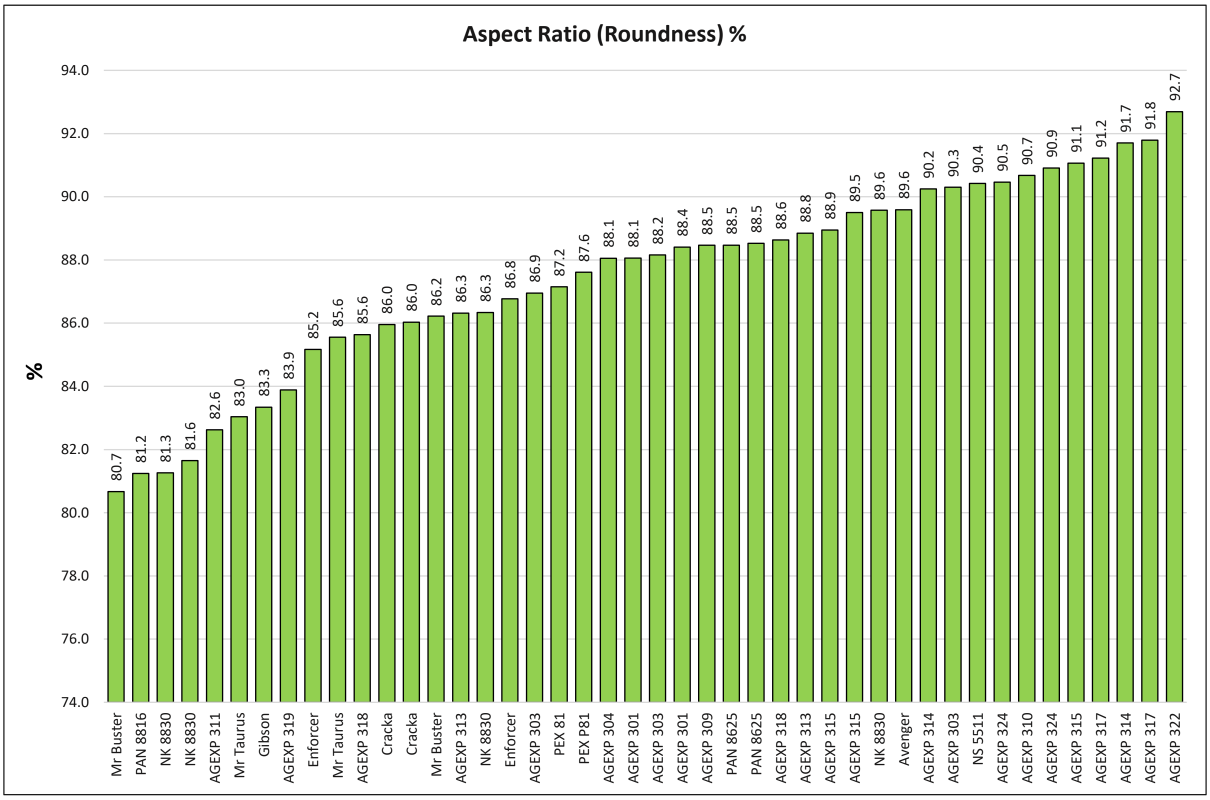



**Figure 22 Ranking of cultivars for average kernel aspect ratio (roundness) expressed as a percentage**

## PART 2: VALIDATION OF THE 4 DAY MALTING METHOD AND RAPID RVA METHOD FOR SDU VALUES

## 2 MODEL VALIDATION

### 2.1 GENERAL FEEDBACK

During the 2021/2022 season optimisation trials were done to:

- SHORTEN THE MALTING TIME BY THE USE OF PREDICTIVE MODELLING
- TESTING OF THE RVA AS AN ALTERNATIVE RAPID ASSAY FOR REPLACING THE SDU TITRATION METHOD

It was originally planned as described in the project proposal to validate both these methods in the 2022-2023 season. However, due to reduced funding only 50% of the planned experimental work could be conducted. This would have produced suboptimal results that would have been too limited for a validation test on both methods.

It was therefore decided to do validation on only one method to optimise the available funding. The RVA rapid method is the most useful of the two methods as it provides a significant cost and time saving, thereby having SDU results ready within as little as 24 hours. This will significantly reduce the costs compared to the SDU reference titration method currently in use.

To do a useful validation on the RVA method, ten sorghum cultivars were selected with one additional sample as a back-up. These samples were malted for 6 days (reference method).

