MANURE MANAGEMENT, TREATMENT, AND UTILIZATION

What We Need to Know about Additive Products for Manure Treatment

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A variety of technologies are available for manure management to reduce odor and gas emissions, keep nutrients in manure, and make manure handling easier. Manure additives are one of the technical options for managing and treating livestock and poultry manure. Because manure additives are often put in manure storage pits, they are sometimes also called "pit additives."

Practices of manure treatment using additives were introduced from Europe to the U.S. as early as the 1890s (Midgley and Mueller, 1940). The first additives were chemical preservatives, such as acid phosphate, used mainly for poultry manure treatment to reduce ammonia loss. After decades of development, more than 50 commercial manure additive products are currently available in North America (Table 1), most of them proprietary. The objective of this publication is to provide a research-based overview for users and potential users of manure additives.

Why invest in manure additives?

Manure additives are generally used by producers for one or more of three reasons:

- To improve air quality by reducing releases of ammonia, hydrogen sulfide, and other odorous gases from manure;
- To preserve nutrients, usually nitrogen, in manure; and
- To reduce solids and liquefy manure for better handling.

Effectiveness of manure additives

Information about the effectiveness of specific manure additives is important for users to make decisions when selecting and purchasing the products. So far, there are mixed results on the consistency and effects of manure additives, especially over long terms. Some additives, e.g., products to acidify manure, can have consistent effectiveness of ammonia emission reduction by 35 to 99% (Nahm, 2003). However, many other products were found to have little or no effect on reducing odor or gas releases (Tengman et al., 2001). Information on effectiveness is available from several different sources, but for many products there are only the manufacturers' unwarranted claims. The duration of effectiveness can also vary, lasting from 24 hours or less to over a period of months.

Manure Additives

Manure additives come in different forms. [A]

Acid chemical additives can reduce barn ammonia emission.

A manure additive shows swine odor reduction. [B]

Some additives are used to improve manure handling.

Scientific research reports

Scientific research reports can be based on observations (e.g., Faith, 1964) and, more recently, on controlled laboratory or field studies that employ measurement instruments or sensors to quantify the effectiveness of manure additives. However, only a small portion of the commercial additives have been tested by third party researchers (Table 1).

A number of controlled experiments on additives have been conducted in the U.S. and other countries, in laboratory as well as field conditions. Controlled experiments are designed to compare differences between additive-treated manure with non-treated manure. Differences can be odor/gas releases from the manure, nutrient retention in the manure, or physical properties of the manure. Statistical analyses are applied to the experimental results to come up with conclusions.

Controlled experiments have been conducted on single and multiple additives. Multiple-additive experiments allow side-by-side comparison of the additives under tests. The laboratory studies with the largest number of additives featured 22 (Warburton et al., 1980; Wheeler et al., 2011) and 35 (Tengman et al., 2001) commercial products (Figure 1).

Figure 1. A controlled laboratory study for the effectiveness of 35 commercial manure additives.

The larger the field test scale, e.g., in multiple commercial swine barns, the fewer additive products can be tested, because these tests are expensive, especially when comprehensive environmental monitoring and frequent odor and manure analyses are involved (Figure 2).

Reports of controlled scientific research usually contain detailed descriptions of methods of evaluations, test results and conclusions. In principle, these descriptions allow step-by-step replication of the studies by others, although in reality an additive test by one researcher group is rarely replicated exactly by other researchers. A number of scientific research papers on manure additive studies is available online or from other public scientific information sources.

However, controlled experiments also have limitations. Laboratory studies engage only small fractions of manure, compared with actual on-farm manure pits or other storages. Therefore, they may not be flawlessly representative of real

Figure 2. Odor air sampling at a pit fan in the field study of an additive at finishing swine barns.

manure storage situations due to scale effects and other environmental factors, such as variations of wind and temperatures on the farms. Controlled field studies actually can also be subject to uncontrollable test circumstances, such as difficulties finding sufficient number of identical testing manure pits or maintaining the same test conditions during the tests. Moreover, both laboratory and field studies can be limited by experimental design (e.g., number of replicates), instrumentation, methodologies, or data processing and analysis tools.

Nevertheless, controlled experiments are still the best available scientific approach for evaluating the effectiveness of manure additives and providing valuable information.

Extension publications and presentations

Extension publications and presentations are prepared for producers and the public using science-based information sources. They summarize the latest scientific knowledge in lay language and provide practical advice and instructions to users for their decision making. Some recent Extension publications on manure additives are in the Reference list marked with an asterisk (*).

