

## **Executive Summary of FPRF Projects October 1999**

**“Development of formulated organic soil amendments for managing populations of soilborne pests, including weeds, nematodes, fungi and bacteria .”**

**Dr. George Lazarovits - Agriculture and Agri - Food Canada**

This work has been progressing since 1994. Laboratory studies have verified the efficacy of meat and bone meal in reducing and eliminating the incidence of major potato diseases. Clear evidence has now been obtained for the existence of two mechanisms of actions responsible for the effects against soilborne pathogens. One being ammonia and the other nitrous oxide and their alteration of soil ph. Thus matching the rate of meat and bone meal and related products to the soil properties and altering application rates an effective broad spectrum and practical alternative to chemical fumigants is entirely possible. Current work is directed at formulation of rendering products of soils requiring ammonia generation whereas nitrous oxide generation for others.

**“Can Prepartum Dietary Tallow Be Used to Increase Body Condition and Prevent Fatty Liver in Dairy Cows?”**

**Dr. James Drackley - University of Illinois**

We proposed that supplemental fat fed to dairy cows during the dry period would help to restore body condition (body fat reserves) to thin cows and help to prepare cows for subsequent milk production. In a previous experiment funded by FPRF, we found that cows fed a diet supplemented with choice white grease had less fatty liver development at calving, which would indicate a more desirable metabolic adjustment to lactation. However, total nutrient intake was decreased by the high-fat diet, so that we could not directly attribute the metabolic changes to the fat supplementation. The objectives of the current project were 1) to determine if the decreased liver fat at calving that we observed previously in cows supplemented with animal fat (grease) during the dry period was due to the fat supplementation or to nutrient restriction from decreased feed intake; 2) to determine if dry period feeding strategy affects lactation performance and incidence of health problems around calving; and 3) to determine if body condition can be added safely to dairy cows during the dry period by adding animal fat to the dry-period diet.

The experiment was conducted with 60 Holstein cows, divided into five dietary treatment groups. The experimental diets were fed throughout the last 60 days before expected calving, and then all cows received one lactation diet after calving. Cows were fed either a fat-supplemented diet or an unsupplemented diet of equal energy content, both for ad libitum (free choice) intake and at a restricted intake. A fifth dietary treatment was a higher-energy diet with supplemental fat. Cows fed either diet at restricted intake during the dry period had greater feed intakes after calving and less liver fat at calving. Although supplemental fat caused some smaller changes in metabolism, we conclude that nutrient intake during the dry period has a much greater effect on metabolic adjustments to milk production than does fat supplementation. Fat supplementation to dry cows or to cows during the transition from pregnancy to lactation may have merits in certain situations, but it does not appear that fat supplementation before calving will benefit all dairy cows.

**“Further Evaluation of the Effects of Processing Temperature and Ash Content on Protein Quality of Animal Meals for Poultry.”**

**Dr. Carl Parsons, University of Illinois**

The results showed that reprocessing MBM at pressures of 15 to 30 psi depressed digestibility for most of the component amino acids in the 5 to 10% range and up to 20% for cystine. Increasing the pressure to 45 and 60 psi cause large reductions in AA digestibility and protein quality. Lysine and cystine are most adversely affected by pressure processing. The type of system in which the pressure processing is achieved may greatly influence AA digestibility.

Utilizing MBM with varying concentrations of ash indicated that increased ash does have a moderate negative effect on its protein quality. The negative effect is due primarily to decreased levels of most analyzed essential amino acids present in the crude protein and not a reduced digestibility. The apparent lower levels of analyzed essential amino acids are due to the undesirable balance or composition of bone protein.

**“Utilization of High Levels of Rendered By-Products in Turkey Rations.”**

**Dr. Jeffre Firman - University of Missouri**

Rations were formulated using meat and bone meal as 10% incremental replacement of soybean meal for growing-finishing turkeys. This was a two part project in which the experiment was repeated with two groups of turkeys. In both experiments the inclusion of meat and bone meal resulted in better or similar performance when compared to control diets with the exception of the highest levels of inclusion (40-50% soybean meal replacement). This was undoubtedly due to the excessive mineral levels that result from the increased MBM inclusion level. The studies illustrate that meat and bone meal can be utilized at levels above that conventionally used. Certainly the use of meat and bone meal levels up to 20% replacement of soybean meal can be used with confidence.

