Gaseous emissions from pig-on-litter systems

Eager workshop

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Pig housing

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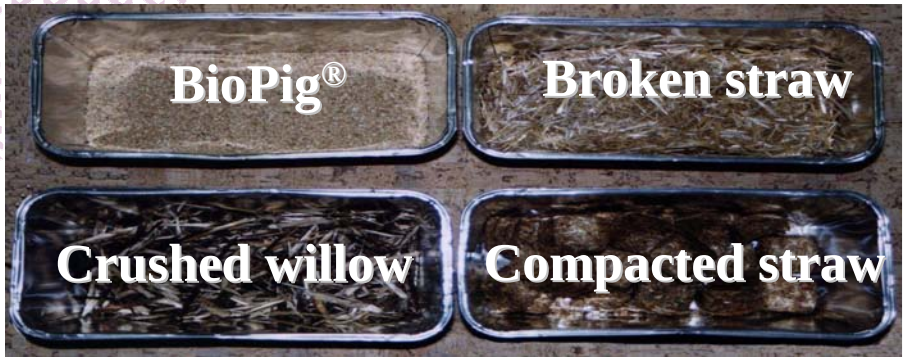
Controlled conditions



3 series of experiments

-the influence of physical structure and chemical composition

4 different types of litter: 2 commercial products (BioPig, straw compacted in small cubes), broken straw, crushed willow

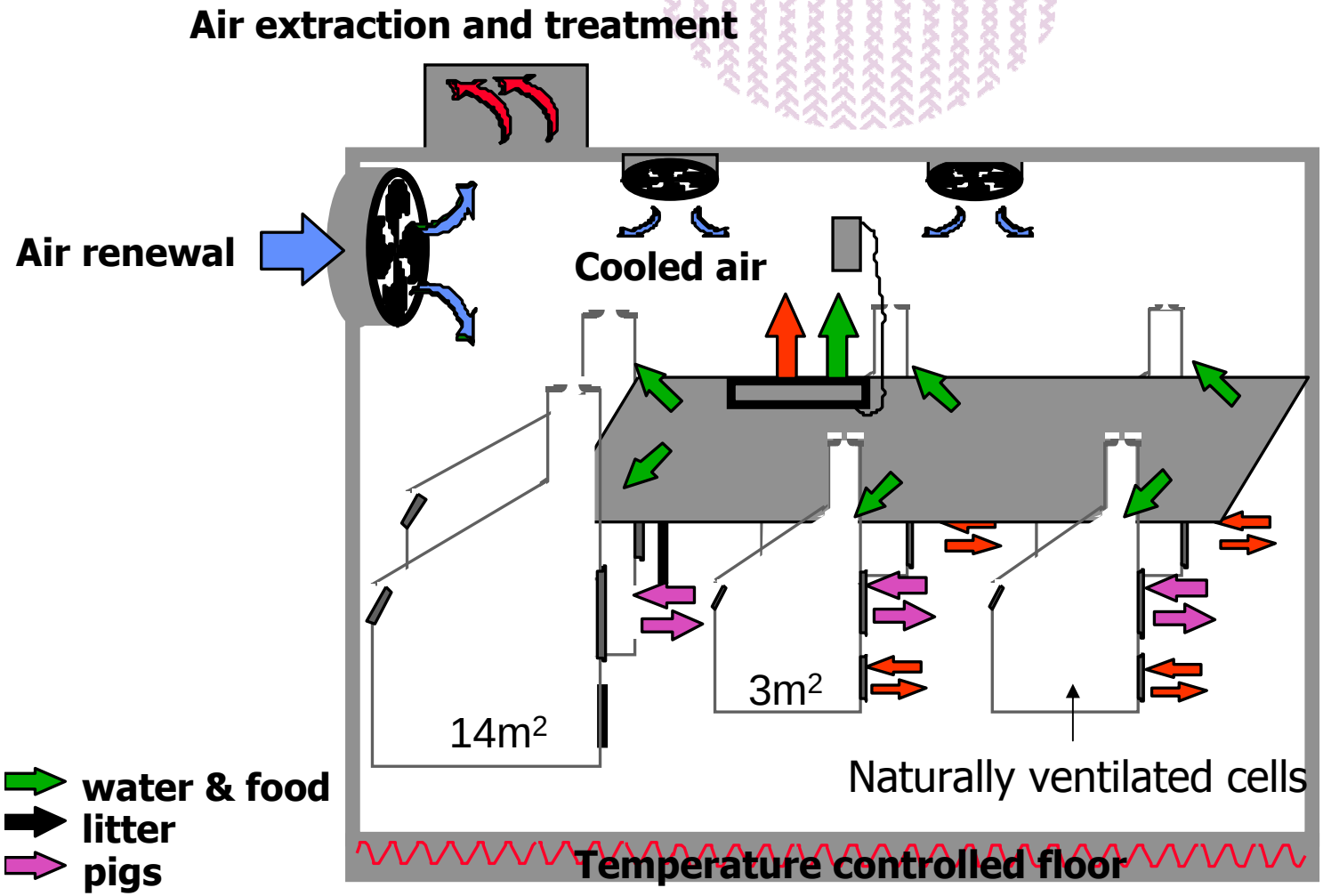
-the influence of using old litter on gaseous emissions

4 different mixtures: old sawdust litter only, old sawdust litter + 1/3 or 2/3 of fresh sawdust, fresh sawdust only

-the influence of turning and excretion input:

