# FINAL PROGRESS REPORT
## NOVEMBER 2006

## PROJECT TITLE
### Evaluation of hectoliter mass equipment in order to recommend a suitable method for determination of hectoliter mass of maize in South Africa

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## Introduction

To facilitate marketing and to identify the best uses for maize produced, grain quality must be determined. The quality criteria assigned to grain are the intrinsic cultivar qualities and those that are environment- or process induced. Quality criteria currently used in South Africa for maize are moisture content and presence of foreign matter and defective maize kernels (based on size, colour and pinked) (No. R. 1013 of 14 August 1998). No consideration is given to other important characteristics affecting grain quality for various end users, i.e., kernel hardness, breakage susceptibility, density and milling properties.

Each type or cultivar of maize when in optimum health and fully mature has a characteristic bulk density. This is defined as the weight per standard volume measured in a standard manner and is determined as hectoliter mass (HLM), also referred to as bushel weight, test weight or specific weight and is expressed in kg per hectoliter, pounds per bushel, pounds per cubic foot or kilograms per cubic meter. Hectoliter mass reflects both the kernel density and the way the kernels pack and the higher the HLM the higher the grade. If the HLM varies the trend is usually downwards and indicative of reduced overall quality of the grain.

In South Africa HLM is one of the indicators on which the remuneration of wheat producers is based. There is currently no official standard method in South Africa for the determination of HLM of maize and HLM is not used as a quality indicator. Although it is known that HLM is not a precise indicator of any specific grain quality property, it does reflect general quality defects, associated with low HLM, which are not reflected in any other single grain quality indicator. The main purpose of incorporating HLM as part of the maize grading system and remuneration should, however, not be to find defects, resulting in reduced remuneration, but to evaluate for optimum quality that could result in rewards or premiums for the producer and optimum and consistent quality for the user. Both producers and users should therefore benefit from the findings of this project, as it is equally important for the producers to obtain optimum remuneration for their product as it is for the user to obtain optimum and consequent quality. HLM determination requires no elaborate or expensive equipment.

HLM is highly correlated with kernel hardness and is particularly useful in predicting dry milling properties. Other factors, which commonly affect HLM, are insect infestation and excessive foreign matter. The density of maize (weight per unit volume) is also important in storage and transportation since it establishes the size of container for either purpose.

Although HLM determination is an easy assay to perform it is complex in that it is dependent on the density and packing characteristics of the grain, i.e., the way kernels pack while filling a device or HLM cup. Packing efficiency is a cultivar characteristic and a high correlation exists between HLM and packing efficiency. It is highly likely that some HLM equipment can be more sensitive to the way it is filled than others that can influence the results significantly. Therefore the need exists to evaluate more than one type of HLM measuring device to be able to recommend a suitable method.

The objective of this project was therefore to evaluate different HLM measuring devices used in Australia, Canada, France, Germany, United Kingdom and North America compared to the chondrometer, currently used in South Africa for HLM determination of wheat and in some instances for maize, in order to recommend a suitable method and device for the determination of HLM of maize for the maize industry in South Africa.

## Materials and Methods

Maize samples were kindly supplied by Tiger Brands, Sasko Grain, Godrich Flour Mills, Noordfed and Ruto Mills. Ten samples were selected to cover as wide a range of HLM as possible. The 10 maize samples were used to evaluate different hectoliter mass devices from different countries as listed in **Table 1** compared to the South African chondrometer of which two were included. The respective devices are illustrated in **Figure 1**.

**Table 1** Hectoliter mass devices evaluated compared to the South African chondrometer.

| **Country** | **Equipment** |
|---|---|
| North America | Filling Hopper with quart cup and strike-off stick |
| Canada | Cox Funnel with 0.5 liter measure and wooden striker |
| Australia | Aluminium 0.5 liter with filler and cutter bar |
| Germany | KERN 220/222 |
| United Kingdom | Farm-Tec Easi-Way Hectoliter Test Weight Kit |
| France | Nilema Liter |

*Operating procedures for the different hectoliter mass devices*

Australian hectoliter mass device

Position the container with the hole in its centre on top of the 500 mL container. The cutter should not be inserted through the slit at this stage. Fill both containers through the filler hole and insert the cutter through the slit. Discard the grain above the cutter and weigh (g) the grain in the bottom 500 ml container on a two decimal balance. Determine the HLM of the grain using the following equation to convert the mass of the grain (g) to kilogram per hectolitre (kg.hl$^{-1}$): mass of the 500 mL grain (g) / 5