**“Using Animal By-Product Proteins to Meet Amino Acid Requirements of Feedlot Cattle.”**

**Dr. Don Beermann - Cornell University**

The use of a by-pass animal protein mixture of 34% porcine meat and bone meal, 25% fish meal, 20.5% blood meal and 20.5% feather meal at the rate of 2.5% or 5.2% of total diet was compared to a soybean meal control and a urea based diet. The diets were formulated with the 1996 NRC model to supply metabolizable energy and protein to provide for a 1.4 kg (3.08 lbs.) average daily gain in medium-large framed 550 lb. implanted steers. Previous studies have indicated a very positive response in both gain and protein (nitrogen) deposition. In this study the 2.5% level of formulation of the animal by-product protein

mixture increased nitrogen retention by 7% but a negative effect on N retention at 5.2%. Daily gains were numerically depressed with both the 5.2% level and the urea diets. Integrating this data with earlier experiments suggests that feeding the described animal by-product proteins in diets not providing adequate protein or N intake significantly increases both efficiency and rate of protein gain. Formulation techniques due to feed composition variances, feed intake and other feedlot conditions does not always result in exact nutrient intakes. This is partially true in very rapidly growing, high lean potential animals and with the use of growth enhancers. If proper formulation has been achieved to meet the animals requirements the replacement of soybean meal or urea with the by-product mixture may not significantly improve either efficiency or rate of protein gain. However the use of animal proteins for their protein sources while utilizing the 1996 NRC model (Cornell Net Carbohydrate and Protein System Model) for development of beef feedlot rations are sound nutritional practices.

#### **“Diet by Fat Interactions in Dairy Cattle.”**

**Dr. Ric Grummer - University of Wisconsin**

This project was initiated late last year with several objectives that include the use of both tallow and choice white grease in rations containing corn silage as the primary forage. The fat source and level (2% and 4%) of fat will be studied. In the preliminary phase fat supplementation depressed average daily dry matter intake at both levels of intake and milk production at the 4% level. Fat supplementation caused a significant decrease in milk fat percentage but tallow at both levels and grease at 4% increased milk protein composition.

The initial results showed a decrease in protozoa counts within the rumen and impaired rumen fermentation when corn silage was the sole forage source accompanying fat supplementation.

#### **“Meat and Bone Meal as a Major Dietary Ingredient for Salmonids Under Several Growth Regimes.”**

**Dr. Gerald Snelling - University of Idaho**

In a series of Meat and Bone Meal replacements in the diets of rainbow trout for fish meal at 25%, 50%, 75% and 100% and fed under several growth regimes that includes enhanced growth via the use of somatotropin, the initial results indicate MBM can be an important component of rainbow trout diets. The MBM being used in these studies is of typical production with 53.8% protein, 12% fat and 26.6% ash. Final analyzed results from the project are expected soon.

#### **“Combinations of Rendered Animal Protein Ingredients as Protein Sources for Salmonid Diets.”**

**Dr. Dominique Bureau - University of Guelph**

The objectives of this research are to evaluate rendered animal proteins individually and in combination as protein sources in the diet of rainbow trout. Spray - dried blood meal and Poultry meal were used at 6% and 12% and 0, 10%, 20% and 30% for replacement of corn gluten meal and fish meal ingredients respectively. These ingredients provided up to 40% of the total digestible protein of the diet. A second series diets were formulated with combinations of feather meal, meat and bone meal and poultry meal in which these rendered animal proteins provided up to 2/3rds of the total digestible protein.

Final fish weight, growth rate and feed efficiency of the fish fed the blood and poultry meals suggests that these ingredients have high nutritive values for rainbow trout. Growth rates of the fish fed diets containing feather, meat and bone and poultry meal combinations were slightly lower than fish fed the control diets. Supplementation of the diets with synthetic sources of either lysine or methionine might suggest the deficiency of another amino acid. This work is progressing towards the development of formulations using complimentary animal proteins for the requirements for optimum fish performance.

