ATTACHMENT NO. G

RESOURCE USE AND ENERGY EFFICIENCY

G1(i) – Devenish Nutrition Feed Information

DEVENISH
NUTRITION

With reference to on-going discussions I can confirm that Devenish Nutrition Ltd have been engaged by Mr Eoin O'Brien with regard to his proposed extension to his piggery at Mogeely, East Cork.

We have been engaged by Mr Eoin O'Brien to provide complete nutritional services designed to minimise odour and fertiliser emissions form the site as per our DeviCare programme, developed in conjunction with Dr John O'Doherty of University College Dublin, which is proven to reduce emissions from pig production, through targeted precision nutrition.

I attach below summary results contained in the attached scientific paper re DeviCare,

1. Completed and published research work by Aidan Leek et al, (Biosource Technology, 2003), which confirms reductions in dietery protein levels result in reductions in odorous emissions

Table 1; Emission Rates per Animal on Varying Protein Diet

	Dietary Crude Protein Levels			
	13%	16%	19%	22%
Odour Emissions (OuEs/animal)	12.1	13.2	19.6	17.6
Odour Emissions (OuEs/livestock unit)	77.6	80.0	115.8	102.9
Ammonia Emissions (OuEs/Animal)	3.11	3.89	5.89	8.27

As has been discussed, we are currently working on DeviCare Phase III, which further significantly reduces protein usage and emissions, and are very encouraged by initial results.

We are ready to implement our programme at any time, as discussed.

Yours Sincerely

Aidan O'Toole
Pig Sector Director
Devenish Nutrition Ltd

Available online at www.sciencedirect.com
SCIENCE DIRECT®
Bioresource Technology 91 (2004) 309–315
BIORESOURCE TECHNOLOGY
ELSEVIER

The influence of diet crude protein level on odour and ammonia emissions from finishing pig houses

E.T. Hayes [a,*], A.B.G. Leek [b], T.P. Curran [a], V.A. Dodd [a], O.T. Carton [c], V.E. Beattie [d], J.V. O'Doherty [b]

[a] Department of Agricultural and Food Engineering, University College Dublin, Earlsfort Terrace, Dublin 2, Ireland
[b] Department of Animal Science and Production, University College Dublin, Lyons Research Farm, Newcastle, Co. Dublin, Ireland
[c] Teagasc, Johnstown Castle, Co. Wexford, Ireland
[d] Devenish Nutrition Ltd., 96 Duncrue Street, Belfast BT3 9AR, Northern Ireland

Received 3 January 2003; received in revised form 15 March 2003; accepted 25 March 2003

Abstract

Feed trials were carried out to assess the influence of crude protein content in finishing pig diets on odour and ammonia emissions. Eight pigs (4 boars and 4 gilts), average initial weight 70.8 kg (s.e. 3.167) were housed in two pens that were isolated from the rest of a pig house at University College Dublin Research Farm, Newcastle, Dublin, Ireland. Four diets containing 130, 160, 190 and 220 g kg^{-1} crude protein were fed during six four-week feeding periods (one treatment per room). The first week of the feeding periods served to allow odour build up in the pens and as a dietary adjustment period. The pens had partially slatted floors that were cleaned and had all the manure removed after each four-week period. Odour and ammonia concentrations were measured on days 9, 14, 16, 21 and 23 of each trial period. Odour samples were collected in Nalophan bags and analysed for odour concentration using an ECOMA Yes/No olfactometer. The odour threshold concentration was calculated according to the response of the olfactometry panel members and was displayed in $Ou_E\,m^{-3}$, which referred to the physiological response from the panel equivalent to that elicited by 40 ppb v^{-1} *n*-butanol evaporated in 1 m^3 of neutral gas. Ammonia concentrations in the ventilation air were measured using Dräger tubes. The odour emission rates per animal for the 130, 160, 190 and 220 g kg^{-1} crude protein diets were 12.1, 13.2, 19.6 and 17.6 $Ou_E\,s^{-1}$ animal^{-1}, respectively ($P < 0.01$). The odour emission rate per livestock unit (500 kg) for the 130, 160, 190 and 220 g kg^{-1} crude protein diets were 77.6, 80.0, 115.8 and 102.9 $Ou_E\,s^{-1}\,LU^{-1}$, respectively ($P < 0.01$). The ammonia emission rates per animal for the 130, 160, 190 and 220 g kg^{-1} crude protein diets were 3.11, 3.89, 5.89 and 8.27 g d^{-1} animal^{-1}, respectively ($P \leqslant 0.001$). There was no significant difference in the average daily intake and the average daily gain for the four diets ($P > 0.05$). Manipulation of dietary crude protein levels would appear to offer a low cost alternative, in relation to end-of-pipe treatments, for the abatement of odour and ammonia emissions from finishing pig houses.

Keywords: Pig; Diet; Crude protein; Odour; Ammonia; Olfactometry; Abatement

1. Introduction

Pig production has changed in Ireland from a small scale enterprise carried out by a large number of farmers as an addition to the main farming enterprises, to a small number of specialist producers operating large scale units using high quality breeding stock and up to date techniques (Lara et al., 2002). Similar to other intensive farm operations, pig production generates substantial quantities of manure (faeces and urine) and mortalities, which lend themselves to a mixture of vapours, gases and dust combinations; odour and ammonia emissions are of particular environmental concern.

