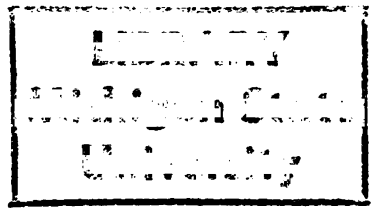

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Evaluating the Nutritional Properties of
Particle Board Process Microbial Mass When
Fed to Dairy Cattle and Sheep

presented by

Amy J. Duffield

has been accepted towards fulfillment
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Roy L. Ernst
Major professor

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# EVALUATING THE NUTRITIONAL PROPERTIES OF A PARTICLE BOARD PROCESS MICROBIAL MASS WHEN FED TO DAIRY CATTLE AND SHEEP

By

Amy J. Duffield

A THESIS

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# ABSTRACT

## Evaluating the Nutritional Properties of Particle Board Process Microbial Mass When Fed to Dairy Cattle and Sheep

by

Amy J. Duffield

The nutritional properties of a particle board process microbial mass (MM) was determined through chemical analysis and three feeding trials. Experiment 1: Growing dairy heifers were fed complete rations and 5% ration dry matter soybean meal (SBM) or MM. MM showed a relative feed value of 81%. Experiment 2: Growing rumen cannulated sheep were placed in a 4x4 Latin square design fed 11 or 13% crude protein from SBM or MM. Significantly lower % nitrogen absorbed and grams nitrogen retained, mean rumen NH3-N, pH, isobutyrate and valerate occurred with MM treatments. No significant difference was in biological value or C2:C3 ratio. Mean relative value nitrogen digestibility of MM:SBM was 73%. Experiment 3: Sheep were used in a 3x4 Latin square design fed MM at levels of 0, 10, 20 or 30% ration dry matter replacing corn. Mean approximate energy digestibility MM is 21%.

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# INTRODUCTION

The human population in the world is expanding at an alarming rate and is exerting pressure for more agricultural efficiency with increasing productivity. Surplus grain may become a luxury of the past and future needs may necessitate its distribution for human consumption only (Smith et al. 1985, Oldfield 1972). Ruminants have the ability to digest cellulose, a plant product undigestible by humans, and can produce high quality, nutritious and palatable foods for humans. At the present time approximatly 350,000 plant species have been described by botanists and of that amount, less than 3000 are currently being used as food, feed or industrial supply (Smith, 1985). Only 100 plant species are cultivated to a great extent and less than 24 are used directly by humans. Animal products, however, provide three quarters of the protein, one third of the nutritive energy and the majority of the calcium, phosphorous, vitamins and other minerals for the diet of an average North American. The need for animal products will not diminish in the years to come but the current production techniques, crops and feedstuffs for livestock will change greatly.

Optional feedstuffs for livestock include processed by-products and wastes (National Academy of Sciences, 1973).

Agricultural and industrial residues may be fed directly, pending a strict screening of hazardous materials, or they may be used to generate microbes and the resulting single cell protein (sludge) may be fed.

In Michigan, manufacture of particle board produces a waste water with a high content of wood solubles and a high biochemical oxygen demand. No other biohazards are present. The waste water is placed in a primary settling pond where heavy wood fines settle out. The water is then transferred to a lagoon and undergoes aerobic treatment. During this period a single cell protein microbial mass is collected and combined with the fiber solids which had settled out in the primary treatment pond, thus making a particle board process microbial mass (MM). Currently this MM is disposed of in two ways. It is either dried and burnt at the plant or it is placed in a landfill. Both options are costly and since the MM contains no toxins or environmental hazards it has potential for being an alternative feedstuff for ruminants.

The purpose of this study was to evaluate the chemical composition of MM, and in addition to determining the digestibility and availability of its protein and energy content. The MM was analyzed and the resulting values used in subsequent feeding trials. Holstein heifers were used in a growth trial comparing the MM to soybean meal. Subsequent trials were conducted with rumen fistulated, growing wethers

to determine the biological value of the protein content in the MM by way of a nitrogen balance and the apparent energy digestibility of MM when compared to corn. Rumen fluid was collected over time and analyzed for pH, rumen ammonia and volatile fatty acid proportions. The rumen parameters were used to interprete degradability of the MM in the rumen.

## LITERATURE REVIEW

### Single Cell Protein (SCP)

Microbial sources of protein show great potential for filling the nutritional needs of the world population. Microorganisms show a growth efficiency far superior to animals. Ingestion of the resulting microbes supplies not only protein but also B vitamins and other growth factors. Generation of the microbes requires relatively little space and can utilize many waste products as energy sources. Pollution control methods take full advantage of the microorganisms ability to degrade harmful substances into environmentally safe by-products. In so doing, large amounts of microbial protein are produced and, at present, discarded.

In the past, microorganisms have been consumed in diets but seldom as a sole food source. Microbes have been used to ferment foods and are ingested along with the food.

During World War I Germans used yeast, primarily Candida utilis, as a protein supplement in their diets (Bunker, 1968).

Potential sources of microbial protein or single-cell protein (SCP) are algae, photosynthetic and nonphotosynthetic bacteria, filamentous fungi and yeasts (Tuse, 1984, Bunker, 1968). Bacteria hold advantages over the other microbes in that they can grow more quickly, use multiple and various energy sources, adjust metabolically to the environment presented and generate large amounts of protein (Tuse, 1984). This versatility allows bacteria greater potential for future use. The choice of micro-organism is equally important as the environment it is placed in (Tuse, 1984). Should the microbe have access to high levels of toxic materials or heavy metals it will often retain some of the toxic substance. The microbial mass produced from fermentation of environmental pollutants must be analyzed carefully for presence of toxic agents prior to consumption.

Composition of SCP

Single cell proteins (SCP) compare favorably with other typical foods, including high quality protein foods, based on proximate composition (Miller 1968, Young and Scrimshaw 1975 ). Miller (1968) states that biological value (B.V.)

for all varieties of SCP are high, approximately 70. Sulfur amino acids are frequently the limiting amino acids in SCP (Shacklady 1974, Calloway, 1974). Two varieties of yeast were assigned biological values of 54 and 61, however, if supplemented with methionine the values increased to 96 and 91 respectively. Torula yeast improved from a BV range of 32 to 48 to 88 when supplemented with methionine (Asplund and Pfander, 1972). In addition to these amino acids, lysine and isoleucine can be marginally limiting (Miller 1968, Asplund and Pfander, 1972). Bacteria have a higher content of methionine than yeast while bacteria have lower lysine than yeast (Kihlberg, 1972). Many studies have shown SCP to have a poor digestibility. Hackler et al. (1957) found similar high BV and low digestibility results with sewage sludge. High levels of algal SCP has led to gastro-intestinal disturbances (Miller 1968, Calloway, 1974). Whether this is due to the algae itself, bacterial contamination of the algae or other factors is not known. Foods containing microbial or SCP.protein may potentially induce allergic reactions with some people (Scrimshaw and Dillon, 1979). Gastrointestinal allergies may be the primary cause of these disorders (Eastham, 1979).

Digestibility

Digestibility of SCP products is improved if the products undergo a treatment that kills the cells (Asplund et al., 1972). Heating can also improve digestibility and is especially true with algae (Young and Scrimshaw, 1975). Processing the SCP will also improve its palatability (Asplund et al., 1972). Some animals are particularly sensitive to the taste of SCP. Rats dislike the SCP (Asplund et al., 1972). Livestock are generally less particular about the taste of SCP. If the SCP is fed as a supplement and mixed properly with the other feedstuffs, palatability problems may be nonexistant.

Nucleic acid content is relatively high for SCP as compared to conventional protein sources (Miller 1968, Young and Scrimshaw 1975, Asplund et al., 1972). Single cell proteins are approximately 8-25 grams of nucleic acid per 100 grams of protein (Young and Scrimshaw 1975, Sinskey and Tannenbaum 1975). This is at least twice the amount found in liver. The purines in the nucleic acid are metabolized to uric acid. In primates the uric acid is not metabolized further and thus presents the possibility of forming kidney stones if concentrations are excessive (Miller 1968, Sinskey and Tannenbaum 1975).

Production

For growth of SCP, nutrient sources are typically waste products. They can be gaseous substances such as methane, petroleum n-alkanes, or carbohydrates. These products serve mainly as carbon sources.

Carbohydrates, the primary storage form of energy found in plants, consist of sugars and polymers of sugars. Hydrolysis of complex carbohydrates results in formation of sugar. Animal products can contain sugars, e.g., lactose. Categorizing carbohydrates based on the principal form is as follows (Tuse, 1984) :

1. Whey
2. Starch crops (grains and tubers)
3. Sugar crops or sugar containing residues.
4. Lignocellulosic materials containing cellulose and hemicellulose.
5. Other (e.g., molasses, sulfite waste liquor)

Single-cell protein production has increased in recent years due to increased treatment of wastes via aerobic fermentation (Asplund et al., 1972). Many industrial, food processing and agricultural wastes are created and these wastes contain a high biochemical oxygen demand (BOD). To lower the BOD, the wastes are placed in a lagoon and undergo aerobic treatment. This results in the formation of a

microbial mass and cleaner water. The objective here is not the production of the sludge but rather in pollution control and discharging environmentally safe water. The sludge is a by-product that could potentially be more fully utilized.