**“Effects of High & Low Levels of UIP fed Prepartum on Postpartum Production and Health on Holstein Cows During Heat Stress.”**

**Dr. William Tucker - Mississippi State University**

A total of forty-four cows have completed a 60 day post partum period with 22 cows per high and low UIP (Undegradable Intake Protein or by-pass protein). A high quality by-pass protein comprised of animal proteins was fed prepartum to the UIP group under the hypothesis that post partum performance will be enhanced. Presently, no conclusions can be drawn in the absence of formal statistical analysis. A final report will be available soon.

**“Comparative Feeding Value of Tallow vs Low and High Free Fatty Acid Yellow Grease in Diets Containing 0.18 and 0.32% Magnesium.”**

**Dr. Richard Zinn - University of California - El Centro**

This completed study demonstrated no differences in fat sources upon the growth performance of feedlot cattle. Feed efficiency was improved 6.1% for all fat treatments compared to the controls. Fats were incorporated into the diets at 4%. The feeding values of tallow, yellow grease and griddle (brown) grease for feedlot cattle are similar. Differences in net energy values are largely a function of level of fatty acid intake. The characteristics of digestion of supplemental fat are not altered by dietary magnesium levels of greater than .18%. However, supplemental fat depresses magnesium absorption, and hence, precaution should be taken to assure that dietary magnesium allowances are adequate to meet specific growth performance requirements when diets are supplemented with fat. Increasing dietary magnesium levels from .18 to .32% increases intramuscular fat deposition (marbling score) in cattle fed fat supplements diets.

**“Does an Unhydrolyzed Vegetable Sucrose Polyester Affect Performance or Pigmentation in Broiler and Laying Hens?”**

**Dr. Bobby Damron - University of Florida**

The first phase of the laying hen portion of the study utilizing UVSP at 0, 2000, 4000, 6000, 8000 or 10000 ppm as supplied from snack chips has been completed. This phase though not statistically analyzed appeared to cause no negative effects. A duplicate hen study has been initiated and the broiler study will be completed during cooler weather.

**“Modeling Ruminant Metabolism of Tallow to Increase Fat usage in Dairy Rations.”**

**Dr. Tom Jenkins - Clemson University**

Previous work has suggested that the negative effects associated with lipids on fiber digestion were related to the concentration of free unsaturated fatty acids (UFFA) in the rumen. Work described in the progress report of this project proposes an equation as follows:

$$\text{Fiber Digestibility Depression (\%)} = 0.0125 (\text{UFFA})^2 - 0.2003 (\text{UFFA}) + 1.38$$

Tallows differing in IV (47, 50 and 53) are being tested by the model in an attempt to quantify how actual concentrations of different lipid types and sources contributes to free unsaturated fatty acids in the rumen.

**“Routine Techniques for Monitoring the Nutritional Value of Animal Meals.”**

**Dr. Theo van Kempen - North Carolina State University**

Approximately 120 meat and bone meal samples have been obtained from members of FPRF. These are being used to calibrate varying (in-vitro) analytical methods that include Near Infrared Reflectance Spectroscopy (NIR), Fourier Transform Infra Red Spectroscopy and Solid State Nuclear Magnetic Resonance (NMR) for amino acid and other nutrient determination. The ultimate objective is to develop calibrations that can be used to accurately predict the nutritional value of an animal meal in 2 to 20 minutes with a variable cost that is not much more than the labor required for handling the sample. The laboratory procedure will be compared to the commonly accepted procedures derived from animal experiments (in vivo) such as the ileal cecal procedure in swine or the Cecotomized Rooster assay. Calls for more industry representative samples will be made soon to advance the project to its next phase.

**“Influence of level of intake on the comparative value of Supplemental fat in finishing diets for feedlot cattle.”**

**Dr. Richard Zinn - University of California - El Centro**

This project was a replacement for one designed to study the effect of UVSP additions to the ration of feedlot cattle. However supplies of UVSP was not sufficient to complete the original approved study. This project is important in optimizing fat supplementation in feedlot cattle.