Odour emissions from pig production units can cause nuisance in the surrounding areas. Several guidelines and recommendations exist for protecting a neighbourhood from odour nuisance and are concerned on the one hand with the determination of set-back distances and, on the other hand, with the implementation of odour reducing techniques (Gallmann et al., 2001). The main sources of odour include building ventilation, manure storage and land spreading. Often these odorous mixtures are a consequence of animal manure decomposing anaerobically to form unstable intermediate by-products resulting in a complex mixture of over 168 volatile

* Corresponding author. Fax: +353-1-4752119.
E-mail address: enda.hayes@ucd.ie (E.T. Hayes).

0960-8524/$ - see front matter

compounds of which 30 are odorous (O'Neill and Phillips, 1992). These compounds created from natural biological reactions include organic acids, aldehydes, alcohols, fixed gases, carbonyls, esters, amines, sulphides, mercaptans, aromatics and nitrogen hetrocycles.

The monitoring and reduction of ammonia emissions from livestock farming is a critical requirement of the European Commission Acidification Strategy and the EU Directive 2001/81/CE on National Emission Ceilings (Commission of the European Communities, 1997) which have called for a limitation of ammonia emissions from all EU countries. There are a number of on-farm sources of ammonia: animal housing, manure storage, field-applied manure and excreta deposited on the land by animals. Ammonia loss from the animal building is stimulated by the area of flooring covered by excreta, the chemical composition of the excreta, the temperature in the house and the ventilation rate of the house (Hutchings and Sommer, 2001). Of the total nitrogen ingested into the finishing animal approximately 50% is returned in the urine and 20% in the faeces (Jongbloed and Lenis, 1992). Ammonia is the product of the degradation of nitrogenous compounds. Bacteria in the faeces produce a urease enzyme, which converts the urea in the urine into ammonia. Atmospheric ammonia contributes to the acidification and eutrophication of soil and surface waters (Sutton et al., 1993; van der Eerden et al., 1998). Ammonia emissions in Europe originate mainly from agriculture, in particular from livestock farming. It is estimated that agricultural enterprises contribute 80–95% of ammonia emissions across Europe. Approximately 50% of ammonia emissions from pig production arises from pig buildings and the storage of manure (van der Peet-Schwering et al., 1999).

Manipulating the diet of finishing pigs by reducing the crude protein can reduce the total nitrogen excretion, reduce the ammonia emissions and alter the components of volatile fatty acids and other odorous compounds while not influencing the animal growth (Sutton et al., 1996). Phillips et al. (1999) identified dietary manipulation as the "best bet" for reducing ammonia emissions based on a ranking and weighting exercise. The aim of the present research was to study the influence of a range of crude protein levels on the generation of both odour and ammonia emissions from finishing pigs on partially slatted floors under controlled environmental conditions.

2. Methods

2.1. Animals

The finisher pigs used in this study were selected from a commercial herd, progeny of a Landrace X Large White Sow and a meat line sire. In total, 24 pigs, 12 boars and 12 gilts, were assigned one of four dietary treatments. Each dietary treatment was replicated 3 times with 8 pigs, 4 boars and 4 gilts, per treatment. Pigs were individually weighed at the start of the experimental period and each treatment was balanced for initial liveweight. Pigs were weighed after collection of the last odour and ammonia measurements and the average daily gain (ADG, $g\,d^{-1}$) over the experimental period was calculated.

Two experimental pens were used at any one time and the diets were analysed in pairs. To minimise any seasonal effect, each dietary replicate was paired with a different diet.

2.2. Animal facilities

Two partially slatted floor pens in the pig finishing house on the University College Dublin Research Farm were individually sealed off from the rest of the building. Each pen was fitted with a variable speed centrifugal fan and thermostatically controlled electrical radiant heater. The pens had separate air inlets and outlets and could be heated and ventilated independently. The ventilation rate was calculated by measuring the airflow from the pens using a Testo 400™ handheld monitoring device fitted with a vane anemometer. The ventilation rate in both pens was kept constant during the trials at approximately 48.3 $m^3\,h^{-1}$ $animal^{-1}$ (s.e. 1.3). The internal temperature in the house was kept constant at approximately 21.0 °C (s.e. 0.32).

2.3. Feed and feeding

Pigs were provided with ad libitum access to un-pelleted meal through a single space hopper located on the solid floor of each pen. Feed intake was noted as the hopper was filled. Remaining feed at the end of the trial was recorded and the average daily feed intake (ADFI, $g\,d^{-1}$) was calculated. Feed conversion ratio (FCR) was determined for each group. Water nipples were located over the slatted part of the pen.

Four diets (Table 1) were formulated using standard feeding values for the ingredients (O'Grady, 1996) to give diet crude protein contents of 220, 190, 160 and 130 $g\,kg^{-1}$ fresh weight. Formulated levels of digestible energy (DE; 13.5 $MJ\,kg^{-1}$) and 'ideal protein' (lysine 11 $g\,kg^{-1}$) were maintained across all the diets.

The diets were fed during six four-week feeding periods. Week 1 allowed the pigs to acclimatise to the experimental diets and excreta levels to build up under the slatted area.

