Removal of Ergot from Barley by Density Separation

K. M. Adam, M. K. Misra, D. R. Thoreson

Abstract. *A laboratory experiment was conducted to determine the feasibility of density separation for reducing ergot contamination in barley. Four 1.1-m^3 (30-bu) lots of contaminated barley were conditioned with an air-screen cleaner followed by density separator. Samples were collected before and after conditioning with each machine. The amount of ergot in collected samples was determined separating and weighing the ergot and calculating the percentage by weight. The ergot contamination level was significantly reduced from 0.52%, 0.16%, 0.10%, and 0.12% to 0.02%, 0.01%, 0.02%, and 0.01%, respectively, for the four contaminated lots near the conditioning operations. An economic analysis indicated that it was advantageous to clean barley and use it as an animal feed rather than to sell it at salvage value.*

Keywords. *Ergot, Barley, Density separator, Conditioning.*

Ergot is one of the oldest known mycotoxins and is produced by the spores of the *Claviceps purpurea*. Ergot is well known as a disease of rye but it also affects wheat, barley, triticale, and other grains (Lorenz, 1979). Ergot-contaminated grains are easily recognizable compared to uncontaminated grain as they appear like black or purplish hardened bodies (sclerotia). Additionally, ergot-contaminated grain kernel can be two to ten times the size of a normal kernel (figs. 1 and 2). The photos of figures 1 and 2 were taken at the same magnification and it can be readily observed that contaminated barley is larger than the normal barley.

In the international grain market, many countries do not permit grain containing ergot to reach commercial food channels because of its harmful effects to humans if ingested (Scott, 1991). Consumption of ergot-contaminated cereals has been found to cause severe illnesses (ergotism). There are two types of ergotism, convulsive and gangrenous. Convulsive ergotism causes the entire body to be racked by spasms accompanied by severe diarrhea (Rehacek and Sajdi, 1990). Gangrenous ergotism causes the affected part (more often a foot than a hand) to become swollen and inflamed giving the patient violent, burning pains. The affected part gradually becomes numb, turns black, shrinks, and finally becomes mummified and dry (Rehacek and Sajdi, 1990). Finally, the gangrenous part often separates spontaneously at a joint. Some incidence of the death due to ergot ingestion has occurred in the past. It was reported that in 1945 in Paris more than 40,000 people died in the epidemic after they ate grain contaminated with ergot (Rehacek and Sajdi, 1990).

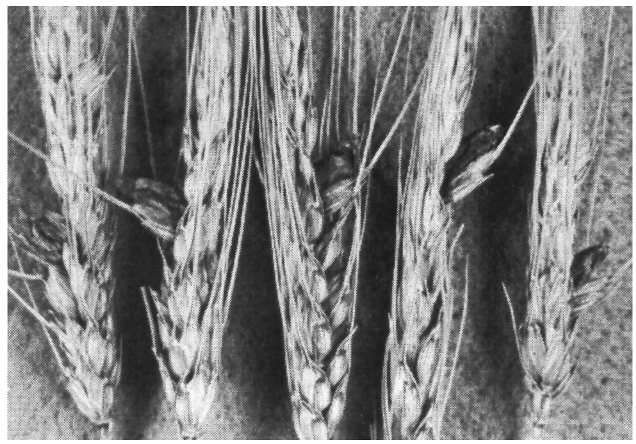

Figure 1. Ergot on spikes replacing whole grains (courtesy Gary Munkvold, Plant Pathology, Iowa State University).

Ergotism is not restricted to humans. It also affects domestic livestock. Brown and Ranck (1915) reported a serious ergot poisoning of livestock in Kansas, Missouri, and Illinois. Similar ergot problems were also reported in Ireland and England when cattle were fed ergot-contaminated silage (McKeon and Egan, 1971; Woods et al., 1966). While Champlin and MacEwan (1942) reported that cattle are most susceptible to the injurious effects of ergot, convulsion ergotism has been reported in horses and sheep but not in cattle (Guilhon, 1955). Gangrenous ergotism can cause loss of extremities including limbs, tips of tails, and ear parts due to diminishing blood supply (Champlin and MacEwan, 1942). A number of signs of ergotism were reported in cattle by Skarland (1972) and Skarland and Thomas (1972), including lameness and swelling of the hind limbs leading to the loss of extremities, increased body temperature, increased pulse and respiratory rates, nervousness, ataxia, abnormal gait, lowered gain in cattle on feed and digestive disturbances. Woods et al. (1966) reported a decrease in milk production in cattle-fed ergot-contaminated grains or roughage. Munkvold et al. (1997) estimated that 10 to 15 dairy cows died and 1000 more displayed symptoms of ergotism, manifested as loss of milk production and hyperthermia, when fed contaminated barley in Iowa.

