Washing Procedures Using Water or Sodium Carbonate Solutions for the Decontamination of Three Cereals Contaminated with Deoxynivalenol and Zearalenone†

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Washing techniques for decontaminating deoxynivalenol (DON)- and zearalenone (ZEN)-contaminated grains were developed. Washing barley and corn three times in distilled water reduced DON concentrations by 65–69% and ZEN by 2–61%. Using 1 M sodium carbonate solution for the first wash reduced DON by 72–74% and ZEN by 80–87%. Stirring barley gently in a 1 M sodium carbonate solution for 4 h caused an increase in the toxin concentration of the solution, to 33 and 95% of the DON and ZEN, respectively, originally in the barley. Stirring barley vigorously for 2 h in a 1 M sodium carbonate solution and then in distilled water caused a 67–89% reduction in toxin concentration. Stirring gently for 4 h in each solution caused an 80–95% reduction. Soaking barley, corn, and wheat in a 0.1 M sodium carbonate solution for 24 or 72 h caused a 42–100% reduction in toxin concentration.

INTRODUCTION

Deoxynivalenol (DON, vomitoxin, 3α,7α,15-trihydroxy-12,13-epoxytrichothec-9-en-8-one) and zearalenone (ZEN, (*S*)-2,4-dihydroxy-6-(10′-hydroxy-6′-oxo-*trans*-1-undecenyl)benzoic acid μ-lactone) are naturally occurring secondary metabolites produced by certain species of *Fusarium* fungi on a variety of cereal grains and typically occur together.

Prevention of mycotoxin contamination, although desirable, is not possible at present. Under certain environmental conditions (with regard to temperature and humidity) *Fusarium* infestation and mycotoxin contamination of grain is inevitable.

Feed contaminated with DON and ZEN has been associated with poor growth, reproductive problems, or illness in farm animals (Trenholm et al., 1988; Cote et al., 1984). Reducing mycotoxin concentrations in grain is of major concern to agricultural and food industries.

To be commercially feasible a decontamination procedure needs to be effective against a number of toxins, work without creating new toxic compounds or altering the nutritional or palatability properties of the feed, and should be simple, inexpensive, and use existing technology (Young, 1985).

Many physical and chemical procedures for decontaminating *Fusarium* mycotoxin-contaminated grain have been attempted with varying degrees of success. Physical methods have included sieving and dehulling (Trenholm et al., 1991), density segregation of contaminated from noncontaminated kernels in water and saturated sodium chloride solution (Babadoost et al., 1987) or water and 30% sucrose solution (Huff and Hagler, 1985), and food processing practices such as milling (Lee et al., 1987; Sietz et al., 1986, 1985; Scott et al., 1984; Young et al., 1984), cleaning or washing (Sietz et al., 1985, 1986; Scott et al., 1983), and baking (Abbas et al., 1988; Sietz et al., 1986; Tanaka et al., 1986; Young et al., 1984; El-Banna et al., 1983).

Chemicals tested for decontamination of DON-contaminated grain include ozone (Young, 1986a; Young et al., 1986), chlorine, ammonium carbonate (Young, 1986a), ammonia (Young, 1986a; Bennett et al., 1980), sulfur dioxide, ammonium hydroxide, hydrogen peroxide, ascorbic acid, sodium hypochloride (Young et al., 1986), sodium bisulfite (Young et al., 1986, 1987; Young, 1986a; Swanson et al., 1984), and calcium hydroxide (Abbas et al., 1988). Chemicals tested for the decontamination of ZEN-contaminated grain include propionic, acetic, and hydrochloric acid, sodium bicarbonate, formaldehyde (liquid or vapor), ammonium hydroxide, hydrogen peroxide (Bennett et al., 1980), calcium hydroxide (Abbas et al., 1988), and calcium hydroxymonomethylamine (Bauer et al., 1987). Few workers (Abbas et al., 1988) have tested the effectiveness of a single-chemical treatment for the decontamination of DON- and ZEN-contaminated grain.

Some chemical treatments are effective at reducing the DON (sodium bisulfite, chlorine gas, moist ozone, and ammonia) or ZEN (calcium hydroxide and formaldehyde) concentration in contaminated grain. However, in most cases the conditions required for effective decontamination have been too severe or the reaction product too unstable for these treatments to have useful commercial applications. Other chemical treatments have only minor effects or are ineffective in reducing either the DON or ZEN concentrations in grain.

