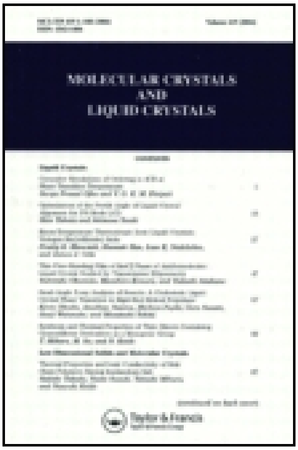

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# Industrial Application of Animal Manure Filled Thermoplastics

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*Animal agriculture is under increasing pressure to produce more and more meat, milk and eggs giving rise to an increasing amount of manures. In the past, manures have been viewed as a waste byproduct used mainly as a fertilizer that has a value of 2 to 4 cents per dry pound. We need to change our view of manures from waste to asset. Destroying manures by burning or lagooning may solve the environmental problem but it does nothing to add to animal income. One of the alternatives is to use animal manures in industrial products. Based on past research at the Forest Products Laboratory in the area of wood and agricultural flours and fibers as fillers in thermoplastics, this research program uses swine and cow manures as reinforcing fillers in HDPE and HDPP. This is a win-win situation as it increases the value of the animal manures, decreases the cost and improves mechanical properties of the thermoplastic composites. A 40% blend of dry swine manure with HDPE and 2% MAPE gives a composite with MOE in bending of 1.31 GPa and MOR of 34.7 MPa as compared to unfilled HDPE MOE of 0.75 GPa and MOR of 15.1 MPa. A 40% blend of dry dairy manure with HDPE and 2% MAPE gives a composite gives MOE in bending of 2.18 GPa and MOR 21.9 MPa as compared to 40% pine flour with 2% MAPE MOE 2.98 and MOR 33.4 MPa.*

**Keywords:** animal manures; bending; dairy; HDPE; HDPP; MOE; MOR; strength; swine; thermoplastics



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## INTRODUCTION

Livestock production in the United States has become increasingly concentrated. This concentration is the result of consumers demand for consistent and low cost animal protein. Both of these consumers' demands are being met with livestock concentration; however there has been the unintended consequence of high volumes of animal waste in small locations. This unintended consequence is causing the rapid demise of the livestock production because local communities and neighborhoods are refusing to allow new construction of livestock production facilities.

Animal agriculture is under increasing pressure from consumers to reduce the volume and impact of its wastes. Increasing cost of solving waste problems will be a certainty unless new technologies are developed. Traditionally manure was an asset to the animal producer, it now is a cost. Animals that were a welcome part of a community are now considered intruders by some.

Livestock manures are all very different. Pig, chicken, duck, cattle, etc. differ in both content and odor. The manure that is most available is from concentrated cattle feed lots and dairy operations. This will be the first manure to be investigated.

Animal agriculture has changed so dramatically in the past generation that many historic norms no longer exist. Fundamental problems and solutions need a new approach and as with most business changes, research and technology play a major role in solving the problems. To remain competitive, animal agriculture must solve the serious environmental and manure disposal problems.

The ultimate processing of manures will use the petroleum industry as a model to separate the useful components. These end products could include chemicals and biologically useful fractions such as fatty acids, proteins, sugars and fiber.

Changes in animal production have evolved size and scope from small family farms to very large producers of today. Confined animal feeding operations (CAFO) are an entirely new animal agriculture entity and have significantly impacted modern methods of animal protein production.

CAFO's are any operations which include a large population of animal confined in a relatively small space. CAFO's are viewed by the non-informed public as negative. The negative attitudes come from several perceptions: factory-type of feeding implying poor animal well-being practices, large corporate ownership instead of family farms, poor animal husbandry causing the use of high levels of antibiotics and large amounts of animal manure which frequently have an unpleasant odor for several miles.

CAFO's have evolved for many reasons but primarily based on the economics of livestock production. Changing mechanical technology allows larger operations to operate at lower cost; improved genetics promote faster and more efficient growth and changing animal nutrition to take advantage of the new genetics are all examples of how technology has changed the livestock production system.

Historically, manure was used by producers as fertilizer on their own land which they also used to grow feed for the animals. The amount of manure used was relatively small and since all the neighbors did the same, the odor problem was either overlooked or ignored. With today's CAFO's, the dynamics are hugely different. The neighbors do not all have animals, the amounts of manure a re very large, and the rural dwellers that work in town do not want their lifestyle affected by the unpleasant odor.

