Efficient Nutrient Management using NIR for the Recirculation of Liquid Farm Fertiliser

Rapid spectroscopic methods have become an integral part of agricultural analyses. For decades, the rapid and cost-effective assessment of feed quality using NIR has been an indispensible requirement for high productivity in animal husbandry. However, practical processes for targeted fertilisation and measurement of liquid farm manure collected for the purpose of recirculation in soil have not been previously available. A new method for the effective implementation of nutrient management plans for liquid manure is presented.

Liquid manure a valuable resource but an environmental risk

Each year in the EU, several millions of tonnes of liquid manure from animal husbandry are used to fertilise grassland and cropland. In Germany alone, around 200 Million tonnes are added to meadows and fields each year. On the one hand, this ensures that plants receive the nutrients they need, but on the other hand, environmental problems may develop if fertilization is not correctly executed.

To fully realise the fertiliser value of the liquid manure and to protect the environment, a nutrient management plan should be made for each field that needs manure. Balancing the nutrients added with plant uptake by the crop or forage prevents nutrient build up and prevents surface and ground water pollution.

For this reason a legal maximum amount of 170 kg N/ha per annum has been regulated, to which farmers must adhere. Although it is theoretically possible to calculate the important nutrient levels using average guideline values, this does not reflect reality, due to variations from farm to farm in the type of fattening used, feed conversion, thinning and ultimately the loss of nutrients in the form of gas.

Liquid manure is a mixture of dung, urine, bedding, scattered feed and various amounts of water. From the point of view of agriculture, liquid manure is not a waste product to be disposed of, but rather a valuable, multi-use fertiliser which usually takes effect very quickly. Not only is it very different from other farm fertilisers such as litter manure or compost; it can also have a significantly variable composition. Table 1 shows some of the important liquid manure parameters and their ranges.

To meet pollution control demands, odour emissions must be reduced and the loss of nitrogen has to be avoided as much as possible. The nitrogen should preferably be organically bound, and the liquid manure should be applied in precise doses to avoid over-fertilisation and contamination of the soil, plant population, surface and ground water.

NIR – a simple method for determining liquid manure parameters

To deploy the optimum amount of liquid manure to specific stitches, farmers can now send the liquid manure sample to a NIRS laboratory and base the balance of nutrients upon established values. Using a beaker, the homogenised liquid manure is simply added to a sample bag that contains a carrier substance (Figure 1). The special mixture of minerals, based on activated clinoptilolite zeolite, holds on to the fluid and absorbs all of the nutrients, making it possible to send the substance in an earth-moist condition within airtight packaging in a hygienic and unproblematic way.

At the laboratory the sample, consisting of the mass of 50.0 g of carrier material and approx. 25 ml of liquid manure, is then weighed and dried for three hours at 55°C. Dry matter, ash, nitrogen, phosphorous, potassium, calcium, and magnesium contents are immediately measured in the NIR spectrometer. The main nitrogen fractions − ammonium, urea and organic bound nitrogen − are determined. These components provide information about the quality of the liquid manure and also

Sample	DM	Ash	N	NH4-N	P	K	pH
Roughage	900 – 925	70 – 200	18 – 26	–	2 – 4	16 – 27	–
Silage maize	900 – 930	14 – 85	5 – 18	–	0.5 – 3	3 – 22	–
Cattle liquid manure	40 – 110	3 – 30	1.0 – 8	0.5 – 5	0.1 – 1.5	1 – 5	6 – 8.5
Hog liquid manure	10 – 90	5 – 20	2 – 6	1.5 – 3	0.5 – 2.5	1 – 2.5	7 – 8

Table 1: Comparison of the range of important parameters in feed and liquid manure samples (all in g/kg), DM = dry matter.

Figure 1: NANOBAG® with carrier materials and measuring spoon.