The present study was undertaken to test the effectiveness of several simple washing procedures, using distilled water and sodium carbonate solutions, for reducing the mycotoxin concentrations in barley, corn, and wheat moderately to heavily contaminated with DON and ZEN.

MATERIALS AND METHODS

Stirring. Grain was suspended in the washing liquid and stirred using a 1/4-in. light production drill (Wolfe Electric Tools Ltd., London, U.K.) equipped with a stainless steel propeller containing three 2-cm blades. A variable autotransformer (Type 2PF-1010, 120 V, 10 A, Staco Inc., Dayton, OH) was used to control the speed of the blades. Speeds used were gentle, approximately 980 revolutions per minute (rpm), or vigorous, approximately 1540 rpm.

Drying and Grinding. Prior to analysis, washed grains were dried overnight (16 h) in a convection oven at 45–50 °C (Precision

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Thelco, Model 28), and then ground to a fine powder in a Retsch grinder (Sybron/Brinkman, Westbury, NY) containing a 0.5-mm mesh screen.

Washing Procedure for Naturally Contaminated Corn or Barley: (*a*) *In Distilled Water.* Kernels of barley (64.7 g, from Nova Scotia) or corn (99.8 g, from southwestern Ontario) were suspended in distilled water at 22 °C. The ratio of grain sample weight to water volume was approximately 1:5. The mixture was stirred gently for 30 min. Twenty milliliters of the liquid was removed for mycotoxin analysis and the remaining mixture sieved through a screen, with a mesh size of 2.0 mm, to separate the grain from the liquid. The sieved grain was rinsed with distilled water (approximately 300 mL), and the excess water was discarded. The entire procedure was repeated twice using the washed, sieved kernels (three washes in total). The washed, sieved kernels were dried and ground. Samples of the starting material, the dried, ground kernel material, and the three liquid samples were analyzed for their DON and ZEN concentrations.

(*b*) *In 1 M Sodium Carbonate Solution and Distilled Water.* The procedure was the same as that described above for washing with distilled water, except that a solution of sodium carbonate (1 M) was used for the first wash instead of distilled water.

Determining the Rate of Extraction of DON and ZEN into 1 M Sodium Carbonate Solution. Barley kernels (100 g) were suspended in 1 M sodium carbonate solution at 22 °C and stirred gently for 4 h. The ratio of sample weight to solution volume was approximately 1:10. One- and five-milliliter samples of the solution were taken for DON and ZEN analysis, respectively, 10, 20, 30, 60, 120, 180, and 240 min after stirring began. To compensate for volume changes, due to removal of samples, a 6-mL aliquot of 1 M sodium carbonate solution was added to the suspension after removal of each sample. The samples were adjusted to neutral pH with 5.2 M phosphoric acid and analyzed immediately for DON and ZEN to avoid problems of toxin decomposition in the carbonate solution.

Washing Contaminated Barley Using 1 M Sodium Carbonate Solution Followed by Distilled Water with Gentle or Vigorous Stirring. Barley kernels (100 g) were suspended in a solution of sodium carbonate (1 M) at 22 °C. The ratio of sample weight to solution volume was approximately 1:10. The mixture was stirred gently for 4 h and then sieved through a screen with pores of 2-mm diameter. The barley material, retained on the screen, was washed with distilled water and the sieved liquid discarded. The sieved, washed barley kernels were resuspended in distilled water, stirred gently for 4 h, sieved, and washed. A similar procedure was carried out on a second sample of barley (100 g), except that the grain/sodium carbonate and grain/distilled water mixtures were stirred vigorously for 2 h each time. The sieved, washed kernels were dried and ground before being analyzed for their DON and ZEN concentrations.

Extraction of DON and ZEN from Contaminated Barley, Corn, and Wheat Using 0.1 M Sodium Carbonate Solution by Soaking (No Mechanical Stirring). Samples of barley, corn, and wheat (100 g each) were suspended in 0.1 M sodium carbonate solutions. The ratio of sample weight to solution volume was approximately 1:10. The mixtures were left without agitation for 24 h, then mixed for 1 min, and sieved through a screen of 2.0-mm mesh to separate kernels from the liquid. The kernels were rinsed with distilled water. Half of the kernels (50 g) were dried at 50 °C for 24 h. The remaining kernels were resuspended in fresh 0.1 M sodium carbonate solution, ratio of grain sample weight to solution volume being approximately 1:10, and left without agitation for a further 48 h (total soaking time, 72 h). The sample was mixed, sieved, washed, and dried as described above for the 24-h sample. The dried kernels were ground before being analyzed for their DON and ZEN concentrations.