**Trial 1.** One hundred crossbred yearling steers with an average initial weight of 446 kg were used in a 100-d finishing trial. Steers will be blocked by weight and randomly allotted within weight groupings to 20 pens (5 steers/pen). Dietary treatments consisted of a steam-flaked corn-based finishing diet supplemented with 0, 1.5, 3 or 4% yellow grease. Steers were implanted with Synovex-Plus at the start of the trial. Fat supplementation increased ADG (13%, quadratic effect,  $P < .05$ ), DMI (3%, quadratic effect,  $P < .05$ ), feed efficiency (8%, linear effect,  $P < .05$ ), and dietary NE (linear effect,  $P < .05$ ). Optimal response in ADG, feed efficiency and dietary NE occurred with 3% supplemental fat, consistent with our hypothesis (Zinn, 1994) the NE value of supplemental fat declines quadratically with increasing total fat intake.

**Trial 2.** The sample collection aspect of this trial related to metabolism studies is completed. Samples are currently being analyzed. We should have results within 2 months

**“Feeding Value of Unhydrolyzed Vegetable Sucrose Polyester in Starter - Grow Swine and Duck Diets.”**

**Dr. B. G. Harmon - Purdue University**

Unhydrolyzed Vegetable Sucrose Polyester (UVSP) is currently being used as a “non-digestible fat” source for human snack foods. A trial has been completed to evaluate its use and energy contribution to the rations of swine and ducks. A second verification trial is being completed and is in its final stages. A final report is pending.

**“Survival of Salmonella in Naturally Contaminated Meat Meal.”**

**Judy O’Brien - Ralston Analytical Laboratory**

This project was initiated to determine *Salmonella* stability in naturally contaminated meat and bone meal during a 12 week period. Twelve *Salmonella* positive meat and bone meal samples obtained from 12 different rendering facilities in the U.S. and Canada were monitored for *Salmonella* stability over twelve

weeks of storage at room temperature. Initial analyses included protein, fat, moisture, *Salmonella* detection (DNA probe) and *Salmonella* counts (MPN/g). Weekly analyses included moisture and *Salmonella* detection. *Salmonella* population numbers were obtained by MPN counts on meal samples with positive *Salmonella* detection results at weeks 3, 6, 9 and 12. Testing was terminated on a sample when the *Salmonella* detection results were negative for two consecutive weeks (defined as *Salmonella* “die-off”). Correlation analysis was performed on the data to determine if there was a significant linear relationship ( $p < 0.05$ ) between the stability of the *Salmonella* population and protein, fat and moisture content. Protein and fat values ranged from 48% to 60% and 9% to 3% with average values of 54% and 11%, respectively. There was no significant correlation between moisture content of the meat meals and *Salmonella* stability. The *Salmonella* MPN values ranged from  $< 0.03$  to 0.93 MPN/g. There was a significant correlation ( $p < 0.01$ ) between the initial *Salmonella* MPN counts and *Salmonella* “die-off”. Higher initial *Salmonella* MPN counts resulted in a longer time required for *Salmonella* “die-off”. Regression analysis of the *Salmonella* detection assay data suggests that the rate of decline in percent positive *Salmonella* was approximately 2% per week after Week 0. A final report has been published and distributed on this project.

### **“Use of Animal By-Products in Practical Swine Rations for Young Pigs” Dr. B. G. Harmon - Purdue University**

The final report of this project reported on an experiment completed on one hundred fifty pigs weaned at 14-18 days that were used to evaluate protein sources in diets of equal lysine levels. All diets contained whey, corn, soybean meal and fat. During the first week, pigs receiving 7% spray dried plasma protein gained significantly more rapidly and consumed more feed than did pigs receiving combinations of fish meal, meat and bone meal, and blood meal or a soybean meal control equaling 7% of the diet.

After the first week, gain was similar for all treatments during the 35-day feeding trial. Gain/Feed ratio was significantly greater during the second week and continued to be greater for the remainder of the study, although not statistically significantly in the final three weeks of the study when a combination of 5% meat and bone meal and 2% blood meal was incorporated into the diet. There were no significant differences in performance during Phase 2 of the study.

The cost of feed per pound of gain was much greater for the pigs receiving spray dried plasma protein at 7% of the diet for 14 days in Phase 1 and 3.5% of the diet for the remaining 21 days in Phase 2. Based on the cost of ingredients and manufacturing costs, the spray dried plasma protein containing diet cost 21 to 27 cents per pound of gain more than did the other diets during the Phase 1 (0-14 days on test) program. During Phase 2 (14-35 days on test), the cost per pound of gain was 8 to 10 cents more for pigs receiving the spray dried plasma and not different among the other treatment groups.

