Wheat for distilling and bioethanol

Richard Weightman, ADAS Boxworth

WIGN Stakeholder meeting 21/11/06

ADAS

Contributors

ADAS

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- Daniel Kindred
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SWRI

- James Brosnan

SCRI

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FOSS

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Green Spirit Fuels

- Malcolm Shepherd

HGCA Research Review completed

Wheat as a feedstock for alcohol production

- **ADAS, SWRI & Greenspirit Fuels (November 2006)**

Issues

- What drives alcohol yield ?
- Measuring and Predicting alcohol yield
- Effects of Variety
- Environmental influences
- Conclusions and ongoing work

What traits might affect alcohol yield ?

Hardness	1B1R
Protein	Starch
TGW, Grain L:W ratio	Amylase activity
Turbidity	Vitreosity
Screenings	Specific weight
Amylose:AP ratio	Granule size distribution

Many….

we require a theoretical framework to understand variation in alcohol yield

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Substrates for fermentation

‘Benchmark’ wheat grain (% dry basis)

Starch	**69.0**	**= 720 kg/tonne**
Sugars	**3.0**	
Non Starch Polysaccharides	**11.0**	
Crude protein (Nx5.7)	**11.5**	
Lipid	**2.5**	
Ash	**2.0**	
Lignin	**1.0**	

Theoretical yields (kg) from fermentation

Carbohydrate	Water		Sugar		Ethanol (litres)	CO_2
1000 +	111	→	1111	→	568 (720)	+ 543
720 + Sugars & starch	80 [- 8% loss for yeast]	→	736	→	376 (477)	+ 360

- Alcohol yield predicted 477 litres/tonne (dry basis) for 'benchmark' grain at 11.5% protein
- 6.6 litres alcohol per % difference in starch content

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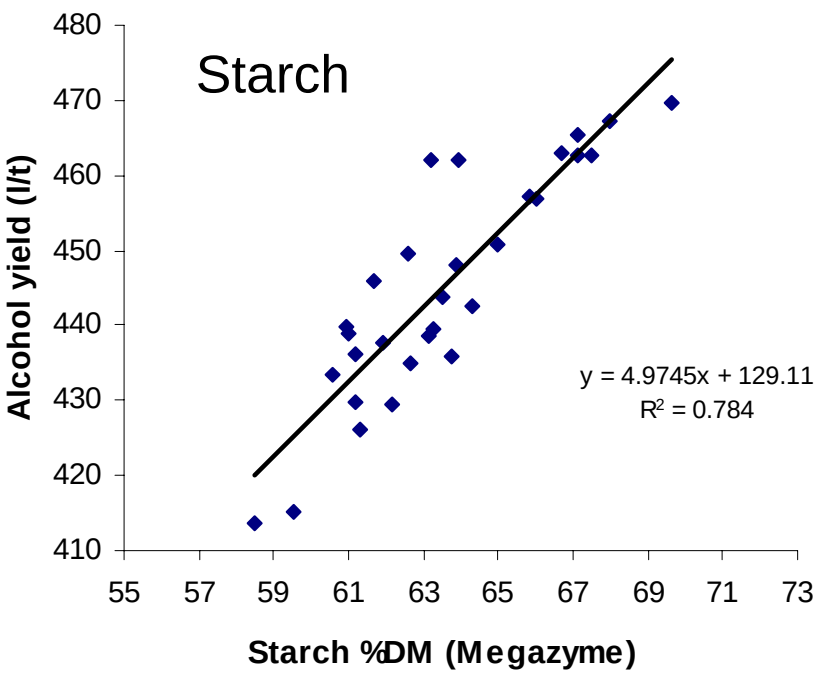
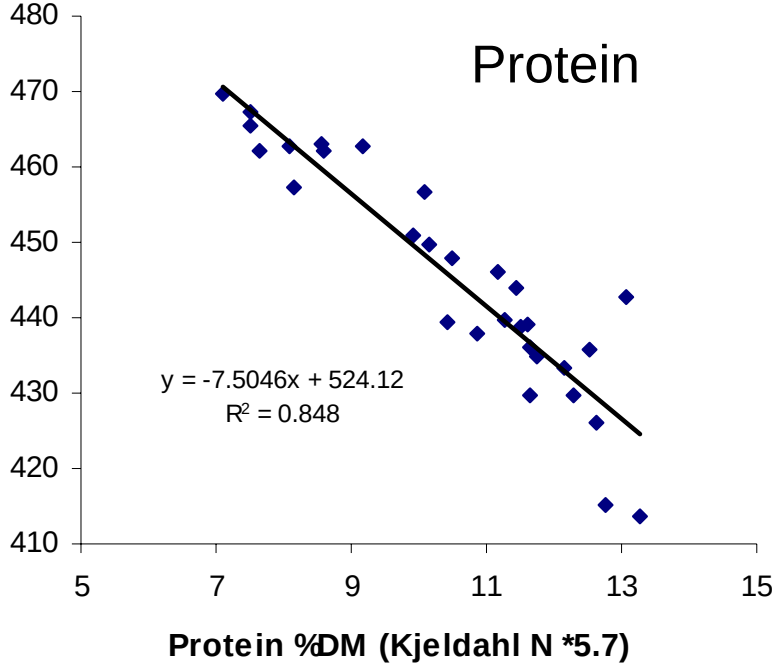
Starch and protein effects on alcohol yield

