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Impacts of DON in the Malting Barley Supply Chain: Aggregate Costs and Firm-Level Risks

D. Demcey Johnson and William Nganje

Department of Agricultural Economics
Agricultural Experiment Station
North Dakota State University
Fargo, North Dakota 58105

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We would be happy to provide a single copy of this publication free of charge. You can address your inquiry to: Carol Jensen, Department of Agricultural Economics, North Dakota State University, P.O. Box 5636, Fargo, ND, 58105-5636, Ph. 701-231-7441, Fax 701-231-7400, e-mail cjensen@ndsuext.nodak.edu . This publication is also available electronically at this web site: http://agecon.lib.umn.edu/ndsu.html

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Abstract

DON is a toxic byproduct of fusarium head blight (FHB), a fungal disease of small grains. Beginning in 1993, a prolonged outbreak of FHB occurred in the Upper Midwest, the traditional source of most six-rowed malting barley produced in the United States. Price discounts associated with DON in barley have been significant. This paper has two objectives. The first is to estimate the impact of DON on the value of malting barley grown in the Upper Midwest. Using crop quality data, we use a linear programming model to derive optimal blends of barley supplies, given discount schedules and the distribution of quality factors. The premise is that blending activities, on a regional scale, allow a larger fraction of the crop to be sold as malting. The second objective is to assess the risks associated with DON in the context of a firm-level blending model. We frame a nonlinear optimization problem in which an elevator seeks to maximize the expected sales value of the barley in its bins. Price discounts for several quality factors are incorporated in the analysis, along with probability distributions for DON. Treating DON as a random quality factor adds some interesting complexity to the standard grain blending problem.

Key Words: barley, malt, DON, fusarium head blight, grain quality, blending

Impacts of DON in the Malting Barley Supply Chain: Aggregate Costs and Firm-Level Risks[*]

D. Demcey Johnson and William Nganje[**]

1. Introduction

The upper Midwest has traditionally accounted for most U.S. production of six-rowed malting barley. Beginning in 1993, this region experienced a prolonged outbreak of fusarium head blight (FHB), a fungal disease of small grains (wheat and barley). FHB led to major yield losses in Minnesota and North Dakota, as well as substantial price discounts for a quality factor, DON, often associated with the disease. DON is an acronym for *deoxynivalenol*, a toxic byproduct of FHB, also known as *vomitoxin*, which has pathological effects when ingested in high concentrations. Although DON in barley used for malt is not subject to FDA advisory levels, it poses other problems for brewers. DON is water-soluble and heat-stable, so it survives throughout the malting and brewing process. DON in malt can cause unacceptable 'gushing' of beer. Equally important is a problem of public perception. Anheuser Busch, the largest U.S. brewer, guards against any suggestion of toxicity in its products by refusing all barley with detectable levels of DON.

So prevalent was DON during the 1993-97 crop years, and so severe the price discounts, that many Midwestern producers shifted out of barley acreage. In fact, barley acreage in the Dakotas and Minnesota has fallen by over 50 percent during the past six years. Malt companies and brewers have reduced their reliance on the U.S. Midwest, shifting more of their procurement to western states and Canada. And Anheuser Busch, which formerly used six-rowed barley malt for about 70 percent of its needs, is now using six-rowed and two-rowed malts in approximately equal proportions. (Western supplies of two-rowed malting barley have been less susceptible to FHB and DON.)

DON presents significant challenges to the grain handling industry. The tests used by most country elevators are not very accurate at low DON concentrations (i.e., less than 1.0 part per million), yet it is in this range that the largest price discounts apply. For malting barley, price spreads between 0.5 ppm and 1.0 ppm have ranged between $.20 and $.70 per bushel in recent years, depending on crop conditions. (Further discounts, typically $.05 to $.10 per ppm, apply for higher DON levels.) Producers of malting barley are justifiably concerned about testing accuracy when an error of 0.1 or 0.2 ppm can negate most of the price premium they receive for malting grade relative to feed value. However, similar risks apply to elevators on the selling side:

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[**]Associate and Assistant Professor, respectively, in the Department of Agricultural Economics, North Dakota State University, Fargo.

contracts are generally settled on the basis of destination grades (i.e., after shipment to the malt plant), and there are large penalties for shipping DON in excess of specified limits.

