

A HACCP Plan Along The Wheat Chain To Prevent Deoxynivalenol (DON) In Wheat Flour In Uruguay

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J. Cea¹, S. Stewart², G. Gutiérrez³

- ¹ Química Farmacéutica. Dpto de Toxinas Naturales, Laboratorio Tecnológico del Uruguay. Av. Italia 6201, Montevideo, Uruguay.
- ² Lic. Biología. Sección Protección Vegetal, INIA, La Estanzuela. Ruta 50 km 11, Colonia, Uruguay.
- ³ Ing. Agrónomo. Cátedra de Ciencias Sociales, Fac. de Agronomía. Av. Garzón 780. Montevideo, Uruguay

Introduction

Fusarium head blight (FHB) has become the most significant disease of wheat in Uruguay in the last decade, not only due to yield losses (up to 47%) but due to hazards imposed to human health by its mycotoxins (Díaz de Ackermann, M. 2003). There were two mayor outbreaks of FHB during two consecutive years, 2001 and 2002, mainly due to above normal precipitations by late September and October. The main *Fusarium* specie found in wheat in the country is *F.graminearum* which is a mayor DON producer. In response to these severe outbreaks, the government set a decree establishing 1 ppm of DON maximum level for commercializing wheat flour and wheat products and by-products.

Hazard Analysis of the Critical Control Point (HACCP) is the food management system that identifies, assesses hazards and tries to control them. This system tries to assure food safety by identifying those factors which are compromising the quality of the product introducing appropriated interventions, instead of relying on end-product testing. Furthermore, nowadays HACCP is the agreed international standard regarding food safety, thus, necessary for exporting foods to many countries. The plan has well-established methods (FAO, 2001) that were put in place to control DON mycotoxin in wheat chain, from the field to the mill.

The plan tries to avoid mycotoxin occurrence in the food chain, using strategies to keep mycotoxin contaminated commodities from entering into the food facilities. Good Agricultural Practices (GAP) and Good Storage Practices (GSP) for the wheat crop, and Good Manufacturing Practices (GMP) at the mill should be considered as pre-requisites for any HACCP plan.

Table 1. Commodity flow chain, hazard analysis for *Fusarium*/DON, possible control measures and type of control.

CFC step	Hazard	Possible Control Measure(s)	Type of control**
1. Seed selection	Fungus (<i>Fusarium</i>) infecting the seed	Select varieties that are not highly susceptible to FHB and purchase healthy seeds or use seed dressings	GAP
2. Soil preparation	Fungus (<i>Fusarium</i>) in stubble on the surface	Plough, bury stubble, any practice that accelerates decomposition, exceptionally burn.	GAP
3. Sowing practice	Fungus (<i>Fusarium</i>) in stubble if zero tillage Concentration of flowering date	If using zero tillage, choose fields that had non-susceptible host (avoid wheat/barley and corn stubbles). Spread out sowing date for the same variety or use varieties with different cycle, so as to not concentrate flowering periods in the field and escape favorable conditions for the disease	GAP
4. Husbandry and disease control	-	Doesn't alter FHB infection	GAP
5. Fungicide application	<i>Fusarium</i> infection if climate is conducive	Apply recommended fungicides at the beginning of flowering based on climate prognostics or DONcast model. The latter model was brought to Uruguay under the FAO project (3), it indicates hazards for DON, and thus FHB, based on climatic data. It is actually being adjusted and validated and it is placed at INIA web site to check for daily hazards (5).	GAP
6. Harvest	<i>Fusarium</i> and mycotoxin contaminated grains	Harvest at approximately 14% humidity content. If infection present: than "open wind" and regulate sieves on combine harvester so as to eliminate the most infected grain	GSP
7. On farm storage	<i>Fusarium</i> and mycotoxin contamination pos-harvest	Harvest dry grain and monitor humidity on storage. Not very common	GSP
8. Transport	<i>Fusarium</i> and mycotoxin contamination pos-harvest	Use clean trucks. Avoid humid grain if transport is far, cover truck to avoid rain	GSP
9. Reception at traders	Fungus and mycotoxins contamination	Segregation is usually done only by commercial classification grades 1, 2 and 3, try segregating within this classification by modified %FDK * truck by truck. Training staff is necessary. Differentiate payment by quality	CCP1
10. Drying	Fungus and mycotoxins contamination	Drying wheat is not commonly required. Certain traders have this option, if needed, usually using wood burning dryers	GMP
11. Pre-cleaning	Fungus and mycotoxins contamination	If modified %FDK is high, pay less and pre-clean wheat using a gravity table	GMP
12. Storage at traders	Fungus and mycotoxins	Segregate based on modified %FDK, trassle (empty a silo, pass the content of a silo to another silo) to maintain temperature and humidity content.	GSP
13. Transport	<i>Fusarium</i> and mycotoxin	Use clean trucks. Avoid humid grain if transport is far, cover truck to avoid rain	GSP
14. Mill reception	Fungus and mycotoxins	Analyze <i>Fusarium</i> affected grain by modified % FDK in truck by truck samples. Segregate in high/medium/low categories. If modified %FDK is high then we should pay less and pre-clean wheat using a gravity table	CCP2
15. Silos and Storage	Fungus and mycotoxins	Segregate based on modified %FDK, trassle (empty a silo, pass the content of a silo to another silo) to maintain temperature and humidity content.	GSP
16. Cleaning	Fungus and mycotoxins	Clean using sieves and wind to minimize <i>Fusarium</i> contaminated grain and mycotoxin levels	GMP
17. Conditioning	Fungus and mycotoxin	Control temperature	GMP
18. Mixture of silos	Fungus and mycotoxins	Analyze DON when trassle to know DON content of each silo and use mixture of silos for desired mycotoxin level	CCP3
19. Milling process	Mycotoxin	Extraction of part of toxin in seed covers	GMP
20. Flour storage	Mycotoxin	Control temperature	GMP
21. Flour mixing	Mycotoxin	Mix flour silo by weight to yield a flour with < 1 DON ppm	CCP4
22. Additives	Mycotoxin	Doesn't alter the toxins level	GMP
23. Packing	Mycotoxin	Avoid humidity and dirt	GMP
24. Flour storage	Mycotoxin	Store in a dry and clean place	GMP
25. Transport	Mycotoxin	Avoid humidity and dirt, use clean trucks specially for bulk transport	GMP