During the 2021/2022 experiments, good correlations were found between the SDU values and RVA peak viscosity, final viscosity, and setback viscosity. These three parameters were then used to develop a multiple regression prediction model for calculating sorghum SDU values. The R-value of the model was 0.86 and the formula is:

**SDU Value = 70.4 - 0.04*(Peak viscosity) + 0.11*(Final viscosity) - 0.55*(Setback).**

The above formula was tested in the validation work (2022/2023). Along with testing of the multiple regression model, a second model using only the peak viscosity values in a logarithmic model fit was tested and compared with the multiple regression model in terms of results accuracy. The logarithmic model was developed using the combined results of both the 2021/2022 and the 2022/2023 seasons and is described in full in the results section.

### 2.2 MATERIALS AND METHODS: VALIDATION OF THE USE OF THE RVA TO PREDICT SORGHUM DIASTATIC UNITS (SDU)

SDUs and malting trials will be done according to the SAGL In-house SOPs MM26 (Steeping of Sorghum Grain) and MM27 (Malting of Sorghum Grain) for six days. Ten cultivars were malted.

The malted samples were then used for the determination of the SDU values and the RVA values according to the method described below (SAGL SOP MC31 with modifications):

Preparation

Moisture contents of the Reference maize starch and the active (live) Malt were determined. Dried malt samples were kept for use as inactive (dead) malt control samples.

The RVA instrument was set up and tested using a maize starch control sample, using the maize starch profile (SOP no MC31), tests were done using distilled water.

Analysing RVA profiles of active (live) malt

To prevent any tannins from inhibiting the alpha-amylase enzymes in the malt, the RVA analysis was done in peptone water instead of pure water. Peptone water was transferred directly into the RVA cup.

RVA display Set-up

For the analysis of the active (live) malt mixture the instrument settings were as follows:

Sample calculated moisture basis: 0 %
Water weight: 25.5 g
Sample weight: 3 g

Samples were then spiked using 0.5 g malt samples. The amount of malt to add to the RVA cup was calculated as follows:

For a 0.5 g spike sample (DB):

Calculate the mixed sample moisture value to be inserted into the machine using the following formula:

[5x (starch moisture %) + 1x (malt moisture %)]/6

Insert the calculated mixed sample moisture value into the instrument display.
The instrument will then calculate the wet mass of the total MIXED sample (wet starch and wet malt) to be placed into the sample cup. (Instrument sample wet mass)

Calculate the wet mass of starch to be added into the sample cup as follows:

For a 0.5 g spike sample (DB):

{2.5g*[starch moisture content %/(100-starch moisture content %)]} + 2.5

Calculate the wet mass of malt to be added into the sample cup as follows:
(Instrument sample wet mass ) – (calculated starch wet mass).

Do the RVA profile of the malt/starch mixture using the maize starch settings (SOP MC31).

Repeat the RVA profile of the malt/starch mixture using a "dead" control malt sample to determine the reference RVA values for inactive malt. This needs only to be done once as it will be the same for all samples.

### 2.3 ADVANTAGES OF USING THE RVA METHOD FOR PREDICTING MALT SDU VALUES

- Direct evidence of actual enzyme activity in a standardised starch solution
- Much shorter analytical turn-around time (24 hours vs three days)
- Significantly reduced costs because there is no necessity for preparation of chemical solutions and doing redox titrations that are time consuming for the analysis
- Significantly reduced level of complexity for the analysts which reduces the potential for errors.

### 2.4 RESULTS AND DISCUSSION

**Table 3 Summary of SDU values and RVA parameters for sorghum cultivars**

| CULTIVAR SAMPLES | | RVA PARAMETERS | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Sample number** | **SDU Value** | **Peak viscosity** | **Trough** | **Breakdown** | **Final viscosity** | **Setback** | **Pasting temp** | **Peak time** |
| PAN8625 | 54 | 273 | 26 | 247 | 36 | 10 | 74.4 | 3.53 |
| PEXP81 | 42 | 235 | 11 | 224 | 16 | 5 | 73.6 | 3.53 |
| Enforcer | 30 | 317 | 23 | 294 | 29 | 6 | 74.4 | 3.60 |
| Mr Buster | 44 | 386 | 46 | 340 | 59 | 13 | 74.5 | 3.60 |
| Mr Taurus | 48 | 252 | 21 | 231 | 28 | 7 | 73.6 | 3.53 |
| AGEXP313 | 39 | 310 | 23 | 287 | 31 | 8 | 73.6 | 3.53 |
| PAN8816 | 14 | 799 | 97 | 702 | 144 | 47 | 74.4 | 3.73 |
| NS5511 | 36 | 495 | 56 | 439 | 74 | 18 | 74.4 | 3.60 |
| Avenger | 40 | 328 | 24 | 304 | 33 | 9 | 74.3 | 3.60 |
| AGEXP313 | 37 | 350 | 27 | 323 | 35 | 8 | 73.6 | 3.53 |
| AGEXP301 | 32 | 329 | 17 | 312 | 25 | 8 | 73.5 | 3.53 |
| Dead malt control (PAN8816) | 0.1 | 3471 | 2541 | 930 | 3015 | 474 | 75.70 | 5.07 |