This study clearly shows the advantage of spray dried plasma during the first week of the study and suggests that a shift to a less expensive Phase 2 diet could economically and biologically be made after one week. The study showed no advantage to continue to feed the plasma protein beyond the first week post weaning.

The cost per pound of gain during both Phases 1 and 2 was similar among all other treatments. Keep in mind that all diets contained animal protein (15% whey in Phase 1 and 10% in Phase 2) throughout the study. However, the least cost of gain resulted when meat and bone meal and blood meal (2.5 to 1 ratio) were incorporated into the diet. This is the same diet that significantly improved during the second week of the study.

**“Estimating Efficiency of Protein Accretion in Cattle Fed by-Product Proteins.”**

**Dr. Don Beermann - Cornell University**

This is a continuation of previous work completed by Dr. Beermann (refer to FPRF 94-A2). This nitrogen balance study is intended to evaluate the hypothesis that a “balanced” mix of animal by-product sources will significantly improve the rate and efficiency of protein use at a fixed level of protein intake in growing - finishing steers. A final report is in final preparation. Dr. Beermann has recently been named as the Head of Animal Sciences Department at University of Nebraska.

**“Real Digestibility of Amino Acids, Phosphorus and Calcium in Meat and Bone Meal for Growing Pigs and Chicks.”**

**Dr. Gary Cromwell - University of Kentucky**

A series of experiments have been completed and in progress to assess the effects of source of meat and bone meal (pork with low ash vs. beef with high ash) on nutrient availability. Previous reports have verified a true digestibility of 80% or 90% the relative value of monosodium phosphate in swine. The following table summarizes the relative phosphorus bioavailability estimates of meat and bone meal with varying characteristics in chicks. This data varies from that reported by Sells and Waldroup from studies previously conducted in turkeys and broilers respectively.

**Relative phosphorus bioavailability estimates of meat and bone meal products in chicks<sup>a</sup>**

MBM	Relative bioavailability		
	Bone Strength	Bone ash, g	Average
Lo-ash	80.7	82.9	81.8
50:50 Blend	80.6	84.2	82.5
High-ash	77.0	81.4	79.2
6-mesh	90.5	88.6	89.6
12-mesh	71.0	74.3	72.7
0 psi	81.5	82.9	82.2
30 psi	76.8	81.4	79.1
60 psi	84.5	85.7	85.1
MBM average	80.3	82.7	81.5

<sup>a</sup>Monosodium phosphate considered 100% available.

**“Availability of Amino Acids in Pork Meat and Bone Meal for Ruminants.”**

**Dr. Terry Klopfenstein - University of Nebraska - Lincoln**

Thirteen, commercially available, porcine meat and bone meal products from both independent renderers and commercial packing plants were evaluated in a lamb digestion study for the following variables: crude protein, undegradable intake protein, metabolizable protein, apparent nitrogen digestibility, and true nitrogen digestibility. As a whole, the products varied widely with respect to all of the variables measured with the exception of apparent nitrogen digestibility, indicating that feeding value of commercially available meat and bone meal products also varies widely, although all of the products tested had acceptable protein digestibilities.

Concentration of crude (CP), undegradable intake (UIP), and metabolizable (MP) protein and percentage apparent (AND) and true (TND) nitrogen digestibility of thirteen porcine meat and bone meal products.

