# Reduction of Greenhouse Gas Emissions from Livestock Manure Management by Feeding Low-Protein Diet

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**National Agriculture and Food Research Organization**

# Treatment of livestock waste in Japan (N flow)

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Livestock housing

(658 Gg/y of N)

**Solid part**

270 - 310 Gg

Piled compost
(Deposition)

158 Gg

Composting

Forced aeration
(Mechanical turn)
(Dry, Incineration … )

**Liquid part**

37Gg

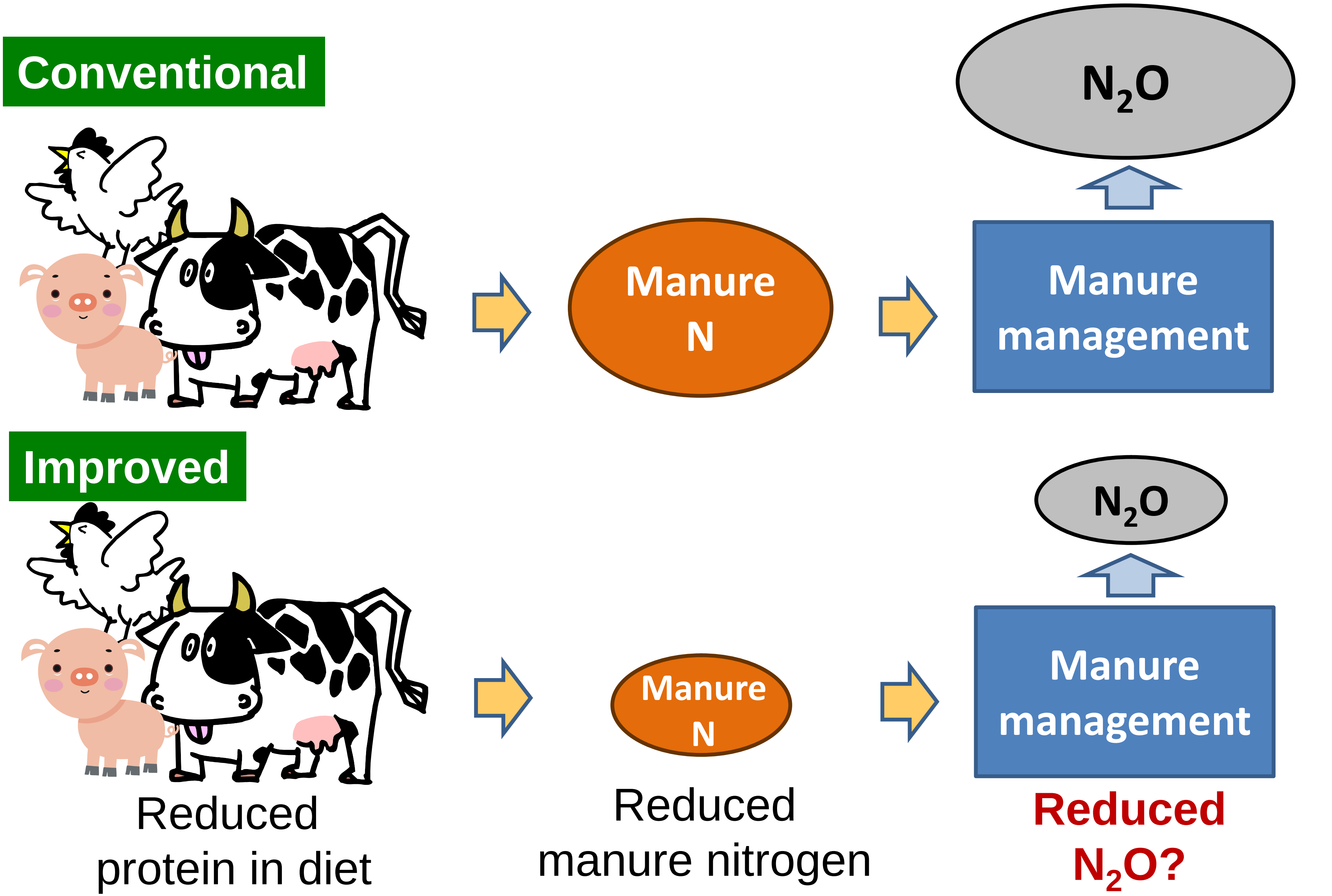
Pit storage
& spread

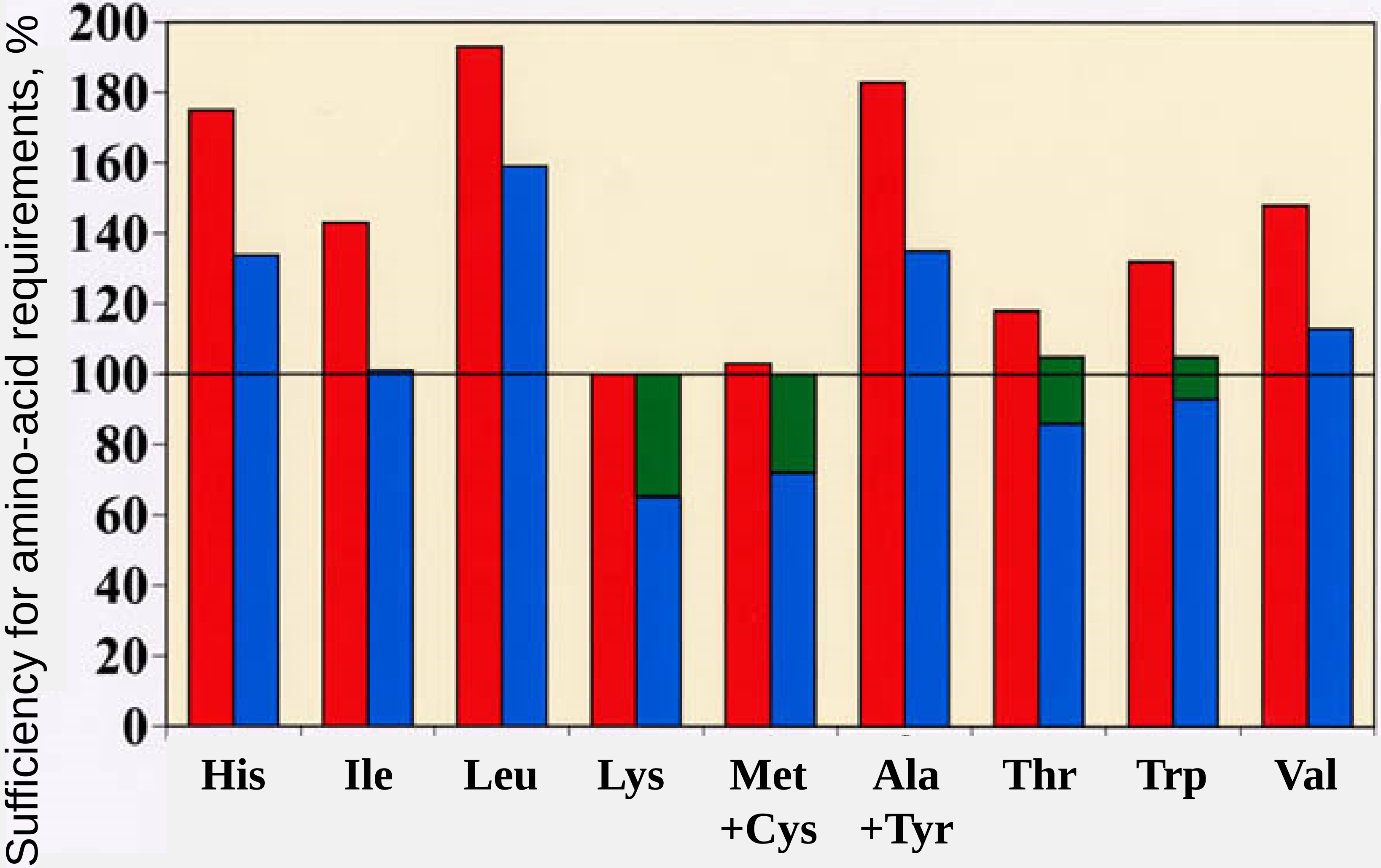
95 Gg

Wastewater
purification

# Concept




Conventional
$N_2O$
Manure
N
Manure
management
Improved
$N_2O$
Manure
N
Manure
management
Reduced
protein in diet
Reduced
manure nitrogen
Reduced
$N_2O$?