Analysis. High-pressure liquid chromatography was performed on equipment obtained from Spectra-Physics (Spectra-Physics, San Jose, CA): Model SP-8810 isocratic pump, SP-4290 integrator, SP-8780 autosampler; Kratos Spectroflow 773 variable-wavelength detector (Kratos Analytical Inc., Ramsey, NJ) set at 220 nm for DON analysis, Kratos Spectroflow 980 programmable fluorescence detector (236-nm excitation wavelength, 418-nm cutoff emission filter) for ZEN analysis.

LC columns were stainless steel , 250 × 4.6-mm i.d., packed with reverse-phase RP-18, 5 μm OD-5A Spheri-5 (Brownlee Labs, Santa Clara, CA). A guard column (Waters Scientific Ltd., Mississauga, ON), filled with Spherisorb S10-ODS1, 10 μm (Phase Separations, Norwalk, CT), was inserted between injector and LC columns. All analyses were done in duplicate and compared by the method of external standards using three different concentrations of freshly prepared DON and ZEN standards.

DON concentrations in grain were determined by the method of Trenholm et al. (1985). To analyze carbonate solutions for DON, 1-mL aliquots were adjusted to pH 6.8 with phosphoric acid (5 M) using phenol red (3 drops) as the pH indicator. The solutions were diluted with 5.25 mL of acetonitrile (Caledon Labs Ltd., Georgetown, ON; HPLC grade) and then allowed to drain through an alumina charcoal column. The column was washed with 9 mL of 21:4 acetonitrile–water and the residue (sample plus washings) evaporated to dryness at 45 °C in 1 atm of nitrogen. Dried sample residue was stored at −20 °C until required for HPLC analysis. Prior to analysis the dried residue was dissolved in the mobile phase, consisting of 10% methanol in water. The samples of distilled water were prepared similarly for DON analysis except that adjustment of the pH to 6.8 was not necessary.

ZEN concentrations in grain were determined by the method of Trenholm et al. (1991). To analyze carbonate solutions for ZEN, 5-mL aliquots were adjusted to pH 6.8 with phosphoric acid (5 M) using phenol red (3 drops) as the pH indicator. One milliliter of phosphate buffer (pH 7.8) was added, and the solution was mixed and then evaporated to a volume of 1 mL in 1 atm of nitrogen. The solution was extracted with 8.0 mL of ice-cold 10% 2-propanol in ether. Two milliliters of chilled sodium hydroxide (0.2 M) was added, the solution was mixed and centrifuged, and the upper ether layer was discarded. The pH of the remaining aqueous layer was adjusted to 6.8 with acetic acid (0.5 M), again using phenol red as the pH indicator. The solution was extracted twice using 3 mL of 10% 2-propanol in ether and then evaporated to dryness in 1 atm of nitrogen. The dried sample residue was stored at −20 °C until required for analysis by HPLC. Prior to analysis the dried sample residue was dissolved in the mobile phase consisting of water–methanol–acetonitrile (5:4:2).

All results were expressed as milligrams of DON or ZEN per kilogram of kernel dry matter (DM).

Safety Procedures. Strict safety procedures were undertaken during the handling of mycotoxin-contaminated materials. Gloves and protective clothing were worn in the laboratory to prevent skin and clothing contact with contaminated materials. Dust masks and safety goggles were worn during the grinding of such material. Hands were washed thoroughly with soap and water after procedures. Laboratory surfaces and equipment were cleaned thoroughly after use, and contaminated material was carefully disposed of. No food or drink was allowed in working areas.

RESULTS AND DISCUSSION

Washing barley (98.4% dry matter (DM), contaminated with 16.1 mg of DON and 0.89 mg of ZEN per kg of DM) three times, with distilled water, resulted in a 69.3% reduction in DON and a 2.3% reduction in ZEN concentration (Table I). Similarly, with corn (92.5% DM, contaminated with 23.9 mg of DON and 1.58 mg of ZEN per kg of DM) washing with distilled water resulted in a 65.3% reduction in DON and a 61.4% reduction in ZEN concentration (Table I).