Canadian hectoliter mass device

Fill the Ohaus measuring container (500 mL) with the grain to be tested. Insert the slide into the Cox funnel to close the opening of the funnel. Pour the grain, already in the measuring container, plus an extra hand full into the funnel. Position the funnel on top of the measuring container in such a way that the notched legs of the funnel fits securely onto the rim of the container. Remove the slide from the opening of the funnel in one quick motion to ensure that the grain drops evenly into the measuring container. Carefully remove the funnel from the container as not to disturb the grain. Any jarring at this moment will result in compaction of the grain and inaccurate results will be obtained. Position the round wooden striker onto the rim of the container and remove the excess grain in the container with three full-length zigzag motions. Weigh (g) the remaining grain in the 500 mL container on a two decimal balance. Convert the weight (g) to kg.hl$^{-1}$ as indicated on the test weight conversion chart supplied with the device.

Niléma Liter French hectoliter mass device

Position the hopper on top of the liter container. Fill the hopper to the upper edge with no settling or lumping. Open the valve of the hopper to release the grain into the container. Insert the cutter fully, with the right hand, into the slit. During the insertion, the container must be held firmly in order to avoid vibration and settling of the grain. Remove the hopper from the container and weigh the grain in the container on a two decimal balance. Multiply the mass (g) with 100 and divide it by a 1000 to obtain the HLM in kg.hl$^{-1}$.

**North America** **Canada** **Australia**

**United Kingdom** **France** **Germany** **South Africa**

**Figure 2** Hectoliter mass devices evaluated.

KERN 220/222 German hectoliter mass device

Fill the pre-filling measure with grain up to the level mark. Pour the grain into the filling hopper from a height of 3-4 cm. Pull the cutter from the slit in one quick motion, without jarring of the device. Insert the cutter into the slit and push through the grain. Care must be taken not to shake or jar the device. Discard the excess grain on top of the cutter and remove the filling hopper and cutter from the top of the measuring container. Weigh (g) the grain in the container on a two decimal balance and determined the HLM in kg.hl$^{-1}$ from the conversion chart supplied with the device.

North American quart cup hectoliter mass device

Fill the funnel with enough grain to overflow the quart cup (measuring container). Open the valve to release the grain into the quart cup. Swing the funnel to the left of the quart cup. Level the grain in the quart cup by positioning the wood striker on the rim of the container and scalp the excess grain off by using three full-length zigzag motions. Weight the remaining grain in the quart cup using a two decimal balance. Convert the weight (g) to kg.hl$^{-1}$ as indicated in the test weight conversion chart supplied with the device.

Easi-Way British hectoliter mass device

Insert the cutter and drop the weight into the measuring cylinder. Fill the cylinder with grain from a height of *ca.* 25 mm. Remove the cutter from the cylinder and allow the weight together with the grain to descend into the lower chamber. Re-insert the cutter through the column of grain to isolate the grain in the measuring cylinder. Discard the excess grain from the cylinder and remove the cutter from the cylinder. Weigh (g) the grain in the container using a two decimal balance and determine the HLM in kg.hl$^{-1}$ from the conversion chart supplied with the device.

South African chondrometer

Fill the funnel with grain. Level the grain in the funnel with the round edge of the wood striker and open the valve to release the grain into the cylinder that should be placed on the raised level. Swing the funnel to the left of the cylinder. Level the grain in the cylinder by positioning the wood striker on the rim of the container and scalped the excess grain in the container off in one movement. Weigh the remaining grain on a two decimal balance. Convert the mass (g) kg.hl$^{-1}$ by dividing the weight of the grain by 5.

*Determination of repeatability of the hectoliter mass devices*

A 12 kg maize sample was divided into 1.5 kg samples resulting in 8 samples, one for each HLM device. The respected HLM devices were tested in random order. Ten repetitions were performed on each device and between each repetition the 1.5 kg sample was mixed by pouring it, five times, from one bucket to another. The HLM of each device was determined as described earlier.