Sludge characteristics can vary based on conditions encountered during the treatment. Lower temperatures and less sunlight can result in a greater sludge accumulation (Schneiter et al., 1983). Aerated lagoons can produce a sludge with total solids ranging from 3.6% up to 20% and volatile solids ranging from 29-93% (Reid, 1970, Christianson and Coutts, 1970, Clark et al., 1970, and Pick et al., 1970). Operation variables can influence the sludge characteristics. Solids retention time can affect the biomass in the system. Increasing the holding time increases the amount of biomass generated. The relatively high values of volatile solids are maintained whether the sludge has a retention time of weeks, months or years. This is possibly due to the continuous presence of algae growth and decay (Schneiter et al., 1984). Another study found a decreasing amount of amino acids present when aerobic digestion continued over a greater time length (Martin and Loehr 1983, Vriens et al., 1983). Supplementing the waste water with nitrogen, phosphorous and ferric chloride will

also increase the amount of microbial mass produced (Vriens et al., 1983).

Ammonium-nitrogen versus nitrate-nitrogen supplementation to nitrogen-limited waste water resulted in greater sludge production and oxygen consumption. In addition to this, pH was less alkaline and there was an improved removal of the chemical oxygen demand (COD) (Emerson and Sherrard 1983).

## Handling and Disposal

Sludge handling and disposal is dictated by the presence or absence of toxic agents. At the present time, most sludges are dispersed into the ocean or landfills and some is placed over soil to improve the organic matter concentration.

Crops grown on soils where sewage sludge had been applied benefit from the macro and micro nutrients but the potential hazards of the heavy metals and persistent organics do present difficulties (Sommers, 1980). Uptake of the toxic substances by the plants and direct ingestion of soil are the two ways animals may be affected.

The soil pH, cation exchange capacity, annual application rates and environmental factors play key roles in whether or not the metals become absorbed and assimilated in the plants (Sommers, 1980). Different crops have differing values of total mineral uptake and portions of the

plants can concentrate the metals. With adequate management, the difficulties of growing crops on sludge amended soils should be greatly reduced.

Feeding Sludges to Animals

Sludges have also been fed directly to animals. In studying the possibilities of feeding sewage sludge to livestock, Firth and Johnson (1955) found that dried activated sludge could be incorporated up to 5% of dry matter in diets for baby pigs without producing ill effects. Initially in this trial baby pigs were fed diets with 10% sludge but at this level growth was inhibited and a lowered feed efficiency occured after only 3 weeks. The 5% level gave results equal to the control diet. To more accurately assess the adequate feeding level, in an additional trial levels of 4, 6 and 8% sludge were fed. They concluded that 6 and 8% sludge did inhibit growth and feed efficiency where as 4% paralleled the control values. Comparing poultry to swine, chicks were then fed the sludge at 2 and 10% in a diet that was B12 deficient. The chicks showed an 8% improved growth rate for both levels of sludge addition when compared to the controls.

Additional studies of feeding sludge to poultry have been conducted recently. One study (Lipstein and Kary, 1984) looked at gamma- irradiated activated sludge

supplementation to diets for the protein, vitamin and mineral values sludge could supply to broiler chicks at ages of 1 - 4 weeks and 5 - 8 weeks. Growth performance and carcass quality were the major parameters studied. Diets contained 0, 6, 12, and 18% activated sludge. Addition of activated sludge up to 12% showed no detrimental effects in both starter and finishing diets. Feed intake was not depressed in any of the diets. Broilers from 5 to 8 weeks of age showed a slightly but significantly ($P< .01$) greater weight gain when fed activated sludge. Feed consumption increased with increasing levels of activated sludge. Feed efficiency during the finishing period, however, was slightly decreased for the 18% diets. This could be due to diets not being isocaloric. Metabolizable energy (ME) values for the activated sludge were over estimated and this confounded expected energy levels for the diets. Internal organ sizes were measured for the liver, spleen, kidneys and pancreas. If the activated sludge contained toxic substances the organs would have become enlarged. No changes were observed.

Toxicological effects of heavy metal content in municipal sludge were studied by Damron et al. (1982). Broiler chicks were fed 0, 3, or 6% Chicago sludge or control diets with cadmium, chromium, copper and iron

supplementation from reagent sources to equal levels found in 6% sludge diet. Laying hen studies (Damron et al., 1982, Johnson and Damron, 1980) fed 0, 3.5, or 7% Chicago sludge or control diets with the same mineral supplementation to equal levels found in the 7% sludge diet have also been conducted. Addition of iron, chromium and cadmium effected chick and hen performance but feeding the sludge at 6 and 7% respectively showed no effect. Mineral concentrations in liver and kidneys did increase in both experiments, however, concentrations were unchanged in muscle.

Sewage sludge and seaweed (Ulva sp.) were compared as feed supplements for chicks (Wong and Leung 1979). When the sludge was fed at levels of 5% or lower, growth rates were similar to chicks receiving the control diet.

Antivitamin effects have been noted in several studies when sludge was fed to chicks. One study (Scott and Adams, 1955) fed varying levels of vitamin D and sludge. They found depressed growth when diets containing 100 units of vitamin D and only 1% sludge was fed. As vitamin D levels increased tolerance for greater levels of sludge increased. No inhibition of growth was observed when diets contained 400 units of vitamin D and 4% sludge.

Vitamin A levels were greatly reduced in chicks when fed anaerobically digested sewage sludge (Kienholz et al.,

1981, Kienholz et al., 1980). The broiler chicks fed a 20% sludge diet inadvertantly received a diet with metabolizable energy 500 kcal/kg less than the control diet but extrusion of the sludge when mixed with corn resulted in even lower vitamin A levels. These studies suggest vitamin A absorption is reduced and vitamin A supplementation is necessary when feeding sludge.

Sows fed 0, 10 or 20% sewage sludge farrowed more live pigs with the 20% diet than the control diet (Beaudouin et al., 1980). Offspring of the 20% diet sows did show lower 21 day weaning weights. These piglets also showed lower daily weight gains and feed efficiency when fed sludge supplemented diets from weaning to market weight.

As mentioned earlier, ruminants have many advantages over non-ruminants when dealing with the toxicity factors of feeding sludge. One study conducted earlier by Hackler et al., (1957) compared utilization of sewage sludge to urea and soybean oil meal (SBOM) supplemented diets when fed to sheep. Diets were made isocaloric by addition of starch. The SBOM, urea and sludge diets were 12.1, 11.9, and 11.5% crude protein, respectively. There was no sulfur supplementation in the urea diet. Nitrogen retention in the sheep was not statistically significantly different. This was a surprising result because the differences of digestibility between the SBOM and sludge protein was 11%.

Greater urinary nitrogen loss was observed with the SBOM diet. The study concluded that possibly the sludge, being a fermented product, had some factor(s) which may have favorably affected the rumen fermentation process. Kienholz et al (1979) fed metropolitan sewage sludge to steers and measured growth performance as well as mineral content in various organs. Animals were fed 0, 4, or 12% of dry matter intake as metropolitan Denver sewage sludge over a 95-day finishing period. The steers receiving the sludge diets grew less than the controls ($P<.025$). If expected gains were calculated on the basis of no energy being furnished from the sludge than observed gains were appropriate. They concluded that no energy was supplied from the sludge. Mineral levels in the tissue tended to be higher in the organs than muscle but none reached toxic levels. It was felt that offering a withdrawal period would eliminate mineral accumulation in the carcasses.

Bertrand et al., (1980) fed municipal sludge and corn that had grown on soil treated with large amounts of sludge to steers for 141 days. Performance data and carcass quality measurements were similar for animals receiving sludge and/or corn grown on sludge amended soil and controls. Steers fed the sludge with or without sludge grown corn have significantly higher levels of cadmium,

copper, iron and lead. Whereas those fed corn grown on sludge amended soil showed no significant difference.

Utley et al., (1972) fed processed garbage to beef cattle for 140 days. The procedure for processing the garbage was to first remove metal, glass and plastics and shred the remaining material and place it in a digesting unit. After 5 days of aerobic fermentation the sludge is dried and pelleted with the addition of urea to aid pelleting. The material was 21.3% crude protein and 51.2% crude fiber. Cottonseed meal with peanut hulls, urea with peanut hulls and processed garbage were compared. Again performance data and carcass quality measurements were not significantly different. Dry matter, crude fiber and cellulose digestibility of the processed garbage diets were greater than those containing peanut hulls. Cottonseed meal diets had less crude protein digestibility than processed garbage and urea diets. The latter two diets showed equal crude protein digestibility values. Lead levels were higher in kidneys and livers in steers fed processed garbage versus control animals.

Ammerman and Block (1964) fed wether lambs rations containing sewage sludge with oak sawdust and compared the nutritive value to Bermudagrass hay. The sludge was placed in a hot air kiln for drying and this could have caused a binding of the nitrogen. Some of the sludge-sawdust mixture

was composted, this improved intake and palatability though consumption never reached desired levels. Crude protein and crude fiber values decreased with composting. The percent total digestible nutrients for the Bermudagrass hay, pre-compost and composted sludge-sawdust mixtures were 76.8, 66.4 and 61.6% respectively. They concluded that the waste material would make an adequate feed supplement when quality protein and roughage feeds were in short supply.

Food processing plants can produce wastewater that requires aerobic treatment. The resulting sludge is not as hazardous as many other industrial sludges. Frequently the plants process numerous fruits and vegetables so the sludge may differ from one plant to another. Esvett (1976) analyzed fruit cannery activated sludge. The nutritional value on a dry matter basis was 39.1% crude protein, 3.2% crude fiber, and 11.64% ash. The sludge, when fed to steers, did not affect digestibility when diets contained the sludge at levels of 5% or less. In a subsequent study feed efficiency was not affected when steers ate as much as 9% sludge.