During the corn washing procedure a black material was removed from the exterior of many of the infected kernels which, because of its small amount, could not be analyzed for DON and ZEN. Previous workers have found that in wheat, during cases of moderate *Fusarium* infestation, the degree of DON and ZEN contamination is usually greater at the exterior of the kernel (Lee et al., 1987; Tanaka et al., 1986; Sietz et al., 1985, 1986). The separation of the black material from the exterior of the

Table I. Deoxynivalenol (DON) and Zearalenone (ZEN) Concentrations in Barley and Corn before and after Three 30-min Washings in Distilled Water (at 22 °C), the Percentage Reduction in DON and ZEN Concentrations in the Grain after Washing, and the Resulting DON and ZEN Concentrations in the Distilled Water

	barley				corn			
	mycotoxin concn,[a] mg/kg		reduction, %		mycotoxin concn,[a] mg/kg		reduction, %	
	DON	ZEN	DON	ZEN	DON	ZEN	DON	ZEN
unwashed kernel	16.10	0.89			23.90	1.58		
washed kernel	4.94	0.87	69.30	2.25	8.30	0.61	65.30	61.40
distilled water								
1st washing	6.68	0.00			7.02	0.14		
2nd washing	3.47	0.03			3.34	0.09		
3rd washing	0.82	0.03			1.98	0.00		

[a] Results are expressed as milligrams of toxin per kilogram of kernel dry matter (DM); DM for barley was 98.4% and for corn was 92.5%.

Table II. Deoxynivalenol (DON) and Zearalenone (ZEN) Concentrations and Percentage Reductions in Barley and Corn after One 30-min Washing in Sodium Carbonate Solution (1 M) and Two 30-min Washings in Distilled Water (at 22 °C)

	barley				corn			
	mycotoxin concn,[a] mg/kg		reduction, %		mycotoxin concn,[a] mg/kg		reduction, %	
	DON	ZEN	DON	ZEN	DON	ZEN	DON	ZEN
unwashed kernel	16.10	0.89			23.90	1.58		
washed kernel[b] (sodium carbonate + water)	4.13	0.17	74.30	80.90	6.61	0.20	72.30	87.30
washing solutions								
1 M sodium carbonate	3.30	0.00			5.60	0.12		
1st distilled water	2.40	0.15			2.20	0.19		
2nd distilled water	1.50	0.00			2.60	0.07		

[a] Results are expressed as milligram of toxin per kilogram of kernel dry matter (DM); DM for barley was 98.4% and for corn was 92.5%. [b] Kernel was washed once in sodium carbonate solution, followed by twice in distilled water, for 30 min each time.

corn kernels during washing may have contributed to the overall reduction of DON and ZEN concentration observed. Moreover, this may have been responsible for the greater reduction in ZEN concentration in corn compared to that in barley. The reduction in concentration of DON in washed barley and DON and ZEN in washed corn were accompanied by increases in DON or DON and ZEN in the water. However, relative to the mycotoxin concentration in the unwashed grain, the DON found in the wash water from the corn (51.7%) and barley (68.1%) was greater than the ZEN found in the wash water from the corn (14.6%) even though the percentage reduction in toxin in the grain was similar. This again suggests that some of the ZEN, removed from the corn during the washing procedure, was associated with the black material that was removed from the kernels.

Other workers have tested the effectiveness of cleaning methods for the removal of DON from wheat contaminated with 0.64–5.10 mg/kg (Sietz et al., 1986). Commercial cleaning, by removing the screenings in a cleaning house followed by washing with water (in a Smico wheat washer), resulted in only approximately half the reduction in DON concentration obtained in the present experiment (an average of 34% for five samples).

Chemically, ZEN is a weak phenolic acid whose solubility is greatly enhanced in alkaline conditions. When 1 M sodium carbonate (pH 11.6) was substituted for water in the first washing, the reduction in toxin concentration in the washed barley was increased from 2.2 to 80.9% (Table II). The reductions in DON concentration in barley and DON and ZEN concentrations in corn were increased to 74.3, 72.3, and 87.3%, respectively (Table II). The increase in the removal of DON from corn and barley when sodium carbonate was used instead of water for the first washing may be related to the finding that DON is unstable in sodium carbonate solution (unpublished observations). Sodium carbonate solution (1 M) increased the removal of DON and ZEN from barley by 5.0 and 78.6%, respectively, and of DON and ZEN from corn by 7.0 and 25.9%, respectively, above that observed with water alone.