*Determination of the effect of repeated analysis on the same sample*

Three 12 kg maize samples with different HLM values i.e., ca. 74.2, 76.7 and 78.2 kg.hl$^{-1}$, respectively, were selected. In order to obtain a well mixed sample each sample was poured through a Boerner Seed Divider three times. Each sample was divided into 1.5 kg samples i.e., one for each HLM device. Ten consecutive repetitions were executed on each HLM device, however, after the first test, only the amount of maize that was needed to do the test was kept for the following nine repetitions. The experiment was repeated for the other two maize samples as well.

*Comparison of the different HLM devices using sub-samples*

Ten 45 kg maize samples of different levels of HLM were selected. Each samples were poured three times through a Boerner divider in order to obtain a well-mixed sample. Each sample was divided into 10 sub-samples of 4.5 kilograms each. These sub-samples were further divided into three, 1.5 kg samples. Each of these 3 samples was tested in duplicate on each HLM device. After each test the work samples was mixed with the remainder of the 1.5 kg sample by pouring it from one bucket to another 5 times after which the duplicate analysis was done.

*Comparison of the different HLM devices using the same sample*

Ten 4.5 kg maize samples of different levels of HLM were selected as before. The samples were poured through a Boerner divider three times in order to obtain a well-mixed sample. Each sample was divided into three, one and half-kilogram sub-samples. The HLM determinations of the three samples were always determined on the USA device first, as this device requires the largest sample. The testing order of the other devices was randomly chosen. The work sample obtained from the American device was subsequently used to test the HLM on the other devices, as well. Duplicate tests were executed on each HLM device with the same work sample. The remaining two sub-samples were tested in the same way.

*Statistical analysis*

Analysis of variance (ANOVA) has been performed to compare average measurements between instruments to determine absolute differences. Additionally the intra-class correlation coefficients (ICC) have been determined as the ICC agreement that correlates measurements with each other while taking also in consideration the difference in absolute values of the respective measurements. The ICC consistency has also been determined which ignores absolute differences, but indicates whether correction factors could be applied. The ICC agreement has also been determined between duplicates to evaluate the accuracy of the repeatability within each instrument.

## Results and discussion

*Determination of repeatability of the hectoliter mass devices*

In this experiment only the repeatability of each device was considered using only one sample. The high degree of repeatability within each instrument can clearly be seen in **Figure 1a** that illustrates very little variation within the 10 measurements of the sub-samples performed on each device. The devices from Australia, Canada and France, however, do seem to result in HLM values higher than those obtained from the other devices.

