Improving Feeding Value Of Deoxynivalenol (DON)-Barley Intended For Swine By The Pearling Procedure – A Review

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Abstract: Grains form the bulk of animal diets resulting in the competition between man and animals for grains. Feed formulators prefer the use of barley to corn and wheat, since they have similar digestible energy values coupled with the cheaper price of barley compare to corn and wheat. However, barley is more susceptible to DON contamination. DON is the major Fusarium mycotoxin-causing major economic losses in the agricultural industry. The presence of DON in cereal grains, such as barley is a major threat to its advantageous use in swine diets. Fusarium graminearum is majorly responsible for DON production. DON menace by F. graminearum is favoured by environmental conditions, such as moisture and high temperature triggering the proliferation of F. graminearum pathogen and DON accumulation in grains. Thus in growing seasons with high regular incidence of rain showers or snow there is the possibility of DON epidemics which may lead to major financial losses to growers and feed formulators as grains may not be suitable for human consumption as well as for animal feeds, especially swine. DON causes emesis, feed refusal and reduced feed intake in pigs. The ultimate goal of growers is how value can be added to their grains while nutritionists to reduce DON from feed grains. Since DON is typically found predominantly near the exterior surface of the kernel where infection begins pearling or polishing off the outer portions dominated by DON would produce a grain that can be incorporated into swine diets without emesis and reduced feed intake thereby culminating in 'acceptable barley' for swine, particularly barrows. This paper delves into the details of the 'modus operandi' of the pearling procedure of converting DON-infected barley to palatable feed ingredient for swine. The pearling procedure comes in handy as currently there are commercial machines that can readily be used to effectively convert DON-barley into a palatable grain for swine, such as the Satake Rice De-huller™.

Key words: DON-Barley, Feeding-Value, Pearling, Procedure and Swine

1 Introduction

It has been acknowledged that despite the best efforts of the agricultural community in combating DON, DON will continue to present wide range menace to the agricultural industry as it relates to foods and feeds. The effectiveness of any procedure to add value to DON-barley largely depends on the distribution of DON throughout the barley kernel as well as the level of contamination [1]. This is an indication that the procedure needed to add value to the DON-barley would require polishing the whole kernel thereby ensuring the brushing off of the hulls containing DON into the polished fractions. The resultant brans from the polished DON-barley tend to now contained higher concentrations of the DON [2]. This therefore, justifies the fundamental principle of the pearling procedure in adding value to DON-barley for use by the animal industry, such as swine. To this point, it had been shown that at low levels of DON contamination ranging between 0.05 to 1.0mg/kg of barley DON is typically found predominantly near the exterior surface of the barley where the infection began [3] – [4]. Nevertheless, it had been speculated that at high levels of DON-barley contamination ranging from 4mg DON and above/kg of barley DON may be more evenly distributed throughout the barley kernel due to its higher amounts and the possibility of its penetration to the interior part of the barley kernel [3]. Later studies [4] demonstrated that DON does not easily penetrate into the inner kernel irrespective of the level of DON-barley rather DON is distributed evenly around the exterior of the barley beginning from the sites of fusarium infection, suggesting that DON concentrations in barley largely depend on the level of fusarium infections within the barley. From this spread pattern of DON, [5] using a small abrasive laboratory machine showed that pearling was effective in removing DON from DON-barley irrespective of the level of DON contamination. This became the window that with availability of commercial machines the menace of DON in barley would become a thing of the past. This paper therefore highlights the techniques of the pearling procedure in order to better manage DON in DON-barley and how the commercial Satake Rice De-huller™ can be used in adding value to DON-barley for swine irrespective of the level of DON contamination.

