Production, Management and the Environment: Environmental Quality

775 Evaluation of a feeding strategy to reduce greenhouse gas emissions from milk production: The level of analysis matters. C. E. Van Middelaar*[1], P. B. M. Berentsen[2], J. Dijkstra[3], and I. J. M. De Boer[1], *[1]Animal Production Systems Group, Wageningen University, Wageningen, the Netherlands, [2]Business Economics Group, Wageningen University, Wageningen, the Netherlands, [3]Animal Nutrition Group, Wageningen University, Wageningen, the Netherlands.*

The dairy sector contributes to climate change through emission of greenhouse gases (GHGs): carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). From an animal perspective, a feeding strategy with high potential to reduce enteric CH4 emission is replacing grass silage by corn silage. Increasing corn silage in the ration, however, affects the farm plan (e.g., plowing grassland for corn cropping; type of concentrate), and consequently GHG emissions along the milk production chain. The level of analysis, therefore, can affect results and conclusions. This study evaluated effects of replacing grass silage by corn silage on GHG emissions, at 3 interdependent hierarchical levels; that is, the animal, farm, and chain level. Linear programming (economic optimization), mechanistic modeling of enteric fermentation, and life cycle assessment were combined to define an economically optimal basis farm (based on an average Dutch dairy farm) and to evaluate GHG emissions at animal, farm, and chain level. Subsequently, starting from the optimal ration, corn silage was fixed at a 1 kg dry matter (DM) higher level per dairy cow per day at the expense of grass silage, and the model was used again to determine the new optimal farm plan for the farm with this strategy, and to compare GHGs emitted with the basis farm. The basis farm has 35 ha of land and a fat- and protein corrected milk (FPCM) production of 8425 kg per cow per year. Per ton FPCM, replacing grass silage by corn silage resulted in an annual emission reduction of 11.2 kg CO2-e at animal level, 13.4 kg CO2-e at farm level, and 17.6 kg CO2-e at chain level. At farm and chain level, however, land use change (i.e., plowing grassland for corn cropping) resulted in non-recurrent CO2 and N2O emissions of 845 kg CO2-e per ton FPCM. From an animal perspective, therefore, this feeding strategy offers potential to reduce GHG emissions, whereas from a chain perspective it takes up to 47 years before annual emission reductions compensate for emissions related to land use change.

Key Words: dairy farming, greenhouse gas emission, feeding strategy

776 Are high production, low GHG emission dairy farms in New Zealand possible? R. E. Vibart*[1], T. White[2], D. Smeaton[3], S. Dennis[4], R. Dynes[4], and M. Brown[1], *[1]AgResearch Limited, Grasslands Research Centre, Palmerston North, New Zealand, [2]AgResearch Limited, Ruakura Research Centre, Hamilton, New Zealand, [3]DairyNZ, Hamilton, New Zealand, [4]AgResearch Limited, Lincoln Research Centre, Christchurch, New Zealand.*

Dairy farming in New Zealand (NZ) is under increasing scrutiny due to growing environmental concerns. Considerable investments have been made in the search for sustainable land management options and opportunities for mitigation of greenhouse gas (GHG) emissions and nutrient losses. High production, low emission systems are hard to run, but a small number of farmers are currently doing this. The objective of this study was to identify and examine dairy farms that were highly productive and profitable while maintaining reduced GHG emissions; these systems needed to carry reduced stock numbers (i.e., less than 3.3 cows/ha). Two suitable farms in the Waikato region and 2 in the Southland region were identified. The whole-farm system models FARMAX and OVERSEER were used to examine feed flow and nutrient balances, as well as profitability, of these systems. Although differing in size, all farms tended to be reliant on homegrown feeds for most of their needs; imported feed ranged from 2.2 to 9.7% of feed consumed. Stocking rates ranged from 2.5 to 3.3 cows/ha, annual production ranged from 377 to 464 kg milksolids (MS)/cow, and operating profits ranged from 1600 to 2350 NZD/ha. Wintering policies (i.e., the use of an off-farm block of land for dry cow wintering and young stock) differed between regions; the Waikato farms used these blocks only for young stock whereas the Southland farms used them for young stock and dry cows. Despite these differences, emissions intensity ranged from 8.4 to 9.6 kg CO_2-e/kg MS, thus below the average NZ farm range (11 - 13 kg CO_2-e/kg MS). Lower emissions intensity farms tended to be more profitable and achieve greater feed conversion efficiencies (kg MS/kg DM consumed). Although low stocked dairying often requires a high level of managerial skill to be successful, these systems were associated with low emission levels and highly competitive farm profitability. These farms are commercial working examples of the opportunities for highly profitable, emission efficient farms.