4 treatments: with/without excretion x with/without turning

Controlled conditions



3 pigs/cell 3m²
25-60kg
Standard food
Ad libitum
$T_{ins} \approx 23°C$

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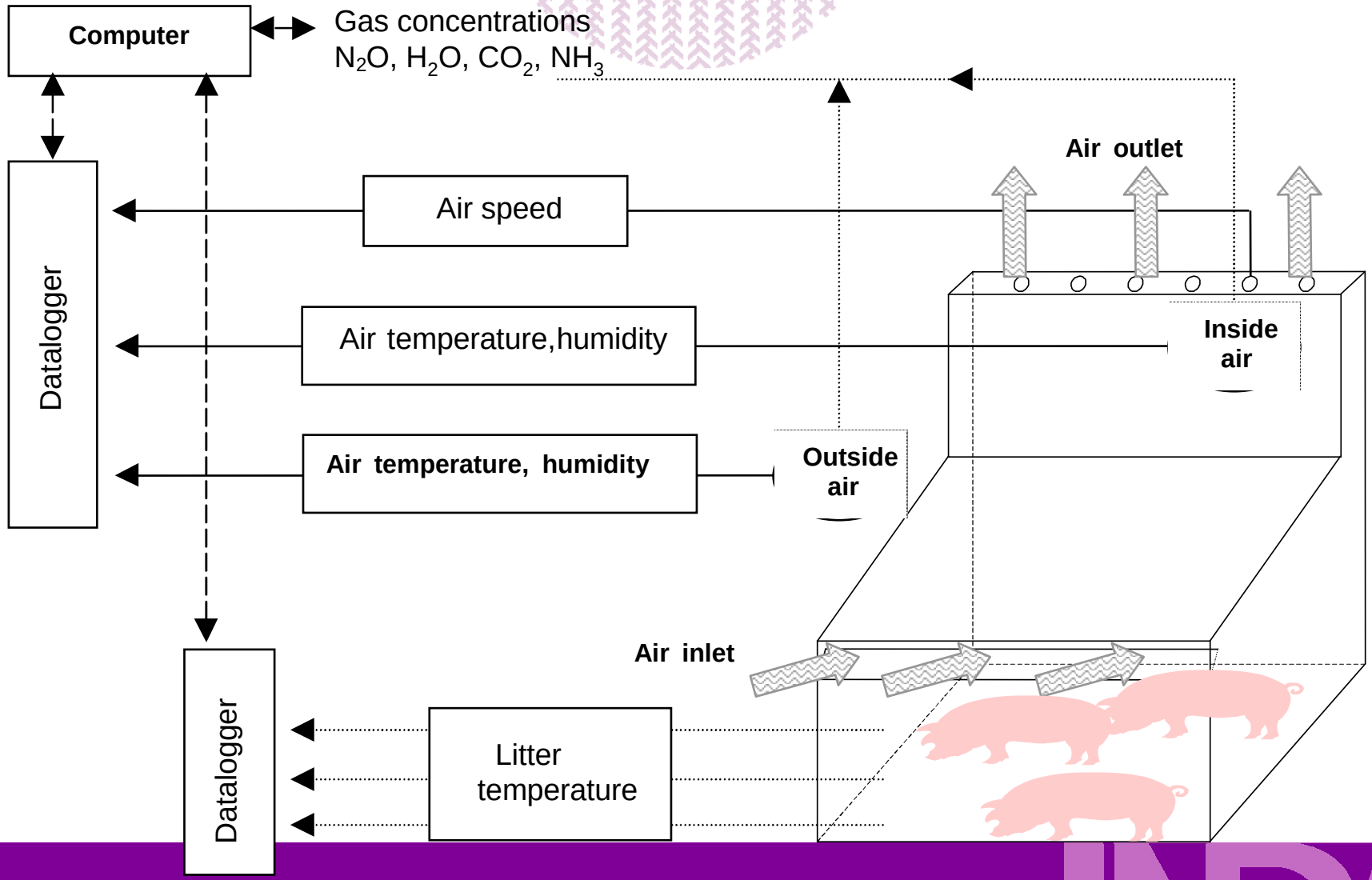
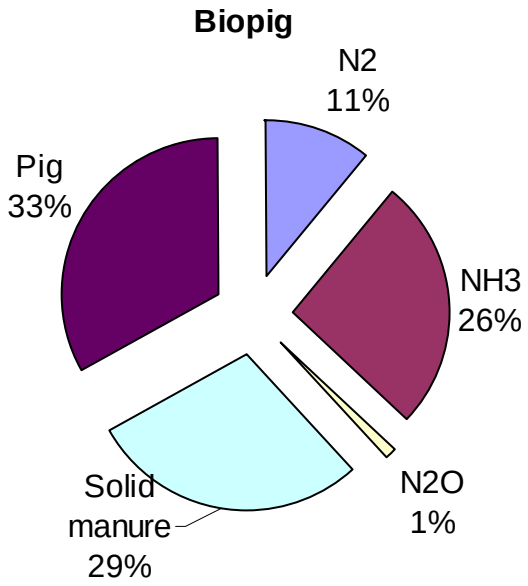
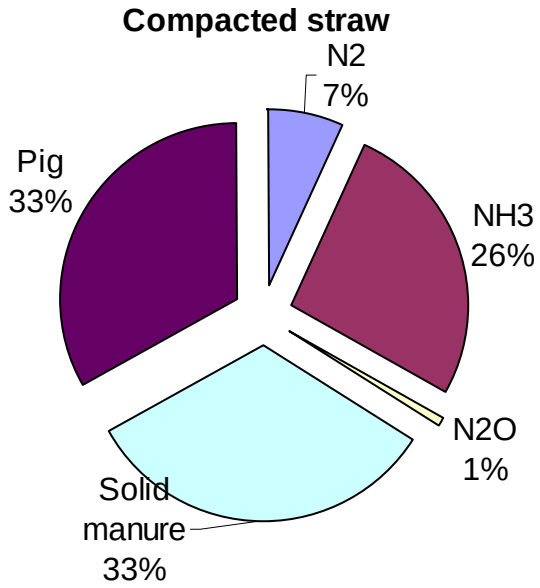
Controlled conditions

