Modelling post-harvest grain development to deliver better storage outcomes for growers

Summary
Outcomes of this project will provide growers with information that can be used to assess storage limits of canola, barley and wheat and when the grain will be at its optimum quality for end-product use. The ability of rapid methods, Near Infrared (NIR) Spectroscopy, seed coat colour, Falling Number (FN) and Rapid Viscosity Analysis (RVA), for assessing grain quality and storage potential were assessed. The results are available in a detailed report and CD. The research showed that colour and NIR provided the earliest indication of deterioration occurring in seed quality. Immaturity in malting barley or new season wheat could be improved with storage, then retained with low temperature storage.

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Conclusions

Storage potential of grain is largely determined by the condition of grain at intake, grain moisture content (MC) and storage temperature. Seasonal conditions and harvest timing play an important part in determining the condition of grain and its level of maturity or degree of weather damage at intake. The ability to predict storage potential of grain loaded into storage is difficult and rapid methods that indicate early deterioration of grain quality are required. Several rapid measure techniques were evaluated in this study, and models developed to provide growers with a useful storage management tool. The measurement of seed coat colour was a useful indicator of early changes in the overall quality of canola, barley and wheat. Contrasts of the NIR spectra for canola and wheat, and Stirring Number (SN) and FN tests for wheat also gave an early indication of seed deterioration. Early detection of quality loss in barley was not as evident using NIR contrasts or SN, although these methods were useful for indicating when seed quality had been lost.

Modelling of canola, barley and wheat data using a specific quality index will enable the storage potential of these grain types to be determined. Such models will provide storage managers with a tool that allows a pro-active approach to storage, and provide the facility to improve the overall quality of their product.

The data used in this modelling study are limited in that they have been collected only from selected regions over two seasons. However, the modelling technique used is a useful approach to develop a tool that growers can use in the management of their grain. Further grain quality data generated from different regions and over a number of seasons need to be incorporated into the model to improve accuracy and robustness.

Recommendations

The following recommendations are given to enable better management of canola, barley and wheat storage:
1. Grain should be stored as dry and cool as practicable. Storage of barley and wheat at MCs at or above 14%, canola above 8% MC, and temperatures exceeding 25°C, are not recommended.
2. Grain with mild weather damage should be stored below 25°C and at MCs below 12% for barley and wheat, and 7% for canola. Such grains are likely to be highly susceptible to rapid loss of germination and quality and are not suitable for long term storage.
3. Monitoring of canola and wheat quality during storage using quick methods, e.g. NIR, seed colour, SN or FN, will allow for early intervention and adjustment of storage management to preserve grain quality. Germination testing is recommended for determining changes in malting barley quality, although seed colour may provide some indication of seed deterioration.

Where active storage strategies for malting barley are an option, the following recommendations for management are given:
1. Germination energy should be measured before storage.
2. If the barley displays dormancy, the use of aeration to cool grain should be delayed to allow further maturation post-harvest. To accelerate maturation in-store, aeration using warm air for a short period of time may be a useful strategy. Grain temperature should not exceed 30°C and seed MC must be below 13%.
3. Germination of the seed should be monitored during storage and storage temperature reduced when malting standards
are reached.

**Outcomes**

Grain growers can obtain a marketing advantage by value adding and adopting quality control to maximise grain quality at out-turn. The selection of suitable combinations of grain MC and storage temperature, for example, can regulate the rate at which malting barley matures in store. Such active storage strategies can make farm based storage a viable alternative for end-users who want to receive grain of consistently high quality. Improved management options will potentially enable growers to move from an on-farm storage risk-management strategy, to an on-farm active storage management plan to value add and deliver grain to the end-user’s specific requirements.

This increased understanding of quality changes in canola, barley and wheat during storage will provide growers with a much sounder understanding of the influence of the stored grain environment on the rate of maturation and changes to quality of the grain with storage. A number of rapid tests were evaluated and the data modelled to determine the relationship between the quality criteria and their correlation to a useable index to assess the storage potential of grain. Such information will enable growers to select the optimum storage management plan for canola, barley and wheat to maintain or increase quality.