Key Words: dairy, livestock emissions, profitability

777 Impact of animal density on predicted greenhouse gas emission from selected conventional, organic and grazing dairy farms in Wisconsin. M. Dutreuil*[1], V. E. Cabrera[1], R. Gildersleeve[2], C. A. Hardie[1], and M. Wattiaux[1], *[1]University of Wisconsin-Madison, Madison, [2]University of Wisconsin Extension, Dodgeville.*

Our objective was to test the effect of animal density (AD) on predicted greenhouse gas emission (PGE) from 3 Wisconsin farms with contrasting management systems. A combination of farm data and model-based predictions, using the Integrated Farm System Model, was used to derive PGE on 1 conventional (C), 1 organic (O) and 1 grazing (G) farm at 2 AD. The farms had a herd size of about 80 cows, 133 ha of forage land, and 0.6 cows/ha. At this low AD (LAD), the PGE were 0.53, 0.70 and 0.77 kg of PGE (CO2eq)/kg of milk for the C, O and G respectively and the main source of PGE was from housing facilities (47, 39, and 31% of total PGE on C, O and G, respectively). The indirect emission sources (manufacture or production of fuel, electricity, machinery, fertilizer, pesticides, and plastic) accounted for 21, 12, and 30% of PGE on C, O and G, respectively. Other important PGE sources at LAD were feed production on C (19%), and grazing on O and G (35 and 14%, respectively). Doubling the AD (HAD, 1.2 cows/ha of forage land) increased PGE by 22.9% on C, mainly due to 48% increase from indirect sources. The emissions from feed production and indirect sources increased by 38 and 29%, respectively on O, but the emission from grazing and housing facilities decreased by 5 and 1.3%, respectively, which led to a 6.4% net increase. Finally, PGE decreased by 3.1% on G as the net result of a decrease in emissions from manure storage and fuel consumption (41 and 20%, respectively) but 8% increase in indirect sources. These results demonstrated that the effect of AD on PGE was different on the 3 selected farms because of different farm management practices such as feeding, manure storage, and housing facilities. Although increasing AD might have a beneficial effect in reducing PGE per unit of milk on the selected G farm, results predicted a slight negative effect in the O farm and a more substantial negative effect on the C farm. Although the scope of the study is limited to the 3 selected farms, combining farm

data with model-based predictions may be useful to study the changes in farm-level management practices on PGE.

Key Words: greenhouse gas, Integrated Farm System Model (IFSM), animal density

778 Life-cycle assessment of greenhouse gas emissions from dairy production in eastern Canada: A case study. E. J. Mc Geough,* S. M. Little, H. H. Janzen, T. A. McAllister, S. M. McGinn, and K. A. Beauchemin, *Agriculture and Agri-Food Canada, Lethbridge Research Centre, Lethbridge, AB, Canada.*

