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Acid Preservatives for High-Moisture Grains

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When used properly, certain organic acids will prevent mold growth and spoilage in stored grains with up to 36 percent moisture.

Propionic and a mixture of propionic and acetic are the principal acids used. They are organic acids which are also produced in the rumen of cattle and are important in ruminant metabolism. The small amounts used in grain preservation, however, would likely result in little added nutritional value.

Other acids being tested are formic butyric, isobutyric, benzoic and a few salts such as sodium propionate and ammonium isobutyrate. Salts are less effective pound for pound than acids but are relatively non-corrosive and safer to handle.

Acid-type grain preservatives inactivate fungi (molds) and related microorganisms and continue to prevent mold growth for one year or longer when applied at the proper level and with proper storage conditions. However, keep in mind that acid preservatives are not an antidote for toxins produced by harmful molds which may have been present in the grain at harvest. The acid penetrates the grain kernel and lowers the pH to about 4 or 4.5. The germ of the grain kernel is killed, so there is essentially no respiration or other biological activity. The process is similar to preserving food in vinegar.

Laboratory tests at Kansas State University indicated pH was of less importance in preservation than the kind of acid. Lactic acid showed little or no effectiveness as compared to similar levels of propionic or a mixture of propionic and acetic acid.

Advantages

1. The preservative effect of acid is retained after grinding and mixing the grain with supplements. Treated high-moisture grain can be ground and mixed into a ration and held in storage or kept in a self-feeder for a couple of weeks or more without spoilage.
2. Using organic acids does not slow the harvesting operation. Acids can be used in conjunction with heat drying of grain. When combining of grain outstrips drying capacity, the excess can be treated with acids and used for livestock feed.

3. Acid-treated grain can be stored in a barn or other temporary storage facility. If stored outside, the treated grain must be protected from weather with plastic covers or by other means.

Disadvantages

1. Acid-treated grains must be used for livestock feed. The grain will not be accepted by elevators or by the grain trade without a price discount.
2. Acids are corrosive to metal or concrete bins. They may corrode steel feeders and other metal equipment such as wagons and augers.
3. Bridging in self-feeders may be troublesome with high-moisture grains.
4. The cost of using organic acids is estimated to be slightly greater than the cost of drying the same grain if metal storage bins are used (Table 1). For grain with moisture greater than 30 percent, organic acids become uneconomical because of the quantity of acid needed.

Table 1. Economic comparison of alternative grain storage systems for 20,000 bushels corn on livestock farms.

Harvest information

Days (harvest 220 acres of 90 bu./acre corn with a 4-row combine)

Commercial dry and store: 15
Dry batch-in bin, store metal bins: 18
Acid treatment, store metal bins: 12
High-moisture airtight storage: 12
High-moisture stave silo storage: 12

Beginning moisture (percent)

Commercial dry and store: 26
Dry batch-in bin, store metal bins: 28
Acid treatment, store metal bins: 28
High-moisture airtight storage: 29
High-moisture stave silo storage: 29

Average moisture (percent)

Commercial dry and store: 23
Dry batch-in bin, store metal bins: 23 **Acid treatment, store metal bins: 24** **High-moisture airtight storage: 26** **High-moisture stave silo storage: 26**

Harvest losses (percent)

Commercial dry and store: 6.5
Dry batch-in bin, store metal bins: 5.7 **Acid treatment, store metal bins: 5.2** **High-moisture airtight storage: 5.0** **High-moisture stave silo storage: 5.0**

"Added" losses over 5 percent

Commercial dry and store: 1.5
Dry batch-in bin, store metal bins: 0.7 **Acid treatment, store metal bins: 0.2** **High-moisture airtight storage: —** **High-moisture stave silo storage: —**

Drying and storage information

Ending moisture (percent)

Commercial dry and store: 14
Dry batch-in bin, store metal bins: 14 **Acid treatment, store metal bins: 24** **High-moisture airtight storage: 26** **High-moisture stave silo storage: 26**

Points removed

Commercial dry and store: 9
Dry batch-in bin, store metal bins: 8
Acid treatment, store metal bins: —
High-moisture airtight storage: —
High-moisture stave silo storage: —

Drying and storage losses (percent)

Commercial dry and store: 2.0

Dry batch-in bin, store metal bins: 1.0

Acid treatment, store metal bins: —

High-moisture airtight storage: 3.0 High-

moisture stave silo storage: 5.0

Investment

(storage sufficient for about 21,000-22,000 bu. Acid treatment: bin capacity 14 percent greater than dry corn. Airtight: 25 x 65 silo, auger unloader. Stave: two 18 x 60 silos sized to remove 4 inches/day top unloader.)

