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In this document, you will find a copy of our presentation, followed by a list of references and some complementary tables and figures, referred to in our comments (column on the right) when necessary.

Understanding the reproductive performance of a dairy cattle herd by using both analytical and systemic approaches

A case study based on a system experiment

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__Introduction__ | *Dispositive* | *Methods* | *Results* | *Discussion* | *Conclusion*

Decline in reproductive performance > **Nutrition** is one explaining factor > **Energy balance** in particular

- To what extent does **analytical research** help to find new **practices** to solve biotechnical problems encountered on farms?
- What kind of conclusions can be reached by using **systemic approaches at the farm scale** as far as **biotechnical problems** are concerned?
- **How can analytical and systemic approaches be mixed** so as to gain a better understanding and solve some biotechnical problems, such as impaired reproductive performance?

➡ **A case-study based on a system-experiment to discuss these 3 methodological questions**

- Reasons for decline in reproductive performance worldwide are numerous and complex and they involve both genetics of the cow, nutrition, health and management factors. Considering nutrition in particular, energy balance is of great interest when economical livestock farming systems need to be designed.
- By analytical research we mean research strictly based on quantitative and animal-related data, mainly using statistics.
- By systemic approaches we mean paying a particular attention to interactions between subsystems ans especially to the farmer and his objectives.
- The system experiment considered is in the INRA experimental Research Unit of Mirecourt (Sad-Aster), in North Eastern France (Coquil *et al.*, 2007).

The system experiment of Mirecourt

- Two complementary organic dairy systems
- Guiding principles : environmental friendliness, economy, self-sufficiency
- 2 breeds: Montbéliarde and Holstein

A grazing system (GS)

37 cows + replacement heifers

78 ha of permanent grassland

A mixed crop-dairy system (MCDS)

60 cows + replacement heifers

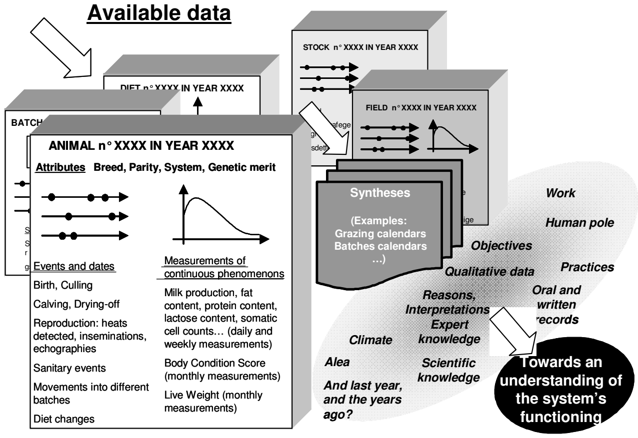
150 ha of permanent grassland and cultivated area

Reproductive problems in 2005 and 2006

=> Reproductive success of 33% for the 2006 breeding season of the GS

- A system experiment is an experiment which is run at the production system scale, and which is guided in its functioning by a specific corpus of general objectives (Chabosseau and Dedieu, 1994).
- For quantifying the reproductive problems, see table 1.

Available data



1. An analytical study for both the GS and the MCDS

Two years studied: 2005 and 2006

Univariate logistic regression procedures

REPRODUCTIVE PERFORMANCE

6 independent variables, binary data
- Delay between date of calving and first detected heat
- Regularity of first heats
- Success to AI1
- Success to AI2
- Final result
- Number of AI

ENERGY BALANCE

29 dependent variables, based on values and evolution of:
- Body Condition Score
- Body Weight
- Raw milk yield
- Protein content
- Fat content
- Lactose content

8 adjustment variables

Breed, System, Year, Parity, GenMilk, GenProt, GenFat, UroGen

For a description of the different variables, see tables 2, 3 and 4.

Introduction | Dispositive | **Methods** | Results | Discussion | Conclusion

1. **An analytical study for both the GS and the MCDS**

2. **A systemic study to consider the reproductive performance of the GS as a result of the consistencies of a whole system**

⇨ Formalising the decision makers' **general objectives** for the functioning of their system… as planned in 2004

⇨ Building a **graphical representation of the strategic pattern** from 2004 to 2007… based on the batches of animals

⇨ **Clustering cows** in a relevant way to understand their reproductive performance

3. **Combining both analytical and systemic studies**

A systemic methodology inspired by:

Cournut, 2001; Gibon *et al.,* 1999; Girard, 1995; Ingrand, 2000; Landais, 1987; Sebillotte and Soler, 1990; Tichit *et al*., 2004.