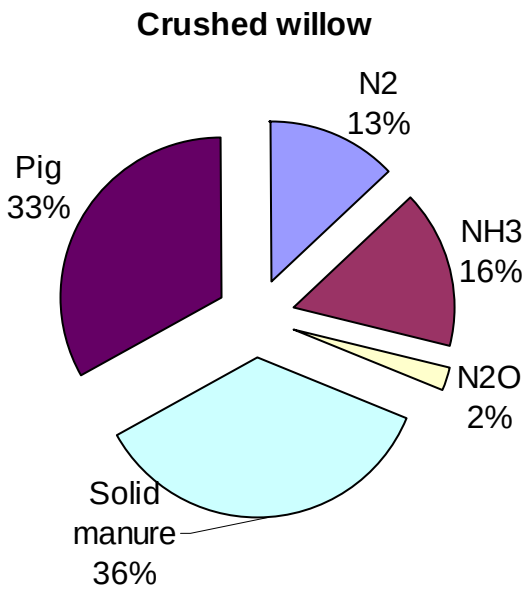


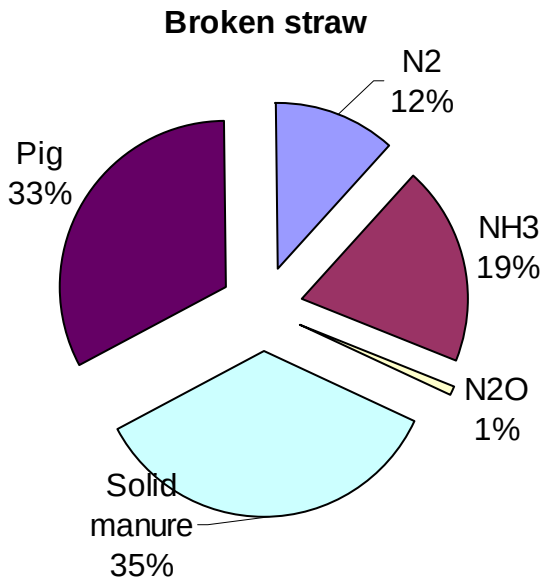
Results

Type of litter



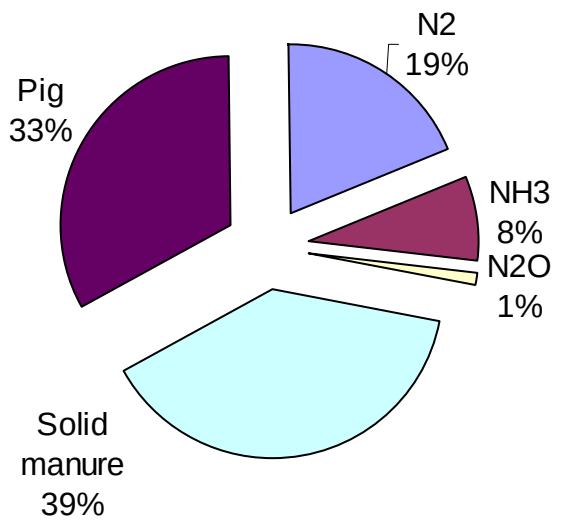




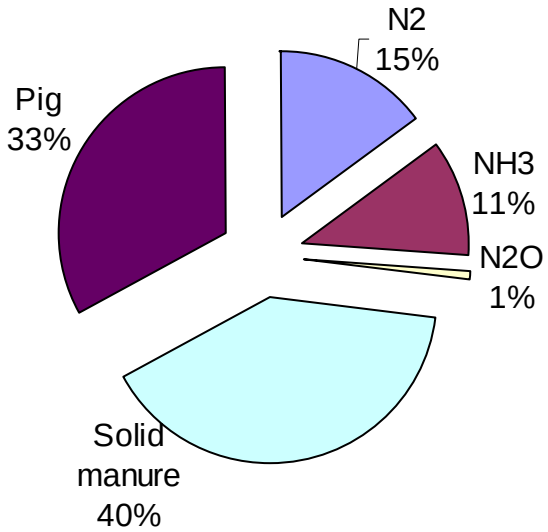


Mixture: old litter/new sawdust

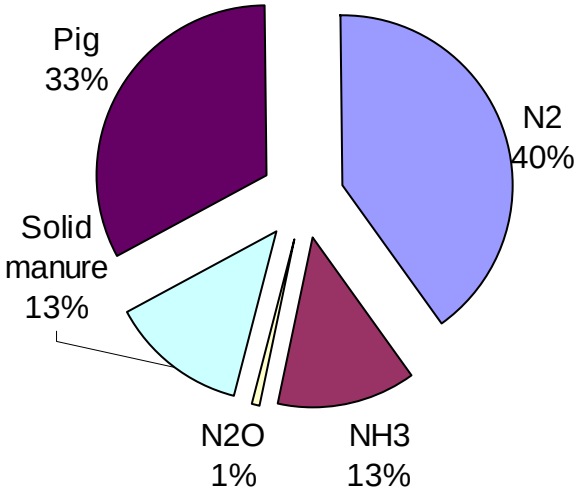
3/3 new sawdust



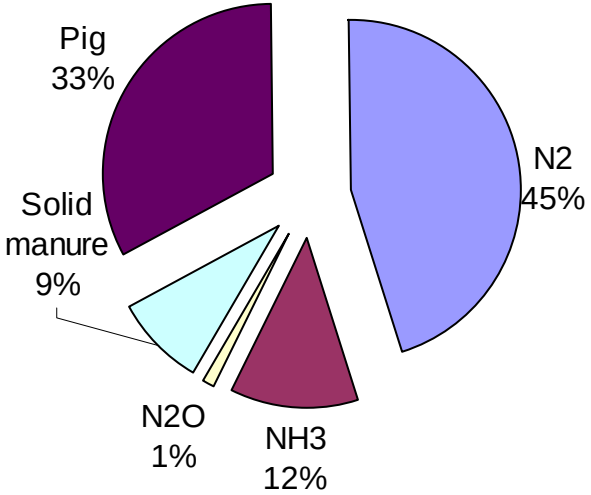
2/3 new sawdust



1/3 new sawdust

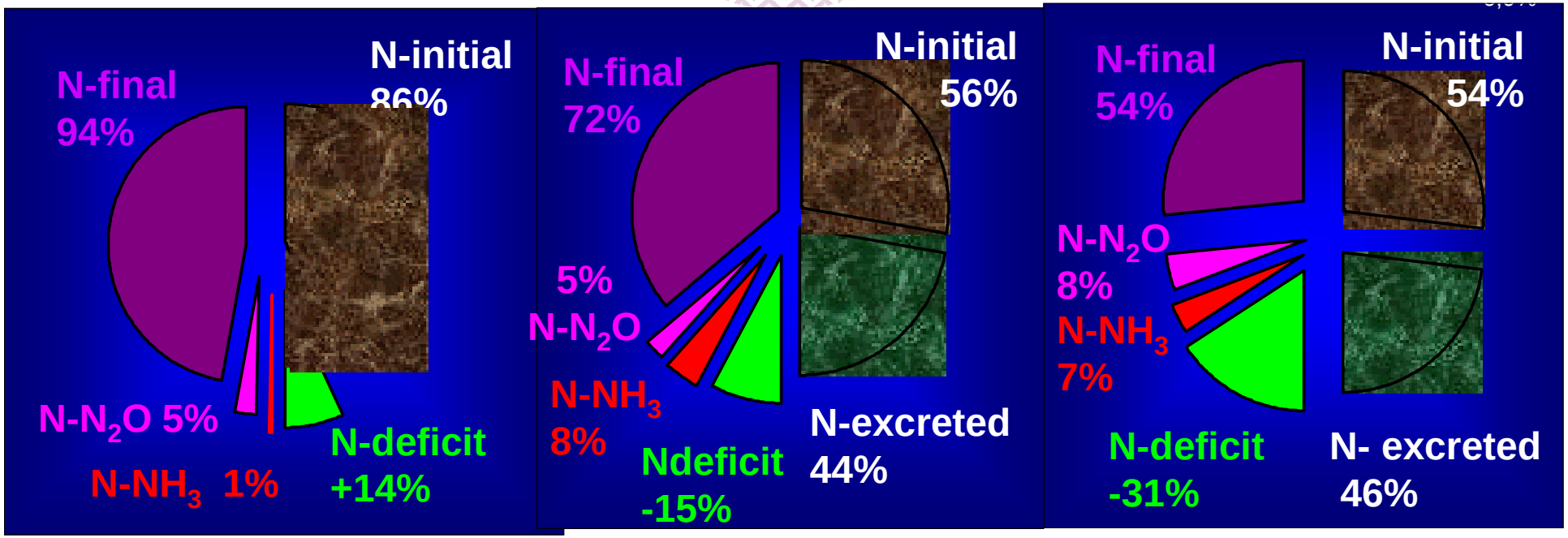


0/3 new sawdust



maximum effects of turning and excretion input

Lying area, turned or not | **Excretion area, not turned** | **Excretion area, turned**



100% — **N conservation** — **0%**

<5% — **N-N_2O emission** — **>10%**

References

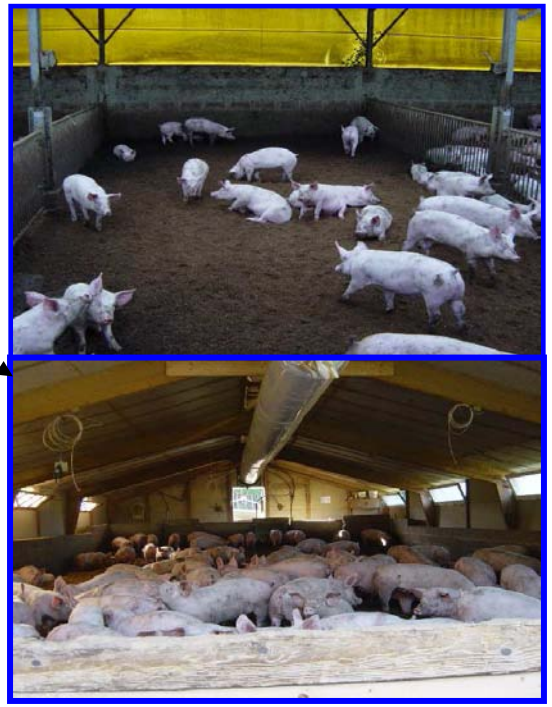
- KERMARREC C. ,1999. Bilan et transformations de l’azote en élevage intensif de porc sur litière. Thèse Université RENNES 1, 185p.
- ROBIN P., DE OLIVEIRA P. A., KERMARREC C., 1999. Journées Rech Porcine en France, 31, 111-115
- KERMARREC C., ROBIN P.,2002. Journées Rech Porcine en France, 34, 155-160.

