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Abstract and Summary

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The potential of triticale as a low input cereal for bioethanol production

by

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1 Abstract

The aim of this work was to quantify the performance of modern triticale varieties grown under UK conditions, to assess their value for the bioethanol market, and to evaluate any potential greenhouse gas savings made in comparison with production of winter wheat. Using twenty samples of winter triticale from UK Descriptive List trials harvested in 2007 (representing thirteen different varieties), alcohol yields (AY; L ethanol/t grain) were quantified as well as starch and protein contents, grain size and hardness. AY was determined based on a modified method for assessment of distilling wheats for the Recommended List, and compared to AY of two Istabraq (wheat) samples of similar protein contents. Triticale was shown to be a feedstock with high potential for bioethanol production, with a soft grain, giving alcohol yields comparable with Istabraq at equivalent grain protein contents (average 436 L/t DM at 11.5% grain protein). Some triticale varieties (Fidelio, SW Fargo, Trimester, Ego and Grenado in particular) showed better than expected AY based on their protein contents, thus demonstrating their potential as feedstocks for bioethanol production. The ratio of conversion of starch to alcohol (6.44 L/10 kg starch) was relatively high compared to values seen previously for wheat. Further work is needed to understand variation in starch and fermentable sugars in modern triticale varieties, and in different agronomic situations. Residue viscosity of the triticale samples was higher than that of wheat, but alcohol yields should now be assessed using industrial enzymes representative of those which would be used in a modern bioethanol plant and which would reduce viscosity. In all scenarios studied using the HGCA Biofuels calculator, the net benefits in terms of reducing GHG emissions associated with bioethanol production, were greater for triticale than for wheat, principally due the lower N requirement of triticale. However, there is considerable uncertainty regarding the average grain protein content of triticale when fertilized at the economic optimum. There is also no data on the relative yields of wheat and triticale grown with their respective N optima, in both high and low yield potential situations. The major advantage of triticale may be in 2nd/3rd cereal positions in the rotation when the yield of wheat tends to be reduced by take-all. More work needs to be carried out to compare these two species side by side in replicated trials.

2 Project Summary

2.2 Objectives of the study

The objectives of this study were to quantify the performance and alcohol processing yield of modern triticale varieties; to assess the residue viscosity of triticale fermented at lab scale and compare to that of wheat; and to evaluate the potential greenhouse gas (GHG) savings of UK grown triticale compared to other UK cereal species.

2.2 Background

Biofuels such as bioethanol provide a renewable alternative to fossil fuels and an opportunity to reduce GHG emissions associated with energy use. In Sweden, both wheat and triticale (a hybrid of rye and wheat) are used for bioethanol production. Triticale has a number of potential advantages as a feedstock due to its lower nitrogen (N) requirement during crop growth, its ability to out-yield wheat in some situations, particularly on light soils, and in $2^{nd}/3^{rd}$ cereal positions in the rotation because of its better take-all resistance. However in UK agriculture, triticale has been undervalued in recent years, yet with N input costs rising and an interest in new markets such as biofuels, it is timely to revisit triticale as an alternative low-cost cereal.

Triticale has a soft grain; therefore its texture resembles more the soft wheats currently preferred by the distilling industry, than hard bread making varieties of wheat. The lower N requirement of triticale will be of great benefit if an accreditation scheme for bioethanol production sets tighter targets in the future with respect to the benefits which should be achieved in terms of minimising GHG emissions. The aim of the present study was firstly to quantify the alcohol yields (AY) of triticale compared to a good distilling wheat, and secondly to estimate the potential benefits from using triticale in order to maximise the net benefits from reducing GHG emissions associated with bioethanol production.

2.3 Materials and methods

Twenty samples of triticale representing thirteen different varieties were sourced from Recommended List trials at 2007 harvest (two sites). Grain size, hardness, starch, and protein content and AY were measured. Alcohol yield was also determined for two samples of Istabraq winter wheat taken from a nitrogen response experiment, for comparison. Modelling of the net benefits from reducing GHG emissions associated with bioethanol production from wheat and triticale was carried out using the HGCA Biofuels calculator, by varying grain yields and N inputs for three different scenarios (effects of disease control, low yield potential and place in rotation).