Manufacturers' product descriptions and anecdotal testimonials

A product description provides information, including instructions and effectiveness data, from the manufacturer or distributor. The exact product composition is not typically provided because it is proprietary. For general-purpose chemicals, such as sulfuric acid, their effectiveness as manure additives will not be specified by manufacturers unless the products are packed or further processed (e.g., mixed with other products) specifically for manure treatment.

Positive anecdotal accounts are often quoted from producers who applied certain manure additives and observed encouraging and beneficial effects. These testimonials are published in sales literature to promote the spreading of product use (Houtsma, 1997). Many of these testimonials are available in the product descriptions and websites of the additive manufacturers and distributors. Although negative accounts exist, they are not typically published.

Word-of-mouth

Producers who have used additives share experiences, usually based on direct or indirect observations, about the products' effectiveness. For example, some producers may describe seeing manure liquefying after an additive product was poured on top of manure crusts; others may have learned from neighbors about the reduction of odor offensiveness. Word of mouth plays an important role in the adoption of additive products among various users.

Commercial manure additives

About 90 manure additive products have been documented in North America. Excluding chemicals, more than 50 such products are currently available in the U.S. and Canada market (Table 1). These numbers change over time as new products are developed and put into the market and old products are phased out. Some products adopt new names for marketing purposes. There are no readily available statistics about which additive products are the most popular, effective, and economically feasible. The current commercial manure additives can be categorized based on their physical forms, working principles, and targeted uses.

Forms of manure additives

The physical forms of manure additives are usually liquid or solid.

- Many commercial manure additives are in liquid form. Liquid additives are relatively easy to prepare (e.g., dilute to desired concentrations) and apply by spraying onto manure surfaces or by pouring directly into manure pits.
- Solid manure additives are easy to store and transport. Some are granular or powders that can be dissolved in water before application or directly applied onto manure surfaces.
- Another form of additive is self-dissolving solids in different shapes. Once introduced into manure pits or lagoons, they slowly release the contents of additive products into the liquid manure over a period of time. Two such products are ASI BioBlocks and ASI Pit Slammers™ (Hog Slat, Inc., Newton Grove, NC).
- There are also dissolvable additives packed in small containers of different shapes, e.g., balls or bricks. The containers are dropped in liquid manure during application (Figure 3).

Figure 3. Bagged manure additives, ball-shaped Agrasphere®, and brick-shaped Agraslat® (Bioverse Inc., Pipestone, MN).

How do manure additives work?

Working principles for manure additives in the market or under development can be roughly grouped under one or more of the following criteria:

Chemical: acids, oxidizing agents, disinfectants

Microbiological: bacteria microbes

Biochemical: enzymes, urease inhibitors

Physical: absorbents, barriers

Physiological: masking agents

Additive products based on chemical, microbiological, or biochemical principles are the most popular. A few additives using physical principles have been reported (e.g., oil floating on manure surface as a barrier preventing odors and gases from releasing into the air). Additives based on physiological principles reduce odor perception and are often sprayed or diffused into the air above the manure storage, whether indoor or outdoor. Sometimes they can be applied directly onto the manure surface.

For most products on the market, the names of additives normally only describe their use and effectiveness for marketing purposes. The working principles are often provided in the product descriptions or data sheets.

Generally speaking, the chemical and physical effects of the additives on the manure itself, the aerial emissions from the manure, and the physiological effects on human sensory perceptions are relatively verifiable and explainable. However, when it involves very complex microbiological or biochemical processes, the mechanisms of manure conversion and emission reduction are far from fully characterized and understood, although most of these processes are perceived and explained as assisting the degradation of cellulose fibers, proteins, fats, and other manure components.

Chemical products

Most additive products treat manure chemically because they alter manure properties, e.g., pH. Early attempts from the end of the 19th century to reduce ammonia concentrations and emissions at poultry buildings mostly used chemicals by lowering the manure pH using acids or accelerating organic compound oxidation using oxidizing agents.