The pens were cleaned after each four-week period and all manure was removed from the underground storage tanks. The diets were mixed on site as required and each batch was sampled. Proximate analysis of diets for dry matter, ash and crude fibre was carried out ac-

Table 1
Composition and analysed chemical composition of experimental diets

Diets				
Crude protein (g kg^{-1})	220	190	160	130
Ingredient inclusion (kg ton^{-1})				
Wheat	637.5	722.5	810.0	887.7
Soya bean meal	309.2	224.2	136.7	60.0
Soya oil				13.3
DeviCare® Supplement[a]	25.0	25.0	25.0	25.0
Amino acid pack[b]	15.0	15.0	15.0	15.0
Analysed composition (g kg^{-1})				
Dry matter	873.2	875.1	873.0	877.1
Crude protein	209.0	184.6	157.4	131.7
Crude oil (ether extract)	29.4	26.9	27.3	33.0
Crude fibre	38.4	39.1	36.4	29.3
Ash	53.2	48.9	46.4	38.2
Gross energy (MJ kg^{-1})	15.98	15.82	15.52	15.81
Relative cost index[c]	1.00	1.05	1.15	1.30

[a] The supplement (DeviCare, Devenish Nutrition, Belfast, N. Ireland) provided minerals and vitamins (per kg diet) as follows 14,000 i.u. Vitamin A (4.2 mg retinol), 2800 i.u. Vitamin D (0.07 mg cholecalciferol), 80 i.u. Vitamin E (80 mg DL-alpha tocopherol), 120 mg copper as copper sulphate and 0.4 g selenium as sodium selenite.

[b] The amino acid pack contained supplementary synthetic lysine to maintain a dietary lysine content of 11 g kg^{-1}, and synthetic methionine, threonine and tryptophan on calcium carbonate carrier maintaining minimum dietary levels of 60%, 65% and 20% methionine + cysteine, threonine and tryptophan, respectively, and relative to lysine in the finished diet.

[c] The relative cost of each diet was estimated according to raw material prices at time of publishing and is largely influenced by the additional cost of synthetic amino acid use in low protein diets. The costs of both soybean meal and synthetic amino acids are influenced by market conditions, which will impact the accuracy of this index.

cording to the Association of Official Analytical Chemists (1984). Ether extract was determined according to the Soxhlet method, using a Soxtec System (Model 1043, Tecator, Sweden). Gross energy was determined in an adiabatic bomb calorimeter (Parr Instruments, Moline, IL, USA). The nitrogen content (crude protein × 6.25) of the diets was determined using a Leco Autoanalyser (Leco Corporation, St. Joseph, MI, USA).

2.4. Olfactometry

2.4.1. Collection of odour samples

Air samples were collected in 8 l Nalophan bags using a battery-powered vacuum pump and a rigid container. The samples were collected using the lung principle whereby the air was removed from the rigid container using a battery-powered vacuum pump at a rate of 2 l/min. A critical orifice controlled the air evacuation rate from the sampling container. This created a vacuum in the rigid container and caused the Nalophan bag to fill through stainless steel tubing with odorous air extracted from the exhaust vents. The air samples were sealed and stored in appropriate conditions. All the samples were analysed within 24 h. The odour measurements were carried out according to the European Standard prEN13725 (CEN, 2001) in the olfactometry laboratory in the Department of Agricultural and Food Engineering, University College Dublin. The odour and ammonia concentrations were measured on days 9, 14, 16, 21 and 23 of each four-week feeding regime. Ventilation rate and internal temperature measurements were carried out on the same days.

2.4.2. Measurement of odour threshold concentration

An ECOMA TO7 dynamic olfactometer (ECOMA, Honigsee, Germany) was used throughout the experimental period to measure the odour threshold concentration of the ventilated air from the fattening pens. The odour threshold concentration is defined as the dilution factor at which 50% of the panellist can just detect an odour. The panellists were previously selected by screening using the certified reference gas *n*-butanol (CAS 71-36-3) and only panellists that adhered to the code of behaviour for olfactometry were selected for odour measurements. The odour threshold concentration was calculated according to the response of the panel members and was displayed in $Ou_E\,m^{-3}$, which referred to the physiological response from the panel equivalent to that elicited by 40 ppbv^{-1} *n*-butanol evaporated in 1 m^3 of neutral gas (CEN, 2001). Odour units were considered a dimensionless unit, but pseudo-dimensions of $Ou_E\,m^{-3}$ have been commonly used for odour dispersion modelling in place of g m^{-3} (McGinley et al., 2000).

2.5. Measurement of ammonia concentration

Ammonia measurements were taken using Dräger tubes. The Dräger tubes have a measurement range of

0–30 ppm. The tubes were stored in the original packaging at room temperature in a shaded area until use. A hand operated bellows pump draws 100 ml of air through the tube with one stroke, during which the air contained in the pump chamber escapes through the exhaust valve. If ammonia is present, the reagent reacts resulting in a colour change of yellow to blue. The Dräger tubes provide a simple and easy way of measuring ammonia. They are designed for on-the-spot measurement and are expected to show a coefficient of variation of 10–15% (Dräger, 1998).