Note: Slope <6.6





Samples from a wide range of varieties and environments

[Data: Green Grain, 2005; Starch analysis at QUB]

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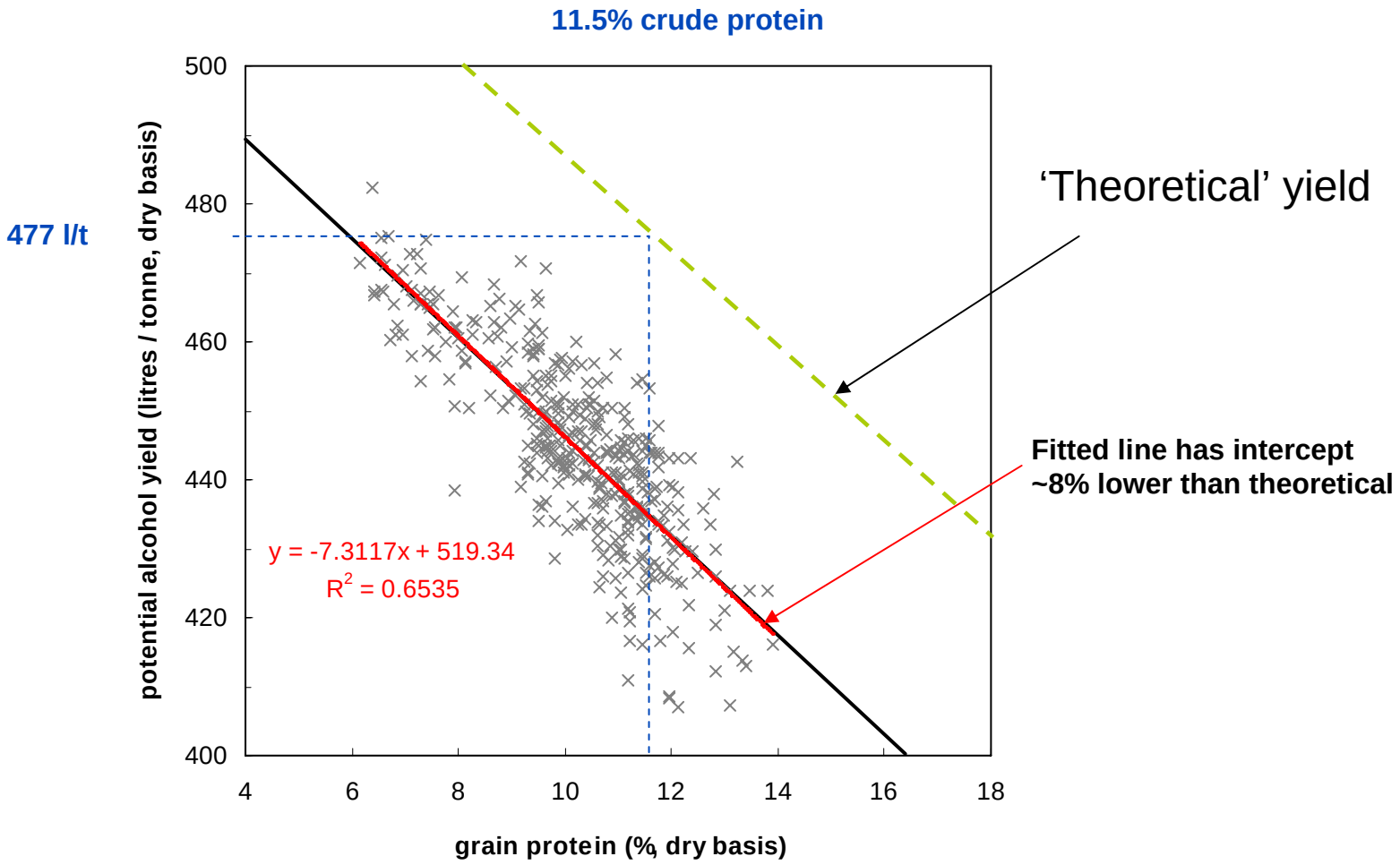
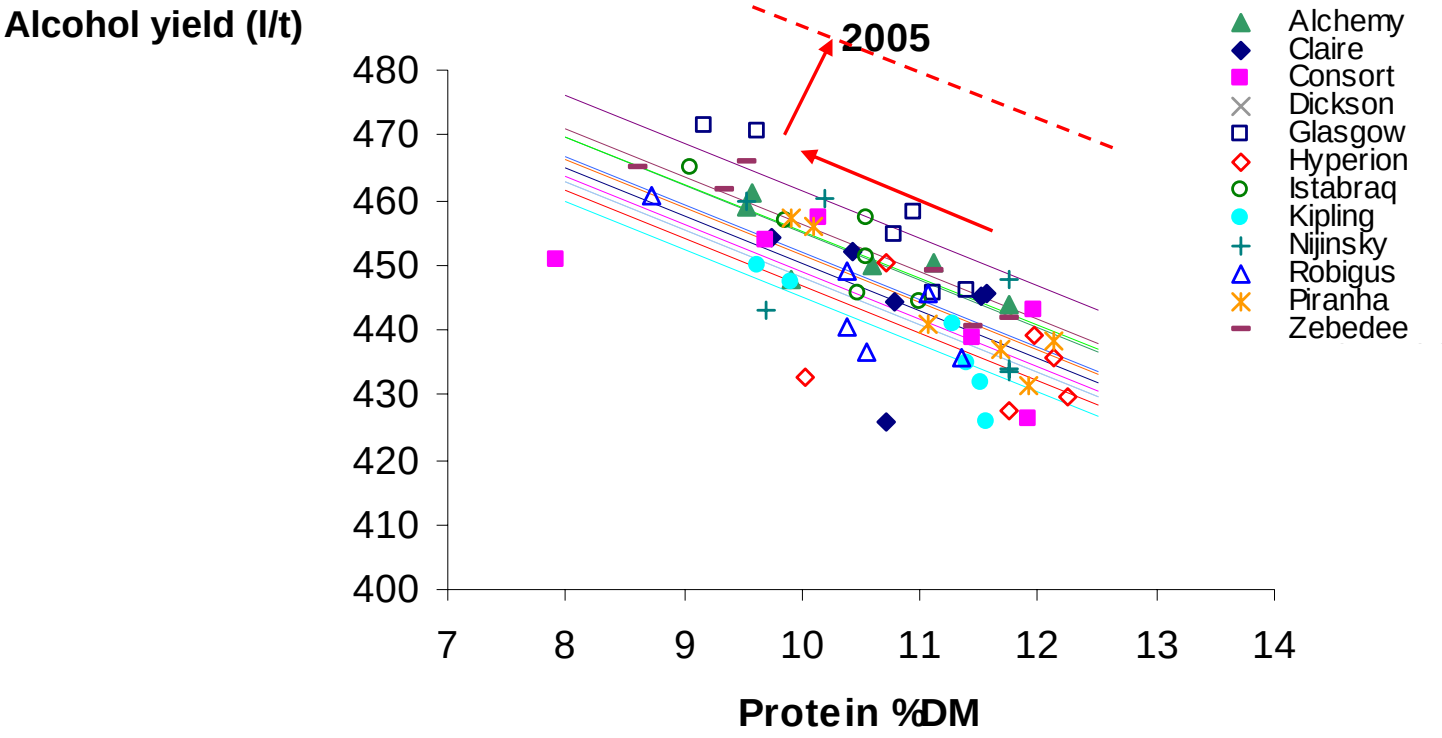
Relationship between alcohol yield and protein



[Data: SWRI, 2003-2005 and Green Grain, 2005]

Varietal effects on alcohol-protein relationship



Regression analysis shows justification for fitting parallel lines

[Data: SWRI, 2005; analysis Daniel Kindred]

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Conversion of starch to ethanol

Low efficiency of conversion suggests:

Variation in fermentation process

- **requirements for yeast growth**
- **CO_2 losses, residual starch… and/or,**

Limited starch availability

- **release of starch from endosperm, vitreosity**
- **viscosity effects, NSP (?)**
- **enzyme inhibitors (?)**

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Samples for high alcohol yield