The objective of this study was to conduct a life-cycle assessment (LCA) of greenhouse gas (GHG) emissions from a typical non-grazing dairy production system in eastern Canada. Additionally, as dairying generates both milk and meat, this study assessed methods of allocating emissions between these co-products. The LCA was conducted over 6 yr for a simulated farm in the province of Quebec. The assessment considered 65 female Holstein calves, of which 60 heifers survived to first calving at 27 mo of age. These animals were subsequently retained for an average of 2.75 lactations. Progeny were also included in the analysis, with bulls and heifers in excess of replacement requirements finished as grain-fed veal (270 kg) at 6.5 mo of age. Cattle were housed indoors, and fed forages and grains produced on the same farm. Pre-farm gate GHG emissions and removals were quantified using Holos, a whole-farm model developed by Agriculture and Agri-Food Canada and based on the IPCC Tier 2 methodologies, with modifications for Canadian conditions. The LCA yielded a GHG intensity of 0.91 kg CO_2e/kg fat and protein corrected milk yield. Methane accounted for 56% of the total emissions, of which 86% originated from enteric fermentation. Nitrous oxide accounted for 40% of total GHG emissions. Lactating cows contributed 64% of the total GHG emissions while cattle under 1 yr contributed 10%, with the veal calves accounting for 3% of this figure. Allocation of GHG emissions between meat and milk were assessed as: a) no allocation, b) economics, c) dairy vs veal animal, and d) International Dairy Federation (IDF) equation using feed energy demand for meat and milk production. Comparing emissions from dairy vs veal calves resulted in 97% of the emissions allocated to milk. The lowest allocation of emissions to milk (78%) was associated with the IDF equation. This LCA showed that the greatest reductions in GHG emissions would be achieved by applying mitigation strategies to the lactating cow, with minimal reductions being achievable in young stock. Choice of co-product allocation method can also significantly impact the relative allocation of GHG emissions to milk and meat.

Key Words: life cycle assessment, dairying, eastern Canada

779 Effects of saponin extracts, in the diet of Holstein steers or added directly to their manure, on gaseous emissions from that manure. W. Li* and W. Powers, *Michigan State University, East Lansing.*

A series of experiments (Exp) were conducted to investigate the effects of saponin extracts, in the diet of Holstein steers or added directly to their manure, on gaseous emissions from that manure. Saponin extracts added to the feed or manure were from *Quillaja saponaria* (quillaja saponin), *Yucca schidigera* (yucca saponin) and *Camellia sinensis* (tea saponin). During Exp 1, manure from Holstein steers fed corn and corn silage based control diet (C1) was compared with manure from steers fed control diets plus 1.5% quillaja (QS) or 0.64% yucca (YS) saponins. In Exp 2, the effect of direct application of 2% yucca (CYS, wet basis) or quillaja saponin (CQS, wet basis) to manure collected from steers fed corn and corn silage based diet (C2) on manure air emissions was investigated. In Exp 3 the effects of dietary tea saponin supplementation (TS, 0.25% DM) and direct addition (CTS, 2% wet basis) to manure collected from steers fed corn and corn-silage based diet (C3) on manure air emissions were compared in the same experiment. Gaseous emissions methane (CH_4), ammonia (NH_3), hydrogen sulfide (H_2S), nitrous oxide (N_2O) and non-methane total hydrocarbons (NMTHC) were reported. When saponin extracts were fed, daily manure CH_4 emission mass was different among treatments ($P < 0.01$; 40.97, 58.12, and 71.49 mg/d, for YS, C1, and QS, respectively). Feeding YS resulted in less ($P < 0.01$) daily manure NH_3 emission mass than C1 and QS (318.18 vs. 391.62 and 365.54 mg/d, respectively). Daily manure H2S emission mass differed ($P < 0.01$) among dietary treatments (10.63, 15.16 and 21.10 mg/d for YS, C1, and QS respectively). In Exp 2 the addition of saponin extracts directly to manure did not affect any gaseous emissions measured. Average daily emission mass of CH_4, NH_3 and H_2S was 11.92 mg/d, 424.25 mg/d and 19.36 mg/d, respectively. Overall, the results of these experiments indicate that manure-derived gaseous emissions are altered by dietary inclusion of saponins rather than by direct application to manure.