Since the 1990s, chemical additives, mainly acids, have received more attention for their use in the poultry industry. In some European countries, they are also applied in swine manure to reduce ammonia emissions. Chemicals that have been tested or applied in poultry houses include, but are not limited to:

- Super-phosphate ($Ca(H_2PO_4)_2$) (Cotterill and Winter, 1953)
- Paraformaldehyde $OH(CH_2O)_nH$ (n = 8–100) (Seltzer et al., 1969)
- Phosphoric acid (H_3PO_4) (Reece et al., 1979)
- Sulfuric acid (H_2SO_4) (Stevens et al., 1989)
- Aluminum sulfate ($Al_2(SO_4)_3$) (Do et al., 2005)
- Aluminum chloride ($AlCl_3$) (Smith et al., 2004; Lim et al., 2008)

Other chemicals that reportedly reduce odors:

- Calcium peroxide (CaO_2) (Govere et al., 2005; Govere et al., 2007)
- Hydrogen peroxide (H_2O_2) (Govere et al., 2005; Govere et al., 2007)
- Potassium permanganate ($KMnO_4$) (Faith, 1964)
- Disinfectants (Faith, 1964)

Plants, minerals, and soils

Certain plants, minerals, soils and their extracts were found useful for treating manure. They can react with manure physically, chemically, and/or biochemically, although the detailed mechanisms are often not known. Some of these include:

- Minced horseradish roots (Govere et al., 2005; Govere et al., 2007)
- Yucca saponin (Saponins are a class of chemical compounds found in various plant species) (Nahm, 2005)
- Zeolite (Nahm, 2005)
- Gypsum (Cotterill and Winter, 1953)
- Lime (Cole et al., 1976)
- Nitrifier seeds, a material obtained from the top centimeters of the dirt floor of a chicken house, or Houston Black clay soil (Tasistro et al., 2007)
- Soybean peroxidase (SBP), an enzyme found in the root, leaf, and hull of the seed Glycine max (Koziel et al., 2014)

Microbiological and biochemical products

Microbiological or biochemical additives come with bacteria, enzyme, or antibiotic products. They can also be microbial-resistant materials, such as humic additives, which are extract solutions from partially decomposed stable organic matter (Brandt et al., 2016).

These products are more complicated to describe in detail compared with other types of additives. Some of the commonly reported types include:

- Urease inhibitors (e.g., Varel, 2002)
- Antibiotics
- Blends of bacteria (e.g., Alken Enz-Odor® 5, Alken-Murray Co., New Hyde Park, NY. See Table 1).

Additive product names and name changes

The names of additives can change over time, for various reasons. Some commercial products adopt new names after improved formulation and effectiveness, modified packaging, or altered application methods. In such cases, explanations about the product's chronological modifications might be available. Other products use new names to renew their public image, although their formulation may remain essentially the same. In those cases, product tracking is usually not available.

Manure additives under development and testing

Some manure additives were developed and tested but might not be marketed the same. An example is Alliance®, which was tested in commercial swine barns (Heber et al., 2000). But the product with the same name has not been found in the searchable market resources.

Additives developed for non-manure use

Some additives that have been applied were originally developed for other applications. An example is the NRP products (NRPGroup, Inc., Wichita, KS), which were sold for wastewater treatment plant (WWTP) applications. Because of the similar chemical and biological characteristics between liquid organic wastes from agriculture, such as manure, and those from other sectors, such as WWTP sludge, such products have been accepted for manure treatment, or sold in attempts to find new markets.

Cost of manure additives

Costs of additives for manure treatment differ significantly. The following factors should be considered.

Application equipment

Most additives do not require special equipment, so this cost factor is uncommon. The cost of special equipment varies substantially, depending on complexity of the facility. The equipment will involve capital, operational, and maintenance costs.

Additive product

This will include the cost of the products, and may also include shipping and handling. Costs of additive products are calculated with different application dosages. For example, the list price of MicroPT™ (Hog Slat, Inc.) is $191.45 for a 2.5-gallon container. Application rate is 1 gallon per 100,000 gallons of waste. A one-million-gallon manure storage needs $1,914 of MicroPT™ additive.

Labor and service

Labor costs depend on how easy and how frequent the additive is applied and the local labor markets. Some additive product manufacturers and distributors offer additive application services. The costs of these services can usually be clearly calculated.

Cost effectiveness

Research has demonstrated cost effectiveness of certain manure additives, e.g., alum to reduce ammonia release from poultry litter (Lorimor et al., 2002). However, calculation methodologies influenced overall cost-benefit analysis. Whereas the costs of manure additive applications are relatively easy to calculate, objectively obtaining the benefits is usually difficult because some benefits are intangible or impossible to quantify and monetize. An obvious example is the reduction in odor or gas emissions and improvement in public relations.

Handling and applications of manure additives

Safety precautions with manure additives

Some manure additives are chemicals or primarily based on chemicals that may be corrosive and hazardous (e.g., strong acids). It is very important to follow relevant safety practices to minimize risks when working with these products. Attention should be paid to health and physical hazards of the products during transportation, storage, and application. Read the Material Safety Data Sheet or other product guidelines of the product before handling and application.