Radiation of SCP

Sewage solids are being studied as a potential feedstuff for livestock. Conventional handling procedures of sewage solids promotes production of SCP and the

associated growth factors. Sewage is high in nutrients and feeding it would take advantage of this plus utilize a waste product and reduce environmental pollutants that require processing (Smith et al. 1979, Beszedits 1981, Smith 1982, Anonymous 1981). It is important to note that in feeding sewage solids the potential for animal and human health hazards do exist. Selection of the source of sewage to be fed can alleviate introduction of many industrial toxic substances to the food chain. Additional hazards to deal with are parasites and pathogenic organisms. Exposing the sewage to gamma-irradiation results in destruction of these organisms (Smith et al. 1985, Smith et al. 1985, Smith 1982, Smith et al. 1982, Smith 1981, Smith et al. 1979). Use of nuclear irradiation has become an effective and acceptable way of preserving food. In 1963 the United States Food and Drug Administration (FDA) approved the preserving process of irradiating bacon for human consumption. By utilizing nuclear waste such as Cs 137, dried sewage solids are treated to a dosage of at least 1 Mrad and then considered relatively safe to feed. When feeding the product to ruminants additional protection from hazardous substances is achieved due to the ruminal fermentation process. This environment can detoxify many materials prior to absorption from the digestive tract. Insoluble salts may form from heavy metals found in the waste and chromium, cadmium,

mercury, lead and other hazardous elements may not be absorbed. The fermentation process that occurs in the rumen must be properly managed, however, to assure no toxic substances are synthesized (Smith, 1981). At the present time, it is illegal to feed sewage to livestock in the United States (Section 409 of the FD and C Act: because it is non GRAS (Generally Recognized As Safe) for this purpose. Robens, 1980).

Trials that were conducted in New Mexico selected "low risk" municipal waste which contained a relatively high amount of nutrients that could be utilized by ruminants. The chemical composition of sewage varied due to numerous trials over long periods of time (Smith et al., 1979). The dry matter was 88 - 96%, crude protein 15.6 - 22.3% of dry matter, ether extract 13 - 17.2%, acid detergent fiber 47.1 - 48.4%, ash 32 - 45%, gross energy 4.4 - 4.9 kcal/g. When the sewage was pelleted for several trials the composition changed slightly. The ether extract and gross energy decreased to 6.2 - 8% and 3.7 - 4.1% respectively while acid detergent fiber increased to 49 - 53% (Smith, 1985). The dried, gamma-irradiated sewage solids (DGSS) was first tested in rumen cultures along with poor quality forages and the microbes survived. The following test for toxicity was conducted on rats. Levels of 10, 20 and 30% DGSS were fed in the rations from weaning through at least one

reproductive cycle. No toxic effect was noted. Sheep and cattle were then used in feeding trials to determine DGSS digestibility, biological value, long term effects and short term effects on organ size, mineral accumulation, elevated levels of enzymes which indicate toxicity, reproductive performance, wool production, growth, carcass characteristics and meat quality.

A general summary of all the trials shows the feeding value of DGSS compares well with cotton seed meal and no health hazards were evident.

Nutritional Value of Wood, Wood Residue and Wood By-products.

Manufacturing of forest products produces a great deal of wood residue and the high cellulose content makes it appear to be an excellent feedstuff for ruminants. Forest residues consist of treetops, branches, and short logs. Wood from processing plants can take on various forms: sawdust, shavings, lumber edge and edge trim, log outer portion slabs, shredded bark and wood pulp (National Research Council, 1983). When conventional food sources have been limited ruminants were fed alternative feeds including wood residues (Scott et al., 1969). Feeding wood residue ceased when other feeds became available and future potential usage of the residue was not pursued until recent years. Studies were made to assess the feed value of

unprocessed sawdust (Kitts et al., 1968, Dinius et al., 1970, Welton and Baumgardt 1970, Mellenberger et al., 1971). It was assesed as an energy source as well as a roughage source when fed with high concentrate rations (Anthony et al., 1968, El-Sabban et al., 1971, Gilbert et al., 1973). The wood residue proved to be a poor feed because it has a relatively high content of lignin. For the digestibility to improve the residue must be treated (Erlinger and Klopfenstein 1975, Keith et al., 1975). When delignified, dry matter digestibility increased to 90% with two hardwoods (Baker et al., 1973). To improve the digestibility, chemical treatments that may be employed are 1.) swelling with alkaline agents; sodium hydroxide and ammonia, 2.) delignification, 3.) steaming, 4.) hydrolysis and 5.) biochemical reaction that occur when fungi decay lignin.

Physically pretreating the wood can also improve the digestibility. Grinding the wood into small particles increases the surface area and allows for more microbial degradation. The use of vibratory ball milling is an effective method for increasing digestibility by rumen microorganisms, however there is a difference of response between wood species (National Research Council 1983, Satter et al., 1981). Average digestibility can range from 80% to 20% with aspens and sweetgums being highly digested and red alders being less digested.

Irradiation with gamma-rays or high velocity electrons will cause greater digestibility of wood by rumen microorganisms. Here, again, there is a difference of response by wood species. (National Research Council 1983, Satter et al., 1981).

Several studies conducted by Baertsche et al., (1986) looked at the possibility of feeding tree biomass to ruminants for utilization of the cellulosic material. The ten hardwood tree species studied were young and intensively cultured. Less mature trees provide a higher leaf to stem ratio, lower percent lignin and potentially offer more nutrients with greater availability. Gross chemical composition and ruminal digestibility studies show that the tree biomass has great potential as a feedstuff for ruminants. When ensiled, the tree biomass did not drop in quality so fermentation is a possible storage technique.

Pulpmill and Papermaking Residues

Lignocellulosic materials and waste liquor are produced from various pulping processes. Two methods used to pulp wood are 1) the kraft process and 2) the sulfite process (Hall, 1979). With the kraft process wood chips are heated in a sodium hydroxide, sodium carbonate and sodium sulfide solution with temperatures 160 - 180 C for 1 - 2 1/2 hours. Following this procedure the wood chips are placed in a low

pressure tank where they explode and wood pulp is formed. This process acts upon the lignin and degrades the aromatic ring structure.

The other, less used process is the sulfite process. Here the chips are placed in an acidic sulfur dioxide solution and heated to 140 C for 6 - 8 hours. This causes a chemical reaction which attacks the aromatic ring of lignin making it more soluble and easily removed (Hall, 1979). Production of particle board also requires fragmentation of wood chips. This is done with the use of steam, boiling water and ferric chloride.

Residues from pulpmill and papermaking are fibrous and may have a 50% content of cellulose. Amounts of primary sludge produced reflect the quantity of fines allowed in the final product. Primary sludge contents and total amounts produced are influenced by the manufacturing process. For use directly in animal diets, nutritional and chemical analysis must be performed on the primary sludge from individual production sites; no assumed values can be used accurately.

Millett, et al (1973) fed pulp and papermaking residues to ruminants. Four typical residues were combined with other feed ingredients and pelleted. In vitro digestibilities ranged from 45 - 60% with some as high as 90% while in vivo digestibilities ranged from 47 - 78%.

Feeding the residues did not affect rumen pH, ammonia or volatile fatty acid production when compared to controls (Dinius and Bond, 1975). One residue in particular, spent sulfite liquor (SSL) is the effluent formed during the delignification process. Without contamination from harmful chemicals or heavy metals it also is a potential feed for ruminants. Production techniques in the papermaking industry are changing which results in varying content and amounts of SSL solids produced and available. Calcium bisulfite which is found in sulfurous acid is being replaced with compounds that are more soluble and require less effort to recover. New reagents include magnesium, sodium or ammonia.

In the pulpmill and papermill industry the primary sludge is the material which has settled to the bottom of primary collection pond. When collected it is approximatly 35% dry matter. Dinius and Bond (1975) conducted a study feeding mixed hardwood, sulfite, primary sludge and unbleached pulp fines to steers and heifers . The cellulose from the pulp fines were 92.8% digestible and the sludge had 61.4% digestible crude protein. Pulp fines affected the rumen by significantly lowering the pH and increasing volatile fatty acid concentration when compared to hay. Improved weight gains were seen when fed to bred heifers and no detrimental effects were noted for calves or calving.

Fitfield and Johnson (1978) fed a clarifier sludge to beef steers. The clarifier sludge was from an ammonia base sulfite pulp mill and averaged 31% dry matter, 0.77% crude protein, 95.61% acid detergent fiber with 15.45% acid detergent lignin. The feeding value of the sludge was compared in two growing and finishing experiments conducted with beef steers. In both trials palatability problems were not encountered. Average daily gains were similar for steers in both trials when fed various levels of sludge in their diets. The determined values of mean percent total digestible nutrients (TDN %), digestible energy (DE, kcal/g), and metabolizable energy (ME, kcal/g) and 31% dry matter clarifier sludge were 65.9, 2.90 and 2.59 respectively.

By-products from pulpmills and papermills include primary clarifier or lagoon sludges. These sludges contain fairly high percentages of ash and lignin (Millett, 1973). As the chemical pulp fiber level increases, so does the digestibility of the sludge (Millett, 1973). Once again, the digestibility of sludges will differ between sources.