Drying equipment

Dry batch-in bin, store metal bins: \$2,200

Acid treatment, store metal bins: —

High-moisture airtight storage: —

High-moisture stave silo storage: —

Bins or silos

Dry batch-in bin, store metal bins: \$17,000

Acid treatment, store metal bins: \$19,000

High-moisture airtight storage: \$38,000 High-

moisture stave silo storage: \$24,000

Other equipment

Dry batch-in bin, store metal bins: \$1,700

Acid treatment, store metal bins: \$1,700

High-moisture stave silo storage: \$8,000

Other investment

Dry batch-in bin, store metal bins: \$20,900

Acid treatment, store metal bins: \$20,700

High-moisture stave silo storage: \$32,000

Investment/bushel

Dry batch-in bin, store metal bins: 1.04
Acid treatment, store metal bins: 1.03
High-moisture airtight storage: 2.10 **High-moisture stave silo storage:** 1.60

Fixed costs

(Depreciation: metal bins for storage of acid-treated grain, 10 years; other storage bins and silos, 20 years; equipment, 10 years. Interest: $9\%/2 = 4.5\%$. Repairs: storage 1%; equipment 2%. Tax and insurance 1.5%.)

Depreciation

Dry batch-in bin, store metal bins: \$1,240
Acid treatment, store metal bins: \$2,070
High-moisture airtight storage: \$2,300 **High-moisture stave silo storage:** \$2,000

Interest

Dry batch-in bin, store metal bins: \$940
Acid treatment, store metal bins: \$931
High-moisture airtight storage: \$1,890
High-moisture stave silo storage: \$1,440

Repair

Dry batch-in bin, store metal bins: \$248
Acid treatment, store metal bins: \$224
High-moisture airtight storage: \$460 **High-moisture stave silo storage:** \$400

Taxes, insurance

Dry batch-in bin, store metal bins: \$313 **Acid treatment, store metal bins:** \$310 **High-moisture airtight storage:** \$630 **High-moisture stave silo storage:** \$480

Total fixed costs

Dry batch-in bin, store metal bins: \$2,741 **Acid treatment, store metal bins:** \$3,535 **High-moisture airtight storage:** \$5,280 **High-moisture stave silo storage:** \$4,320

Fixed cost per bushel

Dry batch-in bin, store metal bins: 0.137 **Acid treatment, store metal bins:** 0.176 **High-moisture airtight storage:** 0.264 **High-moisture stave silo storage:** 0.216

Operating costs per bushel

Hauling and unloading

Commercial dry and store: 0.10
Dry batch-in bin, store metal bins: 0.012 **Acid treatment, store metal bins:** 0.012 **High-moisture airtight storage:** 0.025 **High-moisture stave silo storage:** 0.037

Drying fuel (L.P. 40 cents/gal)

Commercial dry and store: —
Dry batch-in bin, store metal bins: 0.046 **Acid treatment, store metal bins:** — **High-moisture airtight storage:** —
High-moisture stave silo storage: —

Electricity

Commercial dry and store: —
Dry batch-in bin, store metal bins: 0.012 **Acid treatment, store metal bins:** 0.006 **High-moisture airtight storage:** —
High-moisture stave silo storage: —

Acid (12 month storage)

Commercial dry and store: —

Dry batch-in bin, store metal bins: — Acid treatment, store metal bins: 0.306 High-moisture airtight storage: — High-moisture stave silo storage: —

Drying and storage fees

(drying charge 16 cents, storage 20 cents/month with 10 cent minimum)

Commercial dry and store: 0.40

Dry batch-in bin, store metal bins: — Acid treatment, store metal bins: — High-moisture airtight storage: — High-moisture stave silo storage: —

Total operating cost/bushel

Commercial dry and store: 0.50

Dry batch-in bin, store metal bins: 0.07 Acid treatment, store metal bins: 0.324 High-moisture airtight storage: 0.025 High-moisture stave silo storage: 0.037

Total cost per bushel

Fixed + operating

Commercial dry and store: 0.50

Dry batch-in bin, store metal bins: 0.207 Acid treatment, store metal bins: 0.50 High-moisture airtight storage: 0.289 High-moisture stave silo storage: 0.253

Adjustments

(based on corn at \$2.50 per bushel: high-moisture corn for beef is given a 5 percent credit for increased feed efficiency; no storage loss is charged for acid storage, increased energy from acid is assumed to compensate for any loss.)