The Pearling Procedure and Efficacy of DON Removal

The pearling procedure involves bringing the DON-barley into contact with an abrasive rotating disk during which the outer or exterior portions of the DON-barley are polished away. Since DON contamination commences from the exterior section of barley the pearling technique becomes effective in removing DON from the infected barley in a time-dependent fashion depending on the level of DON infection. The findings of [3] also validate this concept and fact. Additionally, in that study, pearling was not only effective in removing DON but was also effective in removing zearalenone (ZEN) and nivalenol (NIV) that are co-produced with DON by fusarium [6] significantly as the barley undergone the pearling process. In the procedure, a reduction of 40 to 100% of DON and ZEN in the barley contaminated with 23ppm/kg of DON and 2ppm/kg of ZEN was achieved with about 19% of the barley mass lost of the pearled or de-hulled barley. Therefore, at low level of DON-barley pearling can remove the entire DON with minimal loss in barley mass. However, at higher DON concentration more pearling time would be required with more losses in barley mass. There are other data in the literature that further substantiated to the efficacy of pearling in adding value to DON-barley. The study [7] that investigated the effect of hull removal and pearling on fusarium species and trichothecenes in hulless barley observed that the greatest numbers of propagules of fusarium species and the highest concentrations of DON and 15-acetyldeoxynivalenol (15ADON) were found in the hulls. The average concentrations of F. graminearum schwabe and DON in barley were reduced: 90 and 49%, respectively as a consequence of laboratory de-hulling; by 95 and 59%, respectively as a result of de-hulling during harvest and 99 and 86%, respectively as a result of pearling. In [3] data, removing of NIV, DON and ZEN by the polishing process was very efficient and effective as polishing of de-husked barley resulted in 48 to 94% reductions in NIV, 82 to 100% in DON and 67 to 100% in ZEN concentrations in pearled barley fractions. For the polishing of unhusked barley, NIV was reduced by 37 to 97%, DON 52 to 100% and ZEN 47 to 100% in pearled barley fractions. These results confirmed that the polishing process brought about significant reductions in the levels of NIV, DON and ZEN in the pearled barley with increasing degree of polishing and was effective in removing DON, ZEN and NIV in naturally contaminated barley. The findings of [3 and 7] were tested in our laboratory using a small scale laboratory de-hulling machine using the pearling procedure and their findings were further confirmed in that study [5]. Accordingly, our results clearly highlighted the fact that pearling was very effective and thus was a reliable procedure of removing DON from DON-barley. In the study, the first 15 seconds (s) pearling duration reduced DON content in the pearled DON-barley by 66% with a minimal loss of 15% of the original grain mass irrespective of the initial level of DON in barley. The results also confirmed that DON concentrations were more on the exterior or outer layers of the DON-barleys than their inner layers. Overall, these findings proved that pearling could serve as a means of 'converting' DON-barley into barley suitable for animals' diets' particularly swine as a result of the anorectic effects of DON [5 and 8]. Additionally, the results of [5] provided clear evidence that pearling could improve the nutritional value of the pearled DON-barley. This was related to the significant reduction in the neutral detergent fibre (NDF) content of the pearled DON-barley leading to the improvement of the calculated digestible energy of the pearled barley. Nevertheless, these results need to be evaluated on a larger scale to better assess the commercial feasibility as to be able to generate sufficient material for in vivo testing in pig studies.

Feeding Value of DON-Barley Subjected to Pearling (Abrasive) Procedure

Pearling involves the sequential removal of the external portions of DON-barley where the concentration of DON is mostly located [5], [7]. In this way, pearling could result in changes to the nutrient profile of the resultant DON-barley after pearling, especially when the extent of hull removal is significant. In a study, [9] with poultry and unrelated to DON pearling had additional benefit by removing some anti-nutritive components associated with barley, such as crude fibre since non-ruminants lack the enzymes that degrade dietary fibre [10]. In the study, a quantitative measure in terms of productive energy content of barley versus pearled barley was given. Based on the results of the study barley had only about 70% the feeding value of corn; pearled barley was reported to have about 82% of the productive energy of corn, respectively (Table 1). Consequently, if one examines the proximate analysis of corn, barley and pearled barley (Table 1) the difference in feeding value of pearled barley compared to corn is ether extract.