This paper has two objectives. The first is to estimate the impact of DON on the value of malting barley grown in the upper Midwest. Using crop quality data, we use a linear programming model to derive optimal blends of barley supplies, given discount schedules and the distribution of quality factors. The premise is that blending activities, on a regional scale, allow a larger fraction of the crop to be sold as malting barley. Our focus is on six-rowed barley grown in North Dakota, Minnesota, and South Dakota; simulations for recent years provide a rough indication of the impact of DON on total crop value. The second objective is to assess the risks associated with DON in the context of a firm-level blending model. We frame a nonlinear optimization problem in which an elevator seeks to maximize the expected sales value of the barley in its bins. Price discounts for several quality factors are incorporated in the analysis, along with probability distributions for DON. Treating DON as a random quality factor adds some interesting complexity to the standard grain blending problem.

The next section of this report provides some additional background. The third section presents our analysis of regional crop quality data, and the fourth section presents the firm-level blending model. The report concludes with a short summary and discussion of implications.

2. Background on FHB and DON

Fusarium head blight, commonly known as 'scab,' has been a recurrent problem in the small grains sector, with infestations dating back a century in Minnesota and North Dakota (Clear). However, recent outbreaks have been especially severe due to adverse weather conditions and an absence of resistant cultivars. Cool, wet weather is conducive to FHB during the heading stage of plant development. Such conditions occurred in 1993 and for several years thereafter in the upper Midwest. FHB has expanded geographically, pushing north and west from its original locus in eastern North Dakota and western Minnesota. Manitoba and parts of Saskatchewan have also experienced scab outbreaks in spring wheat and barley. Yield losses, combined with poor grain quality, have been devastating for many producers.[1]

Although DON is caused by fusarium, it is not always present in scab-damaged kernels. While the presence of scab can be determined through visual inspection, the presence of DON cannot. Testing at most grain elevators is done using a field kit, called Veratox (manufactured by Neogen), based on ELISA (enzyme-linked immunosorbent assay) technology. The Veratox test is relatively fast and inexpensive, but shows inherent variability near its lower limit of measurement, 0.5 ppm. Alternative testing methods, including HPLC (high performance liquid chromatography) and GC (gas chromatography), are more accurate, but also more expensive and

[1]For additional background on the scab epidemic, see McMullen, Jones, and Gallenberg (1997) and Steffenson (1998).

time-consuming. They are primarily used in research laboratories.[2] The U.S. agency responsible for official grain inspections, GIPSA, reviewed commercial testing procedures (including Veratox) for DON. Among its conclusions were the following:[3]

> "No single source of variation has been identified that will significantly reduce variability of DON measurements in an easy and cost-effective manner ... The available technology for rapid testing of DON is somewhat limited and only a few choices exist. The market demand for highly repeatable results may not be achieved with the current technology."

Notwithstanding the limitations of commercial testing technology, discounts for DON in malting barley usually begin at 0.5 ppm. These have varied in recent years, depending on crop conditions. Premiums for 'no detectable DON' (practically, less than 0.5 ppm) were in the 55-60 c/bu range during 1997-98.[4] Typically, additional discounts of 5 cents per point are applied for DON levels above 1.0 ppm, up to a maximum of 4.0 ppm. Barley with DON higher than 4.0 ppm can be sold as feed at a substantial further discount. (However, care must be taken to avoid high levels of DON in livestock rations, particularly swine.)

Discounts for DON ultimately reflect the preferences (and costs) of malt companies and brewers. The following comments by Bruce Sebree of ADM Malting provide some industry perspective:[5]

> "In actuality, we are not really interested in the DON (vomitoxin) content of the malting barley we purchase. What interests us is the processing attributes of that barley into malt and the subsequent malt into beer ... Luckily, the attributes we want appear to correlate fairly well with the DON content of the barley. This correlation is not perfect by any means, but allows us a certain 'probability' that the barley will process into acceptable malt. This ... can change from crop year to crop year and growing area to growing area. In any event, in most years and from most regions, we find that barley up to about 1 ppm DON will process into malt and beer relatively trouble free. When you increase the level up to 2 ppm, you effectively double the potential for problems. For barley between 2 and

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[2]See GAO (1999), pp. 2 and 11-14 for discussion of testing procedures. For a DON concentration of 0.5 ppm, Veratox test results can range between 0 and 1.1 ppm.

