The use of modeling in poultry production: From broiler growth to the production system…




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INTRODUCTION

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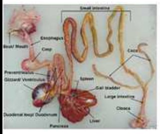
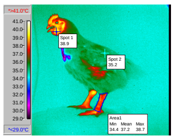
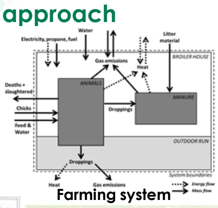
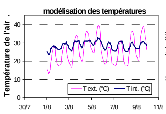
The complexity of knowledge due to multiple levels of approach

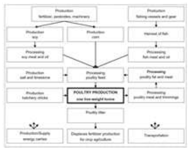

Organs


Animal


Farming system



Housing


Production system


Territory, world

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Why use modeling?

Problem(s) & knowledge

Formalization

MODEL

Exploration of scénarios | *Conception of new systems*

Analysis of results

Take decisions

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MODELING IN POULTRY: MULTIPLE LEVELS OF APPROACH

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Multiple levels of approach

- **Animal scale: modeling of broiler growth**
- Farming system scale: energy and nutrient fluxes in a broiler farming system

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INAVI: Towards a practical tool to simulate broiler growth

Maxime QUENTIN (PhD student),
Michel PICARD (INRA), Isabelle BOUVAREL (ITAVI),
Philippe LESCOAT (INRA)

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INTRODUCTION

Why should we simulate broiler growth ?

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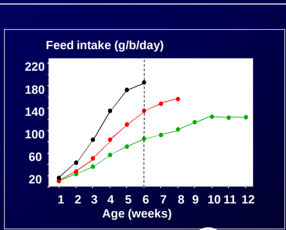
Introduction

Farms



Genotypes

Diversity

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Introduction

INRA, 1984; NRC 1994 etc.

Nutritional recommendations …

- Quite old
- Difficult to update

Classical experiments : limited, high workload…

« Complexity » leads to systemic modelling

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Introduction

Why is a new model proposed ?

- Training
- Easy updating
- Accessibility to users
- Users are actors

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Part I.

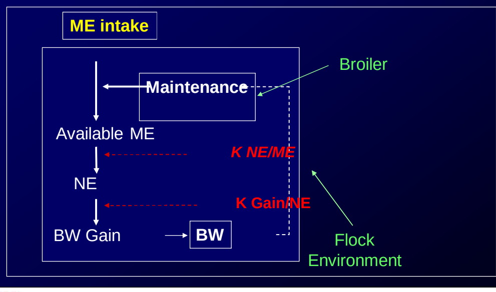
Building of INAVI

Main Characteristics

1. Mecanistic / Dynamic / Deterministic
2. Time step : hour
3. Feed intake as major input/output
4. « Simplification »
5. Users-Friendly

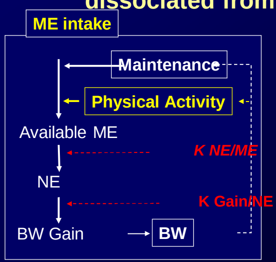
The system !

INAVI 1.0 : Energy as food source



INAVI 1.1 : Physical Activity

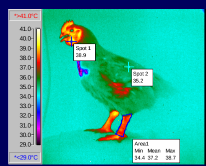
Why physical activity should be dissociated from maintenance ?



- Behaviour
  = group or genotype
- Free ranging
  = production system
- Pellet size
  (Savory, 1978)

Building of INAVI

« Fast growing broilers are always hungry and hyperthermic»



(Yahav et al., 2001)

Thermal homeostasia :

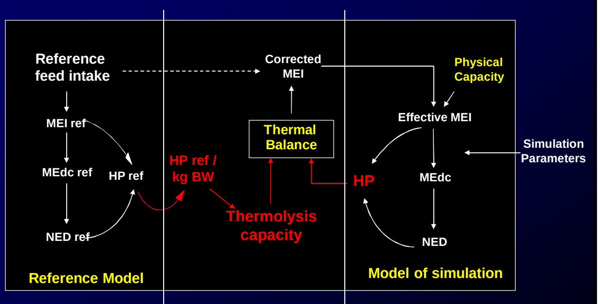
Thermolysis ⇄ Thermogenesis

Feed intake adjustment to a reference capacity of thermolysis..