Unpublished work by R. S. Emery involved conducting a limited trial with lactating Holstein cows being fed a particle board process microbial mass (MM). The MM was sludge produced from aerobically treated waste water originating from a particle board plant. Six cows were

placed on a reversal trial with periods 1 and 2 lasting 17 and 21 days respectively. In period 1, three cows were fed SBM and the remaining three were fed the MM; this was reversed for period 2. Assuming that the MM had an energy level equivalent to corn silage, the rations were balanced to be isonitrogenous and isoenergetic. The total mixed rations were fed for 10% refusal and are shown on Table 1a. The level of crude protein was limited, 85% of NRC recommendations, so that the MM protein availability could be evaluated more accurately. Crude energy availability was evaluated but to a lesser extent so as not to confound the results of the trial. The results, shown on Table 1b, indicate that MM was equal to SBM for all the parameters studied except for body weight change. There was a substantially increased loss when animals were fed MM. Converting milk production to 4% fat-corrected milk (FCM) and accounting for body weight loss, the MM diet gave 31.8 lbs/day of FCM and SBM diet gave 40.6 lbs/day of FCM. Based on actual dry matter intake and the estimated energy of 0.775 Mcal NEl/lb dry matter, FCM milk should have been 45.9 and 47.0 lbs/day with MM and SBM respectively. Low quality ingredients in both diets may be the cause of the inefficient energy utilization during this trial. Low dry matter intake caused the animals weight loss. One animal in particular consumed far less dry matter than anticipated and

this may have skewed the results. Based on weight loss, intake and estimated energy content of MM, it was concluded than animals placed on the MM ration consumed 81% of their energy requirement and those fed SBM consumed 87.5%. With these rations, protein appeared to be more limiting than energy. This trial showed that the animals would eat the MM and receive some protein and energy from it, though further trials would be necessary to determine the exact amount.

Table 1a. Ingredient and chemical composition of rations used in the lactation trial

| | Soybean Meal (% of DM)[1] | By-Product (% of DM) |
|---|---|---|
| Corn Silage | 44.52 | 36.14 |
| High Moisture ear corn | 43.80 | 50.74 |
| Soybean meal | 9.33 | ----- |
| By-product | ----- | 10.77 |
| Minerals[2] | 2.35 | 2.35 |
| Feed composition (100%) dry matter basis): | | |
| Dry matter (%) | 37.8 | 38.7 |
| Crude protein (%) | 11.96 | 11.44 |
| Fiber-bound protein (% of total protein) | 4.60 | 5.88 |
| Acid detergent fiber | 42.7 | 34.8 |

[1]Dry matter.
[2]Minerals mixture was 21% salt, 51% calcium carbonate, 20% monodical (21% phosphorus) and 8% magnesium oxide.

Table 1b. Performance of cows fed particle board process microbial mass (MM)

| | By-product | Soybean Meal | By-Product/ Soybean Meal | S.E. diff. | |
|---|---|---|---|---|---|
| Milk (lb/day) | 55.1 | 54.6 | 1.01 | 2.4 | >.25 |
| Fat (%) | 3.25 | 3.44 | 0.94 | 0.23 | >.25 |
| Fat (lb/day) | 1.68 | 1.88 | 0.89 | 0.15 | -.25 |
| Protein (%) | 3.13 | 3.16 | 0.99 | 0.04 | >.25 |
| Protein (lb/day) | 1.70 | 1.72 | 0.99 | 0.04 | >.25 |
| Intake (lb DM/day)** | 32.6 | 33.1 | 0.98 | 1.7 | >.25 |
| Body wt change (lb/day) | -2.6 | -1.6 | -1.62 | 0.4 | -.07 |

*Probability that the means do not differ. Analysis of variance using split-plot design.
**Includes 4.3 lb dry matter from hay.

# MATERIALS AND METHODS

## Formation of Particle Board Process Microbial Mass (MM)

Manufacturing particle board in Michigan consists of using all trees native to the area, except pine, fragmenting the wood with the aid of steam, boiling water and ferric chloride and then pressing the material into the desired shape. This process incorporates lignin in the finished product. The resulting waste water has a high biochemical oxygen demand (BOD) and must undergo aerobic treatment prior to discharge in the Great Lakes.

First the waste water is placed in a settling tank. The solids are collected and the remaining effluent is transferred to an aeration lagoon. Ammonia and phosphate is added to enhance microbial development. Multiple jets fountain the water causing an increased oxygen content as well as moving the water through the entire lagoon. When the water returns to the initial site, approximately 14 days later, it is re-collected. Flotation and filtration aids are applied and the fluid is subjected to a micro bubbling tank. The small bubbles cause large particles to be pushed upward and results in separation of the microbial mass from the water. Now considered environmentally safe, the water can be returned to the Great Lakes (Figure 1).

The microbial mass is now approximately 2% dry matter. Fibrous solids which were collected from the primary

settling tank are now combined with the microbial mass. This mixture is partially dried by a rotary filter and then placed in a drum drier where it can be dried to 89% dry matter.

At the present time, this material is burnt in the plant at an monetary loss. The particle board process microbial mass (MM) which is the combination of activated sludge and fibrous solids, has a proximal analysis as shown on Table 2. As the MM is dried further, the percent of bound nitrogen increases. Problems have developed at the particle board plant when collecting the MM at D.M. levels less than 60%. Increased moisture levels cause the equipment to plug and malfunction. Changes must be made at this level so nutritive quality can be maintained without hindering particle board plant production.

Collection of Samples for Analysis

All samples were randomly collected from various stages of the process. Sample A was of the microbial mass without the fiber solids added. It was 2.02% DM, and analyzed on an as is basis as 6.5% crude protein (CP) of which 6.37% was acid detergent insoluble nitrogen (ADIN). Samples B and C both contained the microbial mass and fiber solids. Sample B was collected prior to drum drying and sample C had

completed drum drying. They were 14% and 90% DM, and analyzed on a dry matter basis as 37.15 and 36.98% CP of which 17.23 and 26.32% was fiber bound nitrogen. The MM which was fed to the various ruminants was collected after partial drying in the drum drier. This partially dry material was the easiest to handle for feed purposes and maintained a relatively high feed value. It was, however, the most difficult to prepare at the plant due to the problems it caused with the equipment.

At this approximately 30% moisture level the MM did show a great amount of mold growth. Samples were sent to the Michigan State University Animal Health Diagnostic Laboratory for toxicologic examination and had no mycotoxins; aflatoxin, zearalenone, T-2 toxin, DAS or vomitoxin. In subsequent trials, the MM was stored in a freezer and removed as needed. No alteration was performed on the MM, it was fed in the same form as it was received (e.g. no pelleting, extruding, etc.).

Analysis of Samples

MM which was fed for the studies was analyzed in the following ways. Dry matter was determined by placing samples in 60 degrees C forced air ovens for 48 hours. Crude protein ([6.25 x g Nitrogen / g D. M.] 100) was

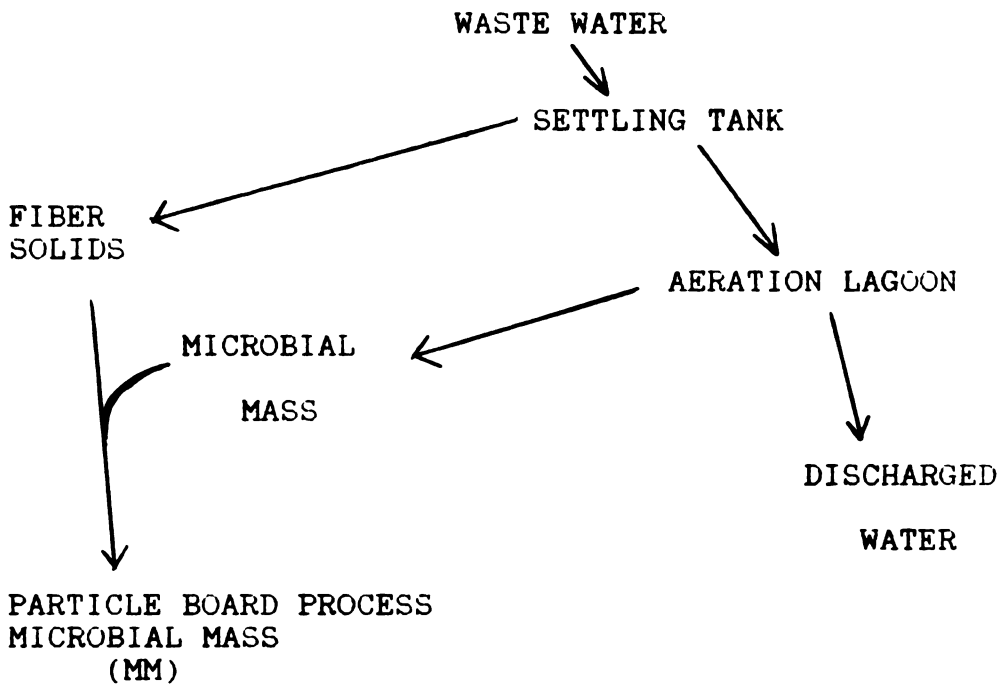


Figure 1. Formation of Particle Board Process Microbial Mass (MM).

determined by the macro-kjeldahl technique (AOAC, 1975). Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined by the method of VanSoest et al (1963). Acid detergent insoluble nitrogen (ADIN) was determined by macro-kjeldahl of the fibrous residue of the acid detergent fiber. In vitro protein degradability was determined by the Nebraska Ficin assay (Poos et al., 1985). In vitro dry matter disappearance (IVDMD) was determined by Tilly and Terry (1963). Dry matter disappearance was also determined by placing 1 gram of MM in nylon bags and suspending the bags within a rumen fistulated cow for 12 hours and compared to alfalfa hay and soybean meal standards. Lignin content was determined by conducting an ADF assay on a 1 gram sample of MM and then soaking the residue in 72% sulfuric acid for 3 hours, filtering and then ashing the retained solids. The difference in weight between the pre and post-ashing weight per dry matter sample is the fraction ADF-L. Percent ash was determined by placing 1 gram sample in a crucible, heating to 550 C for 3 hours and calculating the difference (AOAC, 1975).