[3]Summarized in "Study Examines Testing Methods for DON," *Barley Bulletin*, Vol. 16 No.3, Fall 1998, published by the North Dakota Barley Council.

[4]Whether price spreads are characterized as 'premiums' or 'discounts' depends on the point of reference. Major buyers of malting barley point out that they offer a premium price for no detectable DON. However, for producers in areas of severe infestations, this kind of premium has been largely out of reach.

[5]Bruce R. Sebree, ADM Malting Division, "Impact of Scab on the Malting Industry," June 1998.

3 ppm, the potential for trouble once again doubles and on up to 4 ppm increases probably another 2-3 fold and is nearly unmanageable."

Increased testing and inventory costs are associated with scab-contaminated barley. Traditionally, malt companies have segregated barley on the basis of variety and protein levels; they now must do so on the basis of DON ranges as well. This increases the required bin storage combinations, leading to less efficient use of available bin space. Apart from the direct expense of testing, there may be demurrage charges for barley on rail cars while the malt company awaits test results. Processing costs are also higher due to the reduced value of malting byproducts, increased water usage, wastewater disposal costs, and additional staffing and process control equipment. Further, notes Sebree,

> "An intangible impact of the use of scab infected barley is a certain loss of confidence of brewing customers in their suppliers. Customer concerns and complaints have most definitely increased since the 1993 crop year ... The fact of the matter is that the presence of scab induced factors (not necessarily DON) in the malt appear to make the beer matrix less stable. Thus, even when the malt alone might not cause brewing problems, minor changes or mistakes during brewing that normally go unnoticed, can cause major brewing difficulties. The worst is called gushing, ... [which is] an overfoaming phenomenon."

Thus, the scab epidemic has had important effects not only on barley producers, but on the malting and brewing industries.

There have been few attempts to measure the economic impact of scab, and these have focused largely on lost producer income.[6] The Government Accounting Office (GAO) estimated the cumulative losses of North Dakota barley farmers due to FHB at about $200 million (1997 dollars) during 1993-97. This includes the estimated value of yield losses, abandoned acres, and price discounts. The GAO did not use actual discount schedules in its analysis of producer losses. Rather, it estimated the (average) prices and quantities that would have been observed in the absence of scab, and used these to derive the change in crop value. The analysis discussed in the next section takes a different approach, but focuses more narrowly on market discounts for DON.

3. Impacts of DON on Crop Value

The following analysis draws upon a regional crop quality survey.[7] The annual survey covers major barley growing regions of North Dakota, Minnesota, and South Dakota. Since

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[6]Johnson et al. (1998) estimated the losses of U.S. wheat producers due to FHB through 1997. Cumulative losses were estimated at $1.3 billion, and two thirds of these losses occurred in North Dakota and Minnesota.

[7]Conducted by the Departments of Cereal Science and Animal and Range Science, North Dakota State University, with financial support from barley producers.

1993, DON measurements have been made for a subset of collected barley samples. We confine our attention to six-rowed varieties, which account for the vast majority of barley acres in the region. Figure 1 shows the distribution of DON in each of the last seven crop years. Lines indicate the percentage of the crop (based on collected samples) with less than the indicated level of DON. Attention is drawn to the line for 0.5 ppm. When DON is at this level or below, it is considered 'non-detectable' and no discounts apply. About half of the crop fell into this category in 1999; this is a marked improvement from earlier years.