Commercial conditions

⇒Measurements of gaseous emissions in commercial buildings (pig-on-litter systems):

Contrasted stocking density

Contrasted building insulation



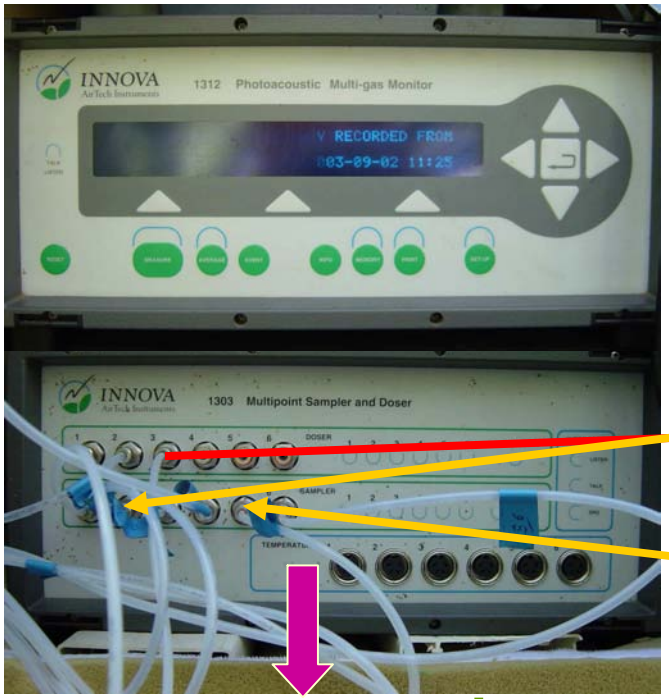
Contrasted seasons (winter and summer)

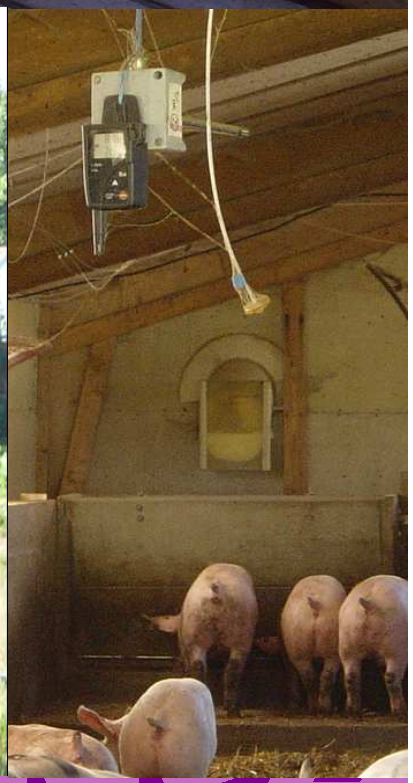
⇒Validation of a simplified method (weekly / continuous)

Commercial conditions

Livestock building		Experimental station			Commercial buildings			
Year of the measurements		2002	2002	2002	2003	2001 2002	2001 2002	2003
Duration (weeks)	Winter Summer	18 21	14 21	20 16	14 14	13	13	13
Number of pigs	Winter Summer	30	40 35	30 40	103 106	3x23	3x23	3x23
Final weight (kg)	Winter Summer	146 143	117 144	146 110	115 105	115	115	115
Measurement technique		Simplified method			Tracer gas	Simplified method		Tracer gas
Initial straw quantity (kg/pig)	Winter Summer	16 16	58 16	16 16	30 30	10	10	10
Straw supply (kg/day.pig)	Winter Summer	0,8 0.5	0 0.7	0,5 0.6	≈0,6 ≈0,6	≈0,6	≈0,6	≈0,6
Litter surface (m^2/pig)	Winter Summer	1,4 1.4	1,0 1.2	1,4 1.0	1,2 1.2	2,6	2,6	2,6

Commercial conditions



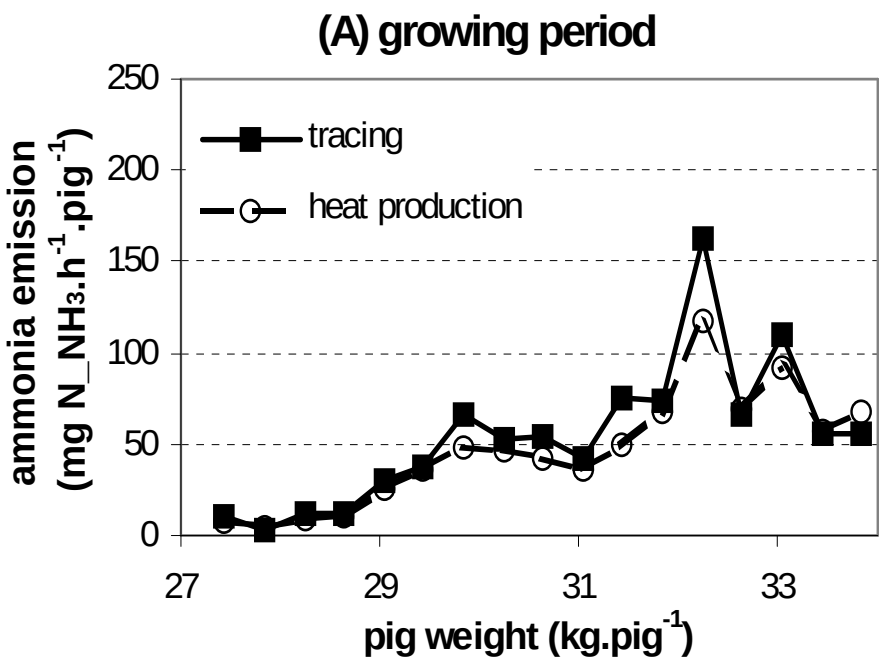


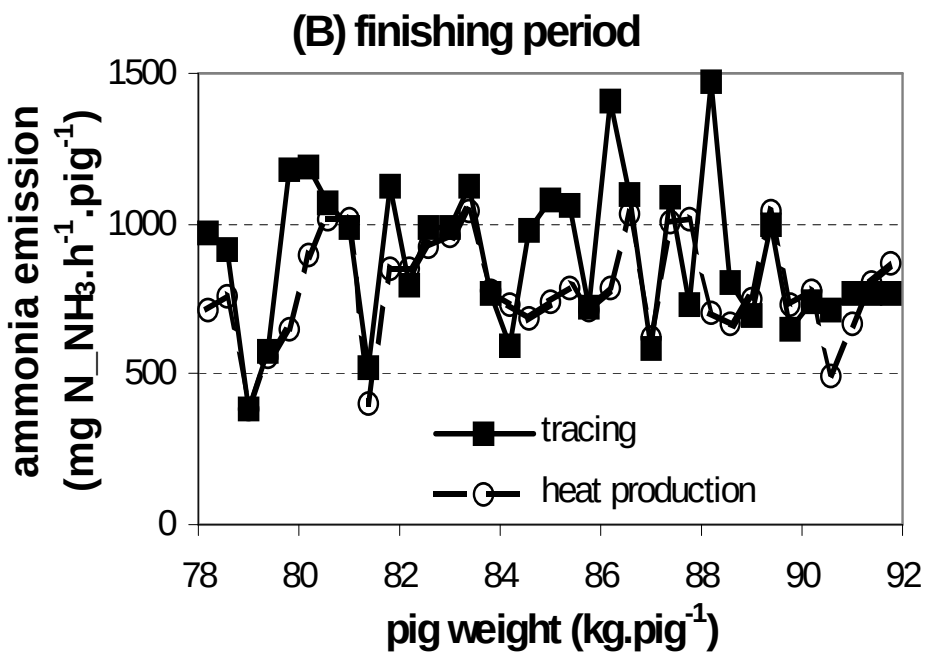
Gas concentrations :
NH_3, N_2O, CO_2, CH_4, SF_6