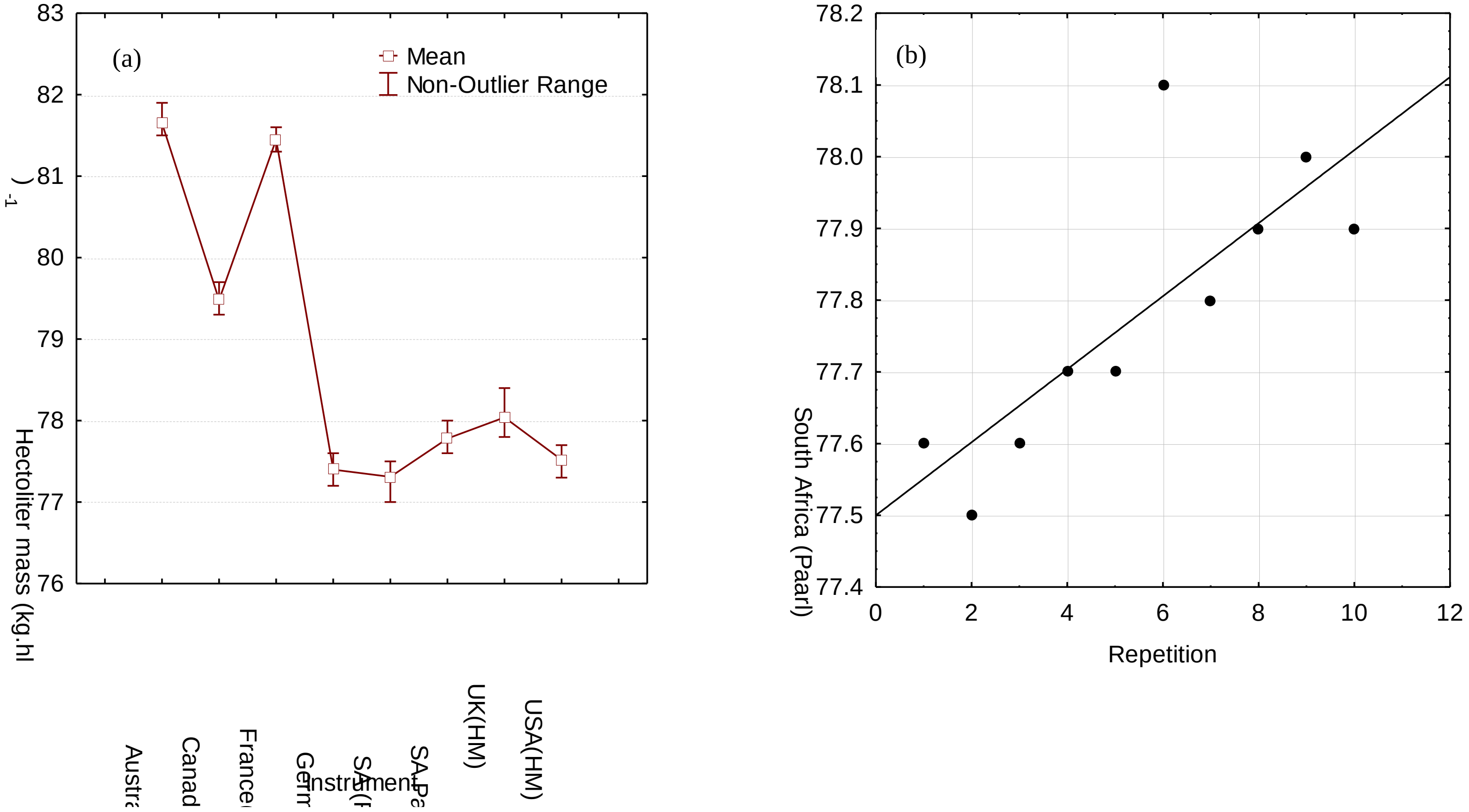

**Figure 1** Repeatability of hectoliter mass devices using sub-samples.

Evaluating the HLM changes after ten repetitions of the sub-samples (with remixing between measurements), it was only within the one South African (Paarl) chondrometer that a trend was noticed (**Figure 1b**). It is, however, important to note that the range within the ten repetitions was only 0.6 kg.hl$^{-1}$ and this trend would therefore not be considered significant.

*Determination of the effect of repeated analysis of the same sample*

When the exact same sample (no remixing between measurements), of three respective maize samples of different HLM values, was measured repeatedly on each device, it was again only for one of the South African (R&D) chondrometers that a trend was observed (**Figure 2**). Again the range within the ten repetitions was less then 1 kg.hl$^{-1}$ and this trend would not be considered significant.

*Comparison of the different HLM devices using sub-samples*

In spite of not having noticed any significant trends when repeatedly measuring the exact same sample on each device it was still decided to compare the different HLM devices with each other using sub-samples of a bulk sample. From **Figure 3** it is evident that the measurements performed on the devices from Australia, France and Canada resulted in significantly higher HLM values than those obtained from the other devices. Measurements performed on the devices from Australia and France in turn resulted in HLM values significantly higher than those obtained from the device from Canada. There were no significant differences between the HLM measurements obtained from the remaining devices. As would be expected variation within the sub-samples were, however, evident.