….The thermostat

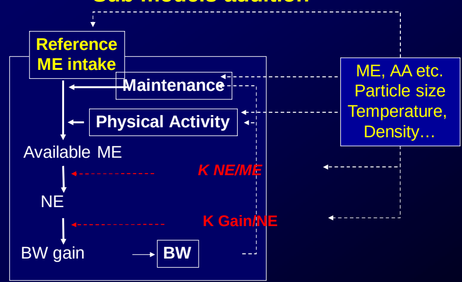
Building of INAVI

The « thermostat »…



Building of INAVI

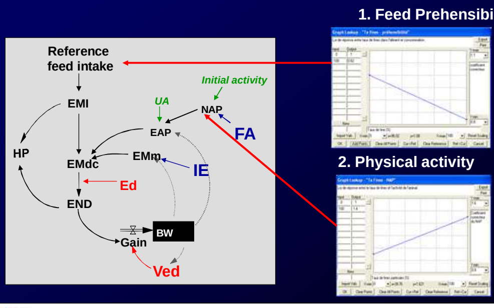
Sub models addition



Building of INAVI

Building and Accessibility to users

Incorporating results in a sub-model



Part II.

Utilization of the software INAVI

Front Page

With Excel

Inclusion of reference data, of calibration simulation ones

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1. Définir une situation de référence

Ross PM3

Age départ	21	Activité Physique initiale (%)	30
Age Fin	42		

Données de référence Quotidienne

Age	Poids Vif (g)	Consommation (g)	Gain de poids (g)	Indice de consommation
7	138	25	24	1,042
14	388	58	44	1,318
21	767	95	61	1,557
28	1274	136	79	1,722
35	1868	166	88	1,886
42	2502	195	91	2,143
49	3131	215	88	2,443
56	3731	226	83	2,723

Caractéristique calculée de l'Aliment

Age (j)	Age (h)	EMA (kcal / kg)	Tx Protéique (%)	Niveau du limitant	Taux de particules fines (%)
1	24	3010	22,00	1	0
2	48	3010	22,00	1	0
3	72	3010	22,00	1	0
4	96	3010	22,00	1	0
5	120	3010	22,00	1	0
6	144	3010	22,00	1	0
7	168	3010	22,00	1	0
8	192	3010	22,00	1	0
9	216	3010	22,00	1	0
10	240	3010	22,00	1	0
11	264	3175	21,00	1	0
12	288	3175	21,00	1	0
13	312	3175	21,00	1	0
14	336	3175	21,00	1	0
15	360	3175	21,00	1	0
16	384	3175	21,00	1	0
17	408	3175	21,00	1	0
18	432	3175	21,00	1	0
19	456	3175	21,00	1	0
20	480	3175	21,00	1	0
21	504	3175	21,00	1	0
22	528	3175	21,00	1	0
23	552	3175	21,00	1	0
24	576	3175	21,00	1	0
25	600	3175	21,00	1	0
26	624	3175	21,00	1	0
27	648	3175	21,00	1	0
28	672	3175	21,00	1	0

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2. Calibration du modèle

Calibration step deals with fitting the model and a reference dataset

Niveau d'entretien	64,00
Facteur d'activité physique	0.23

3. Simulation

Caractéristique calculée de l'Aliment					
Age (j)	Age (h)	EMA (kcal / kg)	Tx Protéique (%)	Niveau du limitant	Taux de particules fines (%)
1	24	3010	22,00	1	0
2	48	3010	22,00	1	0
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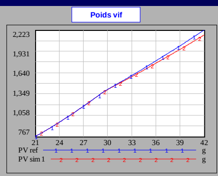
21	504	3175	21,00	1	0
22	528	3175	21,00	1	0
23	552	3175	21,00	1	0
24	576	3175	21,00	1	0
25	600	3175	21,00	1	0
26	624	3175	21,00	1	0
27	648	3175	21,00	1	0
28	672	3175	21,00	1	0
29	696	3225	20,00	1	0
30	720	3225	20,00	1	100
31	744	3225	20,00	1	100
32	768	3225	20,00	1	100
33	792	3225	20,00	1	100