SF_6 → Air flow rate

Commercial conditions

Emission estimates from tracing and heat production give similar values



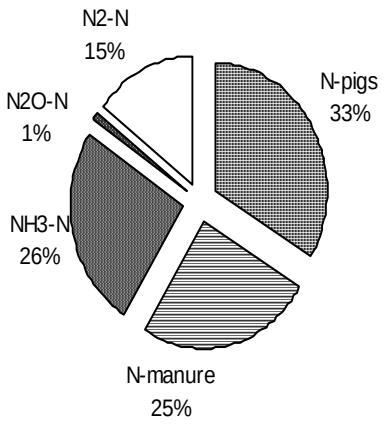


Validation of the results

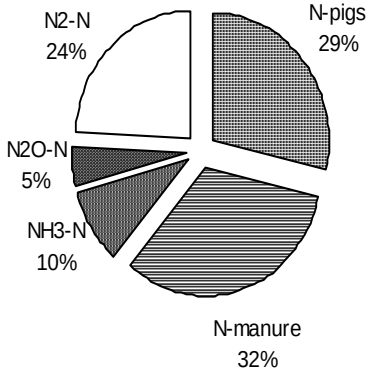
	Water emission	Carbon emission		Nitrogen emission	
Gaz	H_2O (kg H_2O.pig^{-1})	CO_2 (kg C-CO_2.pig^{-1})	CH_4 (kg C-CH_4.pig^{-1})	NH_3 (kg N-NH_3.pig^{-1})	N_2O (kg N-N_2O.pig^{-1})
Tracing	402	92	1,1	1,4	0,01
Heat production	391	84	1,0	1,3	0,01
Concentration ratios [a]	387	91	1,1	0,7	0,01

[a] the water emission of 387 kg H2O.pig^{-1} is the deficit of the mass balance increased by 10% metabolic water produced, the ratios of gas concentration to water vapor are used to calculate the other emissions

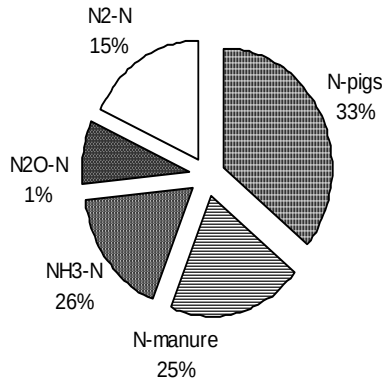
B1 Summer 2003 1,2 m²/pig
5,4 kg N-food + 0,4 kg N straw/pig



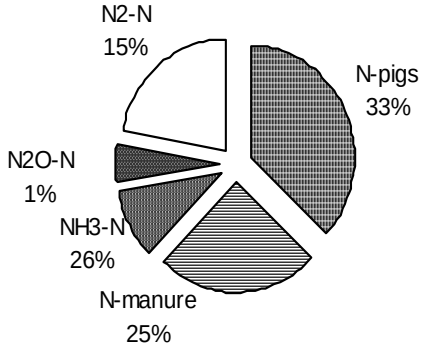
B2-R1 Summer 2002 2,6m²/pig
4,5 kg N-food + 0,5 kg N-straw/pig



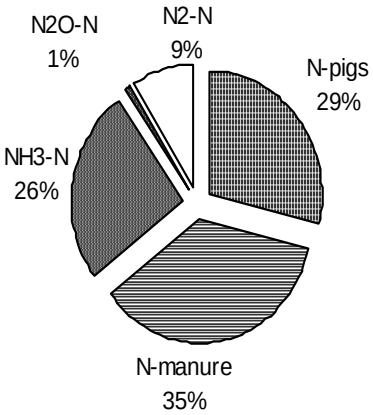
ITP-R1 Summer 2002 1,4 m²/pig
8,5 kg N-food + 0,4 kg N straw/pig



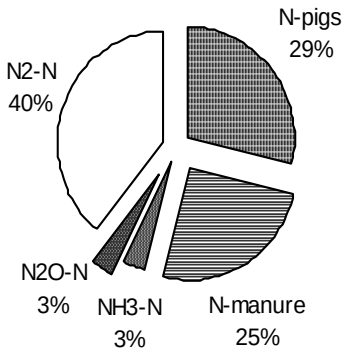
iTP-R2 Summer 2002 1,0 m²/pig
6 kg N-food + 0,4 kg N straw/pig



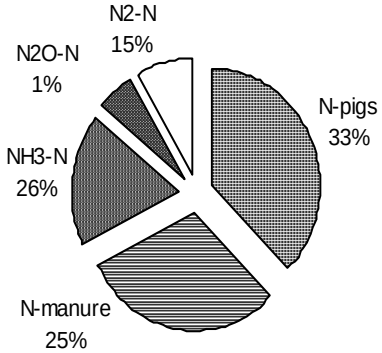
B1 Winter 2003 1,2 m²/p ig
5,4 kg N-food + 0,4 kg N-straw/pig



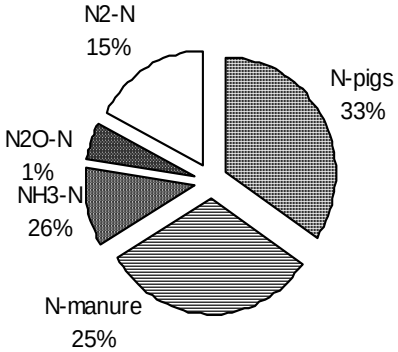
B2-R1 Winter 2001 2,6m²/pig
4,5 kg N-food + 0,5 kg N-straw/pig



ITP-R1 Winter 2002 1,4 m²/pig
8 kg N-food + 0,4 kg N straw/pig



ITP-R2 Winter 2002 1,4 m²/pig
9 kg N-food + 0,4 kg N straw/pig



Discussions

- Influence of the stocking density:
  - Pigs activity
  - Gaseous exchange

- Influence of solid manure water content

- Rather homogenous low nitrogen content in the manure despite the variability in NH_3 and N_2O emissions

Conclusions

For N_2O:

Variations between 0,02 and 0,16kg N-N_2O/kg excreted N

Higher than the given reference for pig-on-slatted floor systems: 0,02 N-N_2O/kg excreted N (IPCC)

$EF(N_2O)$ = 4 - 12% excreted N for livestock buildings with less than 2 m^2 litter/pig

$EF(N_2O)$ = 2 - 8% excreted N for livestock buildings with more than 2 m^2 litter/pig

These emission factors should be reduced when the litter inputs are over 100 kg litter/pig

Conclusions

For NH_3:

Small influence of the indoor conditions, the rearing conditions or the litter management in the livestock buildings with a normal stocking density (between 1 and 1,4m^2/pig), regular straw supplies and thermal insulation of the building

Agreement with English and Danish results: 100 to 400mg NH_3/h.pig (Groot Koerkamp P.W.G et al.,1998)