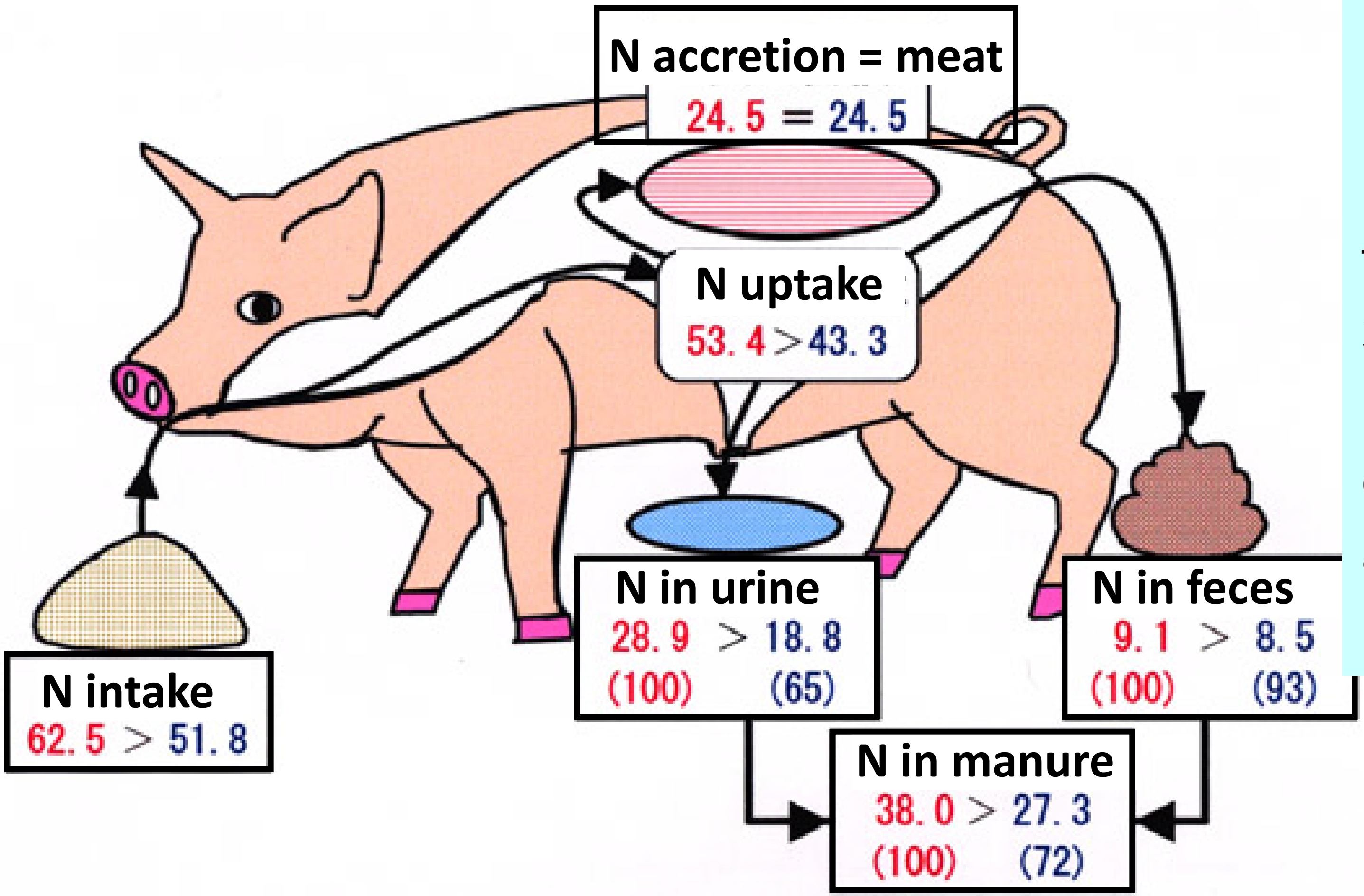

Amino-acid sufficiency of conventional and low-protein diets for requirements of fattening pig

Values of amino-acid requirements are expressed as 100%

Conv. Low-protein diet
Crystalline Amino acid supplement

(Kaji, 2000, translated by the authors)

# Low-protein diet with amino acid for swine




Reduction of nitrogen levels in manure (7% for feces-N and 35% for urine-N) without any deterioration in animal growth performance.

**Nitrogen balance of fattening pig (g N /day)**

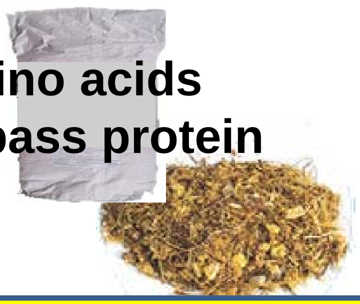
**Red: conventional diet** **Blue: low-protein diet supplemented with amino acids**

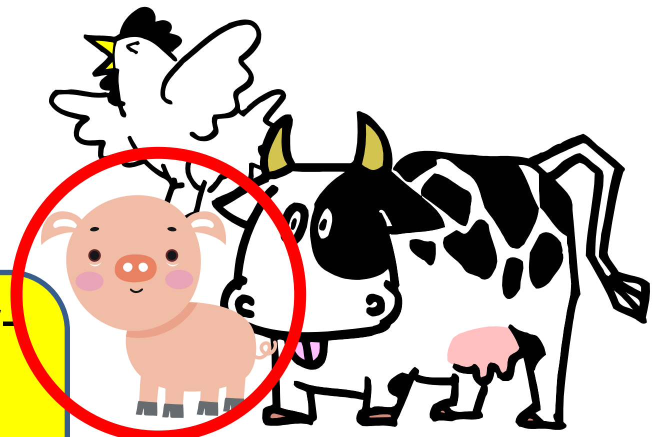
In the case of Fattening pig (Kaji et.al 2000)

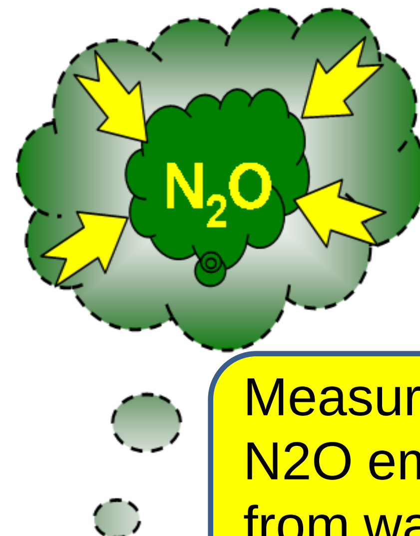
## Development of technique feeding low-protein diet

## Quantification of $N_2O$ reduction from manure management

**Amino acids**
**Bypass protein**

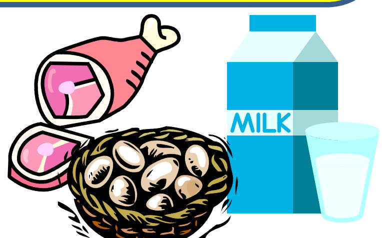







Formulation of low-protein diet supplemented with amino acids etc. and its feeding

Measurement of N2O emission from waste treatment




Verifying stable productivity

Verifying reduction of nitrogen excretion

# Method: feeding study

- 5 LWD barrows with average body weight of 32.7kg
- *ad libitum* feeding in individual cages
- CP17.1% for control diet (**CONT**), CP14.6% for low-protein diet (**LOW**) supplemented with amino acids (Lys, Thr, Met, Trp)
- Twice, 10 days per each
- Daily gain (weight), feed intake, feed efficiency (gain/feed), nitrogen balance, and BUN were measured