* modified % FDK is a method where you separate de FDK by color (pink and white), weight the two categories separately and use a multivariable formula that predicts DON content (4)
 ** GAP: Good Agricultural Practices, GMP: Good Manufacturing Practices, GSP: Good Storage Practices, CCP: Critical control points

In particular, preventive measures as GAP are essential, due to the fact that *Fusarium* is a field fungi that grows in the field, it develops during the flowering season when environmental conditions are appropriated. In addition, DON is a secondary metabolite of the fungus that is produced when the fungus is in active growth, so it also develops in the field. Risks for DON contamination in wheat go all the way back to the field, prior to and at harvest and before entering the mill.

Results

A commodity flow chain (CFC) was elaborated using the information provided by agronomist, farmers, traders, research institutes, private companies and a "case study mill". It was verified through "in situ" visits, and includes 25 steps that start with the selection of the wheat variety to be sown in the field and ends up with the flour in packs at the mill (Table 1).

A hazard analysis was elaborated, possible control measures such as GAP, GMP and GSP were addressed and critical control points (CCPs) were identified (Table 1).

A CCP is defined as a step at which control can be applied and is essential to prevent or eliminate a food safety hazard or reduce it to an acceptable level.

Table 2. Critical Control Points: Critical limits, monitoring and corrective actions

CFC Step	Possible Control Measure(s)	Critical Limits*	Monitoring Procedure	Corrective Actions
9. Reception at Trader or CCP1	Segregate by <i>Fusarium</i> contamination, number of segregation groups will depend on number of available silos: group into High, Medium and Low silos or High and Low If modified % FDK is high then proceed to pre-cleaning at gravity table	Introduce white and pink grain weight into the formula. Accept everything that is ≤ 4 ppm 4-High-2 2-Medium-1 1-Low-0 or 4-High-1,5 1,5-Low-0 If > 4 ppm then send directly to gravity table and pay less to farmer	When silo is filled, trassle (empty the silo to another silo) and sample to do a compound DON analysis	Mix grain from different silos in order to have a wheat ≤ 2 ppm DON
14. Mill reception or CCP2	Segregate by <i>Fusarium</i> contamination: group into High, Medium and Low silos If modified % FDK is high then proceed to pre-cleaning at gravity table	Introduce white and pink grain weight into the formula. Accept everything that is ≤ 4 ppm 4-High-2 2-Medium-1 1-Low-0 If > 4 ppm then send directly to gravity table and pay less to farmer	When silo is filled, trassle and sample to do a compound DON analysis	Mix grain from different silos in order to mill wheat that is ≤ 2 ppm DON
18. Mixing Silos or CCP3	Mixture or proportions of different silos	Mix different proportions of silos using compound DON analysis of the silo: example 50% of High and 50% of Low	Do a compound analysis of DON of the outgoing flour of the batch	Mix flour from different flour silos
21. Flour mixing or CCP4	Mixture or proportions of different flour silos	If flour ≤ 1 ppm then pack If flour > 1 ppm then mix with flour < 1 ppm	Monitor to check if correct flour weight from each silo is being included	Re-mix if incorrect weight is being used

* They are theoretical, they need further validation

Four CCPs were identified in the wheat chain; CCP1 at the traders reception, CCP2 at the mills reception, CCP3 at mixing wheat silos and CCP4 at mixing flour silos. Table 2, shows the CCPs with their possible control measures, the critical limit and the corrective actions proposed to have DON levels lower than 1 ppm in flour which is the law enforced tolerance level in the country.

Conclusions

The CCPs suggested and their critical limits should be validated in a FHB year, unfortunately no FHB favorable year was present during the duration of the project. On a FHB year, all the CCP suggested would be needed to have everything under control. On the contrary, in a year without FHB problems CCP3 and CCP4 could be avoided. If incoming wheat has low % of FDK and compound silo samples of wheat at trassle are low (below 1 ppm) there would be no need for further controls at CCP3 and CCP4. What should not be avoided is verification in flour at regular intervals.

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