The results of the comparative validation between the SDU values and the RVA values are shown in Table 3, as well as in Figures 23 and 24. In Figure 23, the logarithmic model showing the relationship between SDU and RVA peak viscosity is shown for both the 2021/2022 and the 2022/2023 seasons. The mathematical formulas for the two seasons' models are very similar and therefore the data was combined to produce a single model as illustrated in Figure 24.

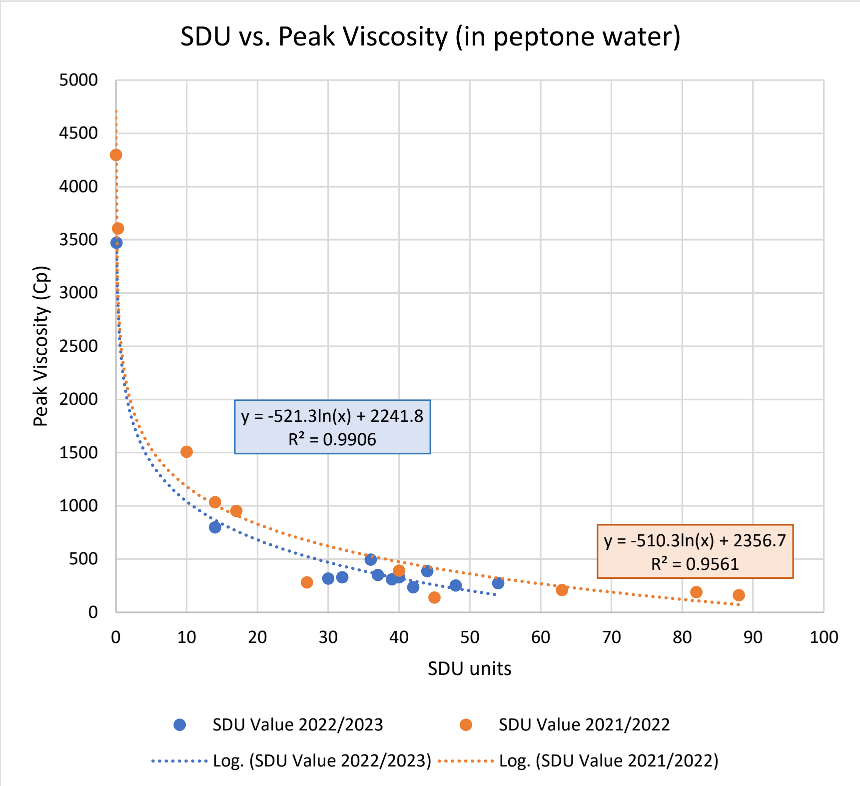



**Figure 23 The effect of SDU units on measured RVA peak viscosity for two seasons' malted sorghum samples.**

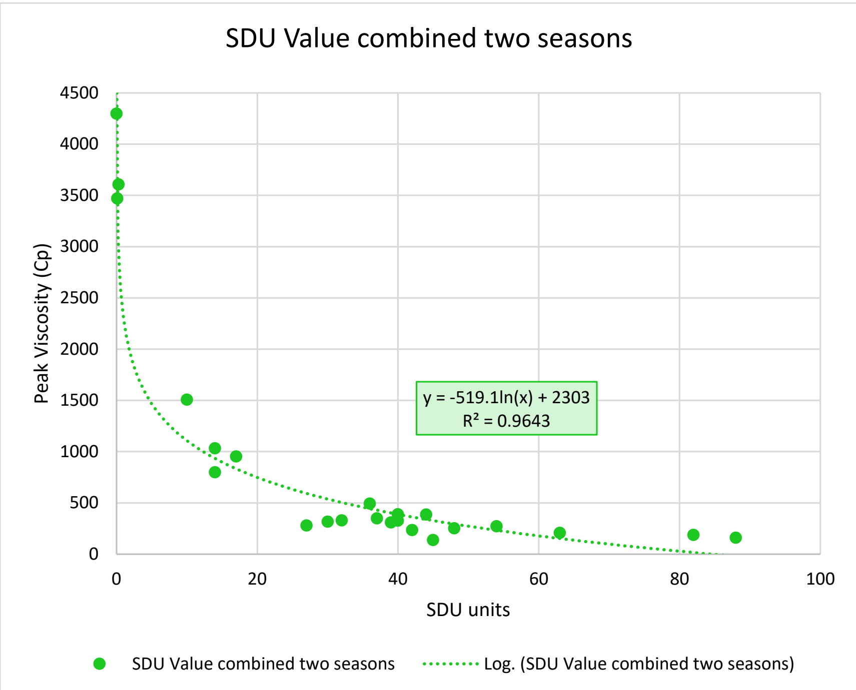



**Figure 24 The effect of SDU units on RVA peak viscosity for the combined data of two seasons showing the new logarithmic regression model fit**

The validation plots for the multiple regression model and the logarithmic model are shown in Figures 25 and 26. Although both models tend to produce calculated SDU values that are higher than the reference value, the logarithmic model (Figure 24) gave much more accurate results than the multiple regression model. The reason for this could be that the logarithmic model only uses the peak viscosity RVA value in the calculation while the multiple regression model uses peak viscosity, setback, and final viscosity in the calculations. Small differences in sample variation will be enlarged by the inclusion of the setback and final viscosity values especially for samples with higher SDU values due to instrument insensitivity for very thin samples. The project did not have the funding to do a comparative evaluation with lower spiking samples (for example 0.4 g instead of 0.5 g) to see if the models could be improved.

The two regression lines in Figure 26 both had a good slope of ±1 which indicates that both models calculate the SDU values correctly. However, the off-set value for the regression model (blue line) has a much higher value than the offset for the log model (orange line). Therefore, the log model's values are more accurate than the multiple regression model. The $R^2$ values for both models are 0.82 (rounded up), indicating that there is no difference in precision between the models. The exact reasons for the unexplained variation are not known at this stage. Ideally the $R^2$ must be >0.9 but given the high probability for variation produced during the malting stage as well as the unknown interactions between the added dry malt samples to the RVA starch inside the sample cup, the $R^2$ values found for the few samples tested are realistic and quite good. Better understanding of the $R^2$ fit on the precision of the results will only become clearer once more samples have been analysed to determine the tolerances of the method at various stages.