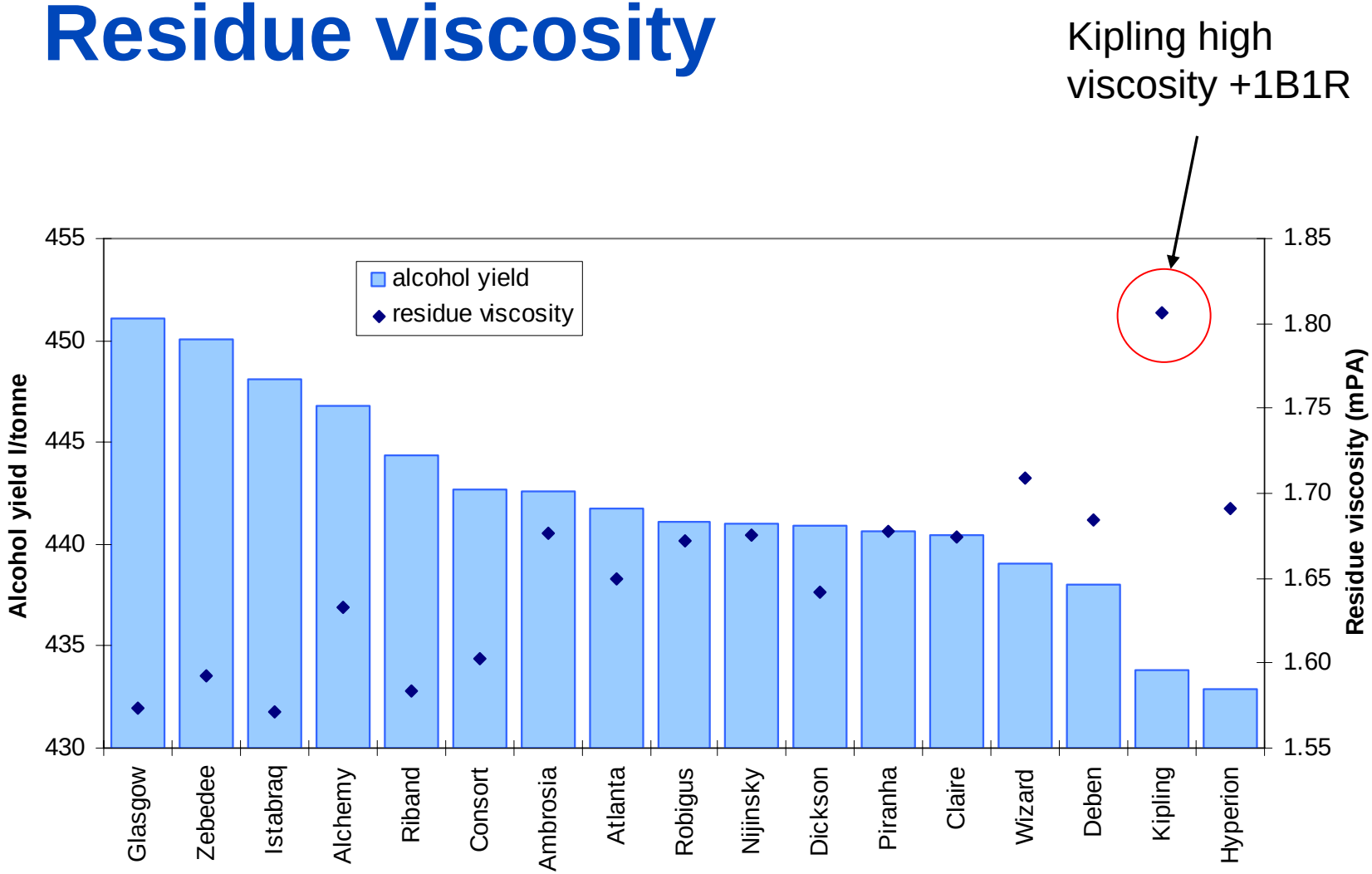
Current selection criteria:

- Low protein grain

- Variety with following characteristics;

- **Soft endosperm**
- **Non 1B1R**
- **High alcohol yield (RL)**
- **High grain yield**

Residue viscosity



[Data: SWRI, 2005; analysis Daniel Kindred]

