# THINKING OUTSIDE THE BOX: BUILDING MATERIALS AND OTHER PRODUCTS FROM ANIMAL PROCESSED FIBER

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Why is it time to think outside the box about manure? It is no secret that manure is on the short list of environmental and social concerns about livestock production. Several decades of increasing specialization in agriculture have concentrated manure resources on farms, in counties, and sometimes whole regions where manure nutrient supplies exceed crop demand (Kellogg et al. 2000). Because of the low nutrient density of manure relative to synthetic fertilizers, the transportation costs of moving it to areas where there is crop demand are often prohibitive (Fleming et al. 1998). Without viable local alternatives, many livestock producers overapply manure (Schmidt et al. 1996, Novak et al. 1998), leading to nitrate leaching, phosphorus accumulation, and other water quality concerns. Large concentrations of manure create other problems, such as odor (Zahn et al. 1997), which communities are no longer willing to tolerate. However, the same scale and concentration that raise environmental concerns also create an opportunity to collect and process manure as a feedstock for value-added manufacturing. With this concentration, it is now possible to envision a livestock production system from which manure becomes a feedstock for new manufacturing processes.

Manure has a number of valuable properties that can be exploited in developing new products. All manures contain protein fractions that include both undigested feed proteins and proteins synthesized by microorganisms in the gastro-intestinal tract. Manures also contain fiber fractions, which include cellulose, hemicellulose, and lignin. These fractions, along with minerals and nutrients, represent a biologically processed feedstock suitable for a wide variety of purposes (Galloway, 1998). The key to transforming manure, currently often viewed as a low-grade waste, into value-added products is the development of refining operations to convert these components into appropriate manufacturing feedstocks.

Many of the new products that can be made from manure have traditional counterparts. Manure has been used for nutrients, energy, and fiber for millennia. While the nutrient uses, particularly as fertilizers for crop production, are most widely recognized, manure has also long been burned as a fuel, in Africa, Asia, Europe, and by Native Americans here in the U.S. And although the idea of using manure in building materials may seem novel today, manure has traditionally been used throughout the world as a fiber source, binding agent, and surface coating in adobe and other masonry construction.

Although today's presentation focuses on the fiber and building material opportunities, it is worth noting some of the new or rediscovered approaches to nutrients and energy production, two of which have already been discussed by the previous speakers.

## Nutrients

The nutrient value of manure is well established, so it is not surprising that this component has attracted considerable attention in recent years. The transformation of manure into composts and pelletized forms provides a more nutrient dense, easily transportable fertilizer and soil amendment. Compost is already being marketed this way by a number of facilities, and the value of this product as a fertilizer and soil amendment for horticulture is well established.

Some types of processing may further enhance compost value, beyond the nutrients and organic matter usually considered. Specially processed composts are now also being used as pesticide substitutes, providing plant pathogen suppression equal or better than chemical pesticides for several common soil borne diseases (Hoitink and Fahy 1986, Hoitink and Grebus 1994), while compost extracts are being used for foliar fungal disease control (Weltzhien 1992, Scheuerell and Mahaffee 2002). Additional agronomic benefits, including erosion control, enhanced water holding capacity, and other soil quality benefits are widely recognized but only partially quantified, particularly from the economic perspective needed to document value and increase the price of manure products. The value of environmental benefits of improved water quality (Hatfield and Stewart 1996) and carbon sequestration (Drinkwater et al. 1998) from better manure management strategies are also not adequately documented. Quantification of the auxiliary agronomic benefits will be important for efficient market pricing, while quantification of the external environmental benefits is essential in the consideration of public subsidies for these practices.