Product Number	CP <sup>a</sup>	UIP <sup>ab</sup>	MP <sup>bc</sup>	ASH <sup>a</sup>	AND <sup>a</sup>	TND <sup>a</sup>
1	54.6	41.5	19.5	29.2	62.1 <sup>de</sup>	78.0 <sup>de</sup>
2	56.0	46.4	27.3	26.6	63.0 <sup>def</sup>	80.9 <sup>def</sup>
3	63.0	53.3	33.5	26.7	62.5 <sup>def</sup>	80.2 <sup>def</sup>
4	54.8	63.0	38.7	29.1	61.5 <sup>d</sup>	75.7 <sup>d</sup>
5	59.7	53.8	31.4	21.4	62.0 <sup>de</sup>	77.6 <sup>de</sup>
6	60.9	50.7	27.7	21.3	61.9 <sup>d</sup>	77.0 <sup>d</sup>
7	65.5	52.2	40.3	25.5	64.8 <sup>e</sup>	88.1 <sup>e</sup>
8	64.7	52.5	36.3	24.8	63.7 <sup>efg</sup>	83.8 <sup>efg</sup>
9	62.9	49.7	30.7	29.3	63.0 <sup>def</sup>	81.0 <sup>def</sup>
10	53.5	48.6	30.2	27.8	63.0 <sup>def</sup>	81.6 <sup>defg</sup>
11	54.9	39.7	21.5	24.8	63.2 <sup>defg</sup>	81.8 <sup>defg</sup>
12	61.9	49.3	28.2	28.3	62.2 <sup>de</sup>	78.9 <sup>de</sup>
13	60.5	45.6	32.1	25.9	64.1 <sup>fg</sup>	86.5 <sup>fg</sup>

<sup>a</sup>CP and ASH as percentage of DM; UIP and MP as percentage of CP; AND and TND as percentages.

<sup>b</sup>Measured by the ammonia release procedure.

<sup>c</sup>MP = UIP - (100-TND).

<sup>defg</sup>Values within a column with unlike superscripts differ (P<.10).

**“Further Definition of the Utilization of Bypassed and Intestinal Digestion of Amino Acids in Meat and Bone Meal.”**

**Dr. Neal Merchen - University of Illinois**

On the basis of past research funded for Dr. Merchen, this project is a cooperative study supported primarily by the Council for Agriculture Research of Illinois. The meat and bone meal used in the study has been coordinated by FPRF. The study is a validation basis animal performance of the values previously determined for MBM especially the Intestinal Digestibility of Available Amino Acids as determined by the In Situ/Precision Fed Rooster Assay.

**“Effects of Supplemental Fat on Growth Performance and Quality of Beef From Steers Fed Barley (and Potato product) Based Finishing Diet.”**

**Dr. Mark Nelson - Washington State University**

To be initiated with an objective depicted by the title of the project.

**“Effect of Bile Salt Supplementation on Fat Digestion in Early Weaned Pigs.”**

**Dr. B.G. Harmon - Purdue University**

**Dr. G.M. Hill - Michigan State University**

**Dr. D.C. Mahan - Ohio State University**

In an attempt to enhance the energy derived from fat additions to the rations of young pigs, bile salts are being added concurrently with 7% percent added fat (lard). The trial is being run concurrently at three separate universities. Bile salts were obtained from a commercial source. It is hypothesized that bile salts via its emulsifying properties will enhance the absorption and utilization of fat in the young pig.

### **“Thermal death Time Values for Rendered Animal Products.”**

**Dr. Annel Greene - Clemson University**

This project is in progress to define the time required to kill specified bacteria at given temperatures. Raw materials of beef, pork, beef bones, pork bones, beef offal, mixed species offal, poultry and feathers have been supplied to the Clemson Laboratory. The thermal viability of eight microorganisms are being investigated : Listeria monocytogenes, Escherichia coli, Enterobacter, Campylobacter, Staphylococcus aureus, Salmonella, Clostridium perfringens and Bacillus stearothermophilus. This industry driven approach to studying thermal death time values for our rendered products will be useful in addressing the questions of origins of foodborne illnesses.

### **“Literature Review of the Energy Values of Tallow and Other Characterized Animal Fats.”**

**Dr. Tom Jenkins - Clemson University**

Several recent reports have questioned the digestibility of fats by ruminants and in particular tallow and thus the net energy for lactation (NE<sub>L</sub>). A major source of confusion results from the variability among experiments. This project involves an intense literature review to :

1. To determine how often descriptive information is provided on the composition of tallow when it is fed as the fat source in ruminant feeding trials.
2. To determine the variation in fatty acid composition of tallow and other fat sources that have been reported in ruminant feeding trials.
3. To determine digestibility coefficients for tallow and other fat sources by lactating dairy cows.