Experiment I - Heifer Growth Trial

MM was fed to 28 Holstein heifers (284 kg body weight) in an 8 - week feeding trial during the summer of 1983 at the Michigan State University Dairy Cattle Research Center.

Table 2. Chemical analysis of particle board process microbial mass (dry matter basis).*

| | |
|---|---|
| Dry matter, % | 72 |
| Crude protein, % | 39 |
| Acid Detergent Insoluble Nitrogen/ Total Nitrogen ($\times 10^2$) | 23.04 |
| Acid Detergent fiber, % | 16.06 |
| Neutral Detergent fiber, % | 47.28 |
| Lignin, % | 10 |
| Ash, % | 9 |
| Calcium, % | 0.83 |
| Phosphorus, % | 0.54 |
| Potassium, % | 0.47 |
| Magnesium, % | 0.13 |
| Sulfur, % | 0.44 |
| Manganese, ppm | 207 |
| Iron, ppm** | 26 |
| Copper | 29 |
| Zinc | 181 |

*Mineral analysis provided by the Ohio Cooperative Extension Service.
**Previous analysis reported 2081 ppm.

Table 3. In vivo and in vitro results for particle board process microbial mass.

| | |
|---|---|
| In Vitro Dry Matter Disappearance, % | 90.82 |
| Ficin Undegradable Protein, % | 76.06 |
| Nylon bag | |
| Dry Matter Disappearance, % | 13.49 |
| Nitrogen Disappearance, % | 11.96 |

Equal numbers of animals were assigned to each of the four pens, with 2 pens per treatment. The dietary treatments for the duration of the experiment consisted of : corn silage - 84% ration dry matter, straw - 9.9%, mineral supplement - 0.7%, and either soybean meal (SBM) - 4.9% or MM - 5.5% (Table 4). Water and a trace mineral salt block were available at all times. Rations were designed from the 1970 Beef Cattle NRC, formulated to be isonitrogenous and fed as a total mixed ration once daily.

Individual body weights were taken at 11:00 AM the first and final two days of the trial and once weekly during the trial. Orts were collected and weighed each morning at 6:30 AM and animals were fed at 7:30 AM.

All heifers were fed a corn silage - soybean meal ration for 4 days for initiation and given a 1 1/2 cc injection of vitamin A and D. Following this initiation period, pens 1 and 3 continued receiving the SBM diet while pens 2 and 4 received the MM diet. Rations were fed for 10% weighback with increases/decreases made in 10% increments. Feed samples were collected and composited for a one week period. All feed composites were kept at -5 degrees C until analyzed.

Table 4. Ingredients and chemical composition of rations used in the heifer growth trial.

| | Treatment 1 (Control) % of D. M. | | Treatment 2 % of D. M. |
|---|---|---|---|
| Corn Silage | 84.48 | Corn silage | 83.84 |
| Soybean meal | 4.92 | MM | 5.52 |
| Straw | 9.95 | Straw | 9.88 |
| MonoDical | 0.146 | MonoDical | 0.319 |
| Limestone | 0.504 | Limestone | 0.441 |
| Total Ration | | | |
| % DM | 34.52 | | 34.02 |
| % CP | 11.33 | | 9.63 |

1 1/2 cc injection of vitamin A & D given at start of trial.

Experiment II - Sheep Nitrogen Balance Trial

A 4 x 4 Latin square design was employed to compare the nitrogen availability of the MM when fed to growing wethers. Again, the MM was compared to SBM.

Four 4 month old wethers were fed diets containing 13%CP or 11%CP from either MM or SBM, and diets were isocaloric assuming the MM had a caloric content equal to corn. The diets on a dry matter basis were approximately : 1) 15% SBM, 30% brome hay, 38% corn cobs, 15% cracked corn and 2% molasses, vitamin/mineral supplement; 2) 12% SBM, 32% brome hay, 39% corn cobs, 15% cracked corn and 2% molasses, vitamin/mineral supplement; 3) 19% MM, 27% brome hay, 34% corn cobs, 18% cracked corn and 2% molasses, vitamin/mineral supplement; 4) 16% MM, 28% brome hay, 35% corn cobs, 18% cracked corn and 2% molasses, vitamin/mineral supplement (Table 5). Treatments 1 and 3 were 13% crude protein and treatments 2 and 4 were 11% crude protein. Throughout the trial, wethers were housed at the Michigan State University Beef Cattle Research Center. The trial ran from August through December 1984. The wethers received the diets during a 9 day adjustment period followed by a 5 day collection period. Feces, urine and orts were measured and analyzed for crude protein. Rumen fluid was also collected

and analyzed for pH, rumen ammonia and volatile fatty acids (VFA's).

All four wethers were surgically fitted with rumen cannulas one month preceding the collection periods. Prior to the trial, all lambs were shorn, feet trimmed, vaccinated for enterotoxemia, treated with an anthelmintic and injected with vitamins A and D and selenium.

During collection periods, rumen fluid was collected via pipette and 40 ml was transferred to sterile 50 ml polypropylene centrifuge tubes. Rumen fluid was collected at 0, 2, 4, 8, and 12 hours post feeding and strained through four layers of cheese cloth, pH determined and 25 ml was acidified with 0.5 ml 50% sulfuric acid. Acidified samples were centrifuged and the supernatant frozen at minus 5 C until analyzed for VFA's and ammonia-nitrogen. Metabolism cages allowed for feeding a known amount of feed and total collection of urine and feces. Plastic containers placed under the metabolism cages containing 5 ml of sulfuric acid to maintain a low pH and reduce nitrogen loss through volatilization. Five liter plastic bottles were used to store the urine during the collection period. Feces were collected in bags attached to harnesses which were emptied at 12 hour intervals. Wet feces were placed in

Table 5. Ingredients for rations used in the sheep nitrogen balance trial.

| | Rations | | | |
|---|---|---|---|---|
| | %CP | | | |
| | 13% | 11% | 13% | 11% |
| | % of DM | | | |
| | Treatment | | | |
| | 1 | 2 | 3 | 4 |
| Brome Hay | 30.00 | 30.92 | 27.35 | 28.28 |
| Corn Cobs | 37.51 | 38.65 | 34.19 | 35.35 |
| Cracked Corn | 14.84 | 15.29 | 17.58 | 18.18 |
| Soybean Meal | 14.84 | 12.24 | ----- | ----- |
| MM | ----- | ----- | 18.60 | 15.84 |
| Molasses | 0.77 | 0.79 | 0.70 | 0.73 |
| Dical | 0.67 | 0.69 | 0.61 | 0.63 |
| Limestone | 1.00 | 1.03 | 0.61 | 0.63 |
| TMS | 0.32 | 0.34 | 0.31 | 0.31 |
| SE 90 | 0.05 | 0.05 | 0.05 | 0.05 |

plastic bags and gross weights were taken at the end of the collection period.

Diets were mixed every 7 days and refrigerated. The rations were placed in individual plastic bags to ease feeding and assure equal amounts fed. Sub-samples of the total mix were frozen for later analysis. The concentrates were pre-mixed. Two of the concentrates contained SBM and one did not. The concentrates were combined with hay, molasses and, when appropriate, MM. Mixing was done in the ribbon mixer located at the Michigan State University Beef Cattle Research Center for 5 minutes. To ease mixing, the hay was cut to 2.5 cm length with a haylage field chopper.

Wethers were placed on the respective diets for nine days and then placed in the metabolism cages where total collections were run for five days. Between periods. the sheep were fed a interim diet of 50% SBM and 50% MM that contained 18%CP. This was done to acclimate the animals to the MM and permit for compensatory growth.

Wethers were weighed on days 0, 9, and 14 of each period.

Rumen fluid pH was determined with an Orion pH meter. The VFA concentration was analyzed with a Hewlett-Packard gas chromatograph containing a column packed with 10% SP 1200/1% H3PO4 on 100/120 Chromosorb.

Rumen ammonia was determined by a Technicon Auto Analyzer (Wall and Gehrke, 1975).

Experiment III - Sheep energy digestibility trial

Three growing wethers were used in a 3x4 latin square to test the effect on energy digestibility when replacing cracked corn and soybean meal with MM at 0, 10, 20 or 30% of the ration dry matter. The diets were 15.0, 15.0, 15.0, and 15.3% crude protein respectively and formulated as follows: 1) Control, 37% corn, 15% SBM, 37% brome hay, 10% molasses and 1% vitamin/mineral supplement; 2) 37% corn, 10% MM, 8%SBM, 33% brome hay, 10% molasses and 1% vitamin/mineral supplement; 3) 36% corm, 20% MM, 33% brome hay, 9% molasses and 1% vitamin/mineral supplement; 4) 28% corn, 30% MM, 31% brome hay, 10% molasses and 1% vitamin/mineral supplement (Table 6).

Wethers were fed the diets for a 9 day adaptation period and a 5 day collection period. During the collection period, the wethers were placed in metabolism cages where urine, feces and orts were collected in the same manner as Experiment II- Sheep Nitrogen Balance Trial. This trial was conducted at the Michigan State University Dairy Research Center from January through March 1985.

The total mixed rations were designed from the 1975 Sheep NRC. Prior to the trial, rations were mixed,

completely frozen and 22.7 kg bags were thawed and fed when needed.

Feed, feces and orts were analyzed for dry matter. Gross energy values were determined on the feed, feces, orts and MM by utilizing an Adiabatic Oxygen Bomb Calorimeter. Animals were weighed on days 0, 9, and 14 of each period.

Statistical Analysis of Data.

For all the trials, the data were compared statistically by analysis of variance techniques described by Gill (1978) for split plot or Latin square designs.