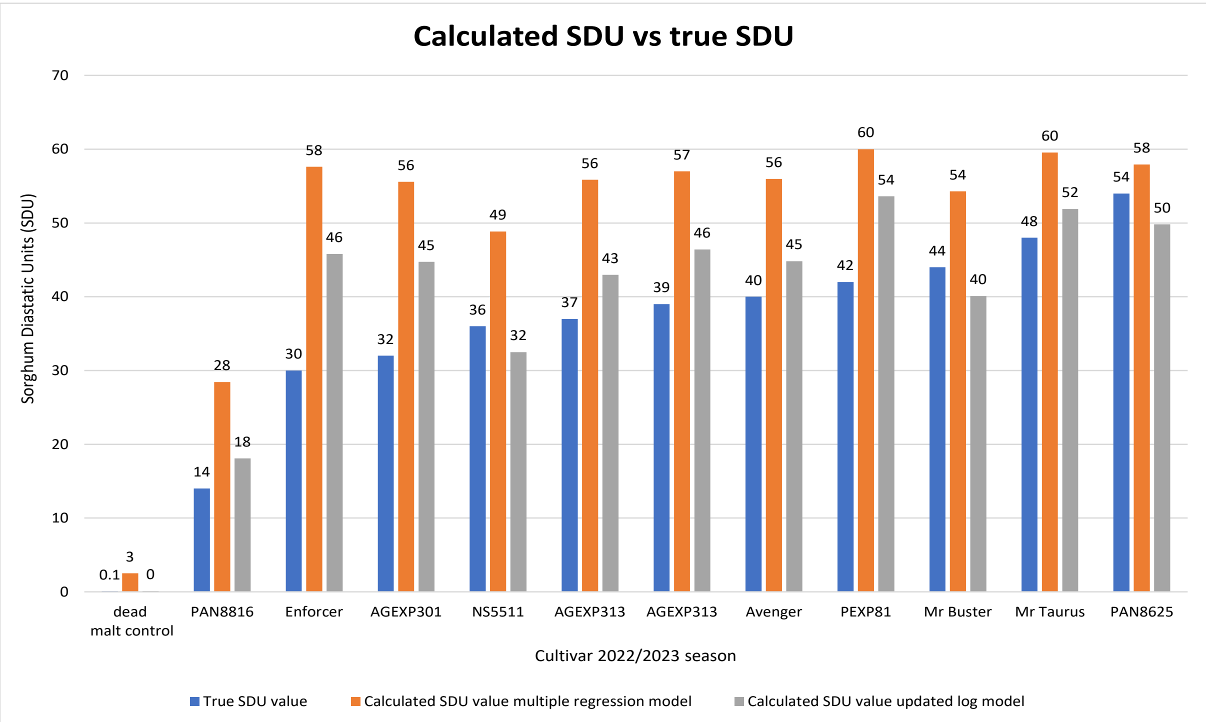



**Figure 25 Comparison between the calculated SDU values using the multiple regression model (section 2.1) and the SDU updated log model (Figure 24) against the reference SDU method values (Table 3).**

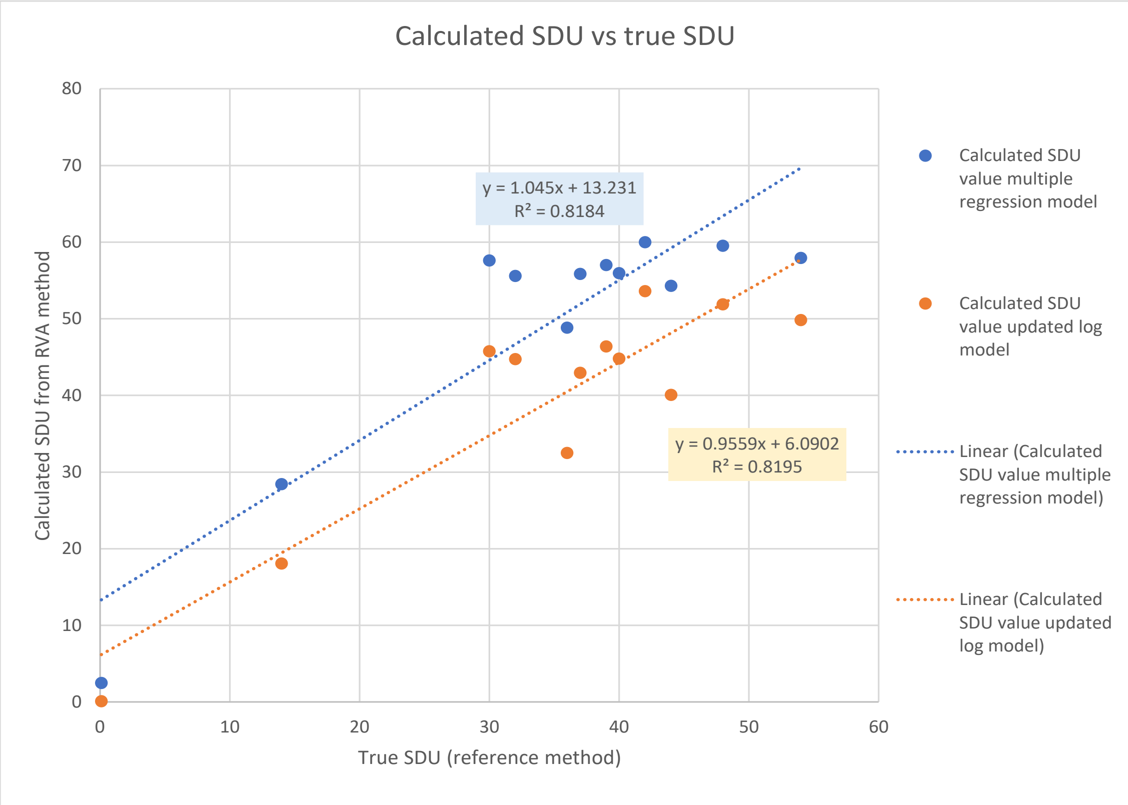



**Figure 26 Regression models comparing the calculated SDU values using the multiple regression model (section 2.1) and the SDU updated log model (Figure 24) against the reference SDU method values (Table 3).**