2.6. Statistical analysis

Data were analysed using the PROC MIXED function in SAS 6.14 for Windows (SAS 1996, SAS Institute Inc., Cary, NC, USA). Dietary influence on odour and ammonia was evaluated using a model that included diet as the fixed effect. The main influences of variation between sampling were removed by including internal room temperature and ventilation rate as random variables. Data were checked for outliers prior to analysis by the RSTUDENT option of SAS PROC GLM. No data points were identified as outliers and all observations were included for analysis ($n = 60$). Data is presented as the least-squared means of the three replicates with the standard error of the mean (s.e.).

3. Results and discussion

3.1. Dietary analysis and pig performance

Results of the dietary analysis are presented in Table 1. The analysed crude protein content of the diets was 209.0, 184.6, 157.4 and 131.7 $g\,kg^{-1}$. The initial live weight of the pigs was 70.8 kg (s.d. 3.16 kg). The ADG was similar ($P > 0.05$) between the dietary treatments (721.5, 859.6, 800.7 and 768.8 $g\,d^{-1}$, s.e. 0.09 in diets 130, 160, 190 and 220 $g\,kg^{-1}$ crude protein, respectively). The ADI was similar ($P > 0.05$) between the dietary treatments (1.90, 2.15, 2.11 and 2.06 $g\,d^{-1}$, s.e. 0.204 in diets 130, 160, 190 and 220 $g\,kg^{-1}$ crude protein, respectively). Consequentially, FCR was similar ($P > 0.05$) between the diets (2.71, 2.49, 2.65 and 2.70, s.e. 0.147 in diets 130, 160, 190 and 220 $g\,kg^{-1}$ crude protein, respectively).

3.2. Odour

The odour emission rates are reported per animal and per livestock unit (LU). One livestock unit is equivalent to 500 kg body weight. Table 2 shows that the odour emission rates were highest for the 190 $g\,kg^{-1}$ crude protein diet. The odour emission rates ($Ou_E\,s^{-1}\,LU^{-1}$) were significantly reduced by 33% and 31% for the 160 and 130 $g\,kg^{-1}$ crude protein diets, respectively, in comparison to the 190 $g\,kg^{-1}$ crude protein diet. Odour emission rate levels were similar ($P > 0.05$) between the 190 and 220 $g\,kg^{-1}$ crude protein diets.

Peirson and Nicholson (1995) reported a reduction in odour emissions per kg liveweight from 0.540 to 0.317 $Ou_E\,s^{-1}\,kg^{-1}$ (41% reduction) for a control and low nitrogen diet, respectively; the protein levels of the diets were not stated in the published data. Research reported by Hobbs et al. (1996) used gas chromatography–mass spectrometry to analyse the headspace gas for ten individual compounds commonly found in pig odour. Manure samples from two reduced crude protein diets, 131 $g\,kg^{-1}$ crude protein and 139.3 $g\,kg^{-1}$ crude protein and one commercial diet, 189.2 $g\,kg^{-1}$ crude protein were analysed. Nine out of ten odorous compounds were significantly reduced using low crude protein diets ($P < 0.05$). The odour emission rates in this study, even from the low crude protein diets, were higher than some published emission rates from commercial pig units (Holste, 1998; Martinec et al., 1998). This might have been due to the orientation of the fans in relation to the manure surface in the experimental unit. High air velocity near the slurry surface caused by the location of the fans in the pens would increase the air movement above the manure surface, thus increasing the potential for the volatilisation of gases.

3.3. Ammonia

Table 3 indicates that ammonia emissions per animal per day were reduced by 62.4% when dietary crude protein was decreased from 220 to 130 $g\,kg^{-1}$. This equates to a reduction of 8.1% for every 10 $g\,kg^{-1}$ reduction in dietary crude protein.

Table 2
Mean odour emission rates

Crude protein	130 $g\,kg^{-1}$	160 $g\,kg^{-1}$	190 $g\,kg^{-1}$	220 $g\,kg^{-1}$	s.e. ($n = 60$)	P value
Odour						
$Ou_E\,s^{-1}$ animal^{-1}	12.11[a]	13.24[a]	19.57[b]	17.59[b]	1.5	0.005
$Ou_E\,s^{-1}\,LU^{-1}$	77.64[a]	80.03[a]	115.80[b]	102.88[b]	8.1	0.009

[a,b]Means with the same superscript within rows are not significantly different ($P > 0.05$).

Table 3
Mean ammonia emission rates and percentage reduction

Diets	130 g kg^{-1}	160 g kg^{-1}	190 g kg^{-1}	220 g kg^{-1}	s.e. ($n = 60$)	P value
Ammonia g d^{-1} animal^{-1}	3.11[a]	3.89[b]	5.89[bc]	8.27[c]	0.509	0.001
Crude protein (analysed)	Total % reduction in NH_3 emissions		Total % reduction in NH_3 emissions for every 10 g kg^{-1} reduction in CP (as analysed)			
209.0–184.6	28.78		12.0			
184.6–157.4	33.96		12.5			
157.4–131.7	0.05		7.8			
209.0–131.7	62.39		8.1			

[a,b,c]Means with the same superscript within rows are not significantly different ($P > 0.05$).