Table 6. Ingredients and chemical composition for rations fed in the sheep energy digestibility trial.

Rations (% of Dry Matter)

| | | % MM | | |
|---|---|---|---|---|
| | Control | 10 | 20 | 30 |
| Corn | 37.48 | 37.46 | 36.51 | 27.61 |
| Soybean Meal | 14.67 | 7.57 | ----- | ----- |
| MM | ----- | 9.84 | 20.60 | 30.05 |
| Brome Hay | 36.67 | 34.06 | 32.53 | 31.45 |
| Molasses | 9.78 | 9.84 | 9.40 | 10.13 |
| Limestone | 1.05 | .91 | .65 | .45 |
| Trace Mineral Salt | .29 | .26 | .25 | .24 |
| SE 90 | .06 | .06 | .05 | .05 |
| Total Ration | | | | |
| % Dry Matter | 87.18 | 86.54 | 84.76 | 82.96 |
| % Crude Protein | 15.29 | 14.98 | 15.00 | 17.90 |

# RESULTS AND DISCUSSION

## Chemical Analysis of MM

Proximate analysis of the MM which was fed to ruminants is shown on Table 3. The nylon bag data show the MM was not readily degraded in the rumen based on the low dry matter and nitrogen disappearance values. The protease undegradable protein value is in agreement with the nylon bag data in that it shows the rumen environment is not favorable to proteolysis of MM.

The % In-Vitro Dry Matter Digestibility results, however, show the MM is degraded. Based on visual appraisal, the MM did not appear to have been affected when suspended in rumen fluid and buffers for 48 hours. The MM particles remained intact when the tubes were agitated. With the addition of HCl, pepsin and incubating 48 hours further, the particles did break apart and the final value was 90.82% IVDMD. This suggests MM may be degraded in the lower gut and be a potential by-pass energy and protein.

## Heifer Growth Trial

When MM was first fed, the heifers were hesitant to eat. The MM does have a distinct odor derived from a combination of volatile fatty acids and burnt wood. After approximately 4 hours, all the heifers were eating. Perhaps

the volatile odors had dissipated sufficiently. No further incidence of delayed intake occurred. Palatability problems occurred in several other trials when sewage sludge or sludge-sawdust mixtures were fed to rats and ruminants (Hackler et al. (1957), C.B. Ammerman et al. (1964)). Dinius and Bond (1975) fed wood pulp fines to heifers and palatability was not a problem.

The two diets were formulated to be isonitrogenous, however, the SBM diet analyzed as being 11.33% crude protein and the MM diet analyzed as being 9.63% crude protein. These differences were discovered after completion of the trial and may have affected the results.

Dry Matter Intake

Figure 2 shows the dry matter intake by week. The great fluctuations were due to the extreme heat and humidity experienced during the trial. When analyzed on a daily basis, dry matter intake did not differ significantly between treatments. Kienholz et al. (1979) found lowered intake with animals receiving Metropolitan Denver Sewage Sludge (MDSS) in their rations. The decreased intake was considered the result of the sludge diluting the diet. Average animal performance values were 6.31 and 6.32 kg dry matter intake per day for the SBM and MM diets respectively with a standard error of 1.16.

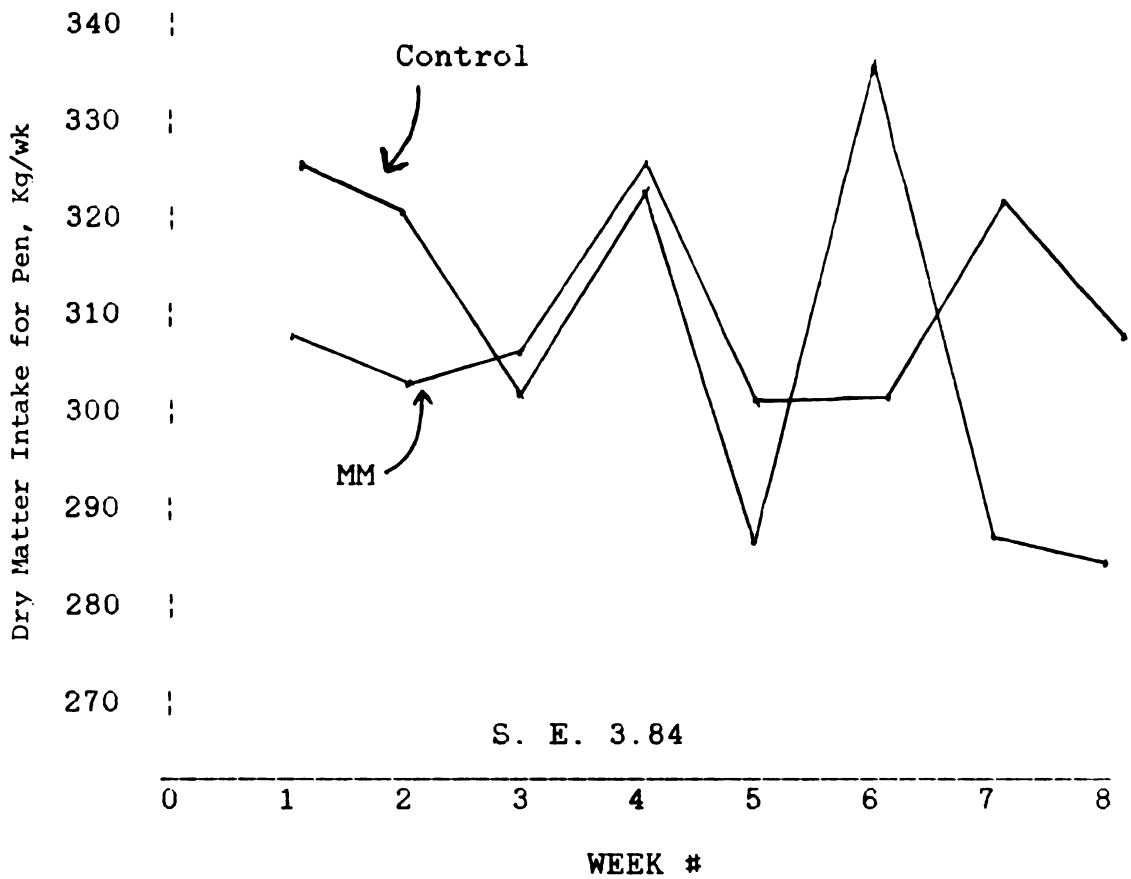


Figure 2. Heifer growth trial
Means of weekly intake per pen

Weight Gains and Efficiency of Feed Utilization

Means of weekly gain by treatment per pen are shown on Table 7. Again, fluctuations could be attributed to the extreme heat and humidity experienced throughout the trial causing erratic intake and, thus, gain. Another confounding factor with the heifer growth performance is the fact that the initial body condition of the control heifers was somewhat fat. Animal performance data are shown on Table 8. Analysis of average daily gain indicated a difference between treatments ($P<.20$). Heifers receiving the SBM diet gained an average of 0.67 kg daily while those receiving the MM diet gained 0.55 kg. Kienholz et. al., (1979) also found a similar difference between control and sludge treated diets. If the sludge was assumed to contain no energy then the gains were expected and acceptable values. When processed garbage (fermented refuse and urea, pelleted) was fed to steers they showed a greater daily gain than steers fed peanut hulls and cottonseed meal (PCM) or peanut hulls and urea (PUREA) (Utley et al., 1972). These steers showed average daily gains (kg) of 1.35, 1.24 and 1.18 respectively.

Feed efficiency ratio, or kg dry matter per kg gain, was 9.19 and 11.38 for the SBM and MM diets respectively. These values are similar to those of Bertrand's study (1980)

Table 7. Heifer Growth Trial.

Means of Weekly Gain by Treatment per Pen

| Week | Control (kg) | MM (kg) |
|---|---|---|
| 1 | 4.87 | 6.40 |
| 2 | 4.84 | 5.16 |
| 3 | 2.53 | 2.43 |
| 4 | 9.05 | 3.57 |
| 5 | 2.17 | -0.45 |
| 6 | 3.25 | 5.78 |
| 7 | 7.56 | 7.14 |
| 8 | 4.12 | 1.10 |
| $\bar{x}$ | 4.80 | 3.85 |
| S.E. | .88 | |

Table 8. Performance of heifers fed particle board process microbial mass (MM).

Animal Performance

| | Soybean Meal | MM | S.E. |
|---|---|---|---|
| Body weight, start (kg) | 284.3 | 284.7 | |
| Average daily gain (kg) | 0.67 | 0.55 | .07* |
| Dry matter intake/day (kg) | 6.31 | 6.32 | 1.66 NS |
| Dry matter/gain | 9.19 | 11.38 | .66 NS |
| Relative value of MM to Soybean meal | | | .81 |

* P < .20

in which Chicago Sludge fed to steers resulted in a feed efficiency ratio of 11.1 for the control ration and 11.8 for the sludge diets. Based upon the feed efficiency ratio values, the relative value of MM to SBM is .81.

At the conclusion of this trial, it was felt that the MM showed potential for being a protein supplement in growing heifer rations. Reduced heifer growth could be attributed to the lower protein, energy or both in MM diets as compared to SBM diets.

Sheep Nitrogen Balance Trial

Intake of diets containing MM were, initally, poor. The original rations were formulated with only 0.70 - 0.79% molasses as percent of ration dry matter. The wethers fed MM went completely off feed for 2 days followed by 3 days of diligent sorting and ingestion of all feed except the MM. All diets were altered to include 10% molasses of the total ration dry matter. The sweet smell and adhesive nature of molasses alleviated the majority of intake and sorting problems. These difficulties arose each time a wether received the MM diet for the first time. Consumption was adequate following the initial 3 - 4 days. Perhaps the excessive dislike of the MM experienced with sheep versus cattle lies in the fact that MM does have a similar appearance to sheep feces. Though we did not change the MM,

perhaps the sheep would have eaten more readily if the MM had been altered in some fashion (i.e. pelleting).