Although different products have different specific requirements, there are some generally applicable safety precautions:

- Store the additive products in cool, safe, well-ventilated places, and avoid direct sunlight.
- Keep the products away from children and animals.
- Wear protective clothes and respiration masks as needed.
- Avoid excessive inhalation of the vapor from the additives.
- Wash hands with warm, soapy water after handling.

When applying manure additives, especially chemical additives, precautions should be taken for worker, animal, and property protection. Application instructions should be followed when applying additives. When power equipment is involved during application, relevant electrical and mechanical safety measures must be followed.

Some chemical-based manure additive products may entail rapid reactions with manure when applied and cause quick release of toxic gases, posing danger to workers and animals. A report in the Netherlands describes an incident in which hundreds of pigs died when lactic acid as a manure additive was poured into the deep pits of pig buildings and large quantities of poisonous hydrogen sulfide were suddenly released (Borst, 2001).

Applications of manure additives

Application methods needed for additive products vary, but most require only simple methods, such as pouring or spreading the products directly into the manure pits. Some products allow introduction through flush tanks, lift stations, or directly into the manure. Application may also require that it be done within certain ranges of ambient temperatures.

However, there are products that need to be sprayed evenly over the manure surface at certain time intervals. In these cases, automatic spraying devices are usually available from the manufacturers.

Application dosage and frequency

Recommended dosages of commercial additive applications provided by product manufacturers should be followed. Calculation bases for the quantity of additive application vary. The most common units are based on the following:

- Per manure volume, in gallons or cubit feet;
- Per manure pit surface area, in square feet;
- Per manure flow rate into lagoons, in gallons per minute;
- Per animal, in head per year (e.g., per cow per year);
- Per animal unit (1,000 lbs.), in animal unit per year.

Most additive products require reapplications after initial use at recommended intervals (e.g., every month or every week). For instance, the Inhibodor® (Conklin Company Inc., Kansas City, MO) requires an initial application of 2 oz. per 1,000 cubic feet of slurry and follow-ups of 0.5 to 1.0 oz. per 1,000 cubic feet of new slurry every 30 days. Other products may require more frequent reapplications after initial use.

The recommended dosages of follow-up applications differ significantly from product to product. For example, Hog Slat, Inc. (Newton Grove, NC) recommends double-dosage of their additive ASI Pit Hammer Plus for the first 2 to 3 months. Some manufacturers and distributers provide technical support to calculate application dosages and make recommendations.

Application time

Additives may require application times that depend on the time needed to reach desired effectiveness under particular situations and field conditions. For example, the Breatdown™ (Homestead Nutrition, New Holland, PA) for "pit rescue" requires application at least 40 days before hauling.

Images and photo in sidebar

[A] Images from the internet.
[B] From Wheeler et al. (2015). Used with permission.

References

(* Extension publications)

Amon, M., M. Dobeic, T.H. Misselbrook, B.F. Pain, V.R. Phillips, and R.W. Sneath. 1995. A farm scale study on the use of De-Odorase® for reducing odor and ammonia emissions from intensive fattening piggeries. *Bioresource Technology* 51(2-3):163-169.

Beke, M. 1997. Additives in slurry to decrease ammonia emission. In *International Symposium on Ammonia and Odour Control from Animal Production Facilities*. Vinkeloord, The Netherlands, Oct. 6-10: NVTL, Rosmalen, The Netherlands, eds, J.A.M. Voermans and G.J. Monteny. Vol. II. p. 635-639.

Borst, G.H.A. 2001. Acute intoxification of pigs with hydrogen sulphide as a result of acidification of slums. *Tijdschrift Voor Diergeneeskunde* 126(4):104-105.

* Brandt, R.C., H.A. Elliott, E.E. Fabian, M.L. Hile, and R.E. Mikesell. 2016. Manure additive shows swine odor reduction. G-111. University Park: The Pennsylvania State University. 6 p.

Cole, C.A., H.D. Bartlett, D.H. Buckner, and D.E. Younkin. 1976. Efficacy of certain chemical and biological compounds for control of odor from anaerobic liquid swine manure. *Journal of Animal Science* 42(1):1-7.

Cotterill, O.J. and A.R. Winter. 1953. Some nitrogen studies of built-up litter. *Poultry Science* 32(2):365-366.