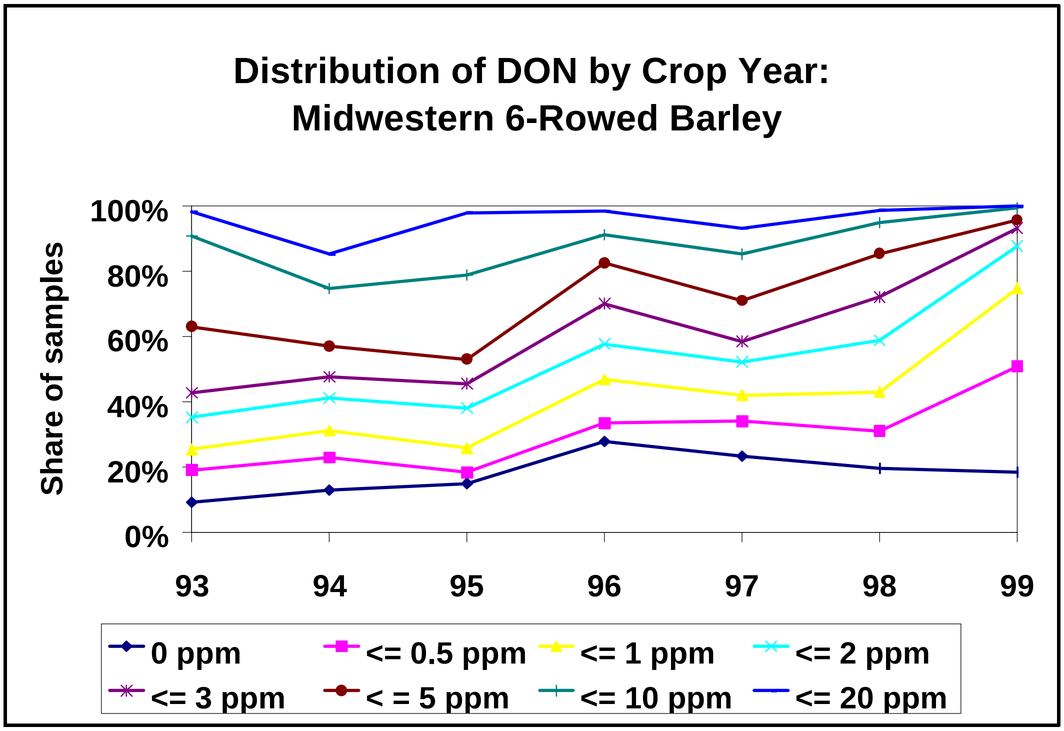

Figure 1. Distribution of DON in Six-Rowed Barley by Crop Year

Average market discounts for DON during 1995-98 are shown in Table 1.[8] Note that large jumps in the schedule occur between 0.5 ppm (maximum) and 1.0 ppm. Buyers of malting barley sometimes term this a 'premium' for non-detectable DON. The next jumps in the discount schedule (i.e., for DON in excess of 1.0, 2.0, and 3.0) are relatively small. However, barley with DON in excess of 4.0 is valued at the feed barley price. The last column shows a weighted average discount for each year. The weights, in this case, are fractions of the six-rowed barley crop falling within indicated DON ranges. This overstates the average loss of crop value due to DON, because even in 'normal' circumstances (with no DON or associated discounts) not all barley grown in the region would qualify for malting. The discount associated with DON in excess of 4 ppm reflects the malting-feed price spread, but downgrading from malting to feed can

[8]These are from an industry source and represent average discounts for barley delivered in Minneapolis in the specified year.

also occur because of other quality factors. Not all barley with high DON levels would have been destined for the malting market.

Table 1. Market Discounts for DON, Midwest Six-Rowed Barley, 1995-98

Marketing Year	Discounts Relative to Zero DON ($/bu)						Weighted Average† ($/bu)
	≤ 0.5 ppm	0.6 - 1.0 ppm	1.1 - 2.0 ppm	2.1 - 3.0 ppm	3.1 - 4.0 ppm	≥ 4 ppm	
1995	0	0.35	0.40	0.45	0.55	1.05	0.66
1996	0	0.34	0.41	0.46	0.54	1.24	0.47
1997	0	0.58	0.88	0.93	0.98	1.48	0.79
1998	0	0.55	0.60	0.65	0.75	1.29	0.57

† Weights are derived from annual crop quality survey.