Similar results were obtained by Kay and Lee (1997) and Canh et al. (1998) between dietary levels of 187 and 130 g kg^{-1} and between 16.5% and 12.5% crude protein, respectively. Reductions in ammonia emission equivalent to 9.8% per 10 g kg^{-1} reduction in dietary crude protein are reported by Kay and Lee (1997). Comparing in vivo and in vitro measurements of ammonia release, Canh et al. (1998) report that emissions were reduced by 10% and 12.5%, respectively, per 10 g kg^{-1} decrease in dietary crude protein. Kendall et al. (2000) reported a reduction in ammonia concentration from 29.6 to 12.9 ppm (approximately a 56% reduction) in the exhaust air from 12.6% and 9.35% crude protein diets, respectively, supplemented with synthetic lysine. The diets were fed to castrates and gilts over a six-week experimental period and ammonia measurements were measured with Dräger diffusion tubes over 4 h.

Peirson and Nicholson (1995) reported an approximate reduction of 33% in ammonia emissions per livestock unit between a control and a low nitrogen diet; the protein levels in the diets however were not stated.

Lower ammonia concentration in pig houses may also have useful benefits to the health of fattening pigs, resulting in associated improvements in pig performance and safety for stockmen. The Control of Substances Hazardous to Health (Health and Safety Executive, 1999) regulation specifies an eight hour time weighted average exposure of <25 ppm, 10 min exposure limit at 25–35 ppm and 0 min at >35 ppm. Animals in an integrated system are constantly exposed, so a maximum level of 20 ppm should be adhered to (Feddes and DeShazer, 1988). Smith et al. (1996) reported that weanling pigs, when given an option of fresh air or ammoniated air, showed a significant decrease in the amount of time spent in the area supplied with ammoniated air.

The use of Dräger tubes in this study gave an on-the-spot grab sample of the ammonia concentration in the air stream; a handheld electrochemical cell will be used for future experiments in order to measure the ammonia concentration and the concentration of other gases continuously.

3.4. Comparison of odour and ammonia emissions

In general as crude protein decreased, odour and ammonia emission rates decreased. However, odour emission rates were lower for the 220 than 190 g kg^{-1} crude protein diets (Table 2). This might have been due to excess protein in the diet that could result in an imbalance in the feed C:N ratios or in insufficient carbohydrates to promote enhanced microbial decomposition resulting in reduced volatile fatty acids (VFA) (Sutton et al., 1996). Williams (1984) stated that pig odour offensiveness is largely related to the volatile fatty acids in the manure.

Ogink and Groot Koerkamp (2001) stated that reducing the emitting surface of the manure could reduce the emissions of odorous compounds. The implementation of dietary manipulation in combination with other abatement techniques such as reducing the emitting manure surface area, frequent manure removal and improved ventilation systems could lead to a significant reduction in odour and ammonia emission rates (EPA, 2002).

3.5. Cost

As seen in Table 1, the relative cost of each diet was estimated. It was largely influenced by the cost of the synthetic amino acids added to the diets low in crude protein. The estimated cost index of the 130, 160, 190 and 220 g kg^{-1} crude protein diets was 1.30, 1.15, 1.05 and 1.0, respectively. Synthetic amino acids may be utilised to reduce the excretion of nitrogen in the manure and reduce the ammonia emissions but the cost of adding them to the diets must be taken into consideration relative to the cost of conventional protein sources. The formulation of a synthetic amino acid balance in the diets of finishing pigs as a replacement for protein is more expensive than conventional finishing diets. Fluctuations in the market price of soya bean meal and synthetic amino acids will affect the cost implications of this strategy. Low dietary crude protein levels would appear to offer a low cost alternative, in relation to end

of pipe treatments, of reducing odour and ammonia emissions from finishing pig houses.

4. Conclusions

Dietary crude protein levels of 130, 160, 190 and 220 g kg^{-1} were fed to finishing pigs during six four-week feeding periods.

- The odour emission rates were highest for the 190 g kg^{-1} crude protein diet. A reduction in the odour emission rates of greater than 30% is achievable.
- The ammonia emission rates were highest for the 220 g kg^{-1} crude protein diet. The ammonia emissions per animal per day were reduced by 62.4% when dietary crude protein decreased from 220 to 130 g kg^{-1}. This equates to a reduction of 8.1% for every 10 g kg^{-1} reduction in crude protein between 209.0 and 131.7 g kg^{-1} of total dietary content.
- Future work on ammonia and odour emission rates from pig and poultry units will utilise a handheld electrochemical cell in order to continuously monitor ammonia and other odorous gases.

Acknowledgements

The authors would like to acknowledge the financial assistance provided by Teagasc, the Irish Agricultural and Food Development Authority for providing funding under the Walsh Fellowship programme and from Devenish Nutrition Ltd. They would also like to thank the members of the olfactometry panels and Mr. Jimmy Callan, Ms. Bernie Flynn and Ms. Denise Cunningham for performing the dietary analysis.

References

Association of Official Analytical Chemists, 1984. Official Methods of Analysis, 14th ed. Association of Analytical Chemists, Washington, DC.

Canh, T.T., Aarnink, A.J.A., Schutte, J.B., Sutton, A., Langhout, D.J., Verstegen, M.W.A., 1998. Dietary protein affects nitrogen excretion and ammonia emissions from slurry of growing-finishing pigs. Livestock Production Science 56, 181–191.

CEN, 2001. Air quality—determination of odour concentration by dynamic olfactometry. Draft European Standard prEN13725. Brussels, Belgium.

Commission of the European Communities, 1997. Communication to the Council and the European Parliament on a Community Strategy to Combat Acidification.