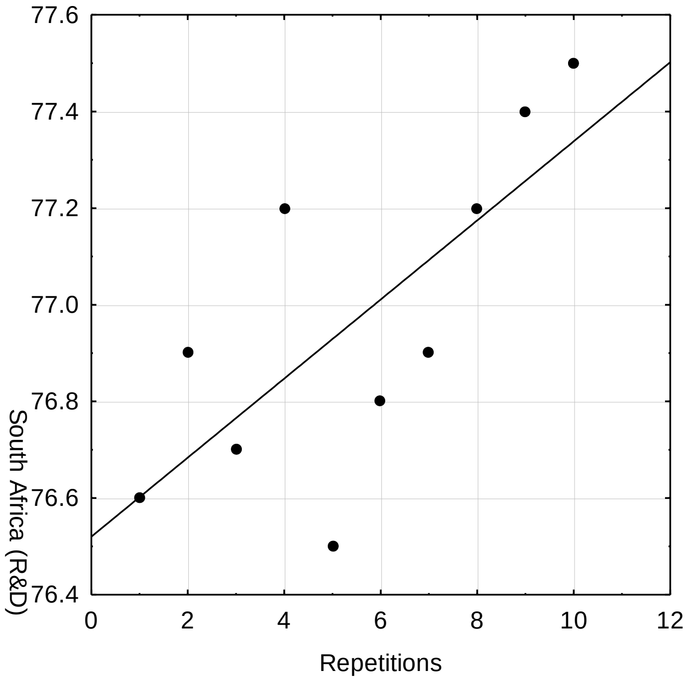

**Figure 2** Trends observed after having measured the same sample repeatedly (10 times) on a South African chondrometer.

ICC agreement correlation (**Figure 4**) between duplicates indicates that the repeatability within the devices from South Africa and North America were most different from the other hectoliter mass devices in terms of actual values. It is, however, important to note that all the ICC agreement correlations values are above 0.96 indicating very little differences in terms of the repeatability of the respective devices compared to each other and would therefore not be considered significant.

*Comparison of the different HLM devices using the same sample*

From **Figure 5** it is again evident that the HLM measurements performed on devices from Australia, France and Canada resulted in significantly higher values than those obtained from the other devices. Measurements performed on devices from Australia and France again resulted in HLM values significantly higher that those obtained on the device from Canada. No significant differences were observed in the HLM measurements obtained from the remaining devices. Variation between measurements within each device, however, was much less as the exact same sample was measured repeatedly on all the respective devices.

ICC agreement correlations between duplicates (**Figure 6**) indicate that the repeatability within the devices from the UK, South Africa and to some extend Canada differed the most from the other devices in terms of actual values. It is, however, important to note that again all the ICC agreement correlations coefficient values are above 0.95 indicating very little differences in terms of repeatability between the respective devices and would not be considered significant.

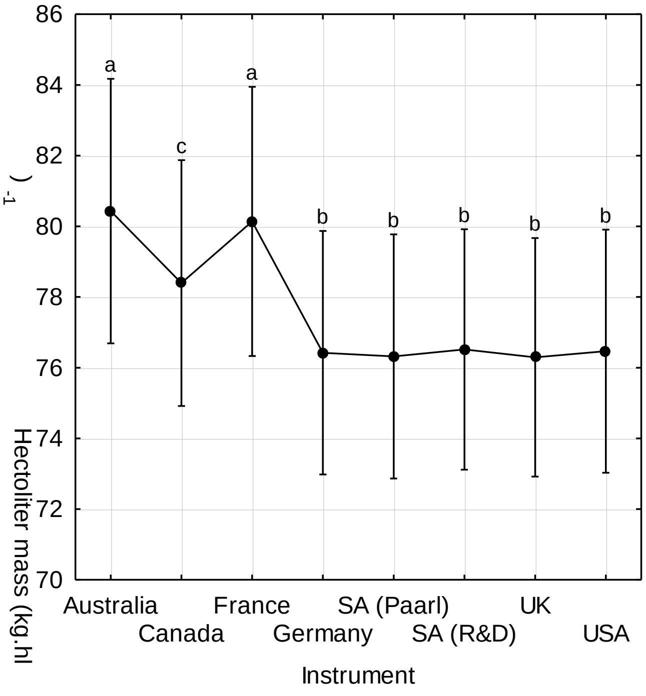

**Figure 3** Least square mean plot indicating differences between the HLM measurements obtained form the different hectoliter mass devices using sub-samples.