Environnement d'élevage						
Age (j)	Age (h)	Lumière (h)	Température (°C)	Hygrométrie (%)	Ventilation (m.s-1)	Densité (poulet/m²)
1	24	24	32	60	0,00	5
2	48	24	32	60	0,00	5
3	72	24	31	60	0,00	5
4	96	24	31	60	0,00	5
5	120	24	30	60	0,00	5
6	144	24	30	60	0,00	5
7	168	24	29	60	0,00	5
8	192	24	29	60	0,00	5
9	216	24	28	60	0,00	5
10	240	24	28	60	0,00	5
11	264	24	27	60	0,00	5
12	288	24	27	60	0,00	5
13	312	24	26	60	0,00	5
14	336	24	26	60	0,00	5
15	360	24	26	60	0,00	5
16	384	24	26	60	0,00	5
17	408	24	25	60	0,00	5
18	432	24	25	60	0,00	5
19	456	24	25	60	0,00	5
20	480	24	25	60	0,00	5
21	504	24	24	60	0,00	5
22	528	24	24	60	0,00	5
23	552	24	24	60	0,00	5
24	576	24	24	60	0,00	5
25	600	24	23	60	0,00	5
26	624	24	23	60	0,00	5
27	648	24	23	60	0,00	5

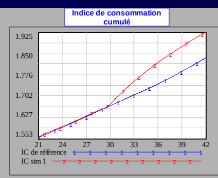
Simulation

Transition from a pelleted diet to meal from 30 days of age

Poids vif



Indice de consommation cumulé



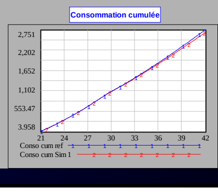
Paramètres environnementaux

Température
Cycle Température
Hygrométrie
Vitesse d'air
Densité
Durée éclairement

Paramètres nutritionnels

Teneur en EM
Niveau en AAE
Taux protéique
Fines

Consommation cumulée

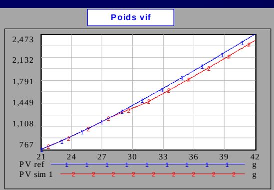


Retour Accueil
Retour simulation chiffrée

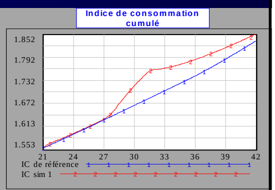
Simulation

Heat stress (increase of 23 to 30° from 28 to 31 days of age)

Poids vif



Indice de consommation cumulé



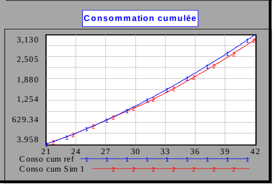
Paramètres environnementaux

Température
Cycle Température
Hygrométrie
Vitesse d'air
Densité
Durée éclairement

Paramètres nutritionnels

Teneur en EM
Niveau en AAE
Taux protéique
Fines

Consommation cumulée



Retour Accueil
Retour simulation chiffrée

Discussion

Users are essential

Vs

Leaping chicken

Research
(try to explain)

Field
(actual facts)

Conclusions

Conclusions

INAVI brings :

- Calibration to various reference data sets,
- Ideas to quantify :
  - Thermostat and Temperature,
  - Physical activity and Maintenance ,
  - Dynamic validation
- A research question about a complex parameter (K EN/EM) identified from a simplified model,
- Adaptability of its lookups = Communication between production and research

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Perspectives: INAVI 2.0

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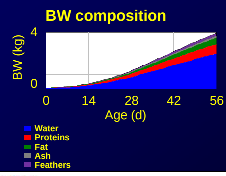
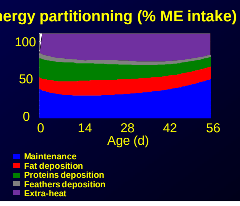
Prediction of body composition

Body Weight Composition:

- Proteins
- Fat
- Water
- Ash
- Feathers

Allometric equations based on experimental data provided by UNESP (Jabiticabal) (Ross 308/Cobb500, Male/Female)





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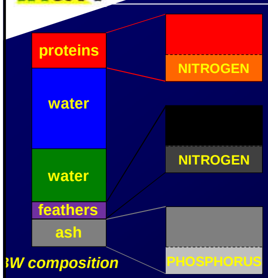
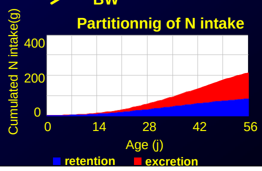
Prediction of excretion of N & P