CP, crude protein; BUN, blood urinary nitrogen

# Composition of diet, %

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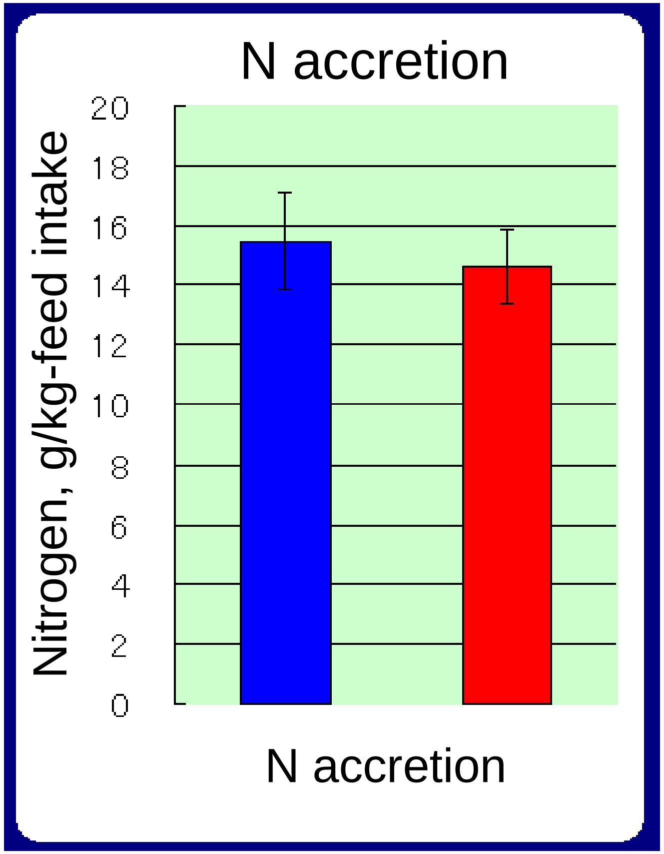
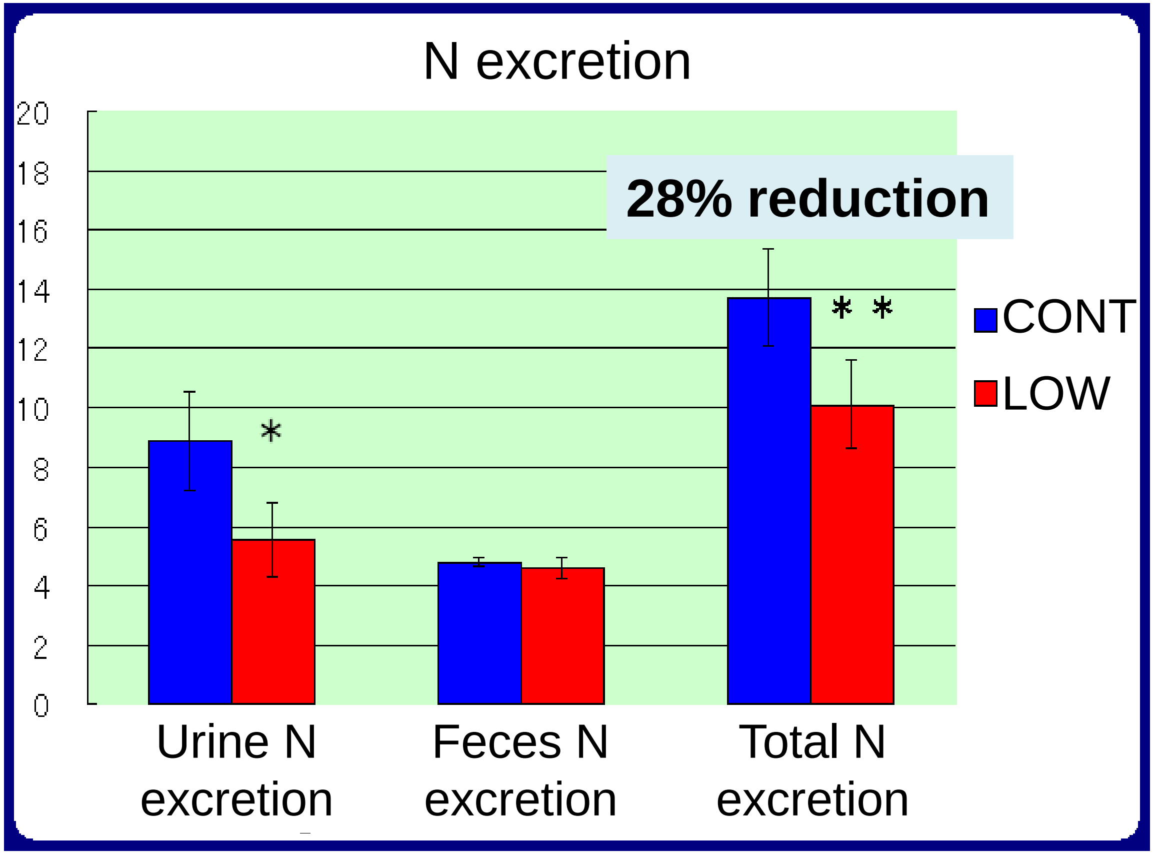
| | CONT | LOW |
|---|---|---|
| CP | (17.1) | (14.5) |
| Corn | 61.90 | 69.05 |
| Soybean meal | 25.50 | 18.00 |
| Brown rice | 10.00 | 10.00 |
| Tricalcium phosphate | 1.60 | 1.60 |
| Salt | 0.30 | 0.30 |
| Vitamine, mineral | 0.60 | 0.60 |
| L-Lysine, HCl | – | 0.21 |
| L-Threonine | – | 0.06 |
| DL-Methionine | – | 0.06 |
| L-Tryptophan | – | 0.02 |
| Chromic oxide | 0.10 | 0.10 |
| Total | 100.00 | 100.00 |

# Nitrogen balance per kg-feed






Average±SE (n=5), *$P$<0.05, **$P$<0.01

# Methods: composting study



● 5kg feces mixed with sawdust per each treatment (65% of MC) was composted for 5 weeks (twice)

● Composting materials were aerated (0.6L/min) and weekly mixed for aerobic fermentation.

● Exhaust gases were carried to gas monitor and gas concentrations were measured.

● Composting was finished based on temperature change and BOD of composting materials.


Innova 1412 photoacoustic gas monitor


Experimental composting apparatus

# Methods: wastewater treatment study

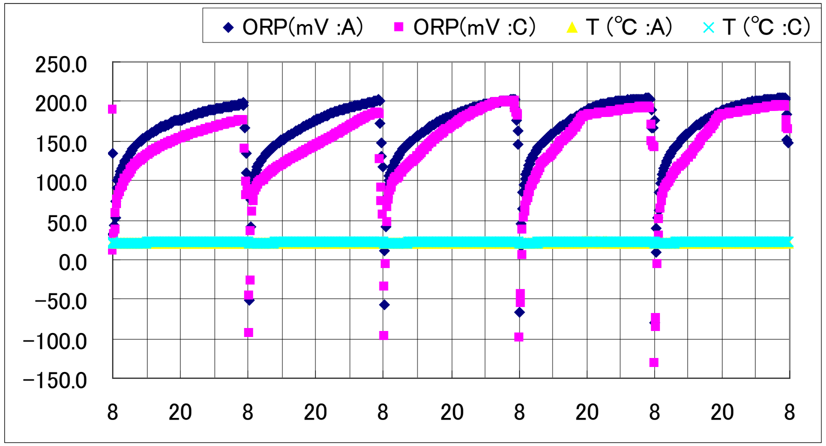
●Urine and 20% of feces from CONT and LOW were treated using experimental activated sludge apparatuses (3L of effective volume) for 6 weeks.

● Wastewater was applied at hydraulic retention time (HRT) of 5d.

●Wastewater contained 2400mg/L BOD and 370mg/L N

●Aeration for 22 hr/d at a rate of 0.5L/min

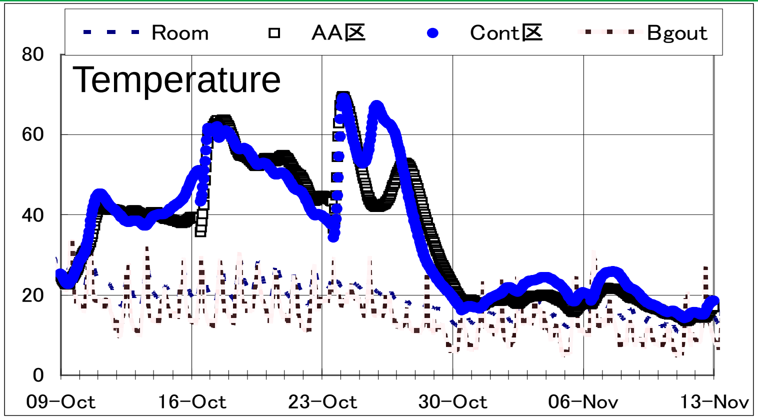

Experimental activated sludge apparatus

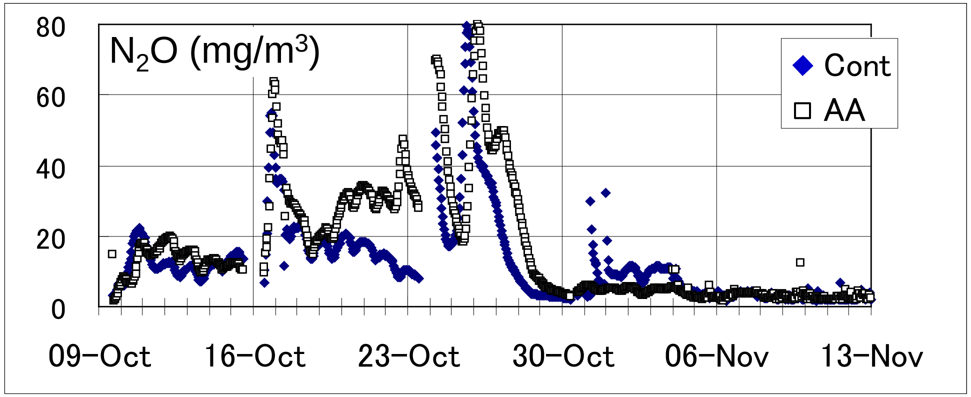


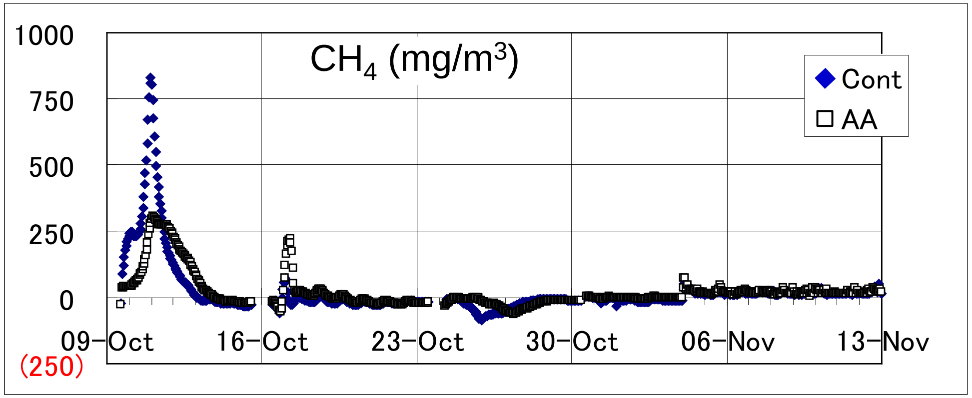

Changes in ORP and temperature in the reactor during experiment.