Dry Matter Intaken and Gain

Mean kg intake and gain values were not significantly different between treatments (Table 9). Any difficulties experienced earlier with intake of MM were alleviated and had no effect during the collection periods.

Nitrogen content for intake and feces was not significantly different (Table 10). Mean grams nitrogen intake values showed a trend to decrease with both the 11 and 13% MM treatments. Fecal nitrogen values showed a trend to increase with the 11 and 13% MM treatments. Though these trends were not significant they do show the MM nitrogen is absorbed to a lesser extent than SBM nitrogen. Lowered excretion of urinary nitrogen shows that nitrogen in MM which is absorbed is retained better than the nitrogen absorbed from SBM.

Nitrogen Absorbed

The percent nitrogen absorbed which is calculated by nitrogen absorbed / nitrogen intake x 100, is significantly different between treatments by $P<.05$ (Table 12). Based on values for percent nitrogen absorbed, the mean relative value of nitrogen digestibility for MM vs. SBM is

Table 9. Performance of sheep fed particle board process microbial mass (MM) for nitrogen balance trial.

Results

5 D Collection Period

| | SBM | | MM | | S.E.D. |
|---|---|---|---|---|---|
| | 13% | 11% | 13% | 11% | |
| Mean KG Intake | 6.82 | 8.17 | 6.89 | 6.67 | .623 NS |
| Mean KG Gain | -2.16 | -0.19 | 0.11 | -0.95 | 1.139 NS |

Table 10. Performance of sheep fed particle board process microbial mass (MM) for nitrogen balance trial

| 5 D Collection Period | | | | | |
|---|---|---|---|---|---|
| | SBM | | MM | | S.E.D. |
| | 13% | 11% | 13% | 11% | |
| Mean N Intake (g/day) | 147.7 | 148.8 | 134.6 | 108.3 | 16.17 NS |
| Mean N Feces (g/day) | 41.7 | 49.6 | 64.1 | 56.8 | 13.15 NS |
| Mean N Urine (g/day) | 54.6 | 32.6 | 21.6 | 15.3 | 10.32* |

*P < .05.

Table 11. Calculations used for sheep nitrogen balance trial

| | | |
|---|---|---|
| % N Absorbed | = | N Absorbed/N intake x 100 |
| N Absorbed | = | N Intake - N feces |
| N Retained | = | N Absorbed - N urine |
| N Retained as % of absorbed | = | N Retained/N absorbed x 100 |

Table 12. Performance of sheep fed particle board process microbial mass (MM) for nitrogen balance trial.

| | 5 D Collection Period | | | | |
|---|---|---|---|---|---|
| | SBM | | MM | | S.E.D. |
| | 13% | 11% | 13% | 11% | |
| % N Absorbed | 72.41 | 67.30 | 53.40 | 48.40 | 6.21* |
| Mean N Retained (g/day) | 51.40 | 66.50 | 48.90 | 36.20 | 8.96** |
| N Retained As % of Absorbed | 45.30 | 67.50 | 68.00 | 66.80 | 14.31 |

*P < .05
**P < .10

approximately 73%. Mean grams nitrogen retained is, again, poorer for the MM diets. Differences are significant at P<.10 between treatments. The nitrogen retained as percent of absorbed, or biological value (B.V.), shows a trend to be somewhat greater for MM than SBM diets though the difference was not significant. This is in agreement with the trends shown earlier pertaining to nitrogen content in feces and urine. Hackler et al., (1957) reported that nitrogen retention was similar between sewage sludge, soybean oil meal and urea supplemented diets. The percent apparent nitrogen digestibility was significantly different between the sewage sludge and the other protein sources with the sludge having lower digestibility (P<.001). A lowered urinary nitrogen loss for animals on the sewage sludge diet resulted in a high B.V., higher than SBOM and urea; 69, 60 and 60 respectively. It was speculated that the sludge, being a fermentation product, may have had some factors that favorably affected the rumen fermentation and biosynthesis of protein.

Rumen Ammonia Nitrogen

Rumen parameters are shown on Tables 13, 14 and 15. The mean mg ammonia nitrogen (NH3-N)/ml values for the SBM diets are initally high, 0 time, and steadily decline. The 13% SBM diet does show a slight increase during the final

Table 13. Mean rumen $NH_3$-N values of sheep fed particle board process microbial mass (MM).

| Time (hours) | 0 | 2 | 4 | 8 | 12 |
|---|---|---|---|---|---|
| Treatment | ---------- | | mg N/ml | | ---------- |
| 13% SBM | .1913 | .1790 | .1497 | .1580 | .1608 |
| 11% SBM | .1859 | .1719 | .1592 | .0919 | .0828 |
| 13% MM | .0833 | .1254 | .0923 | .0406 | .0375 |
| 11% MM | .0877 | .1075 | .0642 | .0716 | .0415 |

Table 14. Mean rumen pH values of sheep fed particle board process microbial mass (MM).

| | SBM | | MM | | S.E.D. |
|---|---|---|---|---|---|
| | 13% | 11% | 13% | 11% | |
| Mean Rumen pH | 6.18 | 6.15 | 5.97 | 6.19 | .094* |
| Mean Rumen $NH_3$-N (mg/ml) | .1677 | .1383 | .0758 | .0744 | .012** |

*P < .25
**P < .005

Table 15. Mean volatile fatty acid values of sheep fed particle board process microbial mass (MM).

Volatile Fatty Acids

| | % SBM | | % MM | | |
|---|---|---|---|---|---|
| m moles/liter | 13 | 11 | 13 | 11 | S.E.D. |
| Acetate | 54.46 | 63.25 | 59.63 | 58.94 | 5.164 |
| Propionate | 14.41 | 14.92 | 12.69 | 13.00 | 1.221 |
| Iso-Butyrate | 1.078 | 1.171 | 0.743 | 1.023 | 0.102* |
| Butyrate | 10.46 | 10.87 | 10.89 | 10.49 | 1.258 |
| Iso-Valerate | 1.370 | 1.581 | 1.054 | 1.255 | 0.223 |
| Valerate | 0.910 | 1.146 | 0.770 | 0.769 | 0.085* |
| Acetate:Propionate | 3.857 | 4.360 | 4.725 | 4.601 | 0.318 |

*P < .05

time collection whereas the 11% SBM diet does not. The 13 and 11% MM diets follow a more expected pattern in that the values start low, peak at 2 hours and then decline.

Overall, MM rumen NH3 values are far less than SBM showing the by-product is not readily degraded and the nitrogen is not as available in the rumen as SBM. The differences in mean rumen NH3-N between SBM and MM are significant at P<.005.

Rumen pH and Volatile Fatty Acids

Mean rumen pH values may differ between treatments at P<.25. The 13% MM treatment might be skewing the difference because the mean value for the 11% MM treatment is similar to 13 and 11% SBM treatments. Just why the 13 % MM treatment shows such a low mean pH is not clear. There is no consistency among the animals becoming ill when placed on that diet.

VFA results (Table 15) show that the only significant differences between treatments are seen with isobutyrate and valerate. Both of these VFA's have lowered mmolar concentration with the MM diets (P<.05).

Acetate to propionate ratio is not significantly different between treatments. There is a trend, however, for a higher acetate to propionate ratio with the MM diets. This, perhaps, is due to the more ADF with the MM diet.

These same rumen parameters were measured in a study by Millett et al., (1973) in which steers were fed pulp and papermaking residues up to 65% of the dry matter diet. These residues consisted of the following: 1. screen rejects from the sulfite pulping of aspen, 2. unbleached parenchyma cell fines from an aspen sulfite tissue mill, 3. unbleached fines from a southern pine kraft mill and 4. bleached fines from a mixed hardwood southern kraft mill. Rumen pH ranged from 6.4 to 6.6 with the lower value being the control ration and the higher value being the 65% residue diet. Rumen ammonia values ranged from 17 to 24mg/100 with 65% and control diets respectively. Volatile fatty acid values ranged from 44 to 83 mmoles/liter for control and 50% residue diets respectively. Also in this study, the rumen microbial population was studied and it was concluded that there was no difference between treatments ($P>.05$).

Conditions of Sheep

While the wethers were housed at the MSUBCRC they frequently became ill during collection periods. On the second day of the second collection period, one wether developed a fever and showed trembling. Following 3 days of treatment he was back on trial. Period 3 had to be re-run completely due to all wethers developing pneumonia during

the collection period. When period 3 was conducted for the second time, one wether had to be removed and replaced due to diagnosed chronic pneumonia. Also during this period another wether went off feed for 2 days. When diagnosed all the wethers suffered from pulmonary disorders which I feel were due to the drafts the animals experienced while housed in the sick-bay at the MSUBCRC in metabolism cages. For period 4 the sheep were re-located to the MSU Dairy. This facility was enclosed and no further incidences of pneumonia occured. All remaining wethers appeared healthy and capable of continuing the research. At the start of the subsequent energy digestibility trial, one wether developed urinary calculi and was destroyed. The 3 remaining wethers completed the energy digestibility trial without difficulties.