Field loss (more than 5 percent)

Commercial dry and store: 0.037
Dry batch-in bin, store metal bins: 0.017
Acid treatment, store metal bins: 0.005
High-moisture airtight storage: —
High-moisture stave silo storage: —

Storage loss

Commercial dry and store: 0.05
Dry batch-in bin, store metal bins: 0.025
Acid treatment, store metal bins: — **High-**
moisture airtight storage: 0.075 **High-**
moisture stave silo storage: 0.125

Feed efficiency (beef credit)

Commercial dry and store: —
Dry batch-in bin, store metal bins: — **Acid**
treatment, store metal bins: (0.125) **High-**
moisture airtight storage: (0.125) **High-**
moisture stave silo storage: (0.125)

Total adjustments (costs)

Commercial dry and store: 0.087
Dry batch-in bin, store metal bins: 0.042
Acid treatment, store metal bins: (0.12)
High-moisture airtight storage: (0.05) **High-**
moisture stave silo storage: 0

Net cost/bushel (beef)

Commercial dry and store: 0.587
Dry batch-in bin, store metal bins: 0.249 **Acid**
treatment, store metal bins: 0.38 **High-moisture**
airtight storage: 0.239 **High-moisture stave silo**
storage: 0.253

Net cost/bushel (hogs)

Commercial dry and store: 0.587

Dry batch-in bin, store metal bins: 0.249 Acid treatment, store metal bins: 0.505 High-moisture airtight storage: 0.364 High-moisture stave silo storage: 0.378

Cash flow per bushel

Years to pay

Dry batch-in bin, store metal bins: 5 Acid treatment, store metal bins: 5 High-moisture airtight storage: 8 High-moisture stave silo storage: 8

Investment/bushel

Dry batch-in bin, store metal bins: 1.04 Acid treatment, store metal bins: 1.03 High-moisture airtight storage: 2.10 High-moisture stave silo storage: 1.60

Annual principal and interest payment

(amortized loan at 9% interest)

Dry batch-in bin, store metal bins: 0.267 Acid treatment, store metal bins: 0.264 High-moisture airtight storage: 0.379 High-moisture stave silo storage: 0.289

Repairs, taxes, insurance

Dry batch-in bin, store metal bins: 0.028 Acid treatment, store metal bins: 0.027 High-moisture airtight storage: 0.054 High-moisture stave silo storage: 0.035

Operating cost

Commercial dry and store: 0.50
Dry batch-in bin, store metal bins: 0.07 Acid
treatment, store metal bins: 0.324 High-moisture
airtight storage: 0.025 High-moisture stave silo
storage: 0.037

Total cash per bushel per year

Commercial dry and store: 0.50
Dry batch-in bin, store metal bins: 0.365 Acid
treatment, store metal bins: 0.615 High-moisture
airtight storage: 0.458 High-moisture stave silo
storage: 0.361

Adjustments (beef)

Commercial dry and store: 0.087
Dry batch-in bin, store metal bins: 0.042 Acid
treatment, store metal bins: (0.12) High-moisture
airtight storage: (0.05) High-moisture stave silo
storage: 0

Adjustments (hogs)

Commercial dry and store: 0.087
Dry batch-in bin, store metal bins: 0.042 Acid
treatment, store metal bins: 0.005 High-moisture
airtight storage: 0.075 High-moisture stave silo
storage: 0.125

Net cash flow per bushel (beef)

Commercial dry and store: 0.587
Dry batch-in bin, store metal bins: 0.407
Acid treatment, store metal bins: 0.495
High-moisture airtight storage: 0.408
High-moisture stave silo storage: 0.361

Net cash flow per bushel (hogs)

Commercial dry and store: 0.587

Dry batch-in bin, store metal bins: 0.407

Acid treatment, store metal bins: 0.620

High-moisture airtight storage: 0.533

High-moisture stave silo storage: 0.486

Feeding value

The feeding value of acid-treated high-moisture grain is usually considered to be equal or superior to dry grain for cattle and equal to dry grain for hogs.

In six trials at Iowa State University high-moisture corn treated with either propionic or ammonium isobutylic acid had the same or slightly greater feed value on a dry matter basis for cattle as heat-dried shelled corn. Dry matter losses during handling and storage were less for acid treated than for heat-dried corn grain. On the basis of dry matter stored, the acid-treated grain was used from 7 to 11 percent more efficiently than heat-dried grain.