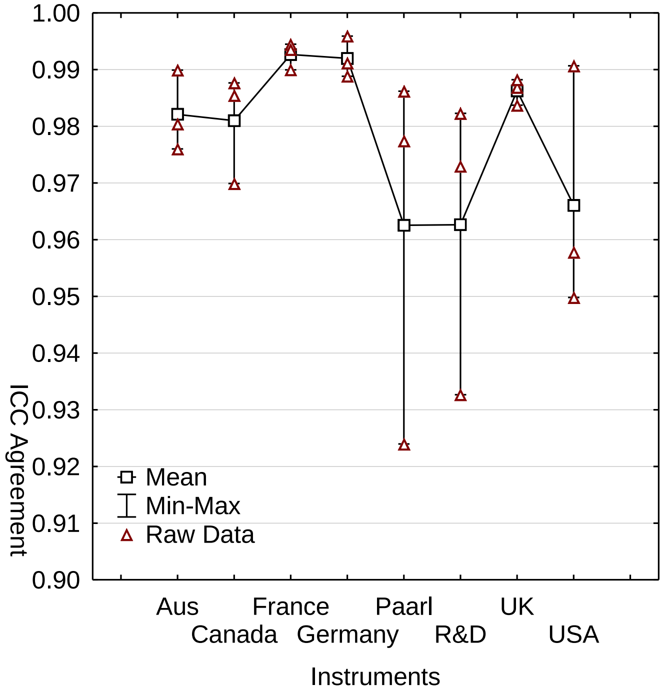

**Figure 4** ICC agreement correlation between duplicates determining the accuracy of the repeatability of the measurements within each instrument using sub-samples.

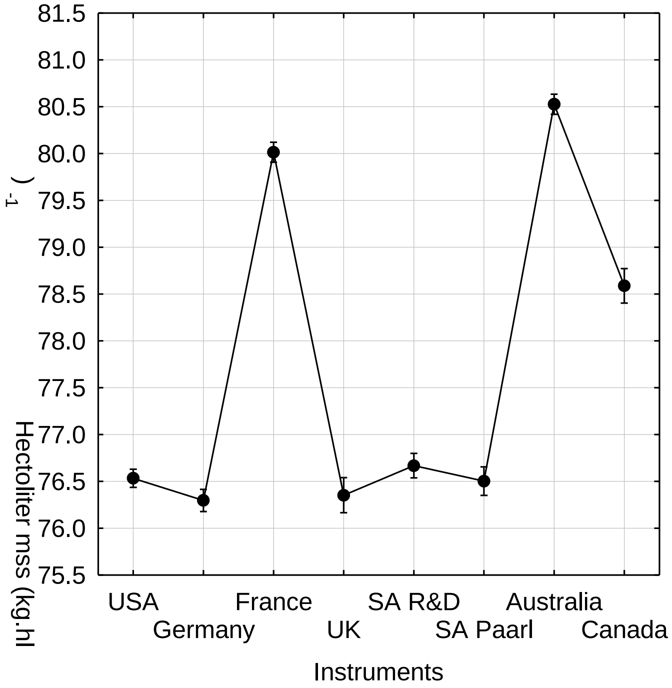

**Figure 5** Least square mean plot indicating differences between the HLM measurements obtained from the different hectoliter mass devices using the same sample.

**Figure 7** shows the ICC agreement correlation coefficients between HLM devices and it is clear that the devices from France, Australia and Canada measure differently from the others in terms of actual HLM values. From the ICC consistency correlation coefficient all the devices correlate with each other in terms of HLM values with an ICC consistency correlation coefficient of above 0.96. This indicates that one should be able to apply correction factors to improve the ICC agreement.

## Conclusions

The repeatability of the measurements within each device is similar between the respective devices as has been illustrated with the ICC agreement correlation coefficients between duplicates. The devices from France, Australia and Canada, however, seem to result in differently HLM values illustrated with the ICC agreement between instruments. However, due to the high ICC consistency correlations it should be possible to compensate for these differences by calculating correction factors.

In contrast to what was expected, and has in fact been found when the different devices was evaluated using wheat, the South African chondrometers did not result in lower HLM values compared to the other devices. As maize is normally not cleaned before determination of HLM it was also the case during the execution of this experiment. We will, however, repeat the last experiment (comparison of devices using the same sample) on clean samples. This might improve the ICC consistency between instruments and is necessary to verify the current results.