## Method Tolerances

Due to the very limited number of assays done thus far, not enough data is available to specify the measurement uncertainties for the RVA method as a replacement method for the reference titration method SDU. Future work will have to focus on analysing a much larger dataset and the designed experimental work must include enough repetitions to enable the calculation of tolerances and other precision parameters for the new method. The existing % RSD for the titration SDU method is 2 % based on triplicate titrations. However, if the entire malting process is repeated, the %RSD varies between 2 % and 15 % depending on the SDU values. Malts with low SDU values have much higher variation in results than malts with high SDUs. These results will also be reflected in the RVA method.

The RVA pasting curves for some of the samples are shown in Figures 27, 28 and 29. In Figure 27, the control starch spiked with inactivated ("dead") malt is shown while in Figures 28 and 29 samples spiked with live malt are shown. The peak viscosity of the live malt samples is significantly reduced compared to that of the inactivated malt. The breakdown of the control sample was 27 % compared to 88 % (Figure 28) and 95 % (Figure 29).

Breakdown % was calculated as (breakdown viscosity)/(Peak viscosity)*100. Final viscosity of the sample in Figure 29 was only 25 cP compared to the control cP of 3015 and therefore the starch sample can be regarded as near completely broken down. The SDU value of the sample in Figure 29 was 32. SDU values are given in Figure 25 and the sample reference numbers are in Appendix A.