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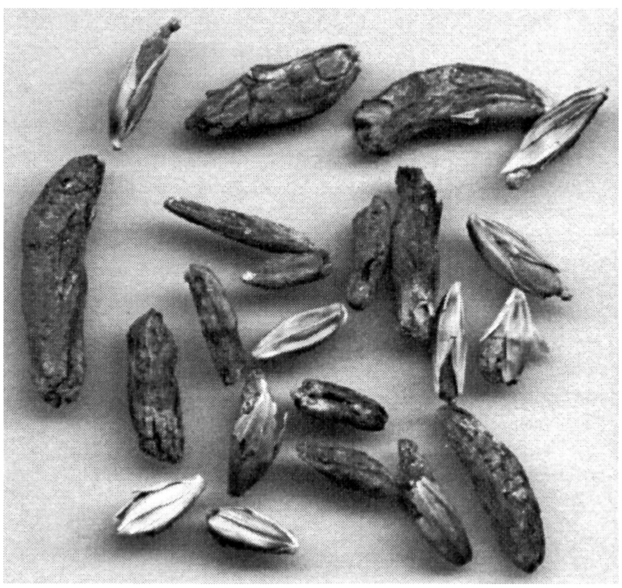
(a)



(b)

Figure 2. (a) Normal barley and (b) ergot-contaminated barley.

There are some beneficial aspects of ergot, historically ergot was used by midwives to hasten uterine contraction during childbirth and to control postpartum bleeding (Rehacek and Sajdi, 1990). Over the centuries, ergot's role has undergone important changes from a toxic parasite on rye to an important source of pharmaceutical substances.

Farm management practices, such as use of clean seed, crop rotation, cutting and removal of wild grasses near the field, and deep planting of varieties in which all the plants flower at the same time, are used to control ergot in the field. Once ergot is present in a lot, however, it is not easy to remove to a level below the tolerance level (0.1%) for feeding purposes (Champlin and MacEwan, 1942). This is because some ergot is of similar size and shape to barley.

Gilles et al. (1972) found that sieves, indent separators and the gravity separator commonly used in the flour mill industry can remove about 40% of ergot. Shuey et al. (1973) were able to remove 52% of ergot from contaminated wheat using an air-screen cleaner and an aspirator, and they removed 40% using 18% saline solution as a floating agent and 1:9 (v/v) methanol-water solutions as a rinsing agent. The difficulty in removing all of ergot from grain would be attributed to the similarities of some ergot bodies to kernels of grain in size, shape, and weight. Young et al. (1983) treated the alkaloid content of wheat ergot with chlorine and were able to reduce it by about 90%. They also found that hydrogen chloride and sulfur dioxide caused <20% decomposition to ergot alkaloid, while ammonia and ozone and ultraviolet radiation had no significant effects on ergot alkaloids removal at all. Rotter et al. (1985) were able to reduce the toxicity of ergot to chicks by treating ground ergot with chlorine. A significant amount of ergot particles were removed from rye grains by flotation in 20% sodium chloride or 32% potassium chloride solutions (Champlin and MacEwan, 1942). None of these cleaning methods were able to reduce the percent of ergot in grain to an acceptable level for feeding.

The main objective of this research was to determine the feasibility of density separation for reducing ergot contamination in barley to the acceptable level (below 0.1%) by density separation. Another objective was to determine if the cleaning could be accomplished at a reasonable financial cost.

Experimental Design and Procedure

Four dairy farmers from northeastern counties of Iowa were selected for this study. Each farmer provided 1.1 m^3 (30 bu) of barley from a contaminated lot. Barley was transported in bulk bags to the Seed Science Center at Iowa State University where it was conditioned with the procedure detailed in figure 3.