Table 1. Proximate analysis of corn, pearled barley and regular barley

Grain Type	Protein (%)	Ether extract (%)	Fibre (%)	Ash (%)	NFE (%)	Moisture (%)	Productive energy (Cal/kg)
Corn	9.9	4.1	2.1	1.4	71.6	10.9	1145
Pearled barley	13.7	1.0	1.0	2.7	72.0	9.6	947
Regular barley	13.1	2.1	6.0	3.1	66.3	9.4	811

Reference: [9]; NFE = Nitrogen free extract

In [9], during pearling approximately 17% weight of the original barley mass was lost. [11] studied the nutritional value of de-hulled corn for pigs and its impact on the gastrointestinal tract and nutrient excretion. The corn grain was processed through a Beal de-huller during which the hulls of the corn grain were removed by an abrading action to leave mainly the intact endosperm grain. This resulted in a lower protein value and gross energy (GE) in the de-hulled corn sample compared to the intact corn. However, the NDF and acid detergent fibre (ADF) contents of the processed corn were significantly lowered by 61 and 32%, respectively compared to the intact corn. It is imperative to note that the hulls of the corn kernel and that in the germ collectively account for the 51 and 16%, respectively of NDF and ADF found in corn. Fibres are anti-nutritional factors in pigs due to pigs' limited ability to digest them. Consequently, in that study, the digestibility of dry matter (DM) and GE in the de-hulled corn was highly more significant than that of the intact corn as: (96% and 96%) for de-hulled corn versus 89 and 87%, for intact corn, respectively, irrespective of the lower protein and GE values of the de-hulled corn. Furthermore, there were reductions of 67% and 29% in DM and protein excretions with the de-hulled corn compared to intact corn. These also resulted in improved ileal digestibility of DM, energy and protein culminating in improved feed efficiency for the de-hulled corn over the intact corn. Based on these findings the authors concluded that processing corn, such as de-hulling to remove the poorly digestible components principally the fibre fractions enhanced nutrient digestibility and thus reduce amount of nutrients released in the pig manure into the environment. As previously stated, barley is primarily used as energy source in swine diets. In [5] the calculated digestible energy (DE) value of pearled barley was higher than that of intact DON-barley based on an established prediction equation for barley DE for swine: DE = 3,526 – 92.8 x %ADF [12] suggesting that pearling apart from DON removal, significantly reduced the anti-nutritional factors in barley, principally NDF and ADF and thus provided a better feeding value for DON-barley. The study of [5] was later confirmed at a larger scale also confirming that pearling can be adopted commercially using the Satake Rice De-huller™. This was actually confirmed in a study using different levels of DON barley contaminations [13]. In the study of [13] DON-barley with a DON concentration of 7.6ppm when de-hulled by way of passing the DON-barley through the Satake™ machine (Satake RMB 10G Rice Polisher) during which it comes into contact with machine abrader 3-time proved to be the most effective and of best nutritional advantage of pearling DON-barley intended for swine feeding. At this level, the removal of about 18% of the DON-barley mass resulted in the removal of about 82% of the DON and about 54% of NDF and 78% of ADF, respectively. It was also the level with minimal loss in grain mass with significantly improved DE values of pearled DON-barley compared with their intact counterparts. It was also the level of pearling that significantly reduced DON content from the 7.6ppm to barley DON content of less than 0.09 ppm with 82% grain mass remaining with improved levels of crude protein (CP) and DE, respectively. In the same study [13] DON-barley of barley concentrations of 1.2 to 5.5ppm were reduced to infinitesimal levels by the 3rd passing or pearling by the Satake™ machine thereby converting again barley not suitable for swine feeding to a palatable barley for swine with about 80% of original grain mass remaining with significantly improved CP and DE. These findings were later confirmed with in vivo studies, involving early weaned piglets [13]. These findings also proved that commercial pearling using the Satake™ abrader machine can be efficiently and effectively used in converting DON-barley to palatable barley for swine; thereby adding feeding-value to DON-barley, particularly those of energy and protein in addition to their improved digestibility for swine.