The effectiveness of alkaline solutions to remove DON or ZEN from contaminated grain has been tested previously with varying success. Bennett et al. (1980) reported that sodium bicarbonate had no effect on the ZEN concentration of naturally or artificially contaminated corn and corn-based feed products. Similarly, ammonium carbonate (Young, 1986a) and ammonium hydroxide (Young et al., 1986) had little effect on the DON concentration of corn. However, treating DON- and ZEN-contaminated corn with calcium hydroxide, followed by baking tortilla dough made from this corn, resulted in a substantial reduction in both DON (72–82%) and ZEN (59–74%) concentrations (Abbas et al., 1988). Heat alone can reduce the level of DON in contaminated corn (Young, 1986a), so it is not clear exactly what contribution the calcium hydroxide made to the overall reduction in DON and ZEN in the baked tortilla dough.

When barley, contaminated with 15.7 mg of DON and 0.97 mg of ZEN per kg of DM, was stirred gently in a solution of sodium carbonate (1 M), the mycotoxin concentration in the carbonate solution increased gradually over a 4-h period (Figure 1). Approximately 33% of the DON and 95% of the ZEN present originally in the barley was extracted into the sodium carbonate solution. With DON, the proportion found in solution and remaining in the barley did not comprise 100% of the toxin initially present in the grain (Trenholm, CFAR, Ottawa, ON, 1991, unpublished observations). In addition, DON subsequently has been found to be unstable under alkaline conditions, the extent of decomposition depending on the pH and the temperature (Trenholm, CFAR, Ottawa, ON, 1991, unpublished observations). Therefore, it appears that sodium carbonate solution acts by leaching DON and ZEN from the grain as well as by causing some decomposition of DON. This contrasts with the mechanism by which sodium bisulfite decontaminates DON-contaminated grain. Sodium bisulfite reduces the DON concentration in corn (Young et al., 1986, 1987; Young, 1986a) as well as its toxic effects on pigs (Young et al., 1987) by converting DON to a less toxic DON-sulfonate (DON-S)

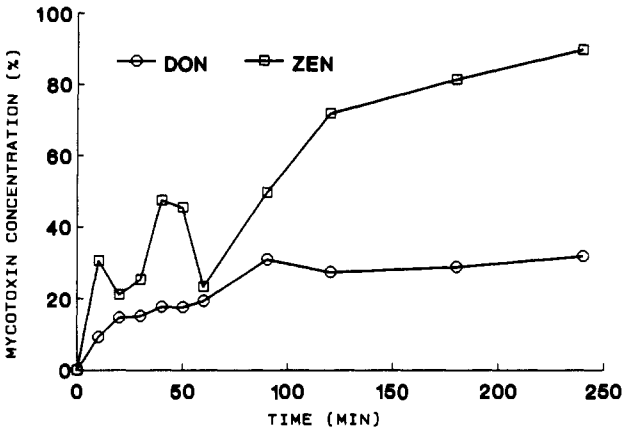

Figure 1. Deoxynivalenol (DON) and zearalenone (ZEN) concentrations (expressed as a percentage of their respective initial concentrations in barley) in 1 M sodium carbonate solution at various times after stirring barley, contaminated with 15.9 and 0.77 mg of DON and ZEN, respectively, per kg DM, gently in this solution.

Table III. Deoxynivalenol (DON) and Zearalenone (ZEN) Concentrations in Barley before and after Stirring in 1 M Sodium Carbonate Solution (at 22 °C) Followed by Distilled Water (at 22 °C) Gently for 4 h in Each Solution (A) or Vigorously for 2 h in Each Solution (B) and the Percentage Reduction in Toxin Concentration

	rate of stirring[a]	stirring time,[b] h	mycotoxin concn,[c] mg/kg DON	mycotoxin concn,[c] mg/kg ZEN	reduction, % DON	reduction, % ZEN
unwashed kernel			15.70	0.97		
washed kernel						
A	gentle	4	3.06	0.05	80.50	94.80
B	vigorous	2	1.79	0.32	88.60	67.00

[a] Gentle stirring was at approximately 980 revolutions per minute (rpm); vigorous stirring was at approximately 1540 rpm. [b] This was the stirring time in each solution, sodium carbonate (1 M) followed by distilled water. [c] Results are expressed as mg/kg kernel dry matter (DM); DM of barley was 98.4%.

compound in the grain. DON-S is unstable under alkaline conditions (Young, 1986b) and during heating (Young et al., 1986) and is reconverted to DON during certain processing steps. This problem would not occur during the processing of grain decontaminated with sodium carbonate because the process removes the DON rather than simply converting it to a less toxic analogue.