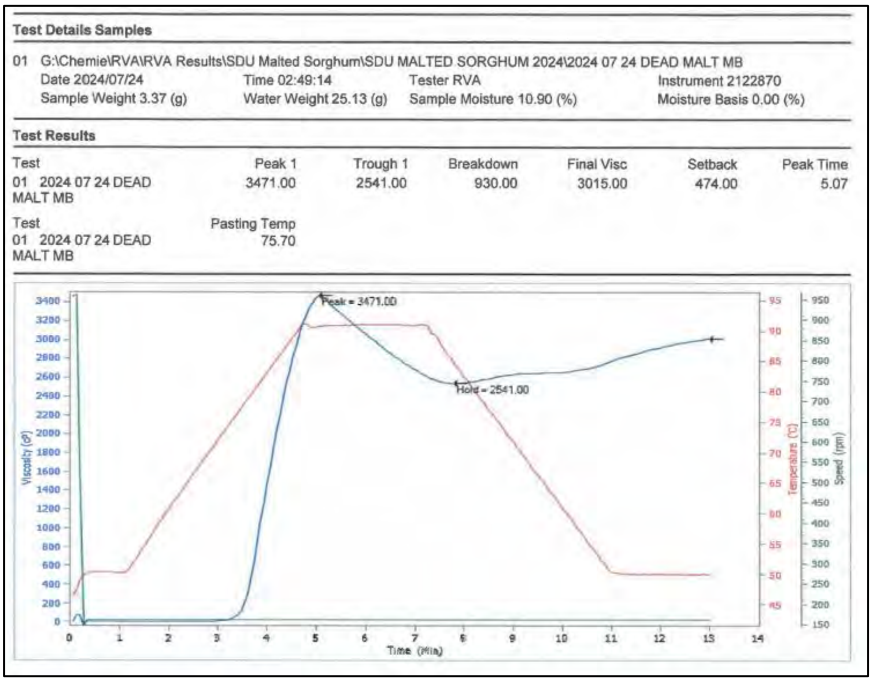



**Figure 27 Viscosity profile of standardised starch solution spiked with heat treated malt with no diastatic activity**

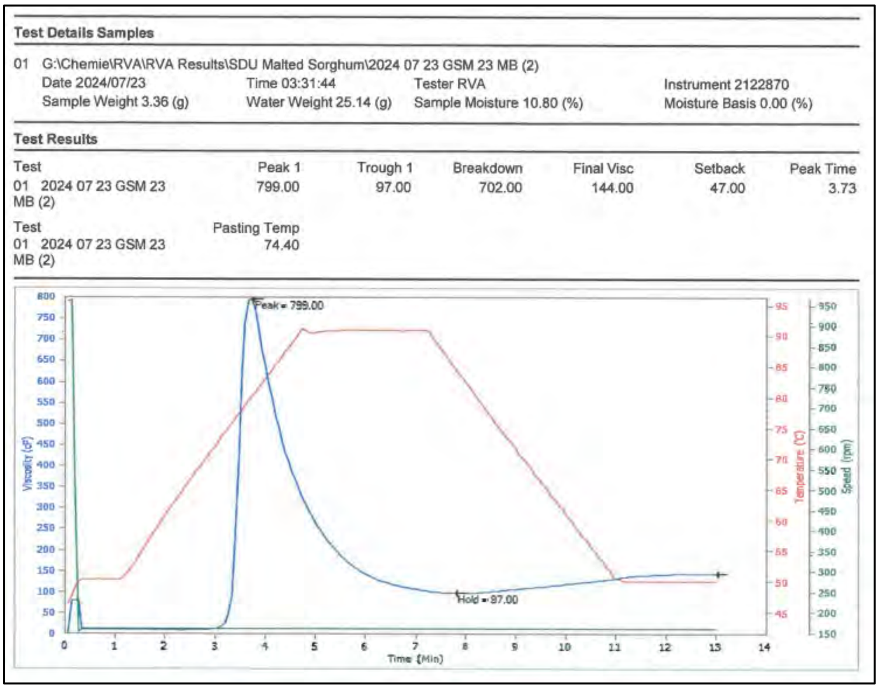



**Figure 28 Viscosity profile of standardised starch solution spiked with malt with a diastatic activity (SDU) of 14**

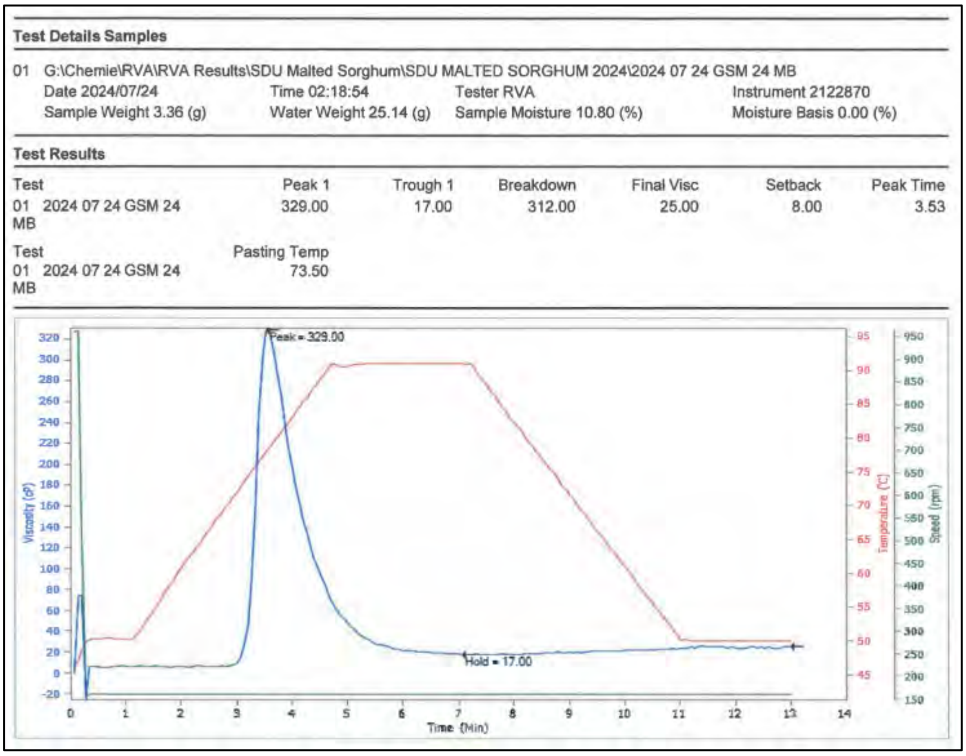



**Figure 29** **Viscosity profile of standardised starch solution spiked with malt with a diastatic activity (SDU) of 32**

## 3. CONCLUSIONS AND RECOMMENDATIONS

Although funding cuts affected the number of samples that could be analysed, 44 cultivars were analysed for processing, physical and chemical quality parameters and ranked accordingly. Focus was applied to validate only the shortened RVA method for predicting sorghum SDU values and although the $R^2$ values of 0.82 could have been better, the slopes of the curves were ±1. The multiple regression model produced SDU values that were consistently higher than those of the log model. In terms of accuracy, the log model gave the best results.