Do, J.C., I.H. Choi, and K.H. Nahm. 2005. Effects of chemically amended litter on broiler performances, atmospheric ammonia concentration, and phosphorus solubility in litter. *Poultry Science* 84(5):679-686.

Faith, W.L. 1964. Odor control in cattle feed yards. *Journal of the Air Pollution Control Association* 14(11):459-460.

Govere, E.M., M. Tonegawa, M.A. Bruns, E.F. Wheeler, P.H. Heinemann, K.B. Kephart, and J. Dec. 2005. Deodorization of swine manure using minced horseradish roots and peroxides. *Journal of Agricultural and Food Chemistry* 53(12):4880-4889.

Govere, E.M., M. Tonegawa, M.A. Bruns, E.F. Wheeler, K.B. Kephart, J.W. Voigt, and J. Dec. 2007. Using minced horseradish roots and peroxides for the deodorization of swine manure: A pilot scale study. *Bioresource Technology* 98(6):1191-1198.

Heber, A.J. 2016. DryLet M2® H2S/Odor Reduction Study. Final Report. Purdue University, West Lafayette, IN. January 18.

Heber, A.J., J.-Q. Ni, T.-T. Lim, C.A. Diehl, A.L. Sutton, R.K. Duggirala, B.L. Haymore, D.T. Kelly, and V.I. Adamchuk. 2000. Effect of a manure additive on ammonia emission from swine finishing buildings. *Transactions of the ASAE* 43(6):1895-1902.

Holly, M.A. and R.A. Larson. 2017. Effects of manure storage additives on manure composition and greenhouse gas and ammonia emissions. *Transactions of the ASABE* 60(2):449-456.

Houtsma, J. 1997. *"Owner's report" on best, worst odor control products*. Farm Show 25(5): pp. 28.

Johnson, J. 1997. Final report - Evaluation of commercial manure additives. Waseca, MN: Agricultural Utilization Research Institute (AURI). October 1. 29 p.

Koziel, J., D. Maurer, K. Bruning, K. Kruger, B. Woodbury, M. Hayes, T. Brown-Brandl, D.B. Parker, G. Jarosh, J. Gray, and P. Baehr. 2014. Testing soybean peroxidase for swine manure treatment and mitigation of odorous VOCs, ammonia, hydrogen sulfide and greenhouse gas emissions. NPB #12-108. Ames, IA: Dept. of Agricultural and Biosystems Engineering, Iowa State University. May 6. 83 p.

Lim, T.-T., C. Wang, A.J. Heber, J.-Q. Ni, and L. Zhao. 2008. Effects of aluminum sulfate and aluminum chloride applications on ammonia emission from a high-rise layer barn. In *Mitigating Air Emissions from Animal Feeding Operations*. Des Moines, IA, May 19-20, eds, E. Muhlbauer, L. Moody, and R. Burns. p. 85-89.

Lorimor, J., S.J. Hoff, and P.T. O'Shaughnessy. 2002. Chapter 10. Emission Control Systems. In: Iowa Concentrated Animal Feeding Operations Air Quality Study, Final Report, Iowa State University and The University of Iowa Study Group. pp. 202-212.

Midgley, A.R. and W.O. Mueller. 1940. Effect of lime on the nitrogen content of cow manure. In: Vermont Agricultural Experiment Station Bulletin. Burlington, VT: University of Vermont and State Agricultural College. Vol. 456. pp. 2-20.

Nahm, K.H. 2003. Current pollution and odor control technologies for poultry production. *Avian and Poultry Biology Reviews* 14(4):151-174.

Nahm, K.H. 2005. Environmental effects of chemical additives used in poultry litter and swine manure. *Critical Reviews in Environmental Science and Technology* 35(5):487-513.

Ni, J.-Q. and A.J. Heber. 2005. Re-Evaluation of the Slick N' Clean Additive under Laboratory Conditions Based on National Pork Producers Council (NPPC) Protocol. Final Report to ADM Alliance Nutrition, Inc. West Lafayette, IN: Purdue University. March. 20 p.

Ni, J.-Q., A.J. Heber, T.T. Lim, S.M. Hanni, and C.A. Diehl. 2017. Laboratory evaluation of a manure additive for mitigating gas and odor releases from layer hen manure. *Aerosol and Air Quality Research* 17:2533–2541.

Reece, F.N., B.J. Bates, and B.D. Lott. 1979. Ammonia control in broiler houses. *Poultry Science* 58:754-755.

Seltzer, W., S.G. Moum, and T.M. Goldhaft. 1969. A method for the treatment of animal wastes to control ammonia and other odors. *Poultry Science* 48(6):1912-1918.