While recycling manure nutrients via crop production makes a great deal of sense, an even more efficient strategy can be to process the manure directly into animal feed. The nutrient content of manure has been shown to be 3 to 10 times more valuable as animal feed than as plant nutrients (Smith and Wheeler, 1979). Part of this increased value is due to the more direct and efficient transfer of nutrients to human foods, while part is in consideration of the energy value as well as nutrient needs in animal diets. While the ability of ruminants to utilize non-protein nitrogen gives them an advantage over other livestock (Smith and Wheeler, 1979; Zinn et al., 1996), refeeding has also been successful with poultry and swine (Day and Sweeten, 1980; McCaskey, 1995). The principal concern with refeeding has historically been animal health concerns, but the use of drying, ensiling, heat and chemical treatment have all been shown effective at eliminating disease transmission (McCaskey and Anthony, 1979). However, the costs of processing combined with lower nutrient values from some processing approaches (such as drying and heat treatment) have limited the application of this strategy primarily to the refeeding of poultry manure and litter to poultry and ruminants (Hauck, 1995).

A somewhat less direct means of converting manure into high protein human foods is through the use of aquaculture and fish ponds. Manure treatment in ponds has been an established practice for centuries in parts of Asia, and is also currently found in Europe and North America (Edwards, 1980; Polprasert, 1989). Fish have a high feed efficiency ratio and with proper design the biological treatment processes in ponds can effectively address most odor and water quality issues, although pathogen survival and transmission can still be a concern with untreated manure (Polprasert, 1989).

**Energy**

Another important product which can be derived from livestock manure using currently available technology is energy. Anaerobic digestion converts much of the energy in manure to methane gas, which can be burned for space and process heating and/or converted into electricity with an engine generator or microturbine (Hashimoto and Chen 1981, Badger et al. 1995). In addition to the recoverable energy produced, anaerobic digestion also reduces the odor content of the manure. While anaerobic digestion has been demonstrated as effective with a wide variety of manures throughout the world, the relatively high capital costs and management skills required have limited its application in the United States (Garrison and Richard 2002). It is important to note that anaerobic digestion does not obviate the need to deal with the excess nutrients challenging many livestock producers. As an enclosed system, ammonia volatilization is reduces, so the nitrogen content is higher than with many other manure management systems. And because anaerobic digestion converts manure solids to water and gas, the moisture content of the manure actually increases during digestion. On farms where land application of digester effluent is constrained by limits on land availability, liquid-solid separation followed by further treatment of both the liquid and solid streams would probably be required.

**Fiber**

Another potentially valuable component of some manure streams is the fiber. Undigested fiber is a significant part of ruminant manure, and fiber is a major component of biomass bedding materials like sawdust, straw, etc. The building materials industry has an urgent demand for alternative fiber sources (Bowyer, 1995, Clancy-Hepburn, 1998), and the use of manure fiber would provide a welcome alternative. One of the principal limitations on biocomposite manufacturing is the relatively high cost of the conventional adhesives used as binders and fibers in the composite matrix. Biorenewable proteins can provide excellent adhesive properties in building materials, as has recently been demonstrated with soy protein. Manure protein and fiber are already blended together, which may allow reductions in the need for conventional adhesives in biocomposite materials. One key to transforming manure is the development of refining operations to separate the fiber and liquid components into appropriate manufacturing feedstocks. Composting may play a role in that refining process, evaporating water using the heat generated by non-fibrous cellular material.

Fiber is the largest single constituent of livestock manures (excluding water) (see table 1), with over 20 million tons generated in the US. These estimates do not include the fibrous bedding and litter used in many dairy and poultry systems, providing an even greater potential for fiber recovery and use. The fibers in feed and bedding are ground, homogenized, softened and coated with bacterial protein during digestion and manure collection. The protein component is likely to substitute for adhesives used in biocomposite manufacturing, serving as a natural glue similar to many protein-based glues developed in the pre-petrochemical age, and new incarnations of these adhesives being developed today (Kuo et al. 1998, Richard et al. 2002). Many of the costs of preparing virgin fiber for use in building materials are thus already accomplished in the normal course of livestock production – leading us to call this new industrial feedstock “Animal Processed Fiber.”