Animal agriculture producers generate nearly 50 million tons of animal waste annually. As a single example, 1260 dairy cows produce 25 million pounds of milk a year and generate 51 million pounds of wet manure.

Currently many State and local zoning restrictions prohibit the construction or expansion of CAFO's. This not only increases the CAFO size at the few local sites which accept them but also threatens the entire US animal feeding industry because many foreign countries are aggressively pursuing large scale animal production. In short, our animal industry is going overseas.

Finding non-fertilizer uses for animal waste is critical to the continued long term animal protein production in the United States. Preliminary research indicates that there are several opportunities that need to be developed. One area of great interest is the incorporation of animal manures as a reinforcing filler in thermoplastic composites.

Interestingly, the animal industries use a wide variety of plastic products including egg trays, feeding bays, internal walls, slotted floors, hutches, frames, and partitions, as well as building materials such as farrowing pens and paddock fences all of which use plastic products in current applications. The first applications of these manure filled thermoplastics is likely to be used in the same industry that generated the manure.

The purpose of this research was to incorporate different levels of both dairy and swine manures in HDPE and HDPP and investigate strength properties.

## EXPERIMENTAL

### Materials

Dairy manure that was mixed with straw bedding was collected from the University of Wisconsin experimental farms and dried. The dried manure was processed through a hammer mill and the fraction of less than 5 mm was collected.

Swine manure was collected from a farm in North Carolina, mixed with waste from a cotton mill, composted for 30 days, pelletized and dried.

### Methods

Different levels of dry dairy manure was compounded in a twin screw extruder with either an ExxonMobil HDPE or HDPP with or without a compatibilizer (maleic anhydride modified high density polyethylene, MAPE) at 163–176°C (325–350°F).

Different levels of dry swine manure was compounded in a twin screw extruder with an ExxonMobil HDPE with or without MAPE at 163–176°C.

Different levels of dry pine flour was compounded in a twin screw extruder with either an ExxonMobil HDPE or HDPP with or without MAPP at 163–176°C.

The extruded ribbon from each compounding was water cooled, chopped into pellets and the pellets were dried at 105°C overnight.

Each type of dried pellets was extruded in a single screw extruder into standard bending test specimens. Standard ASTM 3 point bending test was run on each type of manure and pine filled thermoplastic.

Swine manure specimens were placed in a 90% relative humidity room at 27°C and the increase in weight was measured as a function of time.

## RESULTS AND DISCUSSION

Table 1 shows the bending test results of dairy manure-filled HDPE. As expected, the MOE and MOR increase with increasing levels of manure in the mixture. The addition of MAPE increases the MOR but has little effect on MOE.

Table 2 shows the bending test results of dairy manure-filled HDPP. Again, as expected, the MOE and MOR increase with increasing levels of manure in the mixture. The addition of MAPP increases the MOR but has a negative effect on MOE at the higher filling levels.

**TABLE 1** Bending Tests of Dairy Manure-Filled HDPE

| Manure fraction (%) | MAPE (%) | MOE (GPa) | MOR (MPa) |
|---|---|---|---|
| 0 | 0 | 0.75 | 15.1 |
| 20 | 0 | 1.25 | 21.8 |
| 20 | 2 | 1.26 | 23.3 |
| 30 | 0 | 1.57 | 24.6 |
| 30 | 2 | 1.60 | 27.4 |
| 40 | 0 | 2.08 | 27.8 |
| 40 | 2 | 2.18 | 34.7 |
| 50 | 0 | * | * |
| 50 | 2 | 2.87 | 38.7 |

*Mixture not possible to process.

Table 3 shows the bending test results of 20% and 40% swine manure-filled HDPE with and without MAPE (2%). MOE and MOR increase with increasing levels of manure in the mixture and the MAPE addition resulted in higher MOR values as compared to specimens without MAPE. Comparing the data in Tables 1 and 3, dairy-filled HDPE has higher MOE and MOR values as compared to swine-filled HDPE.

The difference may be due to the small fraction of straw in the dairy manure that adds some higher level of fiber reinforcement.