* Shah, S. and P. Westerman. 2011. Additives for improving hog farm air quality. In: eXtension Air Quality in Animal Agriculture. November. 11 p.

* Shah, S., P. Westerman, and J. Parsons. 2012. Poultry manure amendment. In: eXtension Air Quality in Animal Agriculture. January. 7 p.

Smith, D.R., P.A. Moore, B.E. Haggard, C.V. Maxwell, T.C. Daniel, K. VanDevander, and M.E. Davis. 2004. Effect of aluminum chloride and dietary phytase on relative ammonia losses from swine manure. *Journal of Animal Science* 82(2):605-611.

Stevens, R.J., R.J. Laughlin, and J.P. Frost. 1989. Effect of acidification with sulphuric acid on the volatilization of ammonia from cow and pig slurries. *Journal of Agricultural Science Cambridge*. 113:389-395.

Sun, F., J.H. Harrison, P.M. Ndegwa, and K. Johnson. 2014. Effect of manure treatment on ammonia emission during storage under ambient environment. *Water Air and Soil Pollution* 225(9,2094):1-13.

Tasistro, A.S., M.L. Cabrera, D.E. Kissel, and C.W. Ritz. 2007. Study on the reduction of NH3 volatilization from broiler litter through the promotion of nitrification. *Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering* 42(5):549-556.

Tengman, C.L., A.K. Gralapp, and R.N. Goodwin. eds. 2001. *Laboratory Testing of Manure Additives for Odor Control*. Des Moines, IA: National Pork Board, 197 p.

Vandenberg, C. and R. Elvestad. 2014. Evaluation of enhanced biological wastewater treatment product for livestock operations - Submitted to Environment Depot. Olds College. December 12.

Varel, V.H. 2002. Livestock manure odor abatement with plant-derived oils and nitrogen conservation with urease inhibitors: A review. *Journal of Animal Science* 80(E):1-7.

Warburton, D.J., J.N. Scarborough, D.L. Day, A.J. Muehling, S.E. Curtis, and A.H. Jensen. 1980. Evaluation of commercial products for odor control and solids reduction of liquid swine manure. In: Livestock Waste: A Renewable Resource pp. 309-313. St-Joseph, MI: ASAE.

Wheeler, E.F., M.A.A. Adviento-Borbe, R.C. Brandt, P.A. Topper, D.A. Topper, H.A. Elliott, R.E. Graves, A.N. Hristov, V.A. Ishler, and M.A.V. Bruns. 2011. Evaluation of odor emissions from amended dairy manure: preliminary screening. *Agricultural Engineering International: CIGR Journal* 13(2):1-20.

Wheeler, E.F., R.C. Brandt, M.L. Hile, and R. Mikesell. 2015. Humic manure additive reduces odor from Pennsylvania swine finishing operation. In *ASABE Annual International Meeting,* New Orleans, LA, July 26-29. Paper No. 152182471. St. Joseph, MI.: ASABE.

Zhu, J., D.S. Bundy, X.W. Li, and N. Rashid. 1997. Controlling odor and volatile substances in liquid hog manure by amendment. *Journal of Environmental Quality* 26(3):740-743.