# Results of composting study (1st trial)





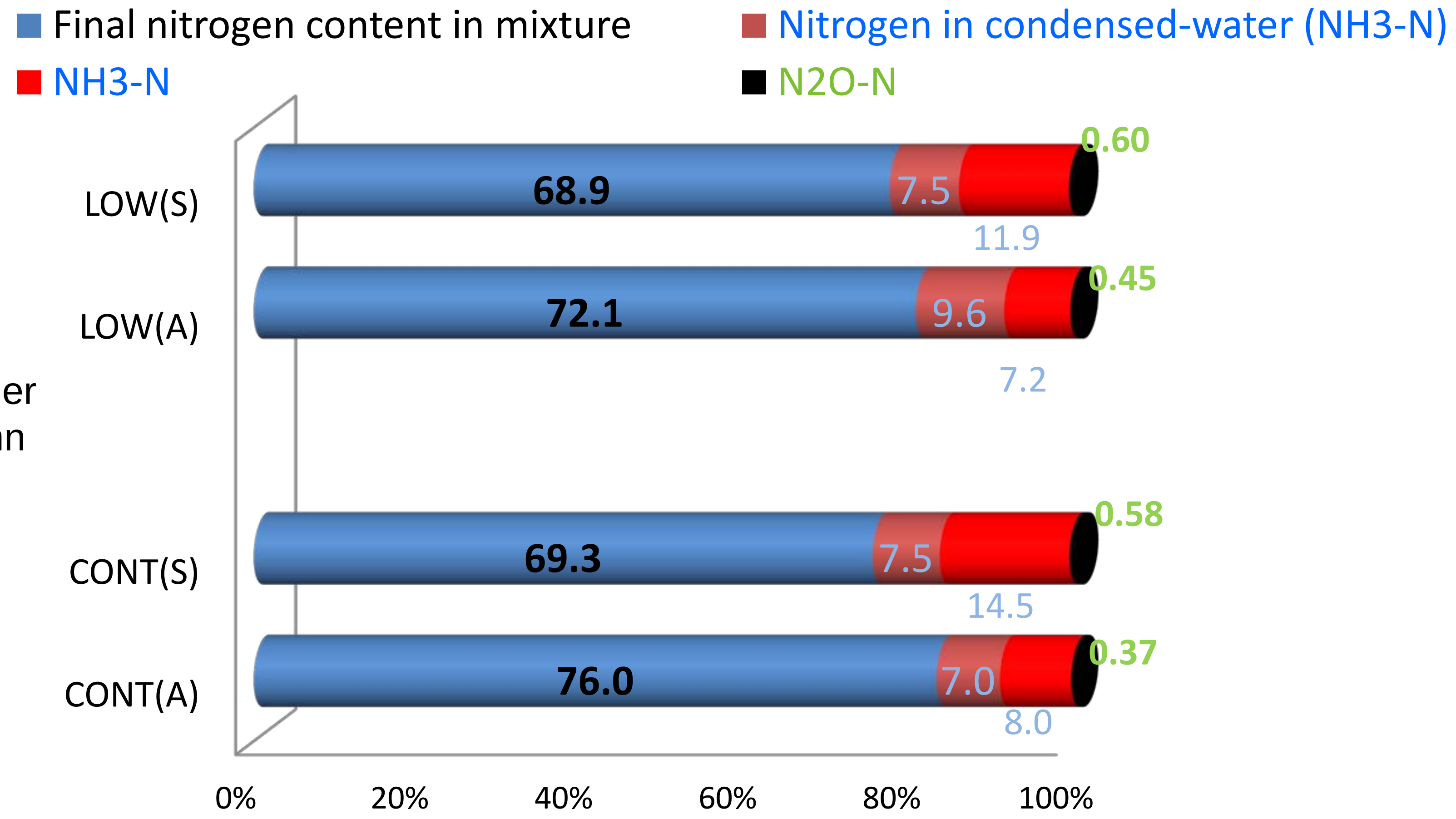

Changes in temperature and GHG emissions

- The temperature increased slowly and reached maximum (70 degree-C) after second turning.
- Total $N_2O$ emissions during the study were 0.28 g for LOW and 0.21g for CONT, and emission factors were 0.43% for LOW and 0.38% for CONT ($gN_2O$-N /gN).
- Total $CH_4$ emissions during the study were 0.35g for LOW and 0.40g for CONT, and emission factors were 0.023% for LOW and 0.030 % for CONT ($gCH_4$/g-OM).

# Results of composting study (two trials)



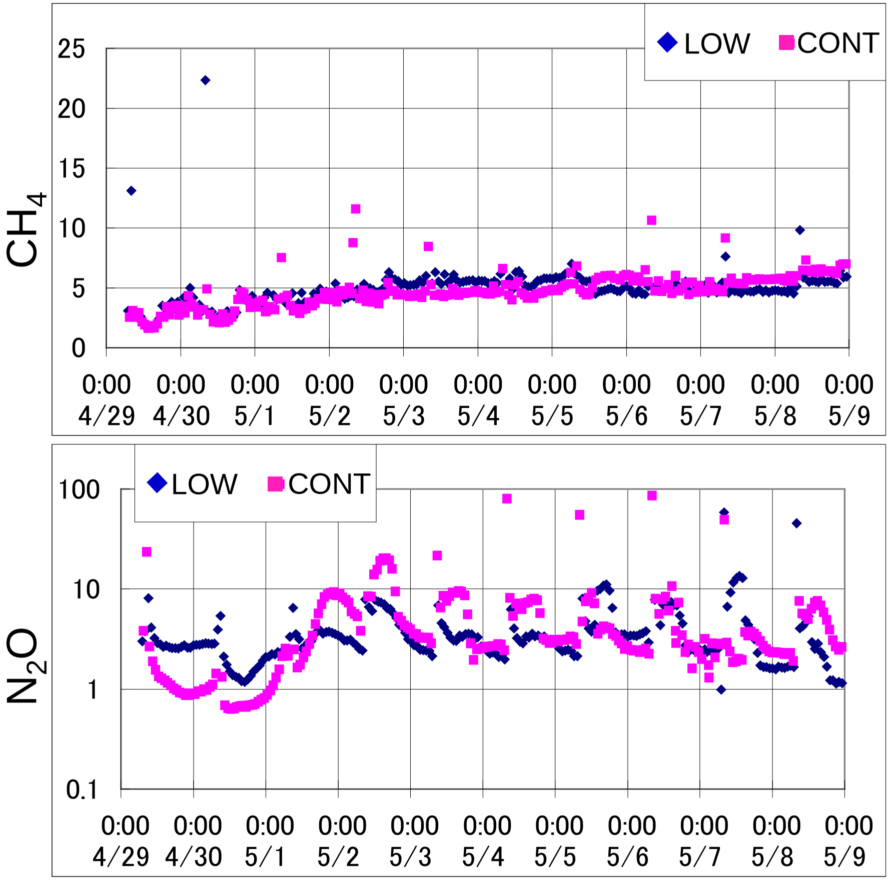
$NH_3$ and $N_2O$ emissions differed between trials (summer and autumn), rather than between LOW and CONT.
70-76% of the initial nitrogen remained in finished compost.
$NH_3$-N emission accounted for 15~22% of the initial nitrogen and is high in summer.
$N_2O$-N emission accounted for 0.45-0.60% of the initial nitrogen and is high in summer.