**Achievements/Benefits**

The effect of storage conditions on the quality of grain is of considerable importance to Australian grain growers. The quality of crops, such as barley and wheat, can be easily lost during storage on-farm. However, controlling the conventional storage process in a farm bin can minimise damage to grain and maintain a high level of value. The use of smart storage technology can even value add to deliver grain to the end-user or marketer at a required specification. Previous GRDC sponsored studies have shown that there are yield and quality advantages associated with early harvested grain. Through active storage, it is also possible to improve the value of early harvested grain and to meet quality standards at a time that benefits both the grower and the buyer. Such pro-active management will benefit the grower by adding flexibility to harvest strategies, and improve farm-gate returns through the sale of a premium product at the most advantageous point in time.

To maximise the quality of on-farm stored grain entering the supply chain, the influence of storage environments on post harvest maturation and changes in quality of contemporary Australian barley, wheat and canola varieties need to be better understood. By understanding the mechanisms that drive the post-harvest physiological and metabolic development of the newly harvested crop, it is possible to actively control the rate of maturation of grain in storage, to reduce dormancy of malting barley, and to improve the commercial quality of other crops by early harvesting followed by active storage. Maturation and even slight deterioration of grain can lead to a more desirable product under certain circumstances, resulting in a better return to growers. In practice, this can be achieved by manipulating storage temperature and MCs. The use of controlled atmospheres is also known to influence aspects of grain quality, but this potential management tool remains largely neglected.

To predict the effect of storage conditions on the quality of common grain types this project extended the exploratory work from previous GRDC funded projects, CSE178 and CSE00012, and projects funded under the Stored Grain Research Agreement, to identify target quality criteria and associated rapid testing techniques with a view to developing applications that can be adopted by industry. The project drew on existing data sets on the storability of three commodities (wheat, barley and canola) to firstly predict the changes in the commercial value of the grain in storage, and secondly to assess which types of rapid tests, e.g. NIR Spectroscopy, seed colour, FN and RVA, could be used to evaluate the grain storage potential.

The modelling system was based on setting storage limits using a specific index. Acceptable values were set for the relevant quality parameters. Any result above or below the set limit was assigned an index number. The larger the index number the lower the grain quality, and from this storage limits, SSafe, could be obtained. The point at which the index was lowest indicated when maximum grain quality, SValue, had been reached. Details on the project methods, data and the ability of NIR to predict quality parameters are given in the attached report.

The quality parameters used to predict SSafe in canola were germination (>90%), contrasts of the NIR spectra of the samples (<2,000 average root mean square difference (RMS(C))) and free fatty acid (FFA, <1%). Germination decreased, and NIR contrasts and FFA levels increased with storage at higher temperatures and MCs. Canola (oil content 35% d.b.) at 6, 7 and 8% MC could be safely stored for 24 months at 20°C, 12 months at 25°C and three months at 30°C. SValue was determined using...
a FFA value of 0.5%, a level found in oils of high quality. SValue showed that storage time was reduced for the samples stored at 8% MC.

NIR contrasts and seed colour provided suitable methods for detecting early loss of canola quality with storage. The ability of NIR to predict changes in FFA levels during storage is considered to be a useful tool for storage managers, but further data need to be added to improve the accuracy and robustness of this model.

Barley varieties varied in quality with Gairdner, Sloop and Stirling exhibiting some degree of dormancy and Tallon and Grimmett being more mature. Germination energy was the most suitable quality parameter used to determine SSafe, which should be more than 95% for malting barley. Gairdner, Sloop and Stirling, which matured with storage, exhibited the greatest storage potentials with samples stored at 15 and 20°C, 10, 12 and 14% MC samples, and at 25°C, 10 and 12% MC samples, being suitable for storage for a period of 12 months or more. Tallon and Grimmett stored well at lower temperatures and moisture contents but quickly deteriorated when stored at 14% MC, or at higher temperatures.

There is a change in malting characteristics as barley matures in store. Beta-glucan and diastatic power were the malting parameters that exhibited the greatest change with storage. Low beta-glucan levels and high diastatic power are highly desirable in malt production. SValue, for barley considered most suitable for malting, was determined using germination (>95%), beta-glucan (low values) and diastatic power (high values).