EF(NH_3) = 15 - 25% excreted N for pigs reared for at least 10 weeks with a litter input in the range 50-80 kg/pig

Conclusions

Hypothesis: combined Effects explain high variability

for pig-on-litter reared for at least 10 weeks, 1,2m²/pig, 50-80kg litter/pig, no turning, normal management (% excreted N):

$EF(NH_3) = 20\%$; $EF(N_2O) = 8\%$; $EF(N_{loss}) = 64\%$

Gas	Variation Factors								
	Litter type		Animal density (m²/pig)		Management		Substrate amount (kg/pig)		Turning
	straw	sawdust	2	1	careful	careless	> 100	< 30	frequent
NH_3	1	1	1.1	0.5	0.8	2	0.8	1.2	1
N_2O	0.8	1.2	0.8	0.5	0.5	0.2	0.8	0.8	2
N_{Loss}	0.88	1.13	1	1.1	1.1	1	0.9	1	1.1

$$NH_3 = 0{,}20 \cdot 17/14 \cdot N_{excret} \cdot E_{AnimalDensity} \cdot E_{Maintenance} \cdot E_{SubstrateAmount}$$

$$N_2O = 0{,}08 \cdot 44/28 \cdot N_{excret} \cdot E_{LitterType} \cdot E_{AnimalDensity} \cdot E_{Maintenance} \cdot E_{SubstrateAmount} \cdot E_{mixing}$$

$$N_{Loss} = 0{,}64 \cdot N_{excret} \cdot E_{LitterType} \cdot E_{AnimalDensity} \cdot E_{Maintenance} \cdot E_{SubstrateAmount} \cdot E_{Mixing}$$

References

ROBIN P., HASSOUNA M., RAMONET Y., TEXIER C., 2004. In : Maitrise des émissions gazeuses en bâtiments sur litière (validation en élevage des résultats acquis en station expérimentale). Rapport final convention MEDD-DE /INRA. GIS Porcherie Verte, UMR SAS, Rennes, 110 p. http://www.rennes.inra.fr/umrsas/documentation

HASSOUNA M., ROBIN P., TEXIER C. 2004 - N_2O and CH_4 emissions in french straw-based pig-on-litter breeding systems. *In : Greenhouse gas emissions from agriculture mitigaton options and strategies Internationa Conference Febr. 10-12 2004 Leipzig Germany,* 245-247

HASSOUNA M., ROBIN P., TEXIER C, RAMONET Y. 2005 - N_2O anc CH_4 emissions in french straw-based pig-on-litter breeding systems. *In : International workshop on green pork production May. 25-27 2005 Paris France,* 121-122.

HASSOUNA M., ROBIN P.,PAILLAT J.M. 2007-Multi-element combined methods increase the reliability of emission factor measurement. *In Ammonia emissions in agriculture, G-J Monteny and E. Hartung, 2007, Wageningen Academic Publishers,* 341-342

RIGOLOT C., ESPAGNOL S., ROBIN P., HASSOUNA M., BELINE F., PAILLAT J.M., DOURMAD J.Y. Mathematical modelling of manure production by pigs: part II NH_3, N_2O, and CH_4 emissions and nutrient and matter flows in animal house and during manure storage and treatment. *To be submitted*

COMPOSTING

J.M Paillat, P. Robin, M. Hassouna

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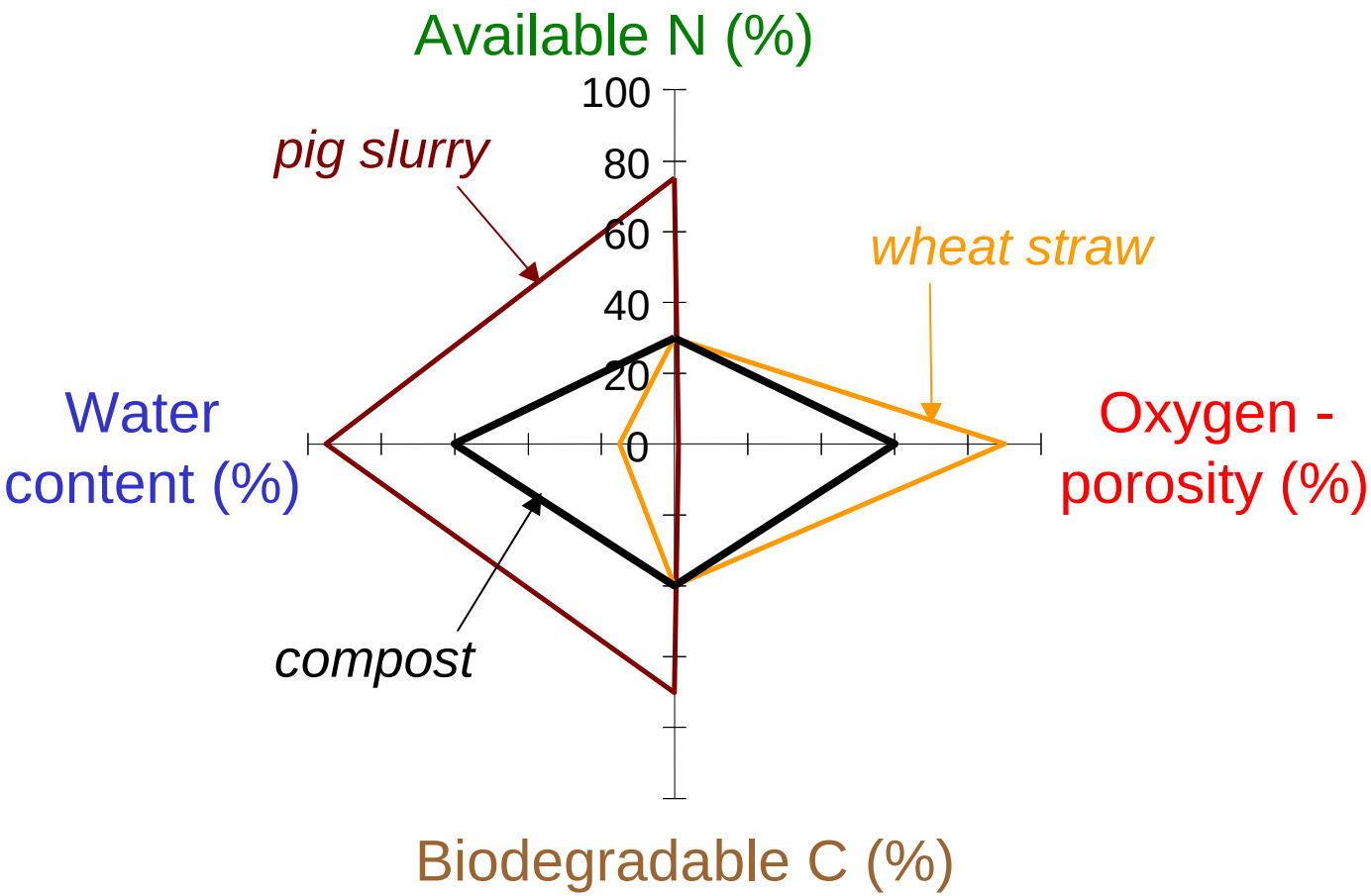
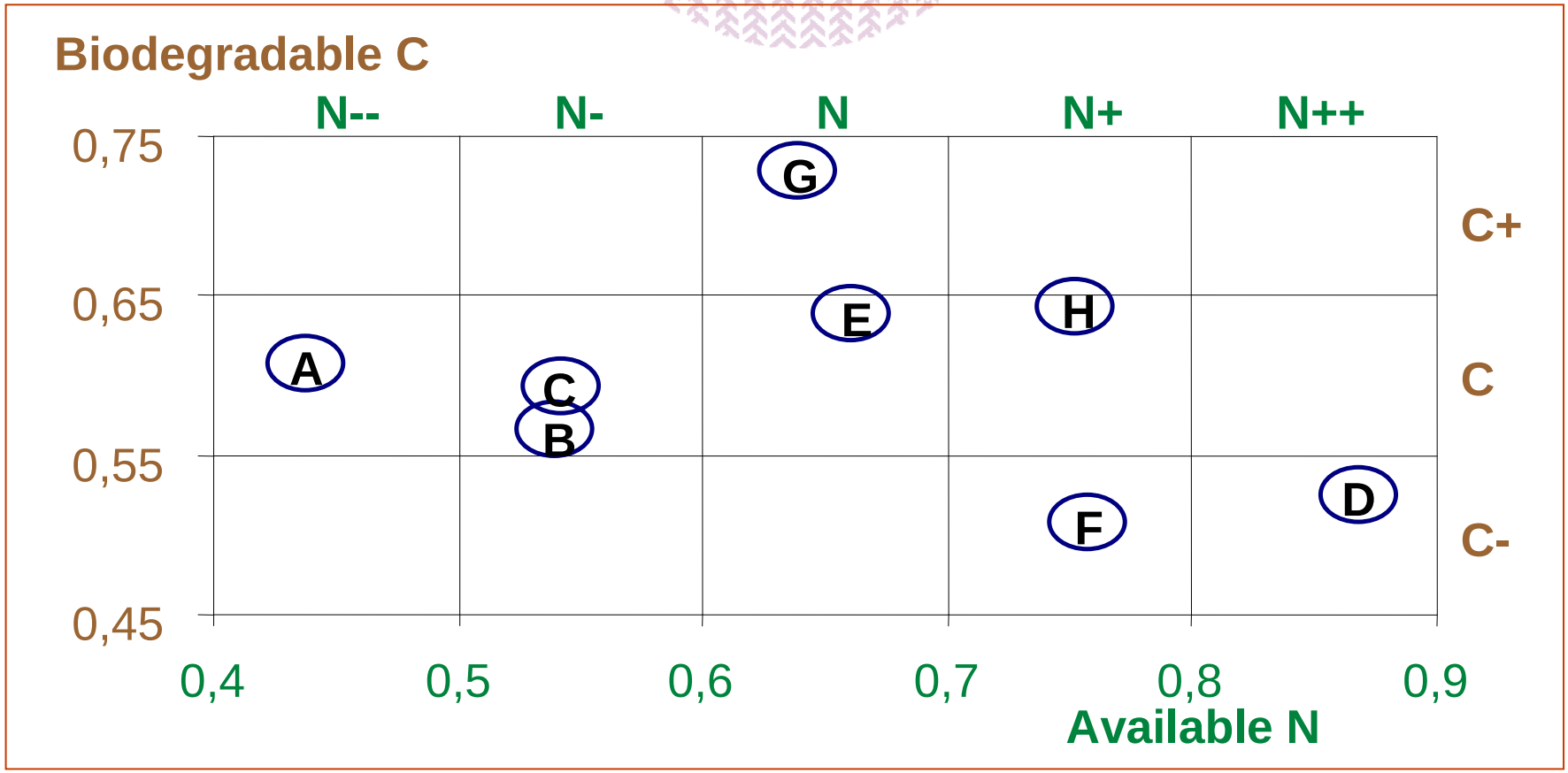
Introduction