S, summer
A, autumn

# Results of wastewater treatment study





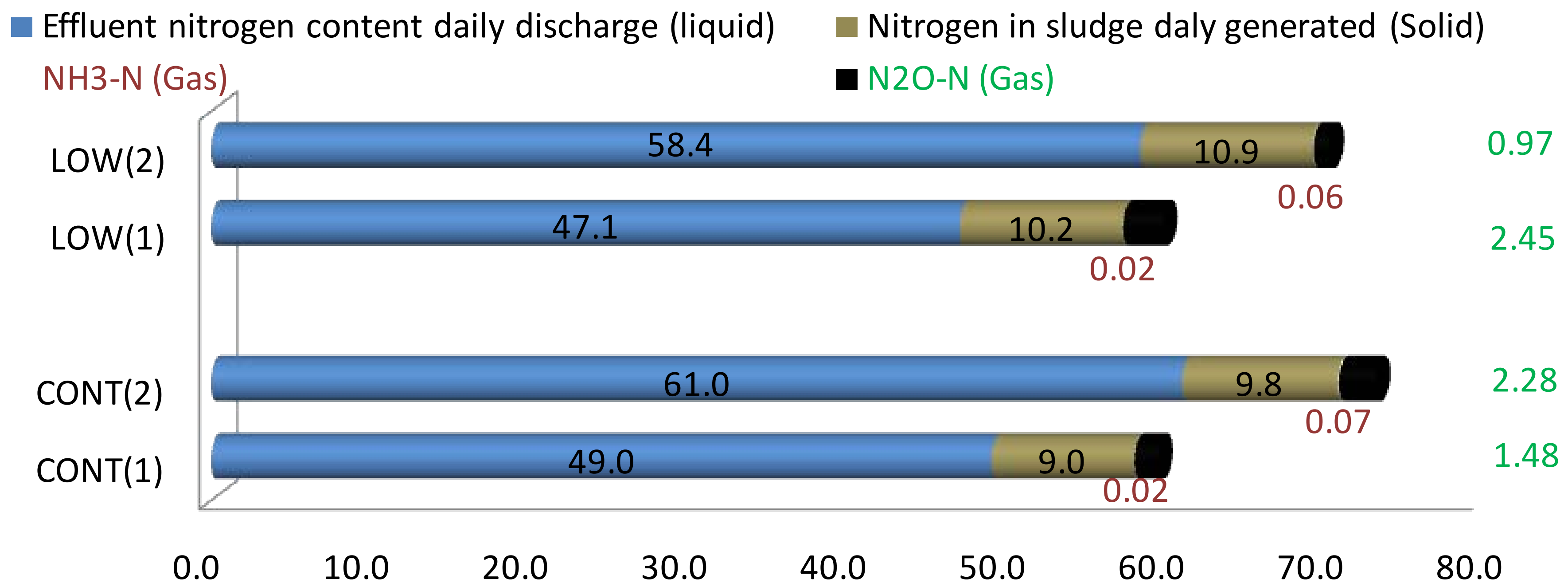

Changes in $CH_4$ and $N_2O$ emissions (ppm) from wastewater treatment study for LOW and CONT.

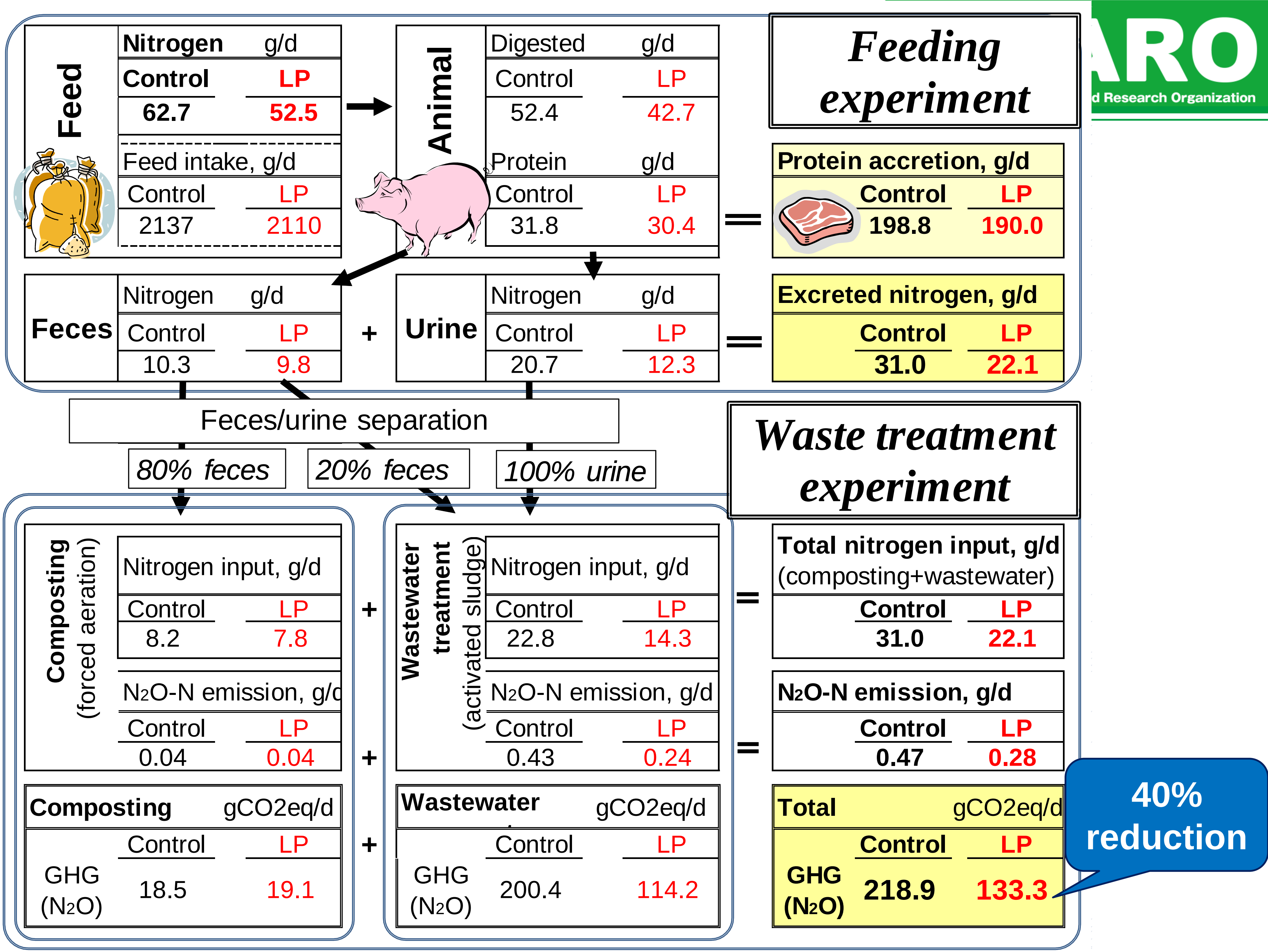
- Wastewater treatment was well done (99% of BOD removal and 60% of nitrogen removal)

- $CH_4$ and $N_2O$ emissions were not largely different between LOW and CONT.

# Results of wastewater treatment study (cont'd)

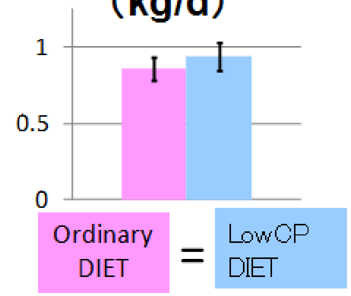
$NH_3$ and $N_2O$ emissions differed between trials (summer and autumn), not between LOW and CONT.
Approximately 10% of the initial nitrogen existed in sludge (mainly in microbes).
$NH_3$-N emission accounted for less than 0.1% of the initial nitrogen.
$N_2O$-N emission accounted for 0.97-2.45% of the initial nitrogen.



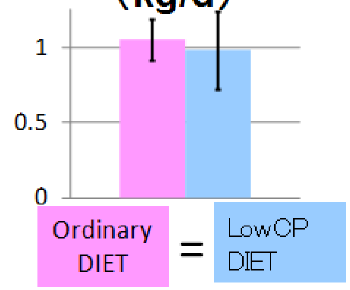

Feeding experiment
Feed
Nitrogen g/d
Control LP
62.7 52.5
Feed intake, g/d
Control LP
2137 2110
Animal
Digested g/d
Control LP
52.4 42.7
Protein g/d
Control LP
31.8 30.4
=
Protein accretion, g/d
Control LP
198.8 190.0
Feces
Nitrogen g/d
Control LP
10.3 9.8
+
Urine
Nitrogen g/d
Control LP
20.7 12.3
=
Excreted nitrogen, g/d
Control LP
31.0 22.1
Feces/urine separation
80% feces
20% feces
100% urine
Waste treatment experiment
Composting (forced aeration)
Nitrogen input, g/d
Control LP
8.2 7.8
N2O-N emission, g/d
Control LP
0.04 0.04
+
Wastewater treatment (activated sludge)
Nitrogen input, g/d
Control LP
22.8 14.3
N2O-N emission, g/d
Control LP
0.43 0.24
=
Total nitrogen input, g/d (composting+wastewater)
Control LP
31.0 22.1
N2O-N emission, g/d
Control LP
0.47 0.28
Composting gCO2eq/d
Control LP
GHG (N2O) 18.5 19.1
+
Wastewater gCO2eq/d
Control LP
GHG (N2O) 200.4 114.2
Total gCO2eq/d
Control LP
GHG (N2O) 218.9 133.3
40% reduction
d Research Organization

# No impact on animal growth,

**Daily gain (growing pig) (kg/d)**

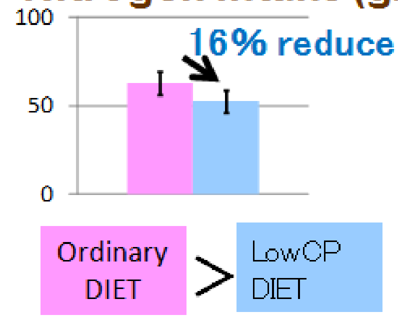



**Daily gain (finishing pig) (kg/d)**

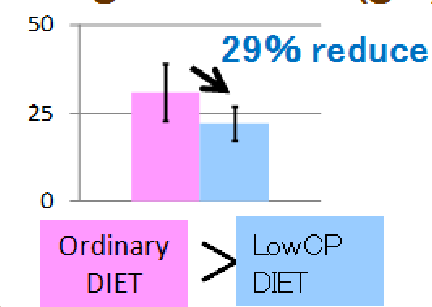



# Surely reduce GHG

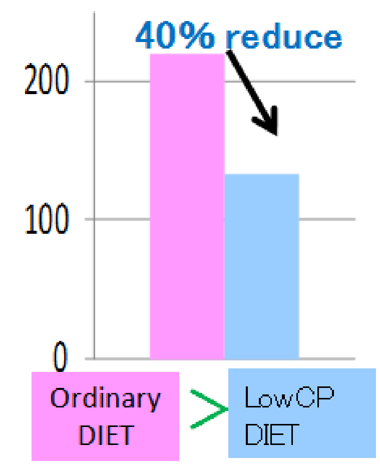
**Nitrogen intake (g/d)**




**Nitrogen excretion (g/d)**




**GHG from manure management ($gCO_2eq$)**



# J-VER




The low-protein diet technique for swine has been adopted in **the carbon offset credit scheme** in Japan named Japan Verified Emission Reduction (**J-VER**).