Table 1. Animal Processed Fiber Potential in the U.S.

| | Manure Produced (dry tons/year) | Fiber Content (as excreted) | Total Fiber (dry tons/year) |
|---|---|---|---|
| Beef (feedlot only) | 12,100,000 | 44% | 5,330,000 |
| Dairy | 23,200,000 | 42% | 9,760,000 |
| Swine | 10,700,000 | 30% | 5,300,000 |
| Poultry | 24,100,000 | 22% | 3,200,000 |
| Total | 70,100,000 | | 23,590,000 |

During the past three years our group has been evaluating bovine manure as a fiber and adhesive component in the manufacture of fiberboard. Bovine manure is composed of two materials that can function as key components in these engineered fiber products, namely fiber and protein. With appropriate processing strategies including solid-liquid separation and drying, these fractions could function as feedstocks for a wide variety of purposes including building materials such as fiberboard.

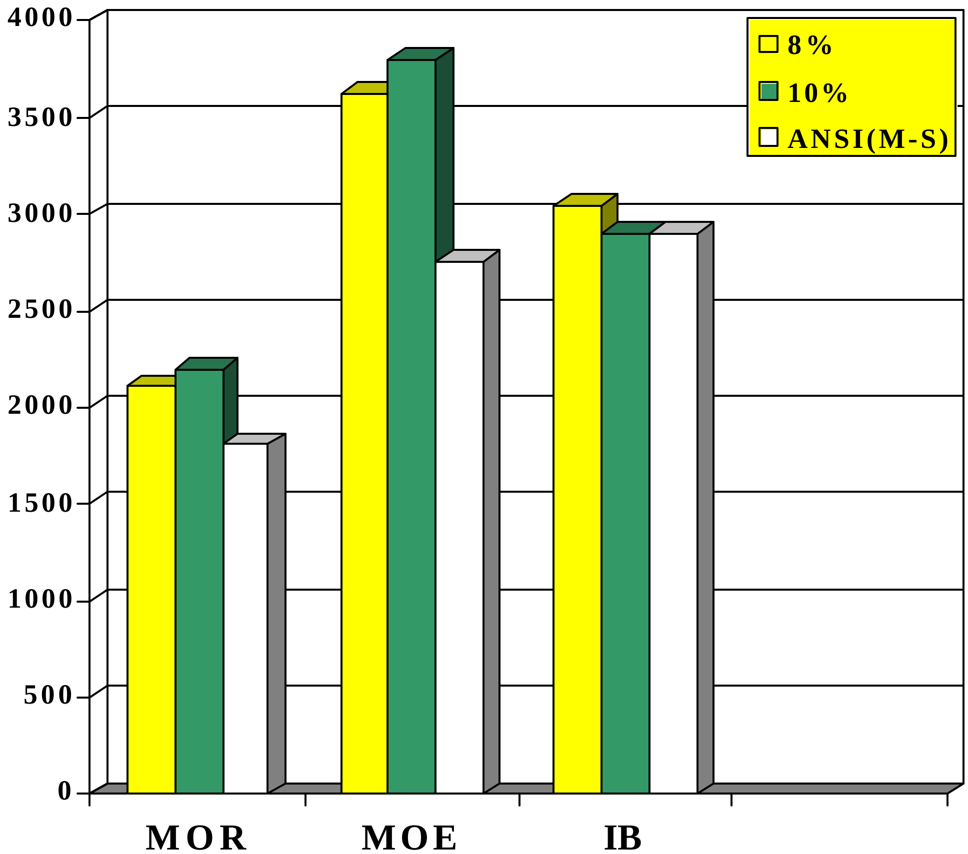


Figure 1 illustrates the performance of a manure-based particleboard in terms of modulus of rupture (MOR, in psi), modulus of elasticity (MOE, x 1000 psi), and internal bonding strength (IB, x 0.02 psi) at 8 and 10% resin strengths. The white bar in each category is the ANSI standard for a medium strength particleboard. It is clear that this product can meet these commercial standards, although issues of efficient drying and optimum adhesive treatments still need to be addressed.

In the future we may see manure converted into even more valuable products, including proteins for animal feed through algael or other microbial conversion processes (Calvert, 1979; Polprasert, 1989; Hauck, 1995), and enzymatic conversions to alcohols or other chemical feedstocks (Spellman, 1994). While such systems may seem difficult to imagine today, with future research the concentrated energy, nutrients and fiber found in livestock manure are certain to be seen as a valuable resource rather than a waste.

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