Dräger-Tube Handbook, 1998. 11th ed. Dräger sicherheitstechnik, GmbH, Lübeck, Germany.

EPA, 2002. Odour impacts and odour emission control measures for intensive agriculture. Final report. R&D Report Series No. 14. EPA, Johnstown Castle Estate, Wexford, Ireland.

Feddes, J.J.R., DeShazer, J.A., 1988. Feed composition as a parameter for establishing minimum ventilation rates. Transactions of the ASAE 31, 571–575.

Gallmann, E., Brose, G., Hartung, E., Jungbluth, T., 2001. Influence of different pig housing systems on odour emissions. Water Science and Technology 44 (9), 237–244.

Health and Safety Executive, 1999. EH40/99 Occupational exposure limits. ISBN 0 7176 1660 6.

Hobbs, P.J., Pain, B.F., Kay, R.M., Lee, P.A., 1996. Reduction of odorous compounds in fresh pig slurry by dietary control of crude protein. Journal of the Science of Food and Agriculture 71, 508–514.

Holste, D., 1998. Schauenburger Str. 116, 24118 Kiel, Germany, personal communication.

Hutchings, N.J., Sommer, S.G., 2001. Integrating emissions at a farm scale. In: Sustainable Handling and Utilisation of Livestock Manure from Animals to Plants, DIAS Report, Proceedings NJF-Seminar No. 320, Horsens, Denmark, 16–19 January 2001.

Jongbloed, A.W., Lenis, N.P., 1992. Alteration of nutrition as a means to reduce environmental pollution by pigs. Livestock Production Science 31, 75–94.

Kay, R.M., Lee, P.A., 1997. Ammonia emission from pig buildings and characteristics of slurry produced by pigs offered low crude protein diets. In: Voermans, J.A.M., Monteny, G. (Eds.), Proceedings of the International Symposium on Ammonia and Odour Control from Animal Production Facilities. Vinkeloord, The Netherlands, 6–10 October 1997, pp. 253–260.

Kendall, D.C., Richert, B.T., Sutton, A.L., Bowers, K.A., Herr, C.T., Kelly, D., 2000. Effects of dietary manipulation on pig performance, manure composition, hydrogen sulphide and ammonia levels in swine buildings. In: Proceedings of the Purdue Swine Day 2000, Purdue University, USA.

Lara, A., Kelly, P.W., Lynch, B., 2002. The international cost competitiveness of the Irish pig industry. Rural Economy Research Series (No. 8) Teagasc Report. Teagasc, Dublin, Ireland.

Martinec, M., Hartung, E., Jungbluth, T., 1998. Daten zu geruchsemissionen aus der tierhaltung. KTBL Arbeitspapier 260, ISBN 3-7843-1998-2.

McGinley, C.M., McGinley, M.A., McGinley, D.L., 2000. Odour basics: understanding and using odour testing. In: Proceedings of the 22nd Annual Hawaii Water Environmental Association Conference, Honolulu, Hawaii, June 6–7, 2000.

Ogink, N.W.M., Groot Koerkamp, P.W.G., 2001. Comparison of odour emissions from animal housing systems with low ammonia emissions. In: Proceedings of the 1st IWA International Conference on Odour and VOC's: Measurement, Regulation and Control Techniques, University of New South Wales, Sydney, Australia, ISBN 0733417698, March 2001.

O'Grady, J.F. (Ed.), 1996. Feed Tables R&H Hall Technical Bulletin.

O'Neill, D.H., Phillips, V.R., 1992. A review of the control of odour nuisance from live stock buildings: Part 3. Properties of the odorous substances which have been identified in livestock wastes or in the air around them. Journal of Agricultural Engineering Research 51, 157–165.

Peirson, S., Nicholson, R., 1995. Measurement of odour and ammonia emissions from livestock buildings. Report for MAFF EPD. ADAS WA0601 Phase 1—Final Report. MAFF, UK.

Phillips, V.R., Cowell, D.A., Sneath, R.W., Cumby, T.R., Williams, G., Demmers, T.G.M., Sandars, D.L., 1999. An assessment of ways to abate ammonia emissions from UK livestock buildings and waste stores. Part 1: ranking exercise. Bioresource Technology 70, 143–155.

Smith, J.H., Wathes, C.M., Baldwin, B.A., 1996. The preference of pigs for fresh air over ammoniated air. Applied Animal Behaviour Science 49, 417–424.

G1(ii) - Material Safety Data Sheet

MATERIAL SAFETY DATA SHEET

PRODUCT NAME:

Hyperox

AS SOLD BY VETOQUINOL CANADA

A Service of

COMPAS
MATERIAL SAFETY DATA SYSTEMS
www.compasmsds.com

Material Safety Data Sheet

DUPONT

Hyperox

Version 2.2

Revision Date 05/09/2014 Ref. 130000018856

This SDS adheres to the standards and regulatory requirements of Canada and may not meet the regulatory requirements in other countries.

SECTION 1. PRODUCT AND COMPANY IDENTIFICATION

Product name	:	Hyperox
MSDS Number	:	130000018856
Product Use	:	Disinfectant
Manufacturer	:	Antec International Limited Windham Road Sudbury / Suffolk - CO10 2XD United Kingdom
Product Information	:	1-800-441-7515 (outside the U.S. 1-302-774-1000)
Medical Emergency	:	1-800-441-3637 (outside the U.S. 1-302-774-1139)
Transport Emergency	:	CHEMTREC: +1-800-424-9300 (outside the U.S. +1-703-527-3887)
Other information	:	professional use

SECTION 2. HAZARDS IDENTIFICATION

Emergency Overview

Inhalation of aerosol or fine spray mist may cause serious respiratory problems.