Table 4 is presented for comparison of different levels of pine flour-filled HDPE and HDPP with and without MAPE. In general, the dairy-filled HDPE has lower MOE and MOR values as compared to pine-four filled HDPE with the exception of the 40% dairy-filled

**TABLE 2** Bending Tests of Dairy Manure-Filled HDPP

| Manure fraction (%) | MAPE (%) | MOE (GPa) | MOR (MPa) |
|---|---|---|---|
| 0 | 0 | 1.60 | 31.9 |
| 20 | 0 | 2.63 | 39.2 |
| 20 | 2 | 2.34 | 42.7 |
| 30 | 0 | 2.67 | 39.5 |
| 30 | 2 | 2.67 | 46.5 |
| 40 | 0 | 3.68 | 41.8 |
| 40 | 2 | 3.10 | 48.5 |
| 50 | 0 | 3.81 | 36.8 |
| 50 | 2 | 3.77 | 48.6 |

**TABLE 3** Bending Tests on Swine Manure-Filled HDPE

| Manure fraction (%) | MAPE (%) | MOE (GPa) | MOR (MPa) |
|---|---|---|---|
| 0 | 0 | 0.75 | 15.1 |
| 20 | 0 | 1.05 | 18.1 |
| 20 | 2 | 1.02 | 19.3 |
| 40 | 0 | 1.53 | 22.7 |
| 40 | 2 | 1.55 | 26.5 |

**TABLE 4** Bending Tests on Pine Flour-Filled HDPE and HDPP

| Wood fraction (%) | MAPE (%) | HDPE MOE (GPa) | HDPE MOR (MPa) | HDPP MOE (GPa) | HDPP MOR (MPa) |
|---|---|---|---|---|---|
| 0 | 0 | 0.75 | 15.1 | 1.60 | 31.9 |
| 20 | 0 | 1.54 | 23.3 | 3.65 | 48.4 |
| 20 | 2 | 1.38 | 23.5 | 3.04 | 47.9 |
| 30 | 0 | 2.11 | 27.3 | 3.70 | 48.7 |
| 30 | 2 | 2.10 | 29.7 | 3.76 | 52.5 |
| 40 | 0 | 2.88 | 29.4 | 4.58 | 49.5 |
| 40 | 2 | 2.98 | 33.4 | 4.46 | 52.3 |
| 50 | 0 | * | * | 5.69 | 48.5 |
| 50 | 2 | 4.03 | 35.3 | 5.73 | 51.9 |

*See above.

**TABLE 5** Moisture Sorption of Swine-Filled HDPE Plus 2% MAPE at 90% RH, 27°C

| Manure fraction (%) | 1 Wk (%) | 2 Wk (%) | 3 Wk (%) | 4 Wk (%) | 5 Wk (%) | 6 Wk (%) | 10 Wk (%) | 15 Wk (%) | 19 Wk (%) | 23 Wk (%) | 28 Wk (%) | 32 Wk (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | 18.7 | 21.2 | 21.2 | 21.2 | – | – | – | – | – | – | – | – |
| 20 | 0.2 | 0.4 | 0.5 | 0.5 | 0.6 | 0.7 | 0.9 | 1.1 | 1.3 | 1.4 | 1.5 | 1.6 |
| 30 | 0.3 | 0.5 | 0.7 | 0.8 | 0.9 | 1.0 | 1.3 | 1.5 | 1.8 | 1.9 | 2.1 | 2.2 |
| 40 | 0.5 | 0.7 | 0.9 | 1.1 | 1.2 | 1.4 | 1.8 | 2.2 | 2.5 | 2.7 | 2.9 | 3.2 |
| 50 | 0.7 | 1.0 | 1.3 | 1.5 | 1.7 | 1.9 | 2.5 | 3.0 | 3.5 | 3.8 | 4.2 | 4.5 |

HDPE with 2% MAPE. In this case, the values for MOE and MOR are almost the same. In the case of pine-flour filled HDPP compared to dairy-filled HDPP, MOE and MOR values for dairy-filled HDPP are lower as compared to the pine-flour filled HDPP.

Table 5 shows the moisture sorption at 90% relative humidity, 27°C over 32 weeks. The pure HDPE specimens do not sorb any moisture during the test period. The pure swine manure has an EMC of 21.2. As the level of swine manure increases in the mixture, the moisture sorption increases with time. All levels of swine manure specimens continue to gain weight with each passing week indicating that an equilibrium moisture content has not been reached for any of the specimens. The highest level of swine manure (50%) has a weight gain of 4.5% and is still increasing after 32 weeks.

## CONCLUSIONS

The results of this research show that animal manures can be used as a reinforcing filler in polyolefins. The higher the level of manure (up to 50%) the higher the MOE and MOR values. The addition of a compatibilizer increases MOE and MOR values at each manure level tested. Moisture sorption increases as the percentage of manure increases. It is expected that the manure-polyolefin filled materials will find applications on farms such as calf hutches, feeding troves, decking, railing, and fencing. Research is continuing using other types of manures and commercial applications are underway.