The samples used for validation were very limited. It is recommended to focus on only the log model using the RVA to predict SDU for future work, to consolidate and focus limited funding on one model that will be of significant use as a quick method at an affordable price. By using the RVA method to determine SDU values, any unknown malt sample submitted to the SAGL can be analysed at a significantly reduced cost and much shorter turnaround time than the current SDU reference method.

# 4. APPENDIX A

| Sample number | Sample reference | | | |
|---|---|---|---|---|
| SAGL sample number | Region | Location | Cultivar Identification | Origin |
| (22/23) GSM 1 | 35 | Lehau | PAN 8625 | GSA |
| (22/23) GSM 2 | 35 | Lehau | PEX P81 | GSA |
| (22/23) GSM 3 | 35 | Lehau | Enforcer | GSA |
| (22/23) GSM 4 | 35 | Lehau | Mr Buster | GSA |
| (22/23) GSM 5 | 35 | Lehau | Cracka | GSA |
| (22/23) GSM 6 | 35 | Lehau | Mr Taurus | GSA |
| (22/23) GSM 7 | 35 | Lehau | NK 8830 | GSA |
| (22/23) GSM 8 | 35 | Settlers | PEX 81 | Limagrain |
| (22/23) GSM 9 | 35 | Settlers | Cracka | Limagrain |
| (22/23) GSM 10 | 35 | Settlers | Mr Buster | Limagrain |
| (22/23) GSM 11 | 35 | Settlers | Gibson | Limagrain |
| (22/23) GSM 12 | 35 | Settlers | Enforcer | Limagrain |
| (22/23) GSM 13 | 35 | Settlers | Mr Taurus | Limagrain |
| (22/23) GSM 14 | 35 | Settlers | NK 8830 | Limagrain |
| (22/23) GSM 15 | 18 | Potch 2 | AGEXP 311 | Agricol |
| (22/23) GSM 16 | 18 | Potch 2 | AGEXP 313 | Agricol |
| (22/23) GSM 17 | 18 | Potch 2 | AGEXP 315 | Agricol |
| (22/23) GSM 18 | 18 | Potch 2 | AGEXP 317 | Agricol |
| (22/23) GSM 19 | 18 | Potch 2 | AGEXP 319 | Agricol |
| (22/23) GSM 20 | 18 | Potch 2 | AGEXP 324 | Agricol |
| (22/23) GSM 21 | 35 | Potch 1 | AGEXP 318 | Agricol |
| (22/23) GSM 22 | 35 | Immerpan | NK 8830 | Limagrain |
| (22/23) GSM 23 | 35 | Immerpan | PAN 8816 | Limagrain |
| (22/23) GSM 24 | 18 | Potch 1 | AGEXP 301 | Agricol |
| (22/23) GSM 25 | 18 | Potch 1 | AGEXP 303 | Agricol |
| (22/23) GSM 26 | 18 | Potch 1 | AGEXP 304 | Agricol |
| (22/23) GSM 27 | 18 | Potch 2 | AGEXP 303 | Agricol |
| (22/23) GSM 28 | 18 | Potch 1 | AGEXP 310 | Agricol |
| (22/23) GSM 29 | 17 | Ottosdal | NS 5511 | GSA |
| (22/23) GSM 30 | 17 | Ottosdal | PAN 8625 | GSA |
| (22/23) GSM 31 | 17 | Ottosdal | Avenger | GSA |
| (22/23) GSM 32 | 17 | Ottosdal | NK 8830 | GSA |
| (22/23) GSM 33 | 21 | Koppies | AGEXP 301 | Agricol |
| (22/23) GSM 34 | 21 | Koppies | AGEXP 303 | Agricol |
| (22/23) GSM 35 | 21 | Potch 1 | AGEXP 315 | Agricol |
| (22/23) GSM 36 | 21 | Potch 1 | AGEXP 314 | Agricol |
| (22/23) GSM 37 | 21 | Koppies | AGEXP 309 | Agricol |
| (22/23) GSM 38 | 21 | Koppies | AGEXP 313 | Agricol |
| (22/23) GSM 39 | 21 | Koppies | AGEXP 314 | Agricol |
| (22/23) GSM 40 | 21 | Koppies | AGEXP 315 | Agricol |
| (22/23) GSM 41 | 21 | Koppies | AGEXP 317 | Agricol |
| (22/23) GSM 42 | 21 | Koppies | AGEXP 318 | Agricol |
| (22/23) GSM 43 | 21 | Koppies | AGEXP 322 | Agricol |
| (22/23) GSM 44 | 21 | Koppies | AGEXP 324 | Agricol |