Genetics
Diet(s) | Breeding environment
↓
Intake
↓
Body retention
↑
BW



Mass balance approach:
Excretion = Intake - Retention

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Multiple levels of approach

- Animal scale: modeling of broiler growth
- **Farming system scale: energy and nutrient fluxes in a broiler farming system**

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MOLDAVI: A model to predict environmental and economic performances of broiler farming systems




B. Meda[1], P. Robin[2], C. Aubert[3], J.-Y. Dourmad[4], M. Hassouna[2]

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Context

- **Poultry production ⇒ negative impacts on environnement (climate change, eutrophication…) (FAO, 2006)**
- **Towards more sustainable farming systems:**
  - *Decrease negative environmental impacts*
  - *Improve/maintain economical performances*
- **⇒ modelling is a relevant approach:**
  - *lower cost compared to experimental approaches*
  - *speed of study (simulations vs. experiments)*

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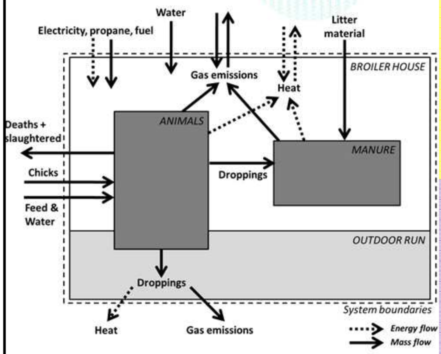
Objectives

- **Develop a model to study the environmental & economical performances of broiler farming systems:**
  - *Dynamic approach (over one batch)*
  - *Environmental fluxes: C, N, P, K, Cu, Zn, water, energy*
  - *Economical performances (profits-costs)*

Model overview



Model inputs
- *Flock management practices*
- *Manure management practices*
- *Farmer objectives*
- *Outdoor climatic conditions*
- *Housing characteristics*
- *Economical data*

Model outputs
- *Animal performances*
- *Energy & water use*
- *Indoor climatic conditions & regulation parameters*
- *Economical performances*
- *Manure characteristics*
- *Gaseous emissions*

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Model construction (1)

- **Biotechnical sub-models ⇒ Integration of available knowledge (literature + expertise) at each scale:**
  - **Animal:** growth, feed intake, mortality, heat production ⇒ **use of INAVI**
  - **Housing:** heating, ventilation, indoor climatic conditions
  - **Manure:** gaseous losses, manure characteristics
  - **(Outdoor run:** outdoor excretion, gaseous losses**)**

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Model construction (2)

Manure composition :

Bedding material (straw) + Excretion – GasEmissions

with $GasEmission = Excretion \times EmissionFactor \times \prod_{i=1}^{n} (VariationFactors_i)$

Excretion = Ingestion - Retention

EmissionFactor, specific for each gas (NH_3, N_2O, CH_4, CO_2)

VariationFactors: litter moisture, litter treatment…

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Model construction (3)

- **Economical performances based on economical references given as models inputs:**
  - **Profits:** *€/kg broiler produced*
  - **Costs:** *€/kg feed, €/chick, energy (€/kg propane), €/L water*

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Model validation (1)

- **External/internal validations for each sub-model :**
  - *simulations vs. literature*
  - *simulations vs. expertise*
- **Full validation of the model: very difficult because it requires a full dataset (i.e. animals, manure, housing data):**
  - *Experimental work (France)*
  - *Broilers, 56 days, 1163m², 18.5 broilers/m²*
  - ***Measurements:*** *gaseous emissions, manure characteristics, indoor climate, animal performances…*

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Model validation (2)

	Measurements	Simulation	Error (S-M)/M
ANIMAL PERFORMANCES			
Weight at slaughter (kg)	2.16	2.18	1%
Feed consumption (kg)	103620	104055	<1%
Feed Conversion Ratio (kg feed/kg LW)	2.31	2.31	<1%
Water consumption (kg)	181671	182096	<1%
GASEOUS EMISSIONS (kg)			
N total losses	771	591	-23%
NH_3	334	440	32%
N_2O	27	24	-11%
CH_4	0	139	*n.a.*
MANURE AMOUNT (kg)	43860	45595	4%
MANURE COMPOSITION			
Dry Matter (%)	54	56	4%
N (g/kg)	17.1	20.3	19%
P (g/kg)	5.3	7.0	32%
K (g/kg)	14.9	16.0	7%

Effect of feed crude protein content on environmental & economical performances (1)

- ↘ crude protein (CP) content ⇒ ↘ N intake
  ⇒ ↘ N excretion
  ⇒ ↘ N gaseous losses
  ⇒ quantify this decrease & impact on economical performances (broiler growth, feed intake)?