2.4 Results and Discussion

2.4.1 Grain quality of triticale and its potential for bioethanol production

The triticale samples showed wide variation in grain size and protein content between varieties and sites, characters which are known to influence alcohol yield in wheat. As expected the site which produced the highest grain protein contents also had the lowest alcohol yields, and as seen with wheat, hardness increased as grain protein increased. The triticale samples studied gave alcohol yields comparable with Istabraq at equivalent grain protein contents (average 436 L/t DM at 11.5% grain protein). Some triticale varieties (Fidelio, SW Fargo, Trimester, Ego and Grenado in particular) showed better than expected AY based on their protein contents, thus demonstrating their potential as feedstocks for bioethanol production. The ratio of conversion of starch to alcohol (6.44 L/10 kg starch) was relatively high compared to values seen previously for wheat. Further work is needed to understand variation in starch and fermentable sugars in modern triticale varieties, and in different agronomic situations. Residue viscosity of the triticale samples was higher than that of wheat, but alcohol yields should now be assessed using industrial enzymes representative of those which would be used in a modern bioethanol plant and which would reduce viscosity.

2.4.2 Benefits of triticale in reducing GHG emissions associated with biofuel production

The outputs of the Biofuels calculator are reported in terms of a percentage reduction in emissions (of CO_2 equivalents) associated with bioethanol production, relative to petrol on a per GJ basis. The results show that both fungicide treated and untreated triticale show greater benefits in terms of reduced GHG emissions (35.6% & 30.7% respectively) than wheat (25.8 & 10.7% for treated and untreated respectively). The better performance of triticale is due to its lower N inputs. The better performance of the treated crops is due to the higher grain yields when diseases are controlled, which reduce the intensity of GHG emissions per tonne of bioethanol produced.

Considering low yield scenarios on a typical sand land site, the net benefits of growing triticale and wheat for bioethanol were similar (17.8 and 16.4% respectively). Using a slightly higher yield estimate taken from Nix ('low production level' for both species), the triticale shows a better reduction in net GHG emissions (32.8%) compared to wheat (22.8%).

Considering place in the rotation, triticale shows greater benefits in terms of reduced GHG emissions compared to wheat, in both 1st and 2nd cereal positions: A reduction in yield of 1 t/ha for wheat and slightly increased N fertiliser (+20 kgN/ha) applied to a second wheat reduces the net benefits of bioethanol production from 25.8 to 12.5%. In contrast, the benefits from growing triticale only reduce from 36.1 to 32.8%, associated with a loss of yield of 0.4 t/ha in the 2nd cereal position and no change in N inputs. The benefit from wheat would be even smaller if a larger yield loss was assumed e.g. in a high take-all situation.

2.5 Key conclusions

1. Triticale is a feedstock with high potential for bioethanol production, giving alcohol yields per tonne of grain comparable with a good distilling wheat (Istabraq) at equivalent grain protein content.

2. In all scenarios studied using the HGCA Biofuels calculator, the net benefits in terms of reducing GHG emissions associated with bioethanol production were greater for triticale than for wheat, principally due the lower N requirement of triticale.

3. Some triticale varieties showed better than expected alcohol yields (L/t) based on their starch and protein contents and further work is needed to understand variation in starch and fermentable sugars in modern triticale varieties, and in different agronomic situations.

4. The Scotch whisky lab method for spirit yield was used here to ensure comparison with existing RL data for wheat, but alcohol yields should also be assessed using industrial enzymes representative of those which would be used in a modern bioethanol plant, particularly in terms of controlling viscosity.

5. There is considerable uncertainty regarding the average grain protein content of triticale when fertilized at the economic optimum, and further work needs to be carried out in trials where wheat and triticale are grown alongside one another.

6. The major advantage of triticale may be in 2nd/3rd cereal positions in the rotation when the yield of wheat tends to be reduced by take-all and more work needs to be carried out to compare these two species side by side in replicated trials.