Key Words: saponin extracts, air emissions, manure

780 Effect of manure source on ammonia emission on first day of application. F. Sun*[1], J. H. Harrison[1], E. Whitefield[1], P. Ndegwa[2], and H. S. Joo[2], *[1]Washington State University, Puyallup, [2]Washington State University, Pullman.*

Three sources of manure were evaluated for their effect on ammonia emission on day of application. Dairy slurry (DS) with large particle solids, dairy slurry with large particle solids removed (DSSR: 0.4 cm diameter × 0.7 cm on center screen), and anaerobically digested manure with large particle solids removed (ADSR) were applied to grass plots in 2010 and 2011. The DS and AD manures were applied to 1m x 1 m grass plots in replicate on 5 occasions in 2010 and 2011. The DSSR manure was applied on 4 occasions to 1 m × 1 m plots in 2011. Measurements of ammonia were obtained at hourly intervals from the air space inside a PVC cap dome (10 cm diameter × 10 cm height) to determine relative loss of ammonia from each manure source. Replicate domes were placed on each plot at hourly intervals for 6 to 10 min and then the concentration of ammonia was obtained in real time with a GasAlert hand-held meter with automated air pump. The day of application ammonia concentration for the combined years of 2010 and 2011 were different ($P < 0.05$): DS, 7.3 ppm, and ADSR, 5.4 ppm. Peak ammonia for the combined years of 2010 and 2011 ranged from 16.4 and 16.9 and was not different due to manure source. When DS, DSSR, and ADSR manure sources were compared in 2011, manure source significantly ($P < 0.05$) affected ammonia concentration with concentrations of DS — 11.0 ppm, DSSR, 8.8 ppm, and ADSR, 5.5 ppm, with all means different from each other. Peak ammonia was greatest ($P < 0.05$) for DS (24.9 ppm), with DSSR (19.3 ppm) and ADSR (17.5 ppm) the lowest, and not different from each other. Data indicated that the effect of anaerobic digestion and amount of solids impact the loss of ammonia from manure on the day of application.

Key Words: manure, ammonia

781 Partitioning of solids, nitrogen, and phosphorus in solids and liquid fractions of anaerobically digested dairy effluent. J. H. Harrison*[1], E. Whitefield[1], and A. Werkhoven[2], *[1]Washington State University, Puyallup, [2]Werkhoven Dairy, Monroe, WA.*

Data on the partition of solids, nitrogen, and phosphorus were collected at a commercial dairy that anaerobically digested (AD) manure (70% of

volume) and pre-consumer food wastes (30% of volume). Daily input into the AD averaged ~60,000 g/d as dairy manure and 30,000 g/d as pre-consumer food wastes (ruminant blood, egg waste, whey, fish stick byproduct, paper pulp waste, grease trap waste). The AD was a modified plug-flow design, operating under mesophilic conditions (23.5°C), with a 17 d retention time, and storage capacity of ~6,100,000 l. Data on flow of post AD effluent and solids were obtained by in-line flow meter (Siemens Magflo MAG 5000) and a stationary mixer wagon (NDE vertical feed mixer), respectively. Anaerobically digested effluent was ~3% solids. In 2008, data were collected when an Eys screw press liquid-solids separator was utilized. In 2011, data were collected when a DT 360 (Daritech) liquid-solids separator was utilized. Solids, nitrogen, and phosphorus separation from the effluent into solids was, mean and (standard deviation): Eys — solids 74% (8.5), nitrogen 13% (5.5), and phosphorus 21% (8.0): DT 360 — solids 21% (8.2), nitrogen 1.6% (0.63), and phosphorus 2.4% (0.97). Mean differences were observed for large particle solids removal from the AD dairy effluent. The majority of the nitrogen and phosphorus remained with the AD effluent after liquid-solids separation.

Key Words: anaerobically digested manure, solids, nitrogen

782 Inoculant volume of a mixed culture of rumen microorganisms on rate and extent of methanogenesis from processed dairy excrement for biofuel production by anaerobic digestion. C. L. Ross,* K. C. Das, and M. A. Froetschel, *University of Georgia, Athens.*