Potential Health Effects

Skin	:	May cause: Severe skin irritation
Eyes	:	Causes: Severe eye irritation
Inhalation	:	May cause irritation of respiratory tract.
Ingestion	:	May be: Harmful if swallowed.
Repeated exposure	:	Respiratory tract damage, Gastrointestinal effects
Target Organ	:	Respiratory Tract, Digestive organs

Carcinogenicity

None of the components present in this material at concentrations equal to or greater than 0.1% are listed by IARC, NTP, or OSHA, as a carcinogen.

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS-No.	Concentration
Hydrogen peroxide	7722-84-1	20 - 30 %
Peracetic acid	79-21-0	3 - 5 %
Acetic acid	64-19-7	3 - 8 %

SECTION 4. FIRST AID MEASURES

Skin contact : Wash off immediately with plenty of water. Take off contaminated clothing and shoes immediately. Consult a physician.

Eye contact : Remove contact lenses. Rinse thoroughly with plenty of water, also under the eyelids. Keep eye wide open while rinsing. Seek medical advice.

Inhalation : Move to fresh air. If victim has stopped breathing: Artificial respiration and/or oxygen may be necessary. Call a physician immediately.

Ingestion : Do NOT induce vomiting. Rinse mouth. If conscious, drink plenty of water. Call a physician immediately.

General advice : Keep upper body upright. Never give anything by mouth to an unconscious person. When symptoms persist or in all cases of doubt seek medical advice.

Notes to physician : Treat symptomatically.

SECTION 5. FIREFIGHTING MEASURES

Flammable Properties Flash point	:	> 96 °C (> 205 °F) closed cup Method : No information available. estimated
Ignition temperature	:	ca. 430 °C (806 °F)
Self-Accelerating decomposition temperature (SADT)	:	45 °C (113 °F)
Fire and Explosion Hazard	:	Do not allow run-off from fire fighting to enter drains or water courses.
Hazardous combustion products	:	Oxygen
Suitable extinguishing media	:	Foam, Dry powder, Water spray
Unsuitable extinguishing media	:	Carbon dioxide (CO2)
Firefighting Instructions	:	Wear self-contained breathing apparatus and protective suit. Use water spray to cool unopened containers. Prevent fire extinguishing water from contaminating surface water or the ground water system.

SECTION 6. ACCIDENTAL RELEASE MEASURES

NOTE: Review FIRE FIGHTING MEASURES and HANDLING (PERSONNEL) sections before proceeding with clean-up. Use appropriate PERSONAL PROTECTIVE EQUIPMENT during clean-up.

Safeguards (Personnel)	:	Evacuate personnel to safe areas. Wear personal protective equipment.
Spill Cleanup	:	Dam up. Soak up with inert absorbent material. Dilute with water. Sweep up and shovel into suitable containers for disposal. Contain spillage, and then collect with non-combustible absorbent material, (e.g. sand, earth,

diatomaceous earth, vermiculite) and place in container for disposal according to local / national regulations (see section 13). Unsuitable material for dilution or neutralization Sawdust

Accidental Release Measures : Do not contaminate surface water. Do not let product enter drains. Dispose of in accordance with local regulations.

SECTION 7. HANDLING AND STORAGE

Handling (Personnel) : For personal protection see section 8. Avoid contact with skin, eyes and clothing. Check packages regularly for any signs of deformation, pressure build-up leakage or temperature rise. Do not breathe vapour. Avoid formation of respirable particles.
Wash hands before breaks and immediately after handling the product.
Regular cleaning of equipment, work area and clothing.

Handling (Physical Aspects) : Keep away from direct sunlight.

Storage : Protect from contamination. Keep in original, vented container. When stacking, do not block cap vent. Keep in a dry, cool place.
Keep away from oxidising agents, strongly alkaline and strongly acid materials in order to avoid exothermic reactions.
Keep away from: Strong bases Combustible material For further information see Section 10 of the safety data sheet.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Engineering controls : Ensure adequate ventilation.

Personal protective equipment

Respiratory protection : Provide adequate ventilation. Use NIOSH approved respiratory protection.

Hand protection : Additional protection: Rubber gloves, Neoprene gloves, Polyvinyl chloride - PVC

Eye protection : Wear coverall chemical splash goggles and face shield when the possibility exists for eye and face contact due to splashing or spraying of material.

Skin and body protection : Where there is potential for skin contact, have available and wear as appropriate, impervious gloves, apron, pants, jacket, hood and boots.

Exposure Guidelines
Exposure Limit Values

None established.