The existence of two markets for barley, malting and feed, complicates the analysis of DON's impact. In most years, Midwestern production of six-rowed varieties suitable for malting[9] has exceeded U.S. utilization, which is fairly constant. (Exceptions were 1988, a year of severe drought, and 1999, after a sharp drop in barley acreage.) Changes in production levels and in average crop quality have caused a varying fraction of the crop to be sold as malting.[10] The larger is the surplus of higher-quality malting barley, the more exacting are malting industry standards. Conversely, a shortage (as in 1988) can induce a substantial relaxation of quality standards (e.g., for protein or percentage of plump kernels). For these reasons, the malting market is a moving target, and it is difficult to establish what proportion of the crop would be sold as malting in the absence of a DON infestation. DON clearly has a more important impact on the value of barley sold for malting than for feed. Although high concentrations are to be avoided in livestock rations (especially swine, but also cattle), the grain handling industry has become adept at 'blending off' the high-DON barley for feed use.

Blending models can provide some insight into the aggregate effects of DON. The following analysis, based on linear programming, combines crop quality data with market discounts to derive optimal blends of regional barley supplies. Price relationships are taken as given. The premise is that the grain handling industry seeks to maximize the value of the crop

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[9]As identified by the American Malting Barley Association (AMBA), which represents the malting and brewing industry. To be sold for malting, barley must be of an approved variety and also meet other quality requirements.

[10]In North Dakota, the fraction sold as malting can be imputed from average prices for malting barley, feed barley, and all barley published by the Agricultural Statistics Service. This has ranged from less than 30 percent in 1993 to over 60 percent in 1998.

(malting premium less discounts, multiplied by quantity sold for malting use), given the distribution of several quality factors.

The analysis is structured as a standard blending model. Four quality parameters are included: % protein, % plump kernels, test weight (lbs/bu), and DON (ppm). This is not an exhaustive list, but includes parameters of great interest to the malting industry. To represent the distribution of these four variables, we use Gaussian quadrature to identify representative barley samples in the crop quality survey dataset.[11] For example, of 158 observations (barley samples) in the 1998 survey, we identify 15. Probability weights are selected so that these 15 observations yield first and second moments (for four quality variables) identical to those for all observations. The probability weights are converted into quantities (summing to total regional supply of six-rowed malting barley) for purposes of the blending analysis. In this way, we derive a blending model of manageable size that duplicates the distribution (up to second-order moments) of four quality variables in the regional barley crop.

Barley sold for malting must meet industry quality requirements. These are specified as: maximum 13.5 percent protein; minimum 70 percent plump kernels; and minimum 43 lbs test weight. Discounts apply for DON in excess of specified limits (0.5, 1.0, 2.0, and 3.0). Discounts were obtained from an industry source. There are no discounts for DON less than 0.5 ppm. A quantity limit of 85 million bushels is imposed for total malting sales; that is approximately the annual U.S. utilization of six-rowed malting barley.

Results for 1998 and 1999 are shown in Table 2. The estimated selling discounts for DON are those received by grain handlers after they have blended available supplies to maximize the value of the Midwestern barley crop. This shows a sharp decline between 1998 and 1999, which is consistent with improved crop quality. The average discount falls from $0.17/bu to $0.06/bu. Although a smaller quantity of barley is sold for malting in 1999, this represents a larger fraction of the crop.

Table 2. Estimated Discounts after Blending

	1998	1999
Total selling discounts for DON ($ million)	14.8	3.7
Average selling discount for DON ($/bu sold for malting)	0.17	0.06
Quantity sold as malting (million bu.)	85	59
Fraction of crop sold as malting (%)	70	92

The analysis assumes that blending takes place on a regional scale, yet ignores the spatial distribution of crop quality parameters and costs of grain movement. Another limitation of the

[11]The authors thank Eric DeVuyst for suggesting this approach.

analysis is that it focuses on total discounts received by grain handlers (after blending), rather than total discounts received by producers. These are not necessarily the same. Indeed, as illustrated in the next section, discount schedules provide profit opportunities for handlers, even if the same schedules apply for grain purchases and sales.