Other studies have indicated the dry matter in acid-treated grain is used more efficiently by cattle than that in heat-dried grain. For example, acid-treated high-moisture corn and milo were similar in feed value to that ensiled when fed to cattle in studies at Ohio, Illinois, and Kansas experiment stations. The dry matter in ensiled high-moisture shelled corn has been used 3 to 5 percent more efficiently than that in dry-shelled corn by beef cattle in many research trials. Ensiled high-moisture milo has often shown a 5 to 8 percent improvement for beef cattle.

Economics

From a cost of storage standpoint, acid treatment appears to have the greater economic advantage when used on an emergency basis for temporary storage or where suitable acid storage facilities already exist. When new storage facilities are being considered, acid treatment may not have an economic advantage.

An economic comparison of acid treatment with both dry and other high-moisture storage systems is shown in Table 1. To avoid farm cost variation because of differences in existing structures, the comparison assumes purchase of all new equipment. Most farmers already have some facilities and these must be considered when comparing on a specific farm.

The investment cost of facilities for acid treatment is about the same as for a farm grain-drying system, when metal bins are used in both systems. More storage space is required for wet corn than dry corn. Metal bins used to store acid-treated grain should also be equipped for aeration. Original equipment cost is lower for acid storage in metal bins than for other high-moisture systems.

The fixed cost for acid storage is greater than dry storage in metal bins. Because acid is corrosive to metal bins, they are depreciated in 10 rather than 20 years for other storage facilities. The useful life of metal bins can be extended by treating them against acid corrosion. However, this increases their cost. Since silo systems have a higher investment cost, they have higher fixed costs than for the acid system.

The acid system has higher operating costs. The cost of acid on a per bushel basis is currently greater than that of drying fuel. Since high moisture silo storage doesn't require drying fuel or acid, the per bushel operating costs are lower for those systems.

When comparing the total cost of acid storage to that of other storage methods, consider differences in losses, labor, and feed efficiency. High-moisture systems, including acid treatment, may result in more rapid harvest which can result in reduced field losses. These systems are also credited for having improved feed efficiencies for beef cattle.

When new facilities are considered, total per bushel cost for acid storage appears higher than for other on-farm storage systems. Acid storage, however, can be competitive with commercial drying and storage. Since many farmers already have facilities suitable for storage of acid-treated corn, cost comparisons could change.

Cash flow. Probably more important than cost, for many farmers, is cash flow — especially for farmers who must borrow to pay for the facilities. When comparing annual cash flow requirements between systems, a critical step is finding the actual loan terms for each system. These vary, depending on the farmer's individual situation.

The example near the bottom of Table 1 assumes that the farmer will borrow 100 percent of the required investment and that he can get a 5-year loan on the bin systems and an 8-year loan on the silo systems.

After the loan is repaid, the annual cash flow requirement becomes essentially the operating cost, plus repairs, taxes and insurance. The longer the repayment period, the longer the high level of cash flow will be required.

In years of a short crop, the principal and interest payment must still be made. In these years the cash flow requirement will actually be higher on a per bushel basis because the total payment is spread over fewer bushels. The cash requirement for operating cost will be the same on a per bushel basis regardless of the number of bushels produced.

Acid treatment requires a high operating expenditure because of the cost of acid. However, when used with existing structures for temporary storage, the farmer is not obligated to long-term principal and interest payments.

Application

Acids for preserving high-moisture grain should be applied immediately after harvest. In warm weather there will be considerable microbial growth, heating, and off-odors in high-moisture grain a few hours after harvest. Thus it is recommended that acid be applied to the grain within four to six hours after harvest. Moisture content of 14 percent is high enough for storage molds to damage grains slowly. Higher moisture levels cause faster spoilage. Shelled corn with more than 15 percent moisture cannot be safely stored in conventional bins.

The rate of application of the acid is directly proportional to the moisture level of the grain, length of storage desired and type of acid used. The amount of propionic to use varies from 3 to 9 fluid ounces per bushel. For winter storage about 4 to 6 ounces are needed per bushel of high-moisture grain, and for summer 6 to 9 ounces are required. A larger amount is needed when acetic and propionic are mixed than when propionic is used alone.

Approximately twice as much acetic as propionic is needed. Consult the company's literature for the amount of their product needed for different moisture levels in the grain. Table 2 gives the recommended application rates for propionic acid.

Table 2. Ounces of propionic acid to apply per bushel of grain.