The major limitation with anaerobic digestion of dairy waste is related to its initial rate of microbial activity and its concentration of volatile organic compounds as substrate for methanogenesis. Inoculating batch anaerobic digesters of dairy excrement with a viable mixed culture of rumen fluid at 30% of digester volume resulted in a several fold increase in methane production as compared with a non-viable (heat-killed) control. Practical application requires that a lower volume of inoculant be established. In vitro batch culture fermentations were conducted to test lower volumes of inoculant and different extracts of dairy excrement in a 3-way factorial designed experiment. Batch cultures with water extracts of fresh dairy excrement or liquid from a solid separator as substrate were inoculated with levels A (1%), B (5%), or C (10%) viable rumen fluid (V/V). Fermentations were conducted in duplicate along with representative blanks of each type of waste extraction and inoculation level. Fermentations were maintained for 0, 2, 4, 7, 9, 12, 14, and 16 d periods. Gas production, CO_2 and CH_4 concentrations, pH, free-ammonia, dry matter digestion, volatile fatty acid production, and gross energy digestion were measured. CH_4 volume averaged 11.4mL for B and 10.9mL for C inoculations, an increase of 176% and 175%, respectively, compared with inoculation A ($P < 0.01$). Differences in gas production were observed between the waste substrates as well. Liquid waste from a solid separator had 24% greater concentration of CH_4 than a fresh waste extract ($P < 0.01$), but total gas and CH_4 volume were 180% and 128% higher from fresh waste extract ($P < 0.01$). As the duration of fermentation was extended from 0 to 16 d the CH_4 volume increased by 200% ($P < 0.01$). Lower levels of viable rumen fluid are effective for inoculating dairy waste for bio-fuel production but require a longer fermentation.

Key Words: methane, anaerobic digestion, microbial inoculation

783 Effects of inorganic versus organic copper on nitrous oxide reductase activity in peat soil. Q. Wang,* M. Burger, A. Castillo, W. Horwath, and F. Mitloehner, *University of California-Davis, Davis.*

Nitrous oxide (N_2O) is a potent greenhouse gas that contributes to global warming and stratospheric ozone destruction. Animal production emits approximately 1.5 Tg of N_2O annually and 51% of these emissions are associated with manure incorporation into soil. Nitrous oxide is mainly produced through the denitrification pathway. Nitrous oxide reductase (N_2OR) is the enzyme responsible for the reduction of N_2O to N_2 during denitrification. Nitrous oxide reductase uses copper (Cu) as its cofactor and its activity is compromised under conditions of Cu deficiency. The present study investigated organic (ORG) versus inorganic (INO) Cu at various concentrations (750, 550, 125, and 60 ug Cu/g soil) applied to soil, respectively, for their efficacy in affecting N_2OR activity. A control treatment (CON) containing soil and water, without added Cu, was also evaluated. The INO and ORG Cu treatments were dissolved in water and added to soil with low existing Cu concentrations in incubation vials. Treatment vials were anaerobically incubated to favor denitrification over a 24 h period. Gas samples were collected from the incubation vials every 8 h and analyzed for N_2O and N_2 concentrations, which were utilized to estimate N_2OR activity. The INO Cu versus CON did not affect N_2OR activity among different concentrations (0.11, 0.10, 0.04, 0.19, and 0.80 ug N_2O/g soil/h for INO 750, 550, 125, 60, and CON treatments, respectively) over sampling time ($P > 0.05$). However, N_2OR activity was higher for all ORG Cu treatments versus CON (11.42, 12.57, 2.67, 2.12, and 0.80 ug N_2O/g soil/h for ORG 750, 550, 125, 60, and CON, respectively) over the sampling time ($P < 0.05$), especially at the increasing Cu concentrations. These results highlight the importance of Cu form and concentration on N_2OR activity. Optimization of N_2OR activity could potentially decrease N_2O emissions associated with manure management in livestock production.

Key Words: organic Cu, inorganic Cu, nitrous oxide reductase

784 Nutrient removal with harvest of soybean forage and soybean seed produced with and without irrigation of dilute swine manure lagoon effluent. A. F. Harper,* D. L. Holshouser, C. D. Teutsch, and M. J. Estienne, *Virginia Polytechnic Institute and State University, Blacksburg.*