4. Firm-Level Blending Models

We begin with an illustration of blending margins under conditions of certainty. Consider the example shown below (Box 1). An elevator has two bins containing malting barley. DON levels in the two bins are zero and 2.1 ppm, respectively. Assume that all other quality parameters are identical between the two bins. Price discounts for DON are as shown: no discount for DON less than 0.5 ppm, 30 cents for DON up to 1.0 ppm, and an additional 5 cents for each additional ppm up to 3. By varying the proportions in a blend, the elevator can raise or lower the level of DON, and hence control the value of the blended grain.

Box 1. Blending Margins Under Conditions of Certainty

Blending from 2 bins with discount schedule

	Bin 1	Bin 2	Blend
DON (ppm)	0.0	2.1	2.0
Discount ($/bu)	0.00	0.40	0.35
Price ($/bu)	2.50	2.10	2.15
Proportions	0.05	0.95	
Blending opportunity cost ($/bu)			2.12
Blending margin ($/bu)			0.03

Base Prices ($/bu)

Malting	2.50
Feed	1.40

Discount Schedule

Max DON (ppm)	0.5	1.0	2.0	3.0	> 3
Discount ($/bu)	0.00	0.30	0.35	0.40	1.10

The 'opportunity cost' is the value of grain without blending: a weighted average of the values of grain in the two bins. The difference between the price of the blended grain and its opportunity cost is the blending margin, $0.03 per bushel in this example.[12]

Figure 2 shows the relationship between the blending margin and the discount schedule for DON that the elevator faces when selling barley. The blending margin equals the vertical distance

[12] In this analysis we ignore any operational costs of blending.

between the discount schedule (a step function) and the straight line representing opportunity cost. Notice its characteristic 'sawtooth' shape, with vertical segments at each point where there is a change in discount. Reading left to right, the first vertical segment occurs at 0.5 ppm. If the level of DON in the blend is exactly 0.5 ppm, the blending margin is $0.10/bu; however, if DON is slightly higher, the blending margin turns negative.