# Low-protein diet for layer

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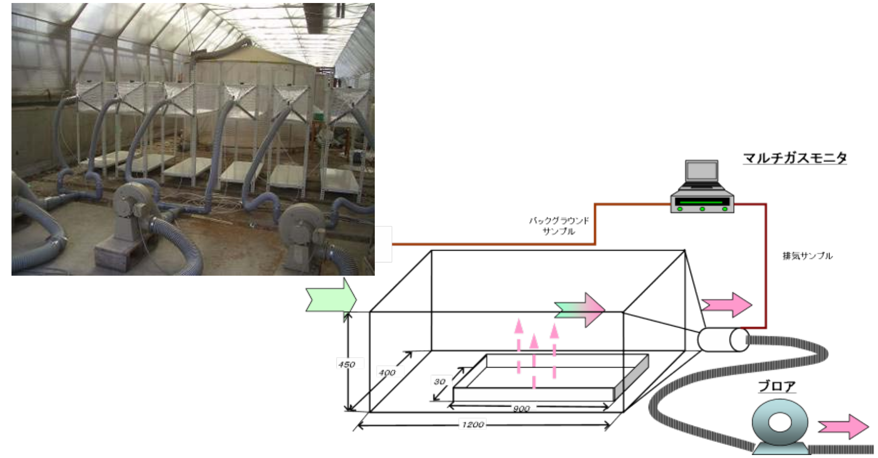
In duplicate

→ **Manure**

**Control diet** or **Low-protein diet with AA**




Drying using experimental apparatus

Composting using experimental apparatus

# Low-protein diet for cattle

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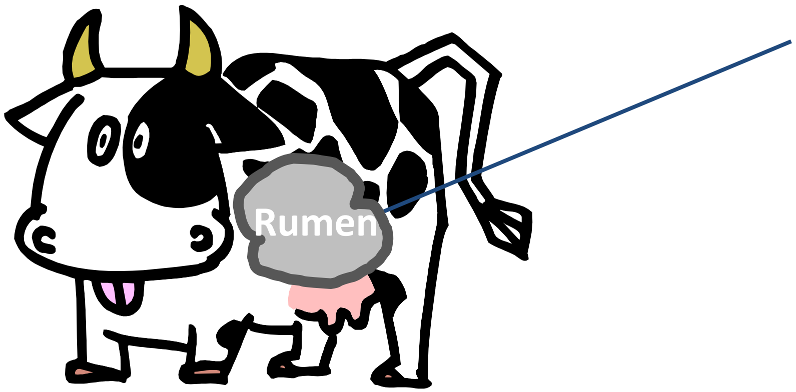



## Cattle has rumen

All kinds of amino acid are synthesized by rumen microbes; however, they are not synthesized in response to requirements of each amino acid.

Possible reduction of nitrogen excretion by feeding low-protein diet supplemented with **bypass protein** or **rumen-protected amino acids**.

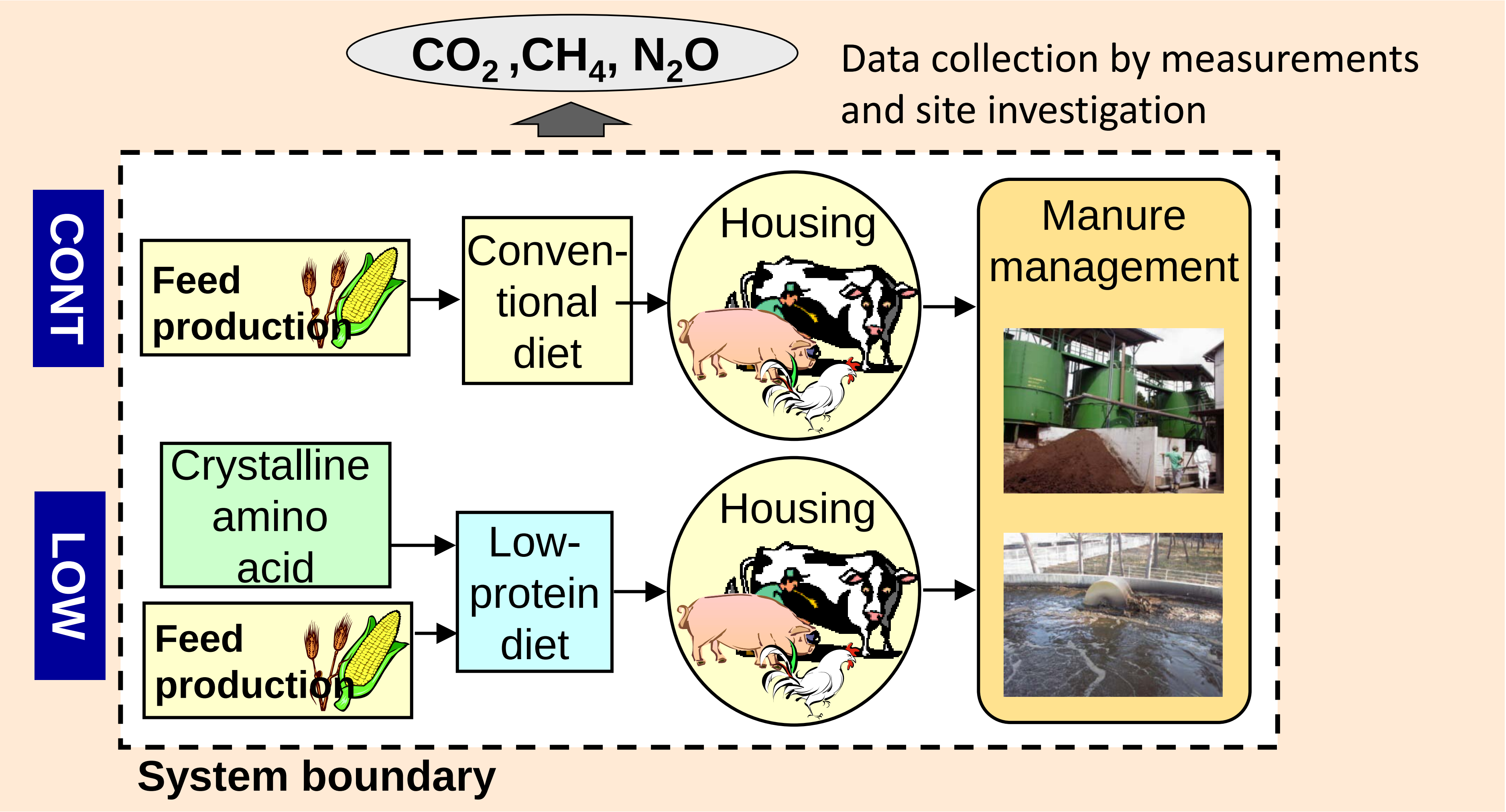
Most portions of bypass protein and rumen-protected amino acids are undegradable and unusable by rumen microbes.