Grain moisture (%)	Storage termination time		
	April 1	July 1	Sept. 1
21 or less	3	4	6
22 to 25	4	6	8
26 to 30	6	8	9

The flow rate of acid and grain must be carefully controlled to ensure the distribution of a small amount of liquid throughout the grain. Untreated grain will cause pockets of spoiled grain in a bin. The most reliable point of treatment is prior to the entry of the whole grain into an auger.

Equipment

An applicator to meter acid on the grain can be purchased for \$750 or more. If your applicator contains an auger, it will cost about \$1,400. The auger is not essential since a 6-inch diameter grain auger works satisfactorily. If ground ear corn is treated, two augers in succession should be used to provide a good mix of the acid with the grain. Most applicators cut off the auger if the acid flow stops to prevent untreated pockets of grain. Applicators usually have a capacity of 1,000 bushels an hour.

A blower should not be used to move treated grain for 30 minutes or more after treatment, to allow time for the acid to penetrate the grain kernels. The wetter the grain, the faster the absorption rate.

Buy or rent a moisture tester, which should be used every morning, since accurate moisture determination is necessary for the correct application of acid. A meter with a testing range of 15 to 35 percent moisture should be used. Moisture testers at a local elevator may not be capable of testing moisture at a level this high. Electronic moisture testers are available. Check the accuracy of the meter by cross-checking a grain sample with a local elevator.

Grain with much trash will not give an accurate reading. The trash should be removed from the sample to get a correct moisture test. Then estimate the extra treatment needed for the trash by increasing the moisture reading by 15 percent, and use the latter to figure the treatment level. Remember that over-treating is better than under-treating; but over-treating is costly. Ordinary grain augers should be washed out every day to prevent corrosion from the acid.

Storage facilities

Acid is corrosive to steel, especially galvanized metal. It may also react with concrete, especially in warm weather. Grain bins should be lined with plastic sheets or coated with an anti-corrosive paint or plastic film. Organic acid-treated grain can be stored in wooden, aluminum, or fiberglass bins without protective coating.

Storage of acid-treated high-moisture grain outside in uncovered piles has sometimes been successful. Heavy rains and warm weather are likely to cause extensive spoilage of treated grain in unprotected piles exposed to the weather. Covering the grain pile with plastic will keep off rain and snow, but it will cause moisture accumulation and spoilage at the top of the pile.

Moisture migration is a problem in bins as well as in piles of grain. This migration of moisture occurs when there are temperature differences in various parts of the bin of grain. As the grain pile cools during fall and early winter, the moisture is moved up through the relatively warm center of the pile and condenses on the cold grain at the top. This causes a wet pocket of grain in the top center of the bin. Grain at the top of the bin may be 10 percentage points higher in moisture than the average moisture for the bin. This condensation at the top of the bin is best avoided by using low-volume aeration to cool the grain uniformly. Moisture migration is most likely in large bins of grain and grains put in during warm temperatures of 60 to 70 degrees Fahrenheit or higher.

One supplier recommends aeration of all volumes greater than 1,500 bushels until grain temperature is below 55 degrees Fahrenheit. The top of the grain pile should be leveled off to reduce moisture condensation in the peaks of the grain. The ventilation of air space above the stored grain is also helpful.

Grain should be checked continually for insect infestation and for hot spots or possibility of grain going out of condition. There is no evidence that acid-treated grains are resistant to insect infestation.

Safety

These acids are mildly caustic and will burn the skin. Wear goggles, a respirator, and rubber or plastic gloves, shoes, and apron in handling the acids. Leather will absorb acid. Avoid breathing fumes during filling or when entering a freshly treated grain bin a day or two after treatment.

Treat outdoors if possible. Indoors, provide proper ventilation to prevent vapor concentration great enough to cause eye and respiratory irritation. Avoid smoking or having an open flame or heating device in treatment storage areas. A quantity of fresh water should be kept close by in case of an acid spill.

If liquid is spilled on clothing, remove clothing and wash exposed skin area thoroughly. Keep an extra change of clothing near the treatment area. Contaminated clothing should be washed before wearing.

Selling treated grain

Acid-treated grain must be used for livestock feed. It will not be accepted by an elevator or other commercial trade channels without a dock. After grain is treated with organic acid, it retains the odor of the acid. This odor diminishes with time, but traces usually remain for the entire storage period.

In addition, a slight sour odor may develop in treated grain in late spring or summer. These odors do not affect its acceptability to livestock. They will, however, cause corn to be graded as sample grade in the commercial trade. This limits treated grain to livestock feed on the farm where it is produced or to sell for livestock feed through channels where no official grading is required.

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