Table 1. List of the current manure additives in North America

Additive name [1)]	Manufacturer or distributer	Main ingredient	Brief summary of claimed product effectiveness	3rd party test [2)]
AgraSphere / AgraSlat	Bioverse Inc., Pipestone, MN	Blend of bacteria and microbes	Lagoon activation, treatment, and maintenance.	
Agriculture Manure Treatment Blend	Acti-Zyme, Grand Forks, BC, CAN	Granular organic microbe	Reduce sludge buildup; break down and liquefy proteins, starches, carbohydrates, and fats.	L & F, 0 (Vandenberg and Elvestad, 2014)
Agri-Clean®	Aspen Veterinary Resources, Ltd. Liberty, MO	Wetting, dispersing and emulsifying agents	Removal of organic matter in poultry, swine and other livestock premises.	L, 0 (Tengman et al., 2001) [3)]
Alken Clear-Flo®	Alken-Murray Co., New Hyde Park, NY	Blend of bacteria	Control odors.	L, + for odors and hydrogen sulfide (Tengman et al., 2001); L, 0 for odors (Wheeler et al., 2011)
Alken Enz-Odor® 5	Alken-Murray Co., New Hyde Park, NY	Dry blend of bacteria	Liquefy, metabolize, deodorize. Not produced for manure, but tested for manure application.	L, 0 for odors (Wheeler et al., 2011)
ASI Pit Slammers™	Hog Slat, Inc., Newton Grove, NC	Bacterial spores	Reduce pit crusting and odor. In solid blocks that can be slipped through slatted floors.	
ASI Anti Foam	Hog Slat, Inc., Newton Grove, NC	N/A	Prevent and break down foam. Use with ASI Pit Hammer.	
ASI BioBlock	Hog Slat, Inc., Newton Grove, NC	Enzyme producing bacteria	Break down solids; reduce odors.	
ASI Maintenance	Hog Slat, Inc., Newton Grove, NC	Bacteria	Reduce organic solids; control odor; provide insect management.	
ASI Pit Hammer	Hog Slat, Inc., Newton Grove, NC	Bacteria	Digest and liquefy solids to reduce odor; control insect infestations.	
ASI Pit Hammer Plus	Hog Slat, Inc., Newton Grove, NC	Bacteria	Digest and liquefy solids to reduce odor; control insect infestations.	
BactZyme®	CA Biological Solutions Inc., Tulare, CA	Bacteria	Accelerate manure digestion; reduce odor. In solid form, self-dissolving.	
Bio-Charge	Bridgepoint Systems, Salt Lake City, UT	Bacteria, enzyme	Deodorize.	F, + (Johnson, 1997)
Bio-Regen Animal Waste	3 Tier Technologies, Longwood, FL	Aerobic/facultative microbes	Control odor and gases.	L, 0 for odors (Wheeler et al., 2011)
Breakdown™	Homestead Nutrition, New Holland, PA	N/A	Control odor; break down solids; maximize manure nutrient value.	
Crust Buster	Direct Biologicals, Inc., Yankton, SD	Bacterial and fungal enzymes	Degrade manure and plant fibers.	
De-Odorase®	Alltech, Nicholasville, KY	30% plant extract, yucca schidigera	Reduce ammonia; eliminate hydrogen sulfide and mercaptans.	F, + (Amon et al., 1995); F, + (Johnson, 1997)
EC-4000	EcoChem Organics, Hanna, AB, CAN	Micronutrient / Biostimulant from plant extracts	Reduce odors.	
EC-4020	EcoChem Organics, Hanna, AB, CAN	Essential nutrients	Reduce odors and ammonia.	
Eco-Cure	Eco-Cure, Inc., Corte Madera, CA	Enzyme	Control odors.	L, 0 (Ni et al., 2017)
EM-1 Waste Treatment	TeraGanix, Inc., South Alto, TX	Microbial	Deodorize.	
GVC Farm Digestant #610	GVC Farm Supply, East Rockaway, NY	Bacterial digestant	Eliminate odors; reduce buildup of solids and gases; increase fertilizer value.	
GVC Farm Digestant #630	GVC Farm Supply, East Rockaway, NY	Natural bacillus bacteria	Reduce gases and insects; retain fertilizer values.	
Inhibodor®	Conklin Company Inc., Kansas City, MO	Yucca schidigera plant extract	Reduce gases and odors.	L, + for hydrogen sulfide (Tengman et al., 2001),
LIQUID IN-GEST-O-BAC	Tomco Chemical, Wantagh, NY	Miro organism	Reduce hydrogen sulfide, BOD, and COD.	
Manure Defoamer	ProfitProAG, Albert Lea, MN	Essential oils	Remove foam at manure pump out.	
ManureMagic™	Drylet, McKinney, TX	Microbes	Reduce odors; liquefy manure.	Tested Drylet's M2®; L, + for odor and hydrogen sulfide (Heber, 2016)
Manure Master™ Dry Concentrate	ProfitProAG, Albert Lea, MN	Bio-vitamins, probiotics and select bacteria cultures	Digest organic solids; reduce odor and gas emissions.	
Manure Master™ FoamAway	ProfitProAG, Albert Lea, MN	Bacteria, enzyme	Knockdown foam in swine facilities.	
Manure Master Plus™	ProfitProAG, Albert Lea, MN	Organic nutrients, essential elements and microbes	Enhance manure digestion and liquefaction; reduce odors.	

continued...