3 scenarios

- **Reference scenario:** *CP content of feed according to breeders recommendations (Ross PM3)*
- **Environmental friendly 1 scenario:** *CP content reduced by 10 g/kg feed compared to breeders recommendations*
- **Environmental friendly 2 scenario:** *CP content reduced by 20 g/kg feed compared to breeders recommendations*

Effect of feed crude protein content on environmental & economical performances (2)

Scenario	Reference	Environmental friendly 1	Environmental friendly 2
Economical performances			
Live weight at slaughter (LW) (kg)	1.99	1.89	1.81
Feed Conversion Ratio (kg feed/kg LW)	1.79	1.79	1.79
Mortality rate (%)	4%	4%	4%
Total feed consumption (t)	67.0	63.6	60.8
Total margin (€)*	8 623	7 858	7 246
Environmental performances			
NH_3 emissions (g/kg LW)	8.18	7.67	7.04
N_2O emissions (g/kg LW)	0.50	0.46	0.43
CH_4 emissions (g/kg LW)	1.61	1.65	1.67
Water use (L/kg LW)	3.4	3.5	3.5
Propane use (kg/kg LW)	111	117	122

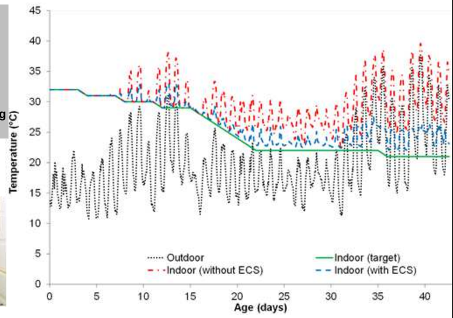
**Broilers sale minus feed and chicks costs*

Effect of an heat wave on environmental & economical performances (1)

Simulations:
- Ross PM3 broilers
- 2kg at 42d
- 20 broilers/m²

2 houses equipped or not with an Evaporative Cooling System

Evaporative Cooling System: water misting in the broiler house



Effect of an heat wave on environmental & economical performances (1)

Scenario	Expected performances	Heat wave without an ECS	Heat wave with an ECS
Economical performances			
Live weight at slaughter (LW) (kg)	1.99	1.56	1.86
Feed Conversion Ratio (kg feed/kg LW)	1.79	2.36	1.79
Mortality rate (%)	4%	35%	4%
Total feed consumption (t)	67.0	46.6	62.7
Total margin (€)*	8 623	-1 818	7 655
Environmental performances			
NH_3 emissions (g/kg LW)	8.18	10.89	8.21
N_2O emissions (g/kg LW)	0.50	0.62	0.50
CH_4 emissions (g/kg LW)	1.61	2.15	1.62
Water use (L/kg LW)	3.4	4.5	6.1
Propane use (kg/kg LW)	17	32	18

**Broilers sale minus feed and chicks costs*

Conclusions

- **MOLDAVI, a model:**
  - *innovative*
  - *generic (turkey, duck)*
- **Systems assessment / Innovative systems design:**
  - *combined approach: environment + economy*
  - *practices combination (synergy/compensation effects?)*

Prospects

- Improvement required (ex: mitigation of gaseous emissions by practices)
- Full validation only done for 1 system ⇒ Data are still needed!
- Integration of MOLDAVI in farm scale models (crops + livestock) for global assessment of environmental & economical performances

GENERAL CONCLUSIONS

Conclusions

- Several levels of approach are needed to evaluate the potential consequences of new breeding strategies
- Need for multicriteria approaches (economy, environment, social)

⇒ Design of new and more sustainable production systems

Obrigado!

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