Nutrient management plans dictate the quantity of swine lagoon effluent and other manures applied to agricultural fields. Within a nutrient management plan, nutrient removal through crop harvest affects capacity for subsequent effluent application. A trial was conducted to compare nutrient removal with production of a forage-type soybean cultivar (soyF; Large Lad, Eagle Seed, Weiner, AR) harvested as forage and a standard cultivar (soyS; USG74A91, UniSouth Genetics, Dickson, TN) harvested as seed when produced with or without irrigation using dilute swine lagoon effluent. Twelve plots of 0.072 ha each planted on May 12, 2010, comprised 3 replications of the following treatments: 1) soyF non-irrigated, 2) soyF irrigated, 3) soyS non-irrigated, and 4) soyS irrigated. The irrigated plots received 6 applications of 2.84, 3.10, 2.54, 2.74, 4.52, 2.13 cm of effluent (0.005–0.022% N, 0.01–0.015% P, 0.02–0.03% K) via sprinkler irrigation from June 30 through August 8, when irrigation was terminated due to depleted effluent volume. Applications coincided with a drought season with mean rainfall of 2.11, 2.57 and 5.18 cm for June, July and August, respectively. The soyF plots were harvested with a plot forage harvester on August 12 and the soyS plots with a plot combine on October 19. Individual treatment means ± SEM (kg/ha) were: DM yield 4302, 8581, 1548, 2572 ± 664; N removal 116.9, 252.8, 95.8, 162.0, ± 20.8; P removal 14.2, 35.5, 10.3, 17.9 ± 2.8; K removal 114.8, 314.8, 34.1, 59.9 ± 22.9 for soyF non-irrigated, soyF irrigated, soyS non-irrigated and soyS irrigated treatments, respectively. There were crop-type by irrigation application interactions ($P < 0.05$) for DM yield, P removal and K removal with these responses being more pronounced when irrigation was applied to soyF than when applied to soyS. As expected more nutrients were removed with soyF than with

soyS harvest. However, under the conditions of this trial, crop removal of certain elements that influence nutrient management plans and effluent application rate were more responsive to effluent irrigation in soyF than in soyS production.

Key Words: effluent, soybean, nutrient removal

785 Effect of fibrous diets and inclusion level on the chemical composition and odors from pig slurry. C. T. Mpendulo* and M. Chimonyo, *Animal and Poultry Science, College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Pietermaritzburg, South Africa.*

Incorporation of high fiber ingredients into pig rations has the potential to reduce pollutants emitted from pig slurry tanks. A study was conducted to test whether diets containing 0, 80 and 160 g/kg of alfalfa hay, sunflower hulls or corn cobs influence the characteristics and odors from pig slurries. A total of 14 pigs weighing an average of 36 kg were kept in individual cages to allow the total collection of feces and urine. All pigs were fed ad libitum. Feces and urine were mixed in a 1:2.3 ratio (wt/wt), stored and fermented for 16 d in a temperature controlled room at 22 to 24 C. The slurry was sampled twice (on d 1 and on d 16) of the fermentation period and analyzed for pH, short chain fatty acids, chemical oxygen demand (COD) and nitrogen on a wet basis. All samples were tested for odor offensiveness using 18 trained panelists from the University of KwaZulu-Natal. A scale of 1 to 5 was used to rank the odor severity, where 1 = not offensive, 2 = mildly offensive, 3 = moderately offensive, 4 = strongly offensive and 5 = extremely offensive. Slurry pH and COD varied with fiber source ($P < 0.05$). After d 16, the COD for alfalfa hay, sunflower hulls and corn cobs were 369, 512 and 425 ± 34.2 mg of oxygen per liter. There was a significant interaction of fiber inclusion level and incubation period on COD and SCFA concentrations. Total SCFA concentration was higher at d 16 than d 1 ($P < 0.05$). Odor offensiveness varied due to fiber source ($P < 0.05$). Sunflower hulls and alfalfa diets were rated as less offensive (mean rank = 2.2) than corn cob diets (mean rank of 4.3). For all fiber sources, no differences ($P > 0.05$) were found between 80 and 160 g/kg. It was concluded that characteristics of pig slurries were influenced by fiber source and inclusion levels. The offensive odor from corn cobs suggests its considerable digestibility. More work still needs to be done to characterize other compounds from a large variety of locally available fiber sources that reduce water and air pollution from pig enterprises.

Key Words: short-chain fatty acids, slurry characteristics, odor offensiveness