### **“Prevalence of Selected Foodborne Pathogens in Rendered Products.”**

**Dr. Fred Troutt - University of Illinois**

This prevalence study of four potential foodborne bacteria and determination of coliform counts has been approved. The study will involve 16 randomized rendering facilities so that rendering systems and species of rendered raw material will be statistically represented. The facilities will be midwest oriented as a method of defraying expenses. Samples will be obtained during winter and summer of raw material, from the cooker discharge and at ingredient load-out. Actual project initiation is scheduled fall 1999.

### **Biodiesel Multi Feedstock - Phase III**

**Mr. John Kinast - Institute of Gas Technology**

The primary objective of this study was to determine if biodiesel from different feedstocks exhibit different emissions performance when tested on a consistent basis. By consistent basis is meant at one laboratory on one engine in a controlled study. To meet this objective we have carefully quantified emissions from seven different biodiesel fuels, from a variety of source materials, on one engine. The EPA heavy-duty transient test (40 CFR Part 86 Subpart N) was employed for all tests. Fuels tested neat include soy methyl ester, canola methyl ester, pork lard methyl ester, edible and inedible beef tallow methyl esters, low free fatty acid (1%) yellow grease methyl ester, and high free fatty acid (10%) yellow grease methyl ester. Several of the fuels were also tested as B-20 blends with certification diesel fuel. Regulated emissions (NO<sub>x</sub>, CO, THC, and PM) were determined, as well as the volatile organic fraction of PM. Several PM samples were also analyzed for sulfate. A minimum of three replicate tests were performed for each fuel and testing of

biodiesel fuels was bracketed with tests using certification diesel. The study design allows a statistical comparison to be made of emissions from the various biodiesels and blends versus emissions from certification diesel. Neat biodiesels were analyzed for C, H, and O content, cetane number, and gross heating value.

The most important observations of this study are that PM emissions are to a very good approximation independent of biodiesel feedstock or chemical structure, but that NO<sub>x</sub> emissions vary. All neat biodiesels reduced PM and increased NO<sub>x</sub> with a high level of statistical significance. The PM emissions reduction relative to certification diesel fuel appears to depend only on the oxygen content of the fuel. For unsaturated biodiesels derived from soy and canola the NO<sub>x</sub> increase was roughly 0.5 g/bhp-h. For fuels produced from more saturated feedstocks (the remaining fuels) the NO<sub>x</sub> increase was much lower, roughly 0.1 g/bhp-h. NO<sub>x</sub> emissions are higher for fuels produced from unsaturated feedstock such as soy or canola, in comparison to saturated feedstocks such as lard, tallow, or grease. One difference between these fuels is cetane number and it appears that higher cetane, more saturated biodiesels, produce lower NO<sub>x</sub>. Energy content or (Btu) based fuel economy was identical for certification diesel and biodiesel fuels. VOF averages about 5.5% for certification diesel, but increases to an average of 21.4% for the diesel. Because PM from fuel combustion is much lower for biodiesel, sulfate as a fraction of total PM is higher, in the 3-4% range. There is no significant difference in the VOF or sulfate emissions for biodiesel from different sources.

#### **NCWM Premium Diesel & Lubricity Testing Jim Peeples - Falls Church, VA**

The National Conference on Weights and Measure (NCWM) a regulatory body has been instrumental in promoting a "Premium Diesel" standard definition for states to enforce consumer protection. It is important that specifications include lubricity. During the lengthy evaluation of each performance criterion including cetane, detergency, cold temperature performance, accelerated stability, Btu content and lubricity it was determined that the current test methods are unreliable and cannot accurately be correlated to a minimum level of protection. Thus this has presented the necessary "round robin" testing procedures for lubricity from proceeding. A very tentative schedule is to initiate "round robin" testing by Fall 1999. Should favorable results be determined the lubricity criterion could be balloted to be re-listed on the NCWM definitions.

#### **ASTM Cetane Testing and Specifications Project Cooperative Study FPRF/NBB**

FPRF has provided biodiesel produced from a mixed feedstock and from tallow for cetane testing by the Diesel National Exchange Group. This information is necessary to establish ASTM (American Society for Testing Materials) final specifications for biodiesel. This work has been completed. A tentative ASTM Specification has been approved. Final balloting is to take place in the summer of 2000. A lubricity guide line is currently included but not expected to pass the ASTM Committee due to the concerns expressed in the Lubricity Project Report.