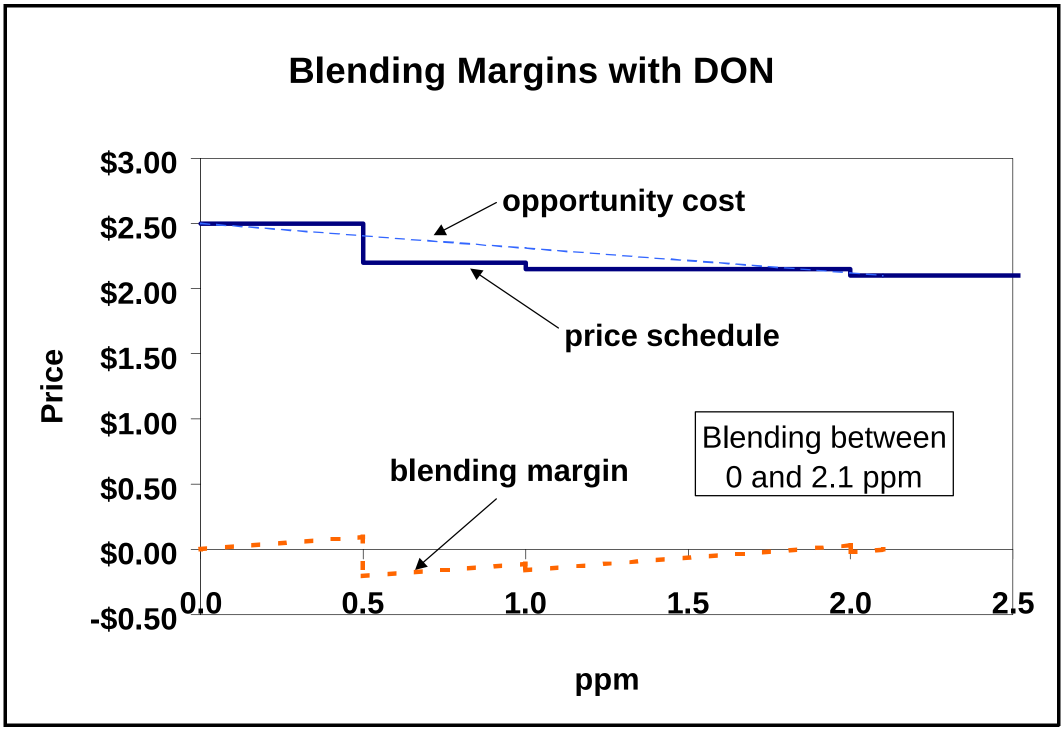

Figure 2. DON Discounts and Blending Margins

Now we consider a blending analysis in which DON is treated as a random variable. Assume that the elevator has malting barley in three bins, and that DON is distributed normally in each bin with known mean and standard deviation. The distribution of DON in a blend is also normal. By changing proportions,[13] the elevator can control the probability that a blend will satisfy a given contract specification for DON (Box 2).

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[13] We use the fact that if X, Y, and Z are independent random variables (i.e., levels of DON in three bins), $Var(aX + bY + cZ) = a^2 Var(X) + b^2 Var(Y) + c^2 Var(Z)$. Note that since blending proportions are positive and sum to one, the variance of a blend cannot exceed the largest variance of its components. A blend can also have lower variance than any of its components.

Probability that blend will satisfy (max) DON limit

	Bin 1	Bin 2	Bin 3	Blend	Limit	Prob
DON (ppm)						
mean	3.1	0.5	1.2	0.81	1	0.77
std dev	1.2	0.3	0.6	0.27		
bu in blend	1	10	2	13		
share	0.08	0.77	0.15			
max bu	5000	5000	3000			

Box 2. Probability of DON in a Blend

The next spreadsheet combines price discounts and quality variation in a nonlinear optimization problem (Box 3). The elevator's objective is to maximize the expected value of barley in its bins. There are three bins, each with different quality levels. The elevator can blend grain from the three bins or sell grain directly from the bins without blending. Discount schedules apply for protein (%), plump kernels (%), and DON (ppm). DON is again treated as a random variable in each bin, normally distributed with known mean and variance. When grain is blended from the three bins, the expected price reflects the weighted average (using probability weights) of discounts for DON. The problem is subject to constraints on quantities and is solved using Excel's Solver.

A variant of the problem adds additional constraints (Box 4). Now the elevator must sell a quantity equivalent to n rail cars (n, an integer), while satisfying a contract limit for DON with known probability.[14] This conforms more closely to the situation of an elevator that ships by rail and seeks to maintain longer-term relationships with buyers through quality assurance. Note that the blending margin is negative in this example.

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[14]A word of caution about optimization with spreadsheets. Nonlinear relationships complicate the search for an optimal solution. Excel's Solver uses a search algorithm for solutions that are feasible (i.e., satisfy problem constraints) and that satisfy optimality conditions. In a problem with nonlinear constraints, only 'local' optimality can be assured. Solver may identify different solutions, depending on the levels of variables at the start of the search algorithm. For that reason, it is advisable to experiment with different starting values for the variables of interest—in this case, bushels blended from the three bins.

Barley blending with DON (Box 3)

	Bin 1	Bin 2	Bin 3	Blend
plump	65	80	70	70.00
protein	14	12	13.4	13.35
DON				
mean	3	0.8	2.1	2.24
std dev	1.5	0.3	1.1	0.85
bu in blend	12000	6000	4000	22000
share	0.55	0.27	0.18	
max bu	15000	6000	4000	
value, c/b	220	251.9	243.3	241.7
contract	218.9	251.9	243.3	
alternate	220	220	220	

base price
270
prem/disc c/b
0
0
-28.3

Blending margin c/b
8.8

	grain value $
blended grain	53174.41
grain not blended	6600.00
total value	**59774.41**

discounts for DON			prob
range (ppm)		discounts	
>	<=	c/bu	
	0.5	0	0.020
0.5	1	-20	0.052
1	2	-25	0.318
2	3	-30	0.427
3	4	-35	0.165
4		-40	0.019
			1.000

discounts			
protein		plump	
%	c/bu	%	c/bu
13.5	0	50	-60
13.6	-2	51	-56
13.7	-4	52	-52
13.8	-6	53	-48
13.9	-8	54	-44
14.0	-10	55	-40
14.1	-13	56	-36
14.2	-16	57	-32
14.3	-19	58	-28
14.4	-22	59	-24
14.5	-25	60	-20
14.6	-28	61	-18
14.7	-31	62	-16
14.8	-34	63	-14
14.9	-37	64	-12
15.0	-40	65	-10
15.1	-43	66	-8
		67	-6
		68	-4
		69	-2
		70	0