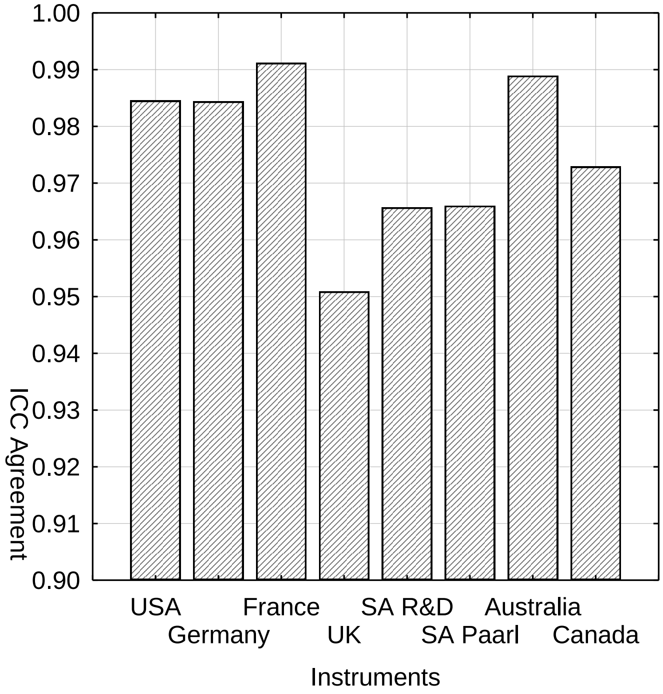

**Figure 6** ICC agreement correlation between duplicates determining the accuracy of the repeatability of the measurements within each instrument using the same sample.

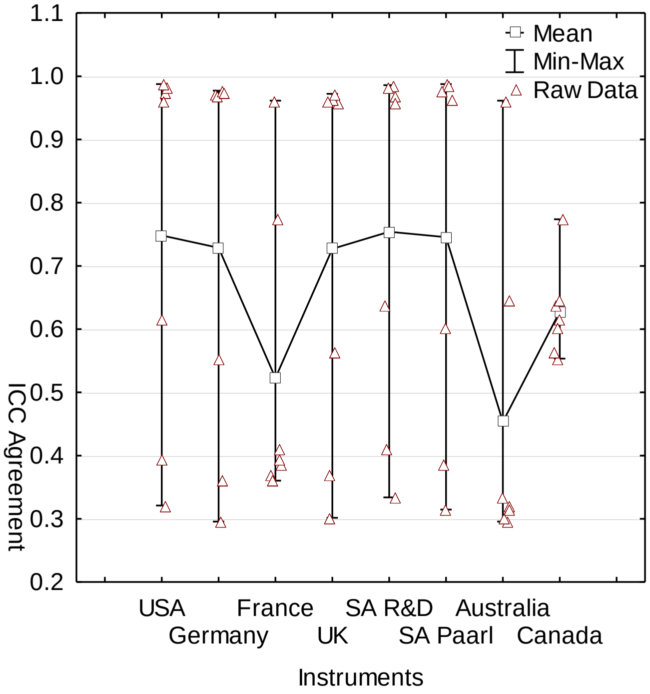

**Figure 7** ICC agreement correlation indicating actual differences between the HLM results obtained from different HLM devices using the same sample.

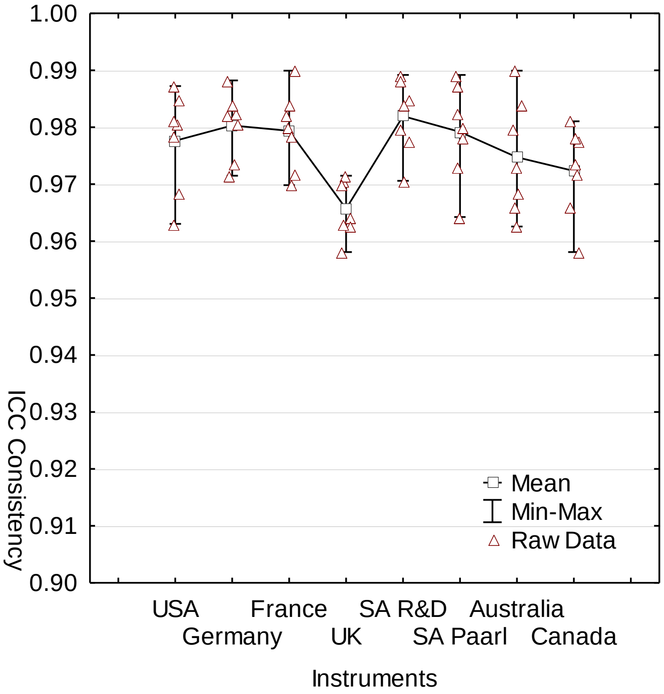

**Figure 8** ICC consistency correlation between the HLM results obtained from different HLM devices using the same sample.