Stirling, which lost dormancy quickly, showed consistent malting quality over the three to 12 month storage in all samples other than the 14% MC stored at 25 and 30°C and the 12% MC stored at 30°C. Storage at higher temperatures was required for Gairdner and Sloop to reach maximum malting potential in the shortest storage period. When Gairdner was stored at lower temperatures, 12 months were required to reach maximum malting potential. Active storage management, using higher temperatures during short term storage, would hasten the breakdown of dormancy in such barley types. The optimum malting potential of Tallon and Grimmett was reached within three months but was only maintained for a short time before maltability decreased.

Changes in quality of barley could be monitored using NIR contrasts, RVA (SN test) and total seed colour change. Seed colour provides the earliest indication of deterioration in seed quality.

Wheat storage trials were carried out on Australian Prime Hard (APH), Australian Hard (AH) and Australian Premium White (APW) wheat. SSafe storage limits were determined using germination (>90%), total colour change (>1.5), NIR contrast (>500), FN (300-600 sec) and RVA SN (130-170). Wheat could be stored for more than 12 months at storage temperatures of 15°C, at 10, 12 and 14% MC, and 20°C at 10 and 12% MC. Storage of wheat at 14% MC and 20°C was limited to 12 months. APH wheat from the second trial was of lower quality and was limited to 12 months storage at the lower temperatures and MC, and exhibited greater deterioration when stored at 14% MC. Storage limits were reduced in wheat stored at 30°C and 12 and 14% MC to three months or less. The storage limits for 10% MC wheat stored at 30°C ranged from 4.5 to 12 months depending on the initial quality.

The specific index parameters to determine SValue for optimum bread making and end-products performance were based on rheology quality parameters e.g. water absorption, development time, stability, extensibility and Rmax. For several wheats, there was an initial period of maturation, with dough properties becoming more ideal as the wheat matured in-store. Storage at 30°C reduced the time that wheat was at its optimum quality. High temperature storage resulted in doughs becoming stronger, which was shown by an increase in Rmax and decrease in extensibility. Development time increased and, in some cases, water absorption and stability decreased. The maximum SValue for wheat stored at the lower storage temperatures varied from six to 12 months. The high variability in the quality of the wheat collected from different seasons makes quality limits hard to define.

FN, SN and NIR provide early indication of quality loss, with seed colour giving the earliest indication of change. Further data from different regions and from different seasons need to be incorporated into this model to improve its accuracy and robustness.

Results from this study provide an indication of the storage potential of canola, barley and wheat when stored under different conditions. The initial quality and maturity of the grain will play an important role in selecting the most suitable storage strategy. Active storage can be used to increase the rate of dormancy breakdown in barley, and wheat is likely to benefit from two to three months in storage to mature to maximum end-product quality. When grain reaches its maximum level of
maturity, storage at low temperatures and MCs is required to maintain quality and maximise its storage potential.

Determining the storage potential of grain when initially loaded into storage using rapid easy methods will enable early detection of quality changes in-store. Appropriate changes in storage management can then be implemented to minimise the loss in grain quality. Total change in colour of the seed signalled the earliest changes in quality in canola, barley and wheat. NIR contrasts of the spectra for canola and wheat, and SN and FN for wheat also gave an early indication of seed deterioration. Early detection of quality loss in barley was not as evident using NIR contrasts or SN, though these methods were useful for indicating when seed quality had been lost.

Other research
1. Analysis of the data by a statistician to improve the understanding of the interactions of storage time, temperature and MC on canola, barley and wheat quality.
2. Continued investigation into rapid methods, NIR, seed colour and RVA, for monitoring changes in grain quality in storage.
3. Investigation of methods for determining the initial quality of the grain when it comes into the store. This will provide some indication of the storage potential of the grain and allow for appropriate storage management to increase or preserve quality in store.
4. To increase the accuracy and robustness of the model by incorporating additional data from grain sourced from different regions and over a number of seasons.