↓

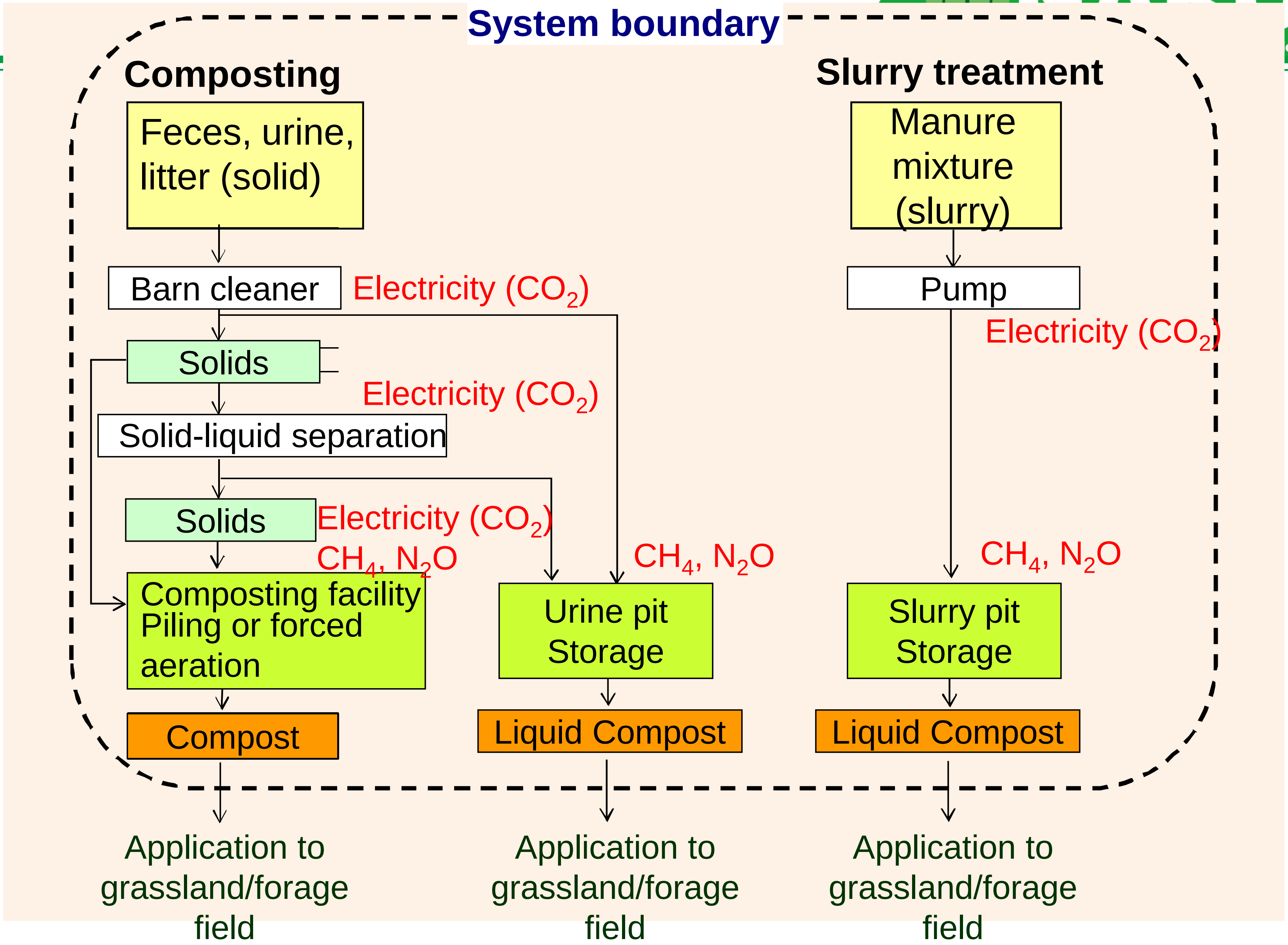
**Feeding study and waste treatment study**

# LCA of low-protein diet technique






Conventional (CONT) and low-protein-diet (LOW) pig production systems evaluated using life cycle assessment (LCA)



System boundary
Composting
Feces, urine, litter (solid)
Barn cleaner
Electricity ($CO_2$)
Solids
Electricity ($CO_2$)
Solid-liquid separation
Solids
Electricity ($CO_2$)
$CH_4$, $N_2O$
Composting facility Piling or forced aeration
Compost
$CH_4$, $N_2O$
Urine pit Storage
Liquid Compost
Slurry treatment
Manure mixture (slurry)
Pump
Electricity ($CO_2$)
$CH_4$, $N_2O$
Slurry pit Storage
Liquid Compost
Application to grassland/forage field
Application to grassland/forage field
Application to grassland/forage field

# Summary

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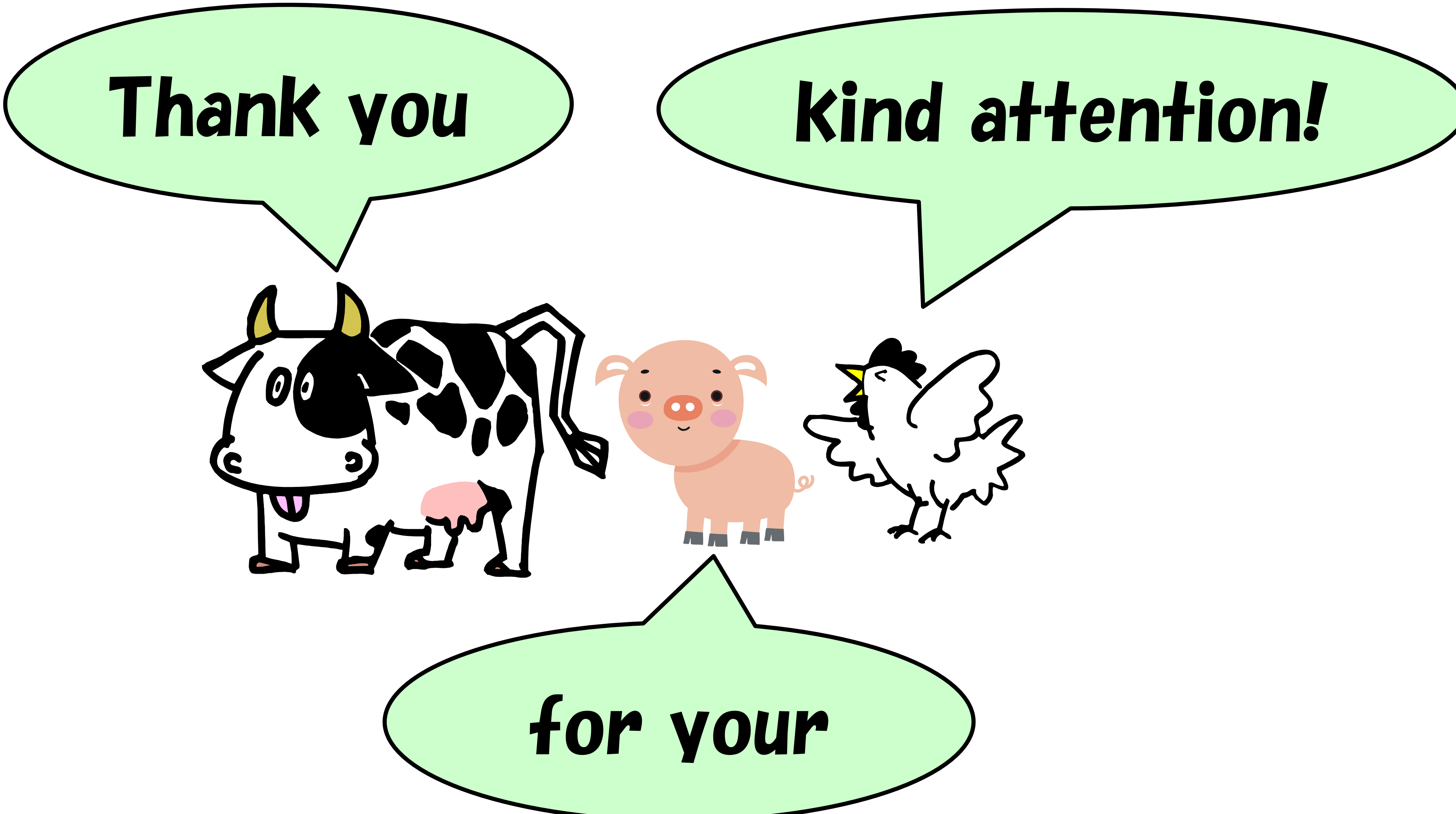
● **Feeding of low-protein diet supplemented with amino acids reduces GHG emissions from swine manure management by approximately 40%.**

● Technique of feeding low-protein diet supplemented with amino acids or bypass protein to cattle and poultry is being developed.

● GHG reduction by using low-protein diet for swine is being evaluated from life cycle perspective, and potential of GHG reduction in Japan by developing mitigation techniques will be evaluated.


Thank you
for your
kind attention!