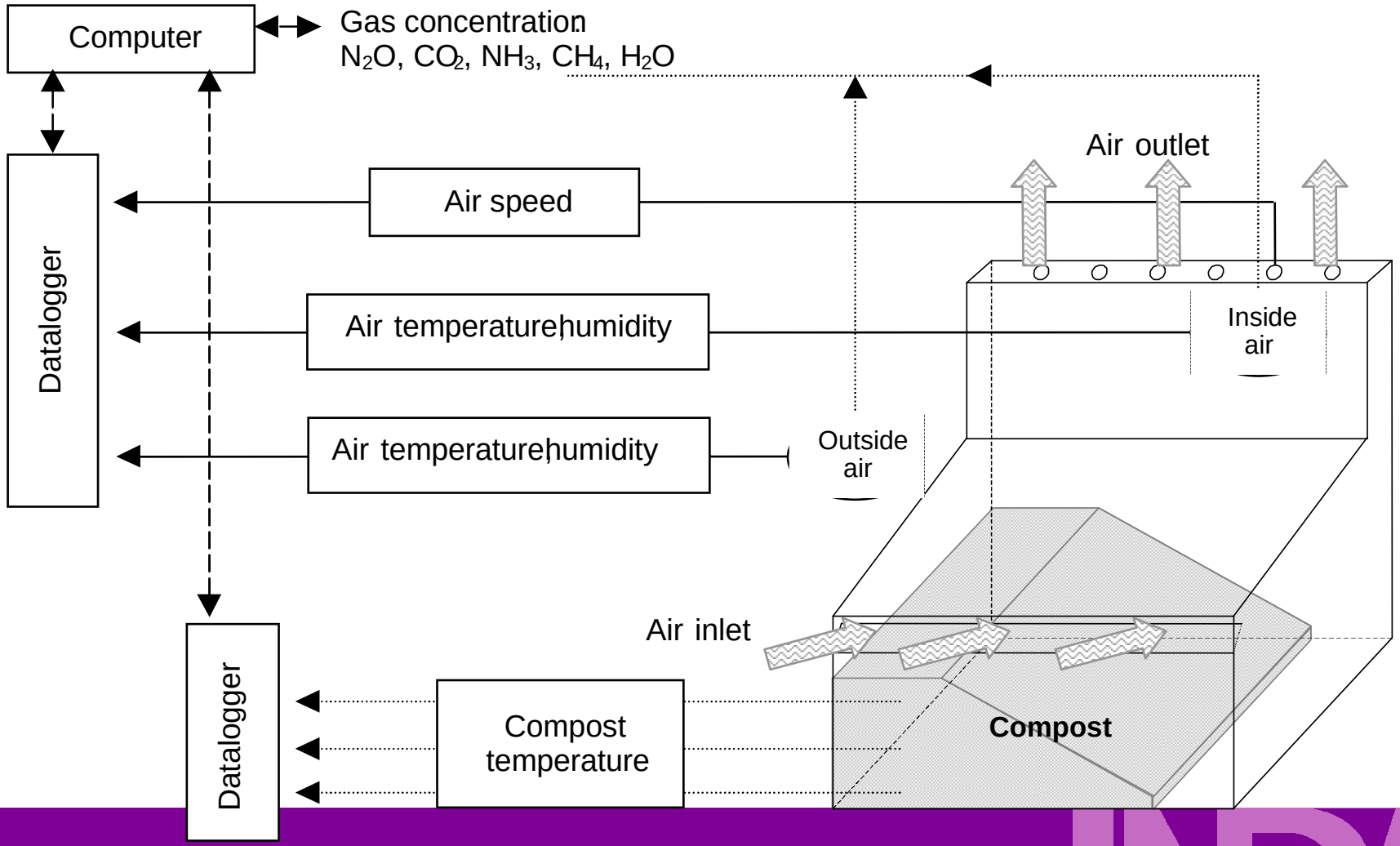


Experimental design



Mixtures with straw, sawdust, pig slurry, solid manure, molasses, urea, and water. Water content ≈70% and free air space ≈70%