Sheep Energy Digestibility Trial

The rations for this trial (Table 6) were adjusted to offer approximatly 15% crude protein with each increasing amount of MM. The amount of protein in the 30% MM ration was calculated to be 15.3% crude protein but actually assayed at 17.9%. The difference can not be explained. The total mixed ration dry matter amount did increase among treatments with each subsequent increase of %MM. The exception was that 20% MM had a dry matter amount equal to

the 30% ration (Table 16). These differences were significant at a level of $P < .10$ . The differences in amount of dry matter did not affect intake. The gross kcal per day was significantly different among treatments ($P<.01$). A trend similar to the ration dry matter amount appears here showing a steady increase from 0% to 20% MM with similar values between 20 and 30% MM. Fecal output did vary among treatments ($P<.05$). The treatments resulted in mean fecal dry matter (kg/day) of 1.883, 2.497, 2.870 and 2.337 for 0, 10, 20, and 30 % MM rations. No explanation can be offered as to why the 20% diet resulted in the highest output.

Apparent Energy Digestibility

Apparent energy digestibility was calculated in the following manner:

$$\frac{\text{Energy intake - Energy in feces}}{\text{Energy intake}} \times 100 = \text{\% Apparent energy digestibility}$$

Composited samples of the five day collection period total mixed ration and feces were assayed and caloric values were entered in the formula. The results (Table 16) show that there was a difference among treatments. The 0% and 30% MM rations showed the highest apparent energy digestibility (63.6 and 61.3% respectively) while the 10 and 20% MM rations showed a lower digestibility (56.5 and 53.8%

Table 16. Performance of sheep fed particle board process microbial mass (MM) for energy digestibility trial.

| | % MM | | | | |
|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | S.E.D. |
| Dry Matter Intake (kg/day) | 1.06 | 1.10 | 1.23 | 1.24 | .07[a] |
| Gross Kcal/day | 4311.4 | 4736.0 | 5690.8 | 5673.6 | 301.8 [c] |
| Mean Dry Matter feces (kg/day) | 1.883 | 2.497 | 2.870 | 2.337 | .051[b] |
| Gross Kcal feces/day | 1571.2 | 2059.4 | 2622.4 | 2169.4 | 221.9 [d] |
| % Apparent Energy Digestibility | 63.6 | 56.5 | 53.8 | 61.3 | 4.02 |
| MM approx. energy, % | 21.03 | | | | |

[a] $P < .10$ [b] $P < .05$ [c] $P < .01$ [d] $P < .025$

respectively). These differences, while not significant did show a trend (P<.25). This trend is difficult to explain. Individual animal performance (Table 17) shows that % apparent energy digestibility is significantly different among animals (P<.05). Though this should not enter into treatment effect it is an interesting response.

Approximate Energy Digestibility

Based upon the values of % apparent energy digestibility a mean relative approximate energy digestibility value of MM was calculated as being 21.03%. This value is possibly a more accurate estimate of the energy digestibility than the apparent energy.

Firth and Johnson (1955) concluded that low levels of dry activated sewage sludge added to baby pig rations ork by Firth and Johnson (1955) concluded that low levels of dry activated sewage sludge added to baby pig rations improved digestibility at the level of 5% (P <.10) while rations with 10% sludge inhibited growth and feed efficiency. It was felt that the fermented product supplied factors which aided digestion until a certain level was reached and then digestion was inhibited. The sheep energy digestibility trial showed no detrimental effects but, rather, somewhat enhanced digestibility when MM was fed at levels greater

Table 17. Performance of individual animals fed particle board process microbial mass (MM) for energy digestibility trial.

| | Animal | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | S.E.D. |
| DMI/D (kg) | 1.20 | 1.16 | 1.12 | .06 |
| Gross Kcal DMI/D | 5271.2 | 5111.0 | 4926.8 | 261.36 |
| Mean DM feces/D (kg) | .471 | .420 | .548 | .05 |
| Gross Kcal feces/D | 2094.6 | 1834.2 | 2388.0 | 192.1* |
| % Apparent Energy Digestibility | 60.6 | 64.0 | 51.8 | 3.48** |

*P < .10
**P < .05

than their trial. The benefits derived from fermentation should already be present with ruminants.

Weight Gains and Efficiency of Feed Utilized

Wethers body weight increased an average of 1.59 kg from day 0 - 9 with no significant differences among treatments or animals (Table 18). One wether did show a negative energy balance and a poorer feed efficiency ratio than the others. The other two wethers showed a positive feed efficiency ratio (Table 19). These conversion ratios for all the animals during the five day total collection periods were consistantly poorer than the previous nine day adaptation periods. The group averaged a negative energy balance during the collection periods and a positive energy balance during the adaptation periods. Perhaps the animals were under stress during these collections (both Nitrogen balance and Energy digestibility trials) and that led to the poorer performance shown at this time. In the study conducted by Kienholz et al., (1979) steers fed 12% Metropolitan Denver Sewage Sludge (MDSS) showed a significantly lower body weight gain than those fed 0 or 4% MDSS. The conclusion was that no energy whatsoever was available from the MDSS. Calculations based on this assumption did equal the lower energy body weight gains which were achieved. The sheep study did show

Table 18. Gain and feed efficiency values of sheep fed particle board process microbial mass (MM) for energy digestibility trial.

| | Treatments (% MM) | | | | |
|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | S.E.D. |
| Mean kg Gain | | | | | |
| Days 0-9 | 1.66 | 1.51 | 1.82 | 1.36 | 1.27 |
| Days 0-14 | 1.66 | 2.12 | 1.21 | 0.75 | 1.22 |
| Days 9-14 | 0.00 | 0.61 | -0.61 | -0.61 | .585 |
| DMI/kg Gain | | | | | |
| Days 0-14 | 9.32 | 8.02 | 14.35 | 23.03 | |
| Days 0-9 | 5.99 | 7.19 | 6.13 | 8.21 | |

Table 19. Gain and feed efficiency values of individual animals fed particle board process microbial mass (MM) for energy digestibility trial.

| | Animal | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | S.E.D. |
| Mean kg Gain | | | | |
| Days 0-9 | 1.81 | 0.80 | 2.16 | 1.10 |
| Days 0-14 | 1.24 | 0.91 | 2.15 | 1.06 |
| Days 9-14 | -0.57 | 0.12 | 0.00 | 0.51 |
| DMI/kg Gain | | | | |
| Days 0-14 | 6.59 | 7.50 | 6.46 | |

nonsignificant trends for poorer feed efficiency performance with the addition of MM to the diets over days 0 - 9. The greatest feed efficiency for the total 14 day treatment period did occur when MM was fed at 10%.

The results from this trial are weakened by the fact that low numbers of animals were used and a great deal of variation occurred with animal performance. These problems may have canceled any significant variation with % apparent energy digestibility and the results may be unreliable.

# GENERAL CONCLUSIONS

These studies have shown several general conclusions about feeding MM to ruminants.

1. The MM appears to be a viable feedstuff for ruminant animals. Based upon chemical analysis the MM provides 40% crude protein, 16% ADF, .83% calcium, .54% phosphorus and other minerals. The nitrogen balance study and several chemical assays, IVDMD, nylon bag and the Nebraska Ficin assay, all indicated that the MM had low degradability in the rumen but could be digested further down the gastro-intestinal tract thus showing potential as a by-pass protein. The rather high amount of acid detergent insoluble nitrogen (ADIN) found with the MM could be lowered if collection technique from the particle board plant were altered in some way.

2. Palatability problems appeared only when the MM was fed to sheep and this seems to have occurred from physical appearance rather than any other reason. Storage of the MM does present some difficulties. Having a high moisture content permits mold growth. For quiescence and stability the MM was frozen for these trials. A more feasible approach for a farm might include fermenting or treatment with propionic acid though these options were not part of this study.

3. The heifer growth trial showed a relative value of MM to SBM of 81%. This value is weakened by the fact that unintentionally the treatments were not isonitrogeneous, MM was given an assumed energy value, control heifers were somewhat overconditioned at the start of the trial and ambient temperatures were extremely hot during the trial.

4. Based on % nitrogen absorption values from the sheep nitrogen balance trial the mean relative value of nitrogen digestibility of MM to SBM is 73%. The % nitrogen absorbed and mean grams nitrogen retained were significantly lower with both MM treatments. Excretion of nitrogen was greater for sheep fed MM so perhaps this explains the trend for greater nitrogen retention as % of nitrogen absorbed when animals were fed those treatments.

5. Rumen ammonia nitrogen values agree with chemical analysis in that MM is poorly degraded in the rumen. The nitrogen which was absorbed must have been beyond the rumen showing that MM appears to be a by-pass protein. Significantly lowered production of isobutyrate and valerate occurs with MM treatments in addition to a trend towards an increased acetate to propionate ratio. The pH of the rumen does not seem to be affected by feeding MM.

6. The sheep energy digestibility trial shows the apparent energy digestibility of the MM is not significantly different from cracked corn. This conclusion is unreliable,

however, due to the low numbers of animals in the trial and the high amount of variation which may have canceled error and resulted in an incorrect conclusion. More accurate, perhaps, is the mean approximate digestibility of MM at 21%.

Suggestions for Further Study of MM

The high occurrence of illness during the nitrogen balance trial and relatively low number of animals for the energy digestibility trial suggest the possible need for conducting both trials again. Repeating may prove valuable for re-assessing the nitrogen availability, however, the energy digestibility trial showed such a low approximate digestibility it may not prove worthwhile to re-conduct.

Adequate facilities for conducting research with sheep is necessary. Enclosed housing and improved collection pens would help greatly.

Stability studies would provide data on the feasibility of various storage methods in addition to changes in nutritive value of MM over time.

Further study of the variation of MM at the plant to determine consistency for a short term basis and with long term seasonal effects. In addition to this, developing a quality control program to be implemented should the MM be sold on a commercial basis is recommended.

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