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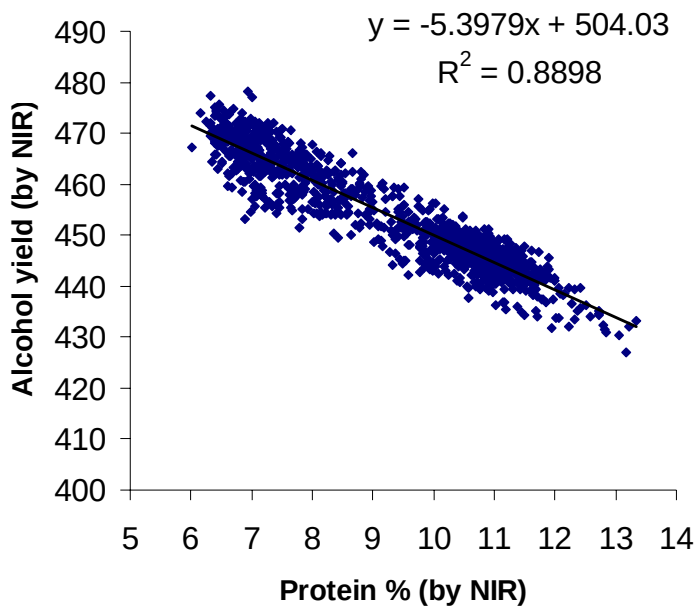
Summary

Grain nitrogen currently gives a better prediction of alcohol yield than starch

- **Problems with starch analysis methods ?**
- **Can we develop an NIR calibration for alcohol yield ?**

Work in progress….



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Summary

Strong effect of N nutrition on alcohol yield

- **Need to reduce N inputs to agriculture while maintaining yields**
- **Implications for agronomy advice**
- **Implications for greenhouse gas emissions**

Strong varietal effect on alcohol yield

- **Both N use/efficiency and ‘starch’ traits**

Conclusions

- **UK wheat shows potential for high alcohol yields (*ca*. 470 l/tonne) – competitive with maize**
  - **but achieving low grain N will be key**
- **Opportunities to reduce N inputs ?**
  - **premia for low-N grain….**
- **Both environment and genetics are important**
  - **Further work required to understand varietal effects…**

GREEN grain Project

Genetic Reduction of Energy use and Emissions of Nitrogen through cereal production

- **Facilitate breeding of wheat varieties that require less N fertiliser and are suitable for distilling, bioethanol and animal feed**

Further information

HGCA Project progress 14

Contacts

- Roger Sylvester-Bradley
- Daniel Kindred
- James Brosnan

Home-Grown Cereals Authority Project Progress 14/Summer 2006

Growing wheat for alcohol/ biofuel production

Producing alcohol from wheat

Wheat is likely to become a major biofuel crop in the UK. Production processes differ between potable and fuel alcohols, but similar principles apply. Usually, cereal grains, such as wheat, are milled and water is added; cooking gelatinises the starch. Enzymes are added to convert the starch to sugar, which is fermented by yeasts. Ethanol is distilled from the fermented mixture. By-products are dried distillers' grains with solubles (DDGS) and carbon dioxide in roughly equal amounts by weight.

- Processors require grain giving high alcohol yields and high processing efficiency. Several characteristics affect these parameters, eg starch content, moisture content and viscosity.
- Low mycotoxin levels are also required because DDGS are usually fed to farm animals.
- Feedstocks for biofuels may have to be produced under an accreditation scheme for associated greenhouse gas (GHG) emissions – see the HGCA **Bioethanol greenhouse gas calculator** (www.hgca.com).

Grain quality for alcohol production is best measured directly in the laboratory. To date, about 400 wheat samples have been analysed by the Scotch Whisky Research Institute (SWRI) using a method mimicking production of potable alcohols. Biofuel processing would be expected to give similar results.

Key messages

If growing wheat for an alcohol market, determine grain specification and crop accreditation requirements.

Research to date suggests that the best strategy will be to:

1. Grow a soft-milling, high yielding variety (see HGCA RL).
2. Select a high yielding situation.
3. Avoid over-application of fertiliser N.
4. Avoid late application of fertiliser N.
5. Manage grain production and drying to avoid mycotoxin development.

Always consider your local conditions and consult a professional agronomist if necessary.

Assessing grain quality

Alcohol processing yields and grain protein were measured on 20 HGCA-funded variety trials from 2003 to 2005. Alcohol yields were related inversely to grain protein content, increasing by about 7 litres/dry tonne for every 1% decrease in grain protein (Figure 1). This is consistent with direct replacement of protein by starch.

Figure 1. Low protein wheats have the highest alcohol processing yields

In the future processors may offer premiums for low protein or high starch. They may analyse grain at point of trade using near infra-red reflectance (NIR). Ongoing work is seeking NIR calibrations for alcohol processing yield.

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Further information

- **Swanston et al. 2005 Determining the spirit yield of wheat varieties and variety mixtures. J Cer Sci, 42, 127-134.**

- **Swanston et al. 2007 Associations between grain characters and alcohol yield among soft wheat varieties. J Sci Fd Ag (in press).**

Thank you

- **Government and industry sponsors**