Mean value	n	N-total	NH_4-N NESSLER	DD-KJELTEC™	Urea-N *	organic-N *
Cattle liquid manure	31	2.47	1.11	1.58	0.47	0.89
Hog liquid manure	62	3.88	2.59	3.39	0.84	0.49

Table 3: Comparison of the N-fractions in cattle and hog manure, N-total = Nitrogen after Kjeldahl digestion, Nessler = Ammonium nitrogen after photometric determination, DD = Nitrogen after direct alkaline distillation
** Urea-N (DD – Nessler) and *organic-N (total – DD) calculated as differences, n = number of samples*
All values in g/kg liquid fertiliser

become effective in the soil at varying speeds. Their relationship is also of importance for the environmental compatibility of the liquid manure.

The carrier material of the NANOBAG® has been carefully selected. It consists of an activated mineral, clinoptilolite zeolite, which has a nanoporous crystal structure that is ideal for the absorption of liquid manure and has a sanitising effect that is essential for shipment.

A FOSS XDS Rapid Content™ Analyser and a FOSS Kjeltec™ system were used to develop the method. Liquid manure samples from 170 businesses raising cattle; 130 raising hogs, plus 110 biogas substrates were tested for dry matter, ash, total nitrogen, ammonia, calcium, magnesium, potassium and phosphorous content. The samples dried in carrier material were simultaneously measured using near infrared spectroscopy. The prediction models developed for different liquid manure samples show the following correlation values (R^2) and standard errors (SEP), (see Table 2).

Simple differentiation of the nitrogen components

In addition to the total nitrogen values according to Kjeldahl (FOSS Kjeltec system) the sum of ammonium and urea was determined by direct alkaline distillation (DD). Differentiation between urea and ammonium is possible using a photometric assay for ammonium by Nesslerisation. The difference of total nitrogen and ammonium nitrogen indicates the total level of organicbound nitrogen, while the difference of the value for the alkaline distillation (sum of urea and ammonium) and the colorimetrically determined ammonium indicates the amount of urea. A differentiation between the content of directly effective fertilisers and those components of liquid manure which are decisive for humus reproduction in the soil can be made:

► **Immediately available nitrogen**: ammonia

► **Short/medium-term available nitrogen**: amides available after alkaline hydrolysis (mainly urea)

► **Long-term available nitrogen for humus reproduction**: Particlebound nitrogen and microbial biomass in the fibres and other residue from feed and bedding, (see Figure 2 and Table 3).

Evaluation in Practice

Some 95 agricultural businesses were invited to take part in a study where liquid samples and samples loaded onto the NIRS-NANOBAG® were sent to HBLFA Raumberg-Gumpenstein and to AGES (Austrian Agency for Health and Food Safety) in Vienna. The comparison of the rapid NIR assessment and the classical wet chemical procedure showed that the new procedure for the determination of the nutritional content of liquid manure is very effective for the determination of total nitrogen and ammonium, (see Table 4).

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Parameter	Liquid manure	R²	SEP
Dry	All samples	0,863	3,45
Matter (g/kg)	Biogas liquid manure	0,810	3,81
	Cattle liquid manure	0,787	3,58
	Hog liquid manure	0,843	2,47
Total	All samples	0,918	0,16
nitrogen (g/kg)	Biogas liquid manure	0,941	0,13
	Cattle liquid manure	0,910	0,11
	Hog liquid manure	0,929	0,15
Ammonia	All samples	0,888	0,09
Nitrogen (g/kg)	Biogas liquid manure	0,952	0,06
	Cattle liquid manure	0,782	0,07
	Hog liquid manure	0,883	0,09
Raw	All samples	0,767	0,96
Ash (g/kg)	Biogas liquid manure	0,682	1,08
	Cattle liquid manure	0,501	1,18
	Hog liquid manure	0,819	0,80
Phosphate	Hog liquid manure	0,990	0,143
P, PO_4 or P_2O_5 g/kg	Cattle liquid manure	0,926	0,080
Potassium K_2O or K g/kg	Hog liquid manure	0,941	0,195
	Cattle liquid manure	0,883	0,555
Calcium	Hog liquid manure	0, 877	0,365
	Cattle liquid manure	0, 894	0,172
Magnesium	Hog liquid manure	0,972	0,147
	Cattle liquid manure	0,967	0,057

Table 2: Results of the NIR calibrations for the main and secondary parameters of liquid manure with the FOSS XDS instrument.