Introduction | Dispositive | Methods | **Results** | Discussion | Conclusion

1. **Analytical study, main results**

Consistent with literature

- **Some early indicators of energy balance could be prognostic tools of reproductive performance?**
  - **Lac1** is associated with the recovery of post-partum cyclicity (*P*<0,01)
  - **Fat1** is associated with the final result of the breeding season (*P*<0.05)
- **BCS and Body Weight change are well associated with reproductive performance**
  - **MinBCS** is associated with the total number of inseminations (*P*<0.01)
  - **DifBW** is associated with the final result of the breeding season (*P*<0.05)
- **Results concerning raw milk production are promising**

  Numerous links with reproductive performance, involving both:

  Milk1, **DifMilk1**, **vMilk** and **Milk20wAfP**

Studying the kinetics of lactation?

- See table 5 for an exhaustive list of the significant results.
- See tables 2 and 3 for the description of the different variables.
- Main references: Buckley et al., 2003; Butler, 2003; Coulon and Pérochon, 2000; Disenhaus et al., 2002; Freret et al., 2005; Garcia and Holmes, 2001; Jorritsma et al., 2003; Martin and Sauvant, 2002; McDougall, 2006; Roguet and Faverdin, 1999.
- Our analytical study did not suggest any precise explanation for the impaired reproductive performance. And it did not suggest any way of improving the situation. But it clearly showed that reproductive performance in the GS and in the MCDS was effectively linked to energy balance, and it suggested that lactation kinetics be analyzed.

Introduction | Dispositive | Methods | **Results** | Discussion | Conclusion

1. **Analytical study, main results**

2. **Systemic approach, main results**

a. Formalising the objectives led us to understand that:

- There is **a concentrated calving pattern** between February and April, for economical reasons.
- **Turnout occurs as early as possible** in the year so as to maximise grazing (late March- early April).

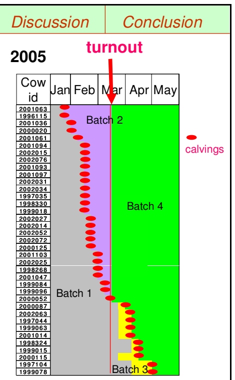
b. The batches calendar showed us that **some cows calved before turnout date, whereas others calved after**

⇒ Different successions of batches

⇒ Different feeding conditions

⇒ Different evolutions of energy balance?

⇒ Impact on reproductive performance?



Taking date of calving into account to cluster the cows?

- There must be a concentrated calving pattern between February and April so as to make the beginnings of lactation and their high feed requirements meet the grass growth period.
- Turnout must occur as early as possible in the year, as soon as there is no risk of soil compaction, which usually occurs aroud late March or early April.

1. **Analytical study, main results**
2. **Systemic approach, main results**

c. **Clustering the cows**

Factor	Modalities			
Month of calving	February	March	April	May
Year	2005	2006		
Breed	Holstein	Montbéliarde		
Parity	Primiparous	Multiparous		

32 groups of cows

Comparing reproductive performance between the 32 groups

1. In 2005, cows which calved in February had better reproductive performance than cows which calved in April or in May.
2. Reproductive performance in 2005 was better than in 2006.
3. Montbéliarde cows tended to have better performance than Holstein cows.

For an exhaustive list of reproductive performance within each group, see table 6.

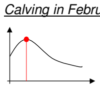
1. **Analytical study, main results**
2. **Systemic approach, main results**
3. **Combining analytical and systemic approaches**

- The statistical analysis suggested to study the kinetics of lactation
- The systemic analysis identified 3 kinds of contrasted reactions of cows

➡ Comparing the shapes of the lactation curves in the three situations identified by the systemic approach

Example: the comparison Calving in February 2005 vs. Calving in April 2005

Calving in February 2005, before turnout

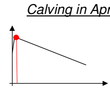


Beginning of the declining phase between w8 and w12 of lactation

Good reproductive performance

Success rate = 82% (n=17)

Calving in April 2005, after turnout



Beginning of the declining phase between w2 and w4 of lactation

Poor reproductive performance

Success rate = 33% (n=10)

Hypothesis: Ingested grass in April quickly stimulated milk production ➡ a greater metabolic load, poor persistency ➡ poor reproductive performance

- For observing the real lactation curves, see figure 1.
- For the two following situations of contrasted reactions (1. 2005/2006; 2. Montbéliarde/Holstein), see figures 2 and 3.