2 Conclusion

The food and Agricultural Organization (FAO) of the United Nations has estimated that 25% of the world's food crops, including grains are affected by DON. Affected grains, such as barley normally have increased anti-nutritive characteristics as it becomes more fibrous in addition with DON. These ultimately results in poor grain quality and render them unfit for human and animal consumption leading to huge economic losses on all stakeholders. Indirect economic losses may be more difficult to quantify; however it also presents major economic losses. These scenarios bring about some secondary or additional costs to feed and food processing arising from extra handling, distribution, processing requirements and chemical analysis to monitor DON in grains. In extreme cases leads to grain disposal due to high DON contents of the grains. In all these, the livestock and poultry producers are affected with skyrocketing costs of production, especially during years of heavy DON infections. However, the anti-dote to dealing with DON in grains, particularly in barley is by the pearling (abrasive) procedure to reduce DON contents of barley and improve its nutritive value using the Satake Rice Abrader Machine™. This technique is very effective, reliable and more dependable than scouting for 'DON-free' barleys that comes with additional costs. Overall therefore, the implications and the take home messages are that heavily contaminated barley grain up to 7.6ppm if first pearled by way of 3 passes through the commercial cereal grain abrader is usable in swine diets as the commercial pearling using the Satake™ pearling machine is effective in de-hulling DON-barley to remove DON, thereby making such barley suitable for swine. Furthermore, the pearling technique results in the improvements of the feeding value of the pearled DON-barley as a result of DON removal, NDF and ADF, respectively.

3 References

[1] L. L. Charmley and D. B. Prelusky. 1994. In: Mycotoxins in Grain. Compounds other than Aflatoxin, Miller J. D. and Trenholm, H. L. (Eds.) Eagan Press, St. Paul, MN, USA, pp. 421-435

[2] A. Visconti and A. De Girolamo. 2002. Fusarium mycotoxins in cereals: storage, processing and decontamination. In: Food Safety of cereals: a chain-wide approach to reduce Fusarium mycotoxins, Scholten, European Commission.

[3] U. S. Lee, M. Y. Lee, W. Y. Park and Y. Ueno. 1992. Decontamination of Fusarium mycotoxins, nivalenol, deoxynivalenol and zearalenone in barley by the polishing process. Mycotoxin Res. 8:31-36.

[4] H. L. Trenholm, L. L. Charmley, D. B. Prelusky and R. M. Warner. 1991. Two physical methods for the decontamination of four cereals contaminated with deoxynivalenol and zearalenone. J. Agric. Food Chem. 39:356-360.

[5] J. D. House, C. M. Nyachoti and D. Abramson. 2003. Deoxynivalenol removal from barley intended as swine feed through the use of an abrasive pearling procedure. J. Agric. Food Chem. 51:5172-5175.

[6] J. W. ApSimon. 1994. In: Mycotoxins in Grains. Compounds other than aflatoxin. Miller, J. D. and Trenholm, H. L. (Eds.) Eagan Press, St. Paul, MN, USA, pp. 3-18.

[7] R. M. Clear, S. K. Patrick, T. Nowicki, D. Gaba, M. Edney and J. C. Babb. 1997. The effect of hull removal and pearling on Fusarium species and trichothecenes in hulless barley. Can. J. Plant Sci. 77:161-166.

[8] T. K. Smith, E. G. McMillan and J. B. Castillo. 1997. Effect of feeding blends of Fusarium mycotoxin-contaminated grains containing deoxynivalenol and fusaric acid on growth and feed consumption of immature swine. J. Anim. Sci. 75:2184-2191.

[9] G. S. Fraps. 1946. Composition and productive energy of poultry feeds and rations. Texas Agric. Exp. Station Bull. No. 678.

[10] NRC, (2012). Nutrient Requirements of Swine (11th Ed.) Natl. Acad. Press, Washington DC.

[11] A. J. Moeser, I. B. Kim, E. van Heugten and T. A. Kempen. 2002. The nutritional value of degermed and dehulled corn for pigs and its impact on the gastrointestinal tract and nutrient excretion. J. Anim. Sci. 80:2629-2638.

[12] S. L. Fairbairn, J. F. Patience, H. I. Classen and R. T. Zijlstra. 1999. The energy content of barley fed to growing pigs: Characterizing the nature of its variability and developing prediction equations for its estimation. J. Anim. Sci. 77:1502-1512.

[13] N. C. Johnson, J. D. House and C. M. Nyachoti. 2005. The nutritive value of pearled deoxynivalenol-contaminated barley (Hordeum vulgare L.) for swine. M. Sc. Thesis, Department of Animal Science, University of Manitoba, Winnipeg, Canada.