# 鶏ふん乾燥･堆肥化中の温室効果ガス測定の流れ

２反復（20羽分）
を混合（3区２反復）

生ふん

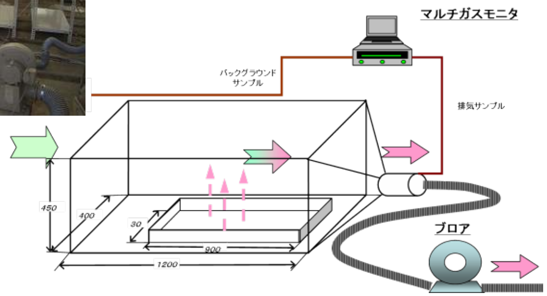
水分75%程度

半乾燥ふん

水分55%程度

堆肥

水分40%程度




乾燥ハウス内の模擬装置にて乾燥

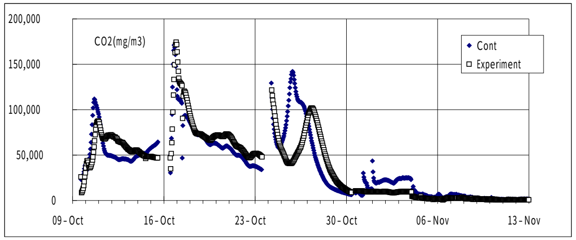
小型堆肥化装置「かぐや姫」にて堆肥化

マルチガスモニタにて測定
（INNOVA　1412）

# 堆肥化試験　(計測と計算)

National Agriculture and Food Research Organization

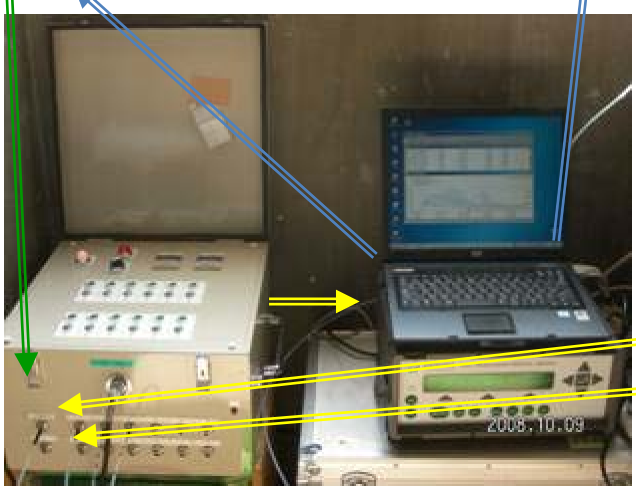
BG

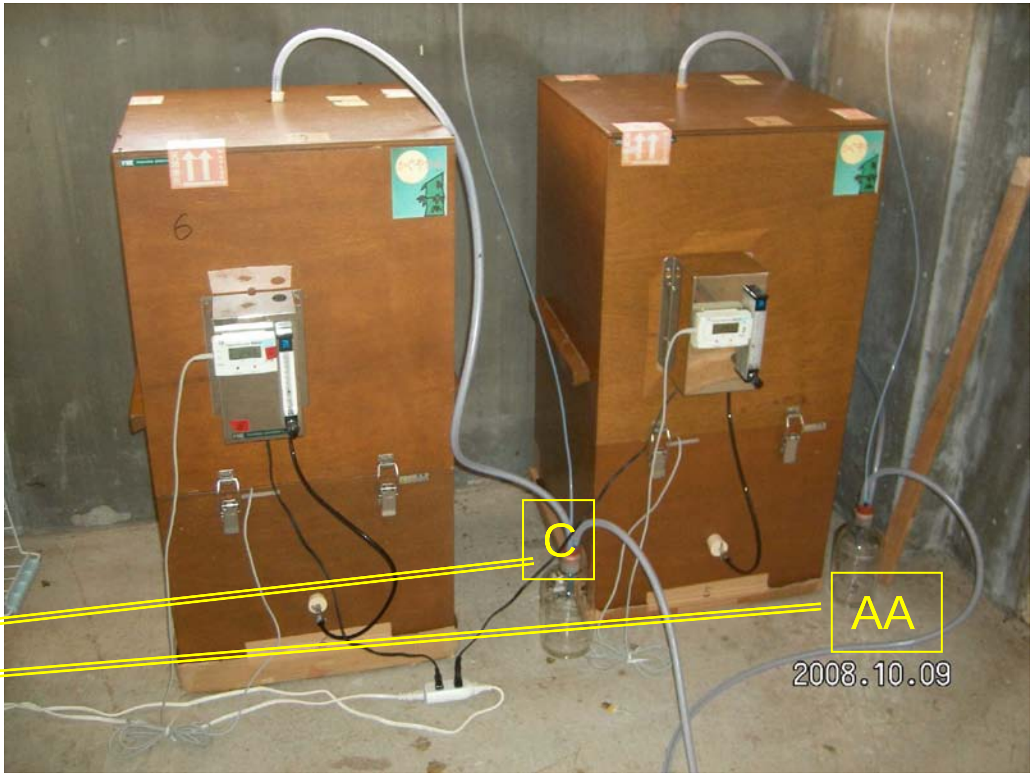



濃度差と排気流量の積が発生量

( AA － BG ) ＊ (0.6L/min＊60) ＝

( C － BG ) ＊ (0.6L/min＊60) ＝



# 堆肥化試験（操作と期間）

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小型試験装置を用いて5週間の試験期間

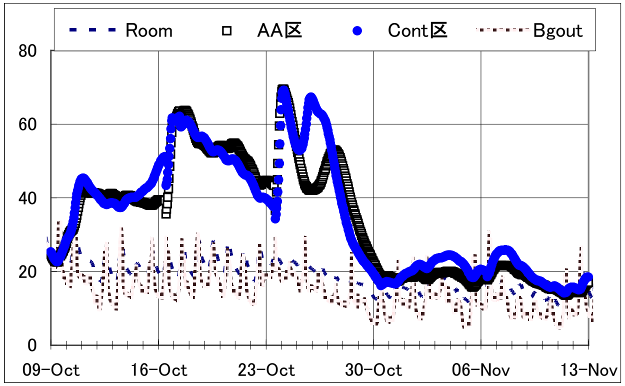
概ね、5kgのふん尿・資材混合物を堆肥化。有機物1500g、窒素は70g程度が含有

堆肥化装置下部からの定量通気（0.6L/min）を行い、週に1度の詰め替え（切返し）を行い好気的な堆肥化を進行

切返し直後の温度上昇、充填物BODを指標に堆肥化終了

（GHGの発生が、5週間後には顕著でないことも確認済み）

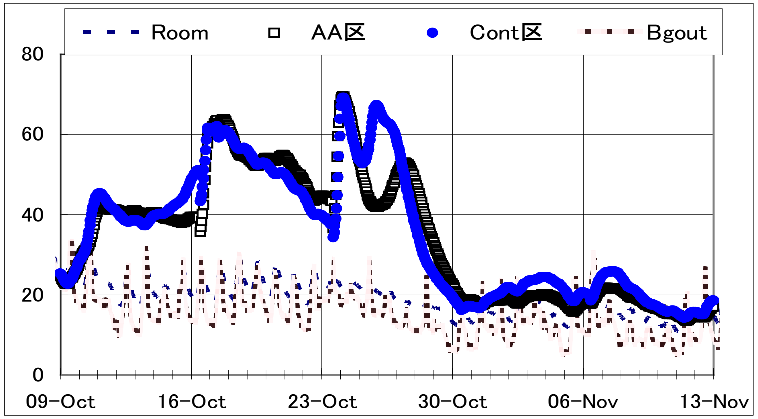

小型堆肥化試験装置

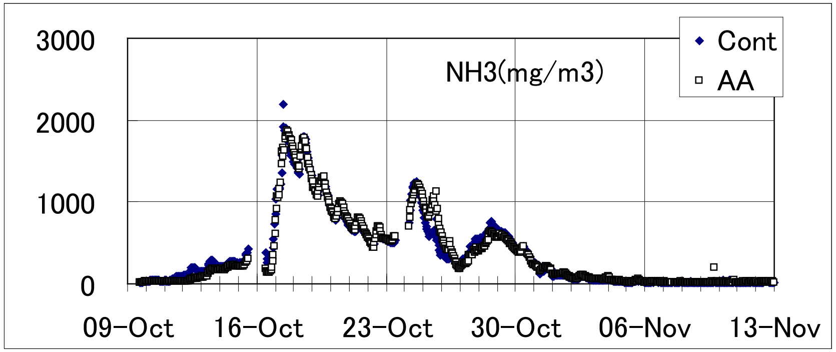


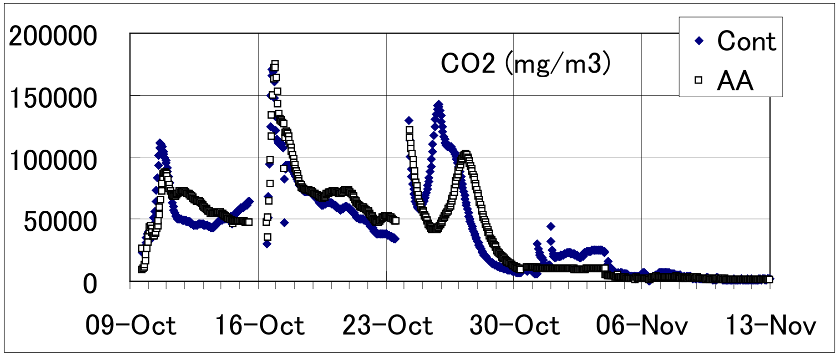

堆肥化試験中の温度変化の事例

# Results on composting, NH3 etc






初回秋季試験　基礎データ（差異は認めず）

堆肥の品温上昇は緩慢で、2週目の切り返し後に最高温度に達した。両試験区で大きな差異はない。3週目の切り返し以降品温上昇は顕著で無く、5週目で堆肥化を終了。

本試験から得られたデータから期間中総発生量を算定すると、アンモニアの排出は凝縮水を含めて、AA区 10.4 g、Cont区 8.57gであり、発生係数は15.7%,15.9%（gNH3-N/g充填物窒素）と差異がなかった。

- ▸Feeding a diet with 14.1% CP in which bypass soymeal was substituted for soymeal reduced nitrogen excretion from mid-lactation cows by approximately 10%.
- ▸Supplementation of diets with methionine to early-lactation cows increased milk production and milk protein content significantly for low-protein diet, and feeding a low-protein diet had a lower nitrogen excretion.