Additive name [1]	Manufacturer or distributer	Main ingredient	Brief summary of claimed product effectiveness	3rd party test [2]
ManureMax	JDMV Holdings LP, Houston, TX	Organic Humus (Fulvic)	Reduce odor.	L & F, + (Wheeler et al., 2015)
MICROBE-LIFT / AOE	Ecological Laboratories Inc., Freeport, NY	Bacteria, enzymes	Removes odors. It contains 4 AOE- products.	
MICROBE-LIFT / DFP	Ecological Laboratories Inc., Freeport, NY	Bacteria, enzymes	Reduce solids and odor; improve manure value. For dairy farm use.	
MICROBE-LIFT / EQ	Ecological Laboratories Inc., Freeport, NY	Bacteria, enzymes	Reduce odor and ammonia; improve waste fertilizer value; accelerate degradation of cellulosic materials. For equine farm use, including 3 products.	
MICROBE-LIFT / HOG	Ecological Laboratories Inc., Freeport, NY	Enzymes	Reduce solids and odor; improve manure value. For hog farm use.	
MICROBE-LIFT / Sludge-Away	Ecological Laboratories Inc., Freeport, NY	Bacteria, enzymes	Bind phosphate; help liquification and nutrient enhancement.	
Microbial Manure Master	ProfitProAG, Albert Lea, MN	Microbe	Break down manure and lock nutrients.	
MicroPT™	Hog Slat, Inc., Newton Grove, NC	Microorganisms	Liquefy solids; reduce ammonia odor.	
More Than Manure®	Verdesian Life Sciences, Cary, NC	Chemical	Reduce N and P losses; reduce solids.	L, 0, (Sun et al., 2014); L, 0 for solids and nitrogen (Holly and Larson, 2017)
Pit Accelerator™	ProfitProAG, Albert Lea, MN	Organic nutrients, essential elements and microbes	Stimulate manure digestion and liquefaction, reduce foaming and gases.	
Pit Additive Pack	Superior Crop Products, LLC, Linn Grove, IA	N/A	Tie up copper sulfate.	
Pit Boss™	Tramfloc, Inc., Tempe, AZ	Based upon hyper-soluble Cu	Control odor.	F, 0 (Beke, 1997); F, + (Johnson, 1997)
Pit Crew	Swine Vet Center P.A., St. Peter, MN	Blend of bacillus bacteria	Keep barn pits healthy. It includes Pit Crew B and Pit Crew SE.	
Pit Digester	Direct Biologicals, Inc., Yankton, SD	Microbes, enzymes	Liquefy solid manure; control odors.	
Pit FX	Superior Crop Products, LLC, Linn Grove, IA	Companion product for Micro PT™	Reduce crust and/or solid buildups. Companion product for Micro PT™.	
PIT Perfect	Assist Natural Products and Services LLC, Lena, IL	Amino acids, natural emulsifiers	Reduce odor, solids, and ammonia; stabilize nutrients for land application.	
Pit Power®	Crop Resources, LLC, Dorsey, IL	Bacteria, bacteria feeders	Reduce solids for easier pumping; reduce odor.	
Pro-Act Biotech	Pro-Act Biotech, Warren, RI	Microbes	Reduce odor and solids.	L, 0 for solids and nitrogen (Holly and Larson, 2017)
SHAC® Manure Digester	Shac Environmental Products Inc. Medicine Hat, AB, Canada	Humic carbon biostimulants	Control solids, odor and gases.	L, + (Zhu et al., 1997) F, + (Johnson, 1997)
Slick N' Clean®	ADM Animal Nutrition, Quincy, IL	Bacteria, enzymes	Reduce solids, odor, manure nitrogen, and ammonia.	L, + for hydrogen sulfide and odor (Ni and Heber, 2005)
SULFI-DOXX	Direct Biologicals, Inc., Yankton, SD	Microbes, lignin, oxidative compounds	Control hydrogen sulfide emissions during agitation and pumping; decrease foaming.	
SUPPRESS®	Westbridge Agricultural Products, Vista, CA	Organic nutrients	Control odors from manure, compost, lagoons, and standing water.	
Ultra Litter Treatment™	H & S Co., Alma, AR	Organic acids, sodium salts, yucca extract	Control ammonia.	
Waste Away®	Advanced Biologicals LLC, Clear Lake, IA	Bacteria, microbes	Digest sludge and crust; improve nutrient value; reduce odor and fly populations.	

Note: [1]A few listed additive products are not originally produced for manure use, but they were tested or applied for manure treatment; [2] The third-party tests were usually conducted by universities or research institutions. The test results can only be qualitatively indicated in this publication. "L" = laboratory test, "F" = field test, "+" = positive results reported, "0" = no effectiveness reported. Details can be found in the cited original reports. [3] Tested when the product manufacturer was Cal-Agri Products, Longwood, FL.

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