SECTION 9. PHYSICAL AND CHEMICAL PROPERTIES

Form	:	liquid
Color	:	colourless
Odor	:	stinging
pH	:	1 at 20 °C (68 °F)
Melting point/range	:	ca. -61 - -60 °C (-78 - -76 °F)
Boiling point/boiling range	:	> 60 °C (> 140 °F)
Oxidising Substance	:	The product is oxidising. Method: Directive 67/548/EEC, Annex V, A.17.
Vapour Pressure	:	27 hPa at 20 °C (68 °F) estimated
Density	:	ca. 1.12 g/cm3 at 20 °C (68 °F)
Water solubility	:	completely miscible

SECTION 10. STABILITY AND REACTIVITY

Stability	:	Decomposes on heating.
Conditions to avoid	:	Exposure to sunlight. Heat.
Incompatibility	:	Metals Contamination, Reducing agents, Bases, Powdered metal salts, Combustible material, Flammable materials, organic solvent, alkalies
Hazardous decomposition products	:	Acetic acid...%
Hazardous reactions	:	Potential for exothermic hazard If contaminated with impurities or incompatible substances, self-accelerated exothermic decomposition may occur. Decomposition in confined spaces and pipes may lead to over-pressure and bursting.

Heating can release hazardous gases.
Oxygen formation is possible.

SECTION 11. TOXICOLOGICAL INFORMATION

Hyperox

Inhalation ALC - Approximate Lethal Concentration	:	0.49 mg/l , rat no data available
Dermal LD50	:	1,147 mg/kg , rat
Oral LD50	:	1,859 mg/kg , female, rat
Skin irritation	:	rabbit
Eye irritation	:	Corrosive, rabbit
Sensitisation	:	Animal test did not cause sensitization by skin contact., guinea pig

Hydrogen peroxide

Repeated dose toxicity	:	Oral rat No toxicologically significant effects were found. Inhalation rat Respiratory tract irritation

Peracetic acid

Repeated dose toxicity	:	Oral rat No toxicologically significant effects were found.
Mutagenicity	:	Tests on bacterial or mammalian cell cultures did not show mutagenic effects. Animal testing did not show any mutagenic effects.
Teratogenicity	:	Animal testing showed effects on embryo-fetal development at levels equal to or above those causing maternal toxicity.

Acetic acid

Repeated dose toxicity : Oral
rat

No toxicologically significant effects were found.

Dermal
mouse

No toxicologically significant effects were found.

Carcinogenicity : Not classifiable as a human carcinogen.
Overall weight of evidence indicates that the substance is not carcinogenic.

Mutagenicity : Tests on bacterial or mammalian cell cultures did not show mutagenic effects.
Evidence suggests this substance does not cause genetic damage in animals.

Teratogenicity : Animal testing showed no developmental toxicity.

SECTION 12. ECOLOGICAL INFORMATION

Aquatic Toxicity
Hyperox

96 h : Oncorhynchus mykiss (rainbow trout) 1 - 2 mg/l

120 h IC50 : Scenedesmus capricornutum (fresh water algae) ca. 0.18 mg/l US EPA Test Guideline OPP 122-2 & 123-2

EC50 : Daphnia 0.5 - 1.1 mg/l OECD Test Guideline 202

21 d : NOEC Daphnia magna (Water flea) 0.05 mg/l

Peracetic acid

33 d : NOEC Danio rerio (zebra fish) 0.0022 mg/l OECD Test Guideline 210

Environmental Fate

Hyperox

Adsorbed organic bound halogens (AOX)	:	Product does not contain any organic halogens.
Biodegradability	:	Readily biodegradable.

Hydrogen peroxide

Bioaccumulation	:	Bioaccumulation is unlikely.

Acetic acid

Bioaccumulation	:	Bioconcentration factor (BCF): 3.16 Bioaccumulation is unlikely.

SECTION 13. DISPOSAL CONSIDERATIONS

Waste Disposal	:	Dispose of as special waste in compliance with local and national regulations. The product should not be allowed to enter drains, water courses or the soil.
Environmental Hazards	:	If recycling is not practicable, dispose of in compliance with local regulations.

SECTION 14. TRANSPORT INFORMATION

TDG_ROAD	UN number	: 3149
	Proper shipping name	: HYDROGEN PEROXIDE AND PEROXYACETIC ACID MIXTURE STABILIZED
	Class	: 5.1 (8)
	Packing group	: II
	Labelling No.	: 5.1 (8)
TDG_RAIL	UN number	: 3149
	Proper shipping name	: HYDROGEN PEROXIDE AND PEROXYACETIC ACID MIXTURE STABILIZED
	Class	: 5.1 (8)
	Packing group	: II
	Labelling No.	: 5.1 (8)
IATA_C	UN number	: 3149
	Proper shipping name	: Hydrogen peroxide and peroxyacetic acid mixture stabilized
	Class	: 5.1 (8)
	Packing group	: II

Hyperox

Version 2.2

Revision Date 05/09/2014 Ref. 130000018856

	Labelling No.	: 5.1 (8)
IMDG	UN number	: 3149
	Proper shipping name	: HYDROGEN PEROXIDE AND PEROXYACETIC ACID MIXTURE, STABILIZED
	Class	: 5.1 (8)
	Packing group	: II
	Labelling No.	: 5.1 (8)

SECTION 15. REGULATORY INFORMATION

DSL : One or more components of this product are not listed on the Domestic Substances List (DSL).

D.I.N. Number : 02240361
Remarks : Regulated under the Food and Drugs Act – WHMIS exempt.

SECTION 16. OTHER INFORMATION

MSDS preparation date : 05/09/2014

The information provided in this Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

Significant change from previous version is denoted with a double bar.