In terms of practicality it was only the device from France that was not suitable for HLM determinations of maize. The opening of the funnel seems to be too small to allow the maize kernels to flow freely into the measuring cylinder. As it has to be poked repeatedly during a single measurement to allow flow into the cylinder it would have affected the packing density. The device from France would therefore not be suggested to be used for HLM determinations of maize.

## Constraints

The maize samples obtained did not vary in HLM values to the degree that would have been ideal for the project. One would have preferred to have a range of at least 10 kg.hl$^{-1}$. As we do not have access to sieves for the Dockage tester to clean maize samples, it must be done by hand sieving. We also still need to access such a sieve and is the reason for not having tested clean maize samples as yet.

## Dissemination of results

The results will be submitted for publication in a peer reviewed scientific journal as well as in a popular magazine such as Farmer’s Weekly.

## Utilisation of project results

We need to finalise the experiment by repeating the last experiment on ten clean samples. As soon as possible after the execution of the final experiment a recommendation will be made to the maize industry regarding the use of the South African chondrometer to measure the HLM of maize in comparison with other international devices.

## Budget and expenditure Statement

To be submitted.

## Acknowledgements

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### Literature reviewed

Aguirre, A., Badiali, O., Cantarero, M., León, A., Ribotta, P. & Rubiolo, O. (2002). Relationships of test weight and kernel properties to milling and baking quality in Argentine Triticales. *Cereal Res. Comm*. **30**(1-2), 203-208.

Dexter, J.E., Matsuo, R.R. & Martin, D.G. (1987). The relationship of durum wheat test weight to milling performance and spaghetti quality. *Cereal Foods World* **32**(10), 772-777.

Donelson, J.R., Gaines, C.S., Andrews, L.C. & Finney, P.F. (2002). Prediction of test weight from a small volume specific gravity measurement. *Cereal Chem*. **79**(2), 227-229.

Dorsey-Redding, C., Hurburgh, C.R., Johnson, L.A. & Fox, S.R. (1991). Relationships among maize quality factors. *Cereal Chem*. **68**(6), 602-605.

FAO (1992). Maize in human nutition. Food and Agriculture Organisation of the United Nations, Rome.

FAO (1994). Grain storage techniques. Evolution and trends in developing countries. (Edited by DL Proctor), FAO Agricultural Services Bulletin No. 109, GASCA - group for assistance on systems relating to grain after harvest, Food and Agriculture Organisation of the United Nations, Rome.

Gaines, C.S. (1991). Associations among quality attributes of red and white soft wheat cultivars across locations and crop years. *Cereal Chem*. **68**(1), 56-59.

Ghaderi, A., Everson, E.H. & Yamazaki, W.T. (1971). Test weight in relation to the physical and quality characteristics of soft winter wheat (*Triticum aestivum* L. em Thell). *Crop Sci*. **11**(4), 515-518.

Greenaway, W.T., Watson, C.A. & Davis, G. (1977). Factors for converting bushel weight to hectoliter weight for six cereal grains, flax and soybeans. *Cereal Chem*. **54**(2), 373-378.

Greenaway, W.T., Watson, C.A., Hunt, W.H. & Liebe, E.B. (1971). Performance evaluation of an automated vs. official weight-per-bushel tester. *Cereal Sci. Today* **16**(5) 146-149.

PusHLMan, F.M. (1975). The effects of alteration of grain moisture content by wetting or drying on the test weight of four winter wheats. *J. Agric. Sci*. **84**(1), 187-190.

PusHLMan, F.M. & Bingham, J. (1975). Components of test weight of ten varieties of winter wheat grown with two rates of nitrogen fertilizer application. *J. Agric. Sci*. **85**(3), 559-563.

Schuler, S.F., Bacon, R.K., Finney, P.L. & Gbur, E.E. (1995). Relationship of test weight and kernel properties to milling and baking quality in soft red winter wheat. *Crop Sci.* **35**(4), 949-953.

Troccoli, A. & Di Fonzo, N. (1999). Relationship between kernel size features and test weight in *Triticum durum*. *Cereal Chem*. **76**(1), 45-49.