Both the rate of stirring and contact time were found to influence the degree of DON and ZEN removal from barley (Table III). When the kernels were stirred vigorously for 2 h in sodium carbonate solution (1 M) followed by 2 h in water, 89% and 67% of the DON and ZEN, respectively, originally present in the grain were removed. When barley was stirred gently for 4 h in each solution, 80% and 95% of the DON and ZEN, respectively, were removed. The removal of DON from barley was marginally more efficient with vigorous stirring for a total of 4 h. The removal of ZEN was more efficient with gentle stirring for a total of 8 h.

When barley, corn, and wheat contaminated with DON at 18.9, 25.1, and 3.0 mg/kg, and ZEN at 0.74, 1.58, and 0.44 mg/kg DM, respectively, were soaked in a solution of sodium carbonate (0.1 M) for 24–72 h a large proportion (46–100%) of the DON and ZEN was removed from the grain (Table IV). The degree of removal increased with increased soaking time (ZEN in wheat was completely removed after 24 h).

The increase in the removal of DON and ZEN by lengthening contact time in 0.1 M sodium carbonate from

Table IV. Deoxynivalenol (DON) and Zearalenone (ZEN) Concentration in Barley, Corn, and Wheat, before and after a 24- or 72-h Soak in 0.1 M Sodium Carbonate Solution (at 22 °C) and the Percentage Reduction in Toxin Concentration Achieved after Each Treatment

	mycotoxin concn,[a] mg/kg DON	mycotoxin concn,[a] mg/kg ZEN	reduction, % DON	reduction, % ZEN
Barley				
unwashed kernels	18.90	0.74		
kernels soaked 24 h	1.42	0.08	92.5	89.2
kernels soaked 72 h	0.36	0.00	98.1	100.0
Corn				
unwashed kernels	25.10	1.58		
kernels soaked 24 h	7.73	0.85	69.2	46.2
kernels soaked 72 h	1.24	0.21	95.1	86.7
Wheat				
unwashed kernels	3.00	0.44		
kernels soaked 24 h	0.31	0.00	89.7	100.0
kernels soaked 72 h	0.00	0.00	100.0	100.0

[a] Results are expressed as milligrams of toxin per kilogram of kernel dry matter (DM); DM for barley was 98.4%, for corn 92.5%, and for wheat 96.4%.

24 to 72 h was 5.6% and 10.8% in barley, 25.9% and 40.5% in corn, and 10.3% and 0% in wheat, respectively. For corn, a soaking time of at least 72 h was necessary for an effective reduction in DON and ZEN contamination. In barley and wheat, however, a high proportion of the toxin content had been removed after only 24 h and all or nearly all had been removed after 72 h.

CONCLUSIONS

Most of the washing or soaking methods tested substantially reduced the DON and ZEN contamination of barley, corn, or wheat. Alkaline conditions were necessary for solubilization and removal of ZEN from barley and improved greatly the removal of ZEN from corn. Minor increases in DON removal also occurred with sodium carbonate solution, probably due to some decomposition of the DON under alkaline conditions.

The most effective treatment for both DON and ZEN removal from barley, corn, and wheat was a 72-h soak in a 0.1 M solution of sodium carbonate. A reaction time of 72 h possibly would be too lengthy for the commercial application of this decontamination procedure. However, some of the other, less time consuming, methods tested also resulted in substantial reductions in toxin concentration. In this study, relatively heavily contaminated grain was used. Shorter washing periods, perhaps with improved agitation, elevated temperatures, or the use of detergents may be very effective with moderately to lightly contaminated grains.

Since sodium carbonate is inexpensive, widely available, and nontoxic to humans and animals, it could feasibly and safely be used to decontaminate grain lightly to moderately contaminated with DON and ZEN. Moreover, sodium carbonate appears to work by leaching the toxins from the grain (as well as causing some decomposition of DON), rather than by reacting with the mycotoxins to form nontoxic compounds within the grain. With sodium carbonate-treated grain, therefore, there would be no possibility of the parent toxins being re-formed during further processing of the decontaminated grain or feed products.

The only foreseeable disadvantage of the washing procedures, described here, is the additional cost of drying the washed, decontaminated grain. This would tend to limit their usefulness for grain destined for storage or for use in dry products. However, these procedures may prove useful for decontaminating grain to be used in manufac-

turing processes that require it to be wetted or tempered prior to processing or as an "on farm" treatment of grain prior to feeding. These procedures could prove to be economically beneficial during seasons of extensive mycotoxin-contamination of grain crops for rendering lightly to moderately contaminated grain safe for animal and possibly human consumption.

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