A Dillon dynamometer scale model MFXF560 with maximum load capacity of 2268 kg (5000 lb) was used to weigh each bulk bag. The grain was then divided into three equal specimens by weight. Each specimen was conditioned by passing it through an air-screen cleaner and a gravity table in a randomized block design for statistical purpose. Statistical Analysis Software (SAS) was used for data analysis.

A Crippen air-screen cleaner Model H-434-A-LH with two scalping slotted screens: 3.6 and 3.2 mm (9/64 and 8/64 in.) and two sifting slotted screens 2.1 and 2 mm (two 1/12 in. and one 1/13 in.) was used as the first machine to clean the product. The cleaned product from the air-screen cleaner was conveyed to a gravity table bin. A Foresberg gravity table model 40VM was used to condition the good barley from the air-screen cleaner. The product was allowed to recycle until optimum separation was achieved. The gravity table separated the product by density to three fractions (heavy, medium, and light). The heavy and light fractions of the gravity table were collected in 0.12-m^3 (32-gal) containers for 4 min and weighed to determining the volume of discard. The medium fraction was recycled back to the feed on the gravity table.

A 1-kg (2.2-lb) sample was taken from each specimen before and after the air-screen cleaner for ergot percent determination. Four discarded fractions from the air-screen

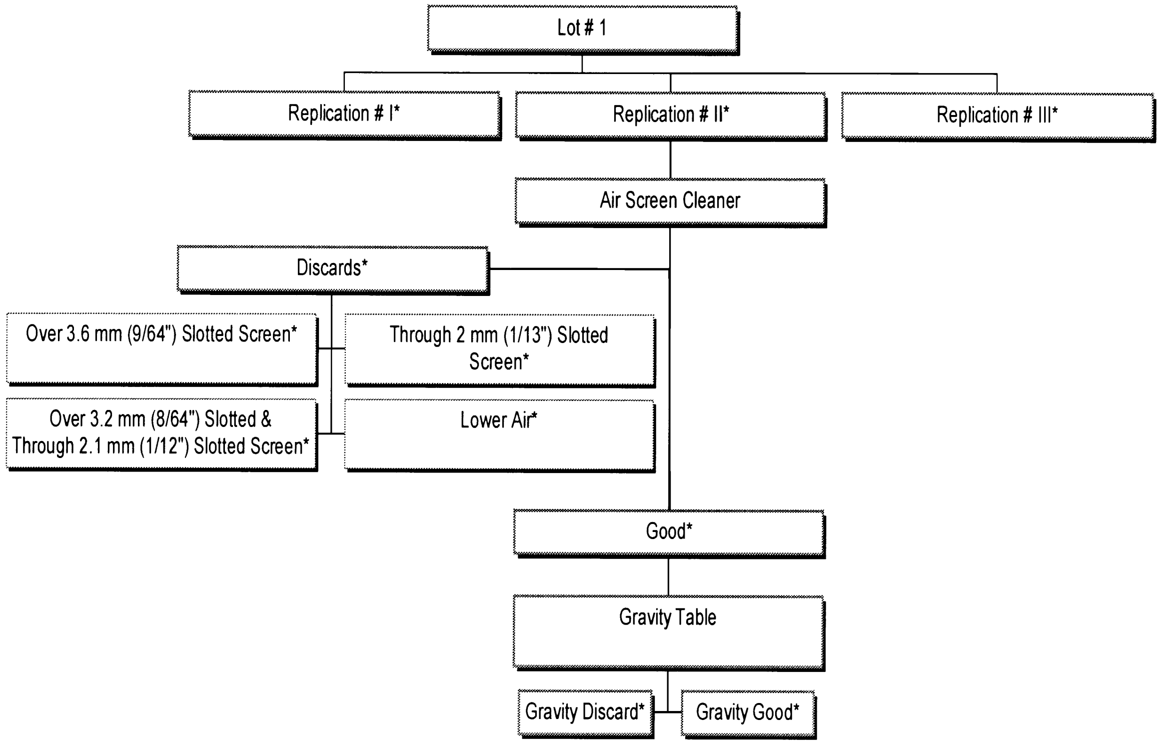


Figure 3. Flow chart for the conditioning steps used for cleaning contaminated barley (Samples were collected at locations marked with *).

cleaner were also collected and weighed. A 0.75-kg (1.65-lb) composite sample was also taken from each discard, and the ergot percent in each sample was determined. A 1-kg (2.2-lb) sample was collected from both the heavy and the light fractions during the course of the 4 min and analyzed for ergot percent determination.