Barley blending with DON (Box 4)

(Fill N rail cars; satisfy DON spec with known probability)

	Bin 1	Bin 2	Bin 3	Blend
plump	65	80	70	75.71
protein	14	12	13.4	12.60
DON				
mean	3	0.8	2.1	1.36
std dev	1.5	0.3	1.1	0.50
bu in blend	0	2357	1768	4125
share	0.00	0.57	0.43	
max bu	15000	6000	4000	
value, c/b	220	251.9	243.3	246.6
contract	218.9	251.9	243.3	
alternate	220	220	220	

base price
270
prem/disc c/b
0
0
-23.4

Blending margin c/b
-1.7

N (# rail cars)	1
max vomitoxin (ppm)	2
desired probability	0.9
estimated probability	0.9

	grain value $
blended grain	10170.75
grain not blended	46773.78
total value	**56944.53**

discounts for DON			
range (ppm)		discounts	prob
>	<=	c/bu	
	0.5	0	0.044
0.5	1	-20	0.194
1	2	-25	0.662
2	3	-30	0.099
3	4	-35	0.001
4		-40	0.000
			1.000

discounts			
protein		plump	
%	c/bu	%	c/bu
13.5	0	50	-60
13.6	-2	51	-56
13.7	-4	52	-52
13.8	-6	53	-48
13.9	-8	54	-44
14.0	-10	55	-40
14.1	-13	56	-36
14.2	-16	57	-32
14.3	-19	58	-28
14.4	-22	59	-24
14.5	-25	60	-20
14.6	-28	61	-18
14.7	-31	62	-16
14.8	-34	63	-14
14.9	-37	64	-12
15.0	-40	65	-10
15.1	-43	66	-8
		67	-6
		68	-4
		69	-2
		70	0

5. Conclusions

DON has had a major impact on malting barley producers in the upper Midwest. Price discounts, combined with scab-related yield losses, have led to sharp reductions in barley acreage. Although the incidence of DON was much lower in the 1999 crop, it seems unlikely that barley acres will recover to their pre-epidemic levels. This poses a challenge to the U.S. malting and brewing industries, which for decades have depended on barley production (particularly six-rowed varieties) in the Dakotas and Minnesota.[15]

The aggregate costs of DON to producers are difficult to estimate. One approach is to apply market discounts to regional crop quality data. However, this overstates the costs borne by producers because even in ‘normal’ years not all barley production is destined for the malting market. DON is only one of several quality factors that can cause barley to be graded as ‘feed,’ rather than ‘malting.’ An alternative approach developed in this paper involves optimal blending of regional barley supplies. The premise is that grain handlers seek to maximize the value of the crop by blending to meet malting specifications. Results of the blending analysis indicate that the aggregate value of discounts for DON will fall in 1999 due to improved crop quality conditions.

Firm-level blending models provide some perspective on problems of quality control in the grain handling system. Mathematically, the discount schedules for DON are described by step functions. Blending margins can change sharply from positive to negative with small changes in blending proportions. This is not unique to DON; premiums and discounts for other grain quality parameters are also characterized by step functions. However, DON is subject to an unusual amount of measurement uncertainty, and penalties for excess DON pose an unusual level of risk for grain handlers. Treating DON as a random quality factor adds some complexity to a blending analysis; however, this is within the reach of computer spreadsheets.

While this paper has focused on grain handlers, DON affects all segments of the malting barley value chain. Tradeoffs between quality risk and cost are important for malt companies and brewers—and indeed, other agricultural processing industries. Areas for future research include the impacts of quality risk on procurement and inventory strategies.

[15] The rise in U.S. malting barley imports from Canada since 1993 is largely attributable to FHB and associated quality problems in the Midwest crop. Barley imports from Canada have also moderated the price impacts of FHB in U.S. growing regions. (GAO, pp. 10-11).

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