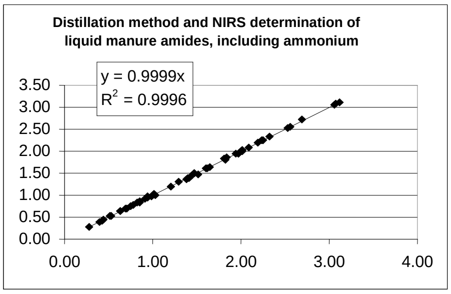

Figure 2: Correlation of ammonium and urea according to the Kjeltec direct distillation method and the NIR predicted values using the FOSS XDS instrument (g/kg).

AGES Vienna Wet Chemical analysis				IPUS Rottenmann NIRS analysis			
DM	OM	N	NH_4-N*	DM	OM	N	NH_4-N**
4.87	3.62	0.24	0.11	4.37	3.51	0.21	0.083

Table 4: Evaluation of the NANOBAG® method: Comparison of the average values of 96 test samples (in percent of original matter)
**Direct alkaline KJELTEC™ distillation, ** according to NESSLER*
DM – Dry Matter, OM – Organic Matter, N – total nitrogen.

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Conclusions

The NIRS-NANOBAG®-Method makes the shipment of liquid manure easier and more hygienic, implementing a rapid NIR analysis technique with a related prediction model. The entire procedure – from taking and shipping the sample to calibration and prediction of result – has been developed for cattle and hog liquid manure and biogas substrate.

The prediction model, based on the data from over 400 samples, allows the rapid determination of the following parameters in fluid agricultural manure in a single analysis: DM, N-total, NH_4-N, urea, ash, Ca, Mg, K and P.

Good agricultural practice (GAP) demands the limitation of excessive environmental contamination by over-fertilisation. Due to a lack of rapid and accurate on-site methods, and partially due to high costs and efforts for transportation, preservation, and traditional liquid manure analysis, it has only been possible to make rough calculations and estimations in agricultural manure management and nutrient balancing. The presented method avoids these shortcomings and enables one to work with real-time values for precise recirculation of nutrients onto the land. ■

by Wilfried Wenzl, HBLFA Raumberg-Gumpenstein, wilfried.wenzl@gumpenstein.at

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Growth environment

Demands for analytical services are changing by the day. Diane Young, director of analytical laboratory start up Foundation Analytical describes how dialogue with customers combined with investment in the right technology provides a future-proof concept.

Diane Young: "The exciting part is that clients view us as an extension of their business, as partners".

A former insurance office in the Midwest city of Cherokee Iowa is now home to a new laboratory providing analytical services for food, agricultural and environmental industries. Happily for visitors and employees alike, the original seventies-style brown and orange décor has been replaced with a sleek grey, black and white design, colour coded according to the three main business areas.

But there is much more to the laboratory than a new image.

Co-owner and director, Diane Young explains how previous experience at a food distribution company helped her to form the concept for the new laboratory. Her job involved visiting food production facilities across the country and wherever she went, she could see how critical the laboratory results were to the processors and clients. She could also see how there was a growing need to get more than just a number on a page. Customers needed a close dialogue regarding analysis results, with an opportunity to ask about a particular sample and relate it to their own particular situation.

Opened in July 09, the Foundation Analytical Laboratory service has been designed with exactly this type of customer demand in mind.

People

At the top of the shopping list for the new lab was a team of people with the right skills and knowledge to live up to the