All samples collected were sent to the seed-testing laboratory at the Seed Science Center of Iowa State University where the ergot contamination level was determined. The percentage of ergot in each sample was determined by manually separating the ergot from the barley and calculating its percentage in the sample, by weight. This procedure indicates only that ergot is present and does not provide any information on the alkaloid content or the types of alkaloids present.

RESULTS AND DISCUSSION

CLEANING EFFECTIVENESS

The overall results, as shown in table 1, indicated that the ergot contamination level was significantly reduced from 0.52%, 0.16%, 0.1%, and 0.12% initially to 0.02%, 0.01%, 0.02%, and 0.01%, respectively for the four contaminated lots at the 0.05% confidence level.

Table 1. Ergot percentage before and after each conditioning step.

Conditioning Step[a]	Lot Number 1[b]	2	3	4
(Initial)	0.52 b*	0.16 b	0.10 b	0.12 b
AA	0.31 c	0.08 c	0.08 b	0.08 b
GH (Final)	0.02 d	0.01 c	0.02 c	0.01 c
GL	1.40 a	0.50 a	0.44 a	0.76 a
LSD (α = 0.05)	0.06	0.07	0.04	0.04

[a] AA: After air-screen cleaner, GH: Gravity table heavy fraction, GL: Gravity table light fraction.

[b] Numbers with the same letter in each column are not significantly different.

The air-screen cleaner reduced the contamination level from 0.52%, 0.16%, 0.1%, and 0.12% initially to 0.31%, 0.08%, 0.08%, and 0.08%, respectively, for the four contaminated barley lots. In three seed lots the air-screen cleaner was able to reduce the contamination enough to meet the acceptable feeding standard. The air-screen cleaner was unable to clean the barley lot with highest level of initial contamination to below the threshold acceptable for feeding purposes (0.1%).

The gravity table significantly reduced the contamination level from 0.31%, 0.08%, 0.08%, and 0.08% to levels of 0.02%, 0.01%, 0.02%, and 0.01%, respectively. The percentage of ergot removed by the lower air of the air-screen cleaner was significantly lower than any of the other fractions of the air-screen cleaner. The percentage of ergot in the light fraction of the gravity table varied from 0.44% to 1.4% and was significantly higher than that of the heavy fraction (table 1). This finding was true for all barley lots tested. This finding indicated that the gravity table was able to effectively reduce the contamination level of all barley lots including the lot with highest initial level of ergot contamination.

The overall cleaning was achieved with a total barley discard ranging from 7.82% to 19.95% depending on the initial level of contamination (table 2). The air-screen cleaner discards ranged from 4.43% to 6.63% barley (table 3), and the gravity discards ranged from 2.36% to 14.39% (table 4).

ECONOMIC ANALYSIS OF CLEANING BARLEY

The best salvage price for contaminated barley at the time of cleaning was \$34.28 per m^3 (\$1.20 per bu) on farm. Since

Table 2. Percentage of total barley discarded with the air-screen cleaner and the gravity table.

Specimen Number	Lot Number			
	1[a]	2	3	4
1	20.02 a	14.74 b	13.08 a	8.38 a
2	19.54 b	14.10 b	12.95 a	7.75 b
3	20.30 a	16.82 a	10.62 b	7.34 b
Average	19.95	15.22	12.22	7.82
LSD (α = 0.05)	0.38	1.42	1.38	0.52

[a] Numbers with the same letter in each column are not significantly different

farmers do not typically own gravity tables, the farmer would need to take his contaminated barley to the cleaning site. The costs for cleaning and hauling barley were estimated to be \$11.33 and \$2.29 per m^3 (\$0.40 and \$0.08 per bu), respectively. The market price for clean barley for dairy feed was \$62.43 per m^3 (\$2.20 per bu). Based on this information, the cost-benefit analysis of cleaning 35 m^3 (1000 bu) of barley can be calculated as follows:

The percent of ergot in the samples discarded by the screening and the air-lifting action from the air-screen cleaner varied from 2.98% to 22.69% of the discard (table 5). For all barley lots tested, the 3.6 mm (9/64 in.) slotted screen scalped off the highest percentage of ergot, indicating that some ergots were larger than the barley. The lower air fan removed a very low percentage of ergot indicating that most ergots were about the same weight as barley.