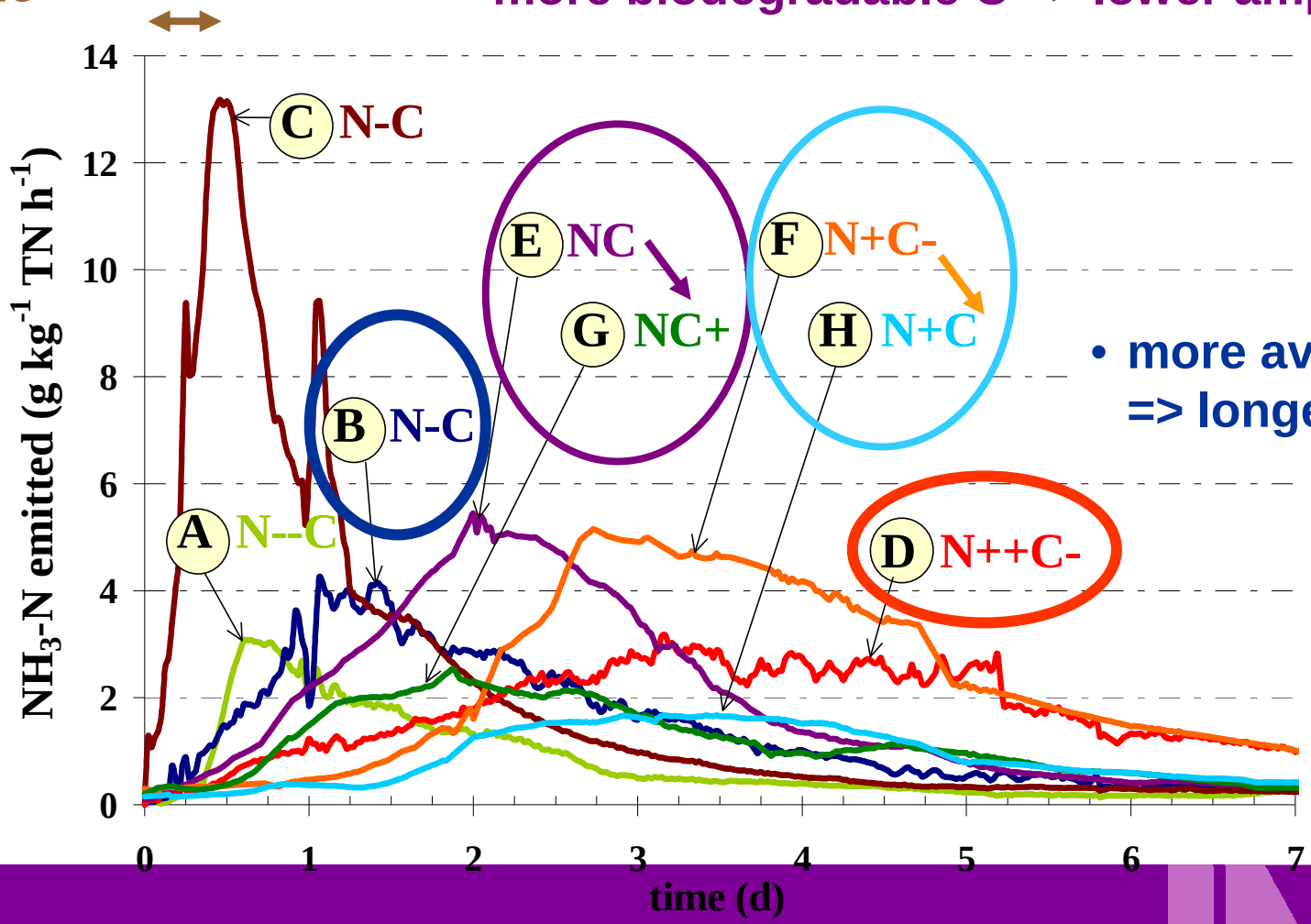
Material and method



Results

•more manure => shorter response time

•more biodegradable C => lower amplitude



• more available N => longer emission

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Results

Heap identification	A N--/C	B N-/C	C N-/C	D N++/C-	E N/C	F N+/C-	G N/C+	H N+/C
N-NH_3 (g kg^{-1} totalN)	165	275	387	489	362	479	248	249
C:N	29.0	24.7	17.6	19.0	19.5	21.2	19.6	19.5
Wheat straw	18.5	28.1	10.0	26.0	21.0	12.7	15.3	19.4
Sawdust	-	-	-	-	-	10.6	-	2.2
Sugarcane molasses	-	-	-	-	-	-	7.5	10.9
Pig manure	45.0	15.3	80.1	-	-	-	-	-
Pig slurry	36.5	-	-	72.8	78.9	52.9	71.9	15.6
Urea	-	0.5	0.4	1.2	0.1	0.6	-	0.8
Water	-	56.2	9.5	-	-	23.2	5.3	51.1

Composition (% on wet weight basis) of the composting mixtures

Results

After 2 months of storage, the emissions observed ranges were :

EF(C-CO_2) =19- 61% of the initial carbon content

EF(CH_4)=0,02-0,29 % of the initial carbon content

EF (N-NH_3)=9-48% of the initial nitrogen content

EF (N-N_2O)=0,4-1,2% of the initial nitrogen content

Results

NH_3-N emitted at 56 d = 16,38 SN – 0,903 SH_{VS} + 643,7

(N=8; P<0,05 ; R^2 = 0,82)

CO_2-C emitted at 28 d = 0,683 SH_{VS} -58,92

(N=8; P<0,01 ; R^2 = 0,84)

with NH_3-N expressed in g kg^{-1} TN, CO_2-C in g kg^{-1} TC, SN and SH-VS en g kg^{-1} DM. NH_3.

SN : Soluble Nitrogen

SH_{VS} : Soluble + Hemicellulose-like fractions from the Van Soest analysis

These relations are valid for heaps with water content ≈70% and free air space ≈70%

Results

Équations « dynamiques » de Jean-Marie pour C,N,O2,H2O

.

SN : Soluble Nitrogen

SH_{VS} : Soluble + Hemicellulose-like fractions from the Van Soest analysis

Conclusion

Biodegradable C, available N influence NH_3 emissions; O_2 content influence NH_3 and CO_2 emissions

NH_3-N and CO_2-C potential emission can be calculated for the thermophilic phase

The model describing the 5 main influencing factors (C, N, O_2, H_2O, time) on N-NH_3, C-CO_2, H_2O potential emissions during composting of animal manure will be published

Other experiments have been done for model validation with various climate, cover sheet, bovine or poultry manure

High uncertainty: N_2O after thermophilic phase

References

Paillat, J.-M., Robin, P., Hassouna, M. & Leterme, P. (2005). Predicting ammonia and carbon dioxide emissions from carbon and nitrogen biodegradability during animal waste composting. Atmospheric Environment, 39(36), 6833-6842.

Paillat, J.-M., Robin, P., Hassouna, M. & Leterme, P., 2005. Effet du compostage d'effluents porcins sur les émissions gazeuses et les teneurs en éléments polluants. Rapport final convention ADEME-INRA 0375C0077, GIS Porcherie Verte, UMR SAS, Rennes, 106 p.

http://www.rennes.inra.fr/umrsas/documentation