The average value of 35 m^3 (1000 bu) of contaminated barley is \$1200.

Assuming the average discard of 14% (based on this study, see table 2), 35-m^3 (1000-bu) contaminated barley yield 30 m^3 (860 bu) of clean barley. Cleaning charges are on cleaned barley.

Cleaning charges for 30 m^3 (860 bu) is \$344.00

Hauling charge for 35 m^3 (1000 bu) of unclean barley is \$80.00

Hauling charge for 30 m^3 (860 bu) clean barley is \$68.80

Total cost of cleaning and hauling of contaminated barley is \$492.80

The value of 30 m^3 (860 bu) clean barley is \$1892.00

Income is: (\$1892.00 - \$492.80) \$1399.20

Difference in income gained is as a result of cleaning barley: \$1399.20 - \$1200.00 = \$199.20

Table 3. Percentage of barley discarded with the air-screen cleaner.

Specimen Number	Lot Number			
	1[a]	2	3	4
1	5.26 b	4.50 a	7.10 a	5.78 a
2	5.67 ab	4.40 b	7.26 a	5.44 b
3	5.77 a	4.39 b	5.54 b	5.16 b
Average	5.57	4.43	6.63	5.46
LSD (α = 0.05)	0.27	0.06	0.95	0.31

[a] Numbers with the same letter in each column are not significantly different.

Table 4. Percentage of barley discarded with the gravity table.

Specimen Number	Lot Number			
	1[a]	2	3	4
1	14.76 a	10.24 a	5.98 a	2.60 a
2	13.87 b	9.70 a	5.69 a	2.31 b
3	14.53 a	12.43 b	5.08 b	2.17 b
Average	14.39	10.79	5.58	2.36
LSD (α = 0.05)	0.46	0.45	0.45	0.22

[a] Numbers with the same letter in each column are not significantly different.

Table 5. Ergot percentage in the air-screen cleaner discards.

Air-Screen Cleaner Discard	Lot Number			
	1[a]	2	3	4
Over 3.6 mm (9/64 in.)	14.94 a	4.78 a	1.30 a	4.27 a
Through 2 mm (1/13 in.)	3.98 b	2.32 b	0.74 ab	2.92 b
Over 3.2 through 2.1 mm (8/64 through 1/12 in.)	3.40 c	0.74 c	0.73 ab	0.61 c
Lower air	0.37 d	0.55 c	0.21 b	0.32 c
Total	22.69	8.39	2.98	8.12
LSD (μ = 0.05)	1.86	1.04	0.66	1.20

[a] Numbers with the same letter in each column are not significantly different.

The farmer also has the option of substituting barley with corn on a pound per pound basis. Assuming that, corn was \$79.50 per m^3 (\$2.80/bu or \$0.05/lb), and a bushel of corn is 25.4 kg (56 lb), the value of 1 kg of corn is \$0.11 (\$0.05/ lb).

Assuming a bushel of barley is 21.8 kg (48 lb), the value of 21.8 kg (1 bu) is \$2.40 on feed value basis.

30-m^3 (860-bu) clean barley at \$68.8/m^3 (\$2.40/bu) is \$2064.00

Cleaning and hauling charges is \$492.80

Income = \$1571.20

Total income gained over salvage on original bushels is: \$1571.20 - \$1200.00 = \$371.20

Therefore, an additional income of \$199.20 will be gained if the farmer sells the cleaned barley in the market. However an income of \$371.20 will be gained if the farmer cleans the barley and feeds it to the livestock on the farm.

Conclusions

The following conclusions can be drawn from this study:

- Ergot contamination was effectively reduced to the 0.1% acceptable level for feeding purposes with the combination of an air-screen cleaner and a density separator. However, the air-screen cleaner alone was not able to clean all lots to the acceptable level.
- Cleaning ergot-contaminated barley with an air-screen cleaner and a gravity table is cost effective netting \$199.20 per 35 m^3, for current hauling, cleaning, and feed costs.

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