Analytical analysis (logistic regression procedures)

Suggestion to analyse the shapes of the lactation curves

In our system experiment, reproductive performance is linked to energy balance

Systemic analysis (characterizing the decision makers' objectives and their feeding practices)

3 types of contrasted reactions of cows with regards to reproductive performance

3 conclusions for the GS

(i) Cows which calve before turnout date have better reproductive performance than cows which calve after.

(ii) Feeding conditions that enhance milk production at turnout are linked to poor reproductive performance.

(iii) Montbéliarde lactation curves are smoother than Holstein cows' and Montbéliarde reproductive performance is better.

Practical interest: a suggestion to improve the situation:
In 2007, breeding period one month earlier in the year

Having the breeding season one month earlier in the year in 2007 was aimed at maximising the number of cows which would calve before turnout date in 2008.

- **Analytical research** is **far** from the **livestock practices**…
- **Systemic approaches** are **far** from the **biological phenomena**…

Mixing analytical and systemic approaches makes it possible to:

(i) Gain a better understanding of biotechnical problems

(ii) Suggest ways of improvement

Transposing this approach to commercial farms?

Difficulties:

formalising the objectives, time-consuming, no systematic methodology…

Nevertheless…

In a context made up of rapid change and uncertainty…

… we find it of crucial importance **to build innovative research methodologies that make scientific knowledge meet practical action at the farm level**

Thank you for your attention

And thanks to the organising committee

And to the entire staff of the INRA experimental Research Unit of Mirecourt (Sad-Aster)

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Table 1

Reproductive performance of dairy cows during the first two years of running of both the GS and the MCDS

	GS 2005			GS 2006			MCDS 2004-2005			MCDS 2005-2006		
	GS	HN	MO	GS	HN	MO	MCDS	HN	MO	MCDS	HN	MO
Fertility rate AI1 and AI2 (%)	51	38	69	20	8	28	56	48	63	56	52	60
Fertility rate (%)	62	52	75	33	33	33	69	66	71	83	76	89

Some complementary tables and figures

Table 2

Dependent variables for the logistic regression procedures (1/2)

First quartile, median and third quartile

BCS1	Body Condition Score during first week of lactation	2	2.5	3
MinBCS	Minimum value of Body Condition Score during lactation	1.5	1.5	2
DifBCS	**BCS1-MinBCS**	0.5	1	1
BW1	Body Weight during first week of lactation (kg)	600	650	700
MinBW	Minimum value of Body Weight during lactation (kg)	550	600	650
DifBW	**BW1-MinBW** (kg)	20	40	75
Fat1	Geometric mean of first three measures of fat content (g/kg)	40	45	50
MinFat	Minimum value of fat content during lactation, when considering five-week moving average (geometric means) (g/kg)	34	36	40
wMinFat	Week of lactation during which MinFat was observed	8	15	24
Prot1	Geometric mean of first three measures of protein content (g/kg)	33	35	36
MinProt	Minimum value of protein content during lactation, when considering five-week moving average (geometric means) (g/kg)	28	29	30
wMinProt	Week of lactation during which MinProt was observed	6	8	12
Lac1	Geometric mean of first three measures of lactose content (g/kg)	46	47	48
MaxLac	Maximum value of lactose content during lactation, when considering five-week moving average (geometric means) (g/kg)	48	50	52
wMaxLac	Week of lactation during which **MaxLac** was observed	7	13	26
MinProtFat	Minimum value of Protein/Fat ratio among first three measured ratios	0.6	0.7	0.8
Milk1	Mean of raw milk production during days 4, 5 and 6 of lactation (kg)	15	20	25
MaxMilk	Maximum value of raw milk production, when considering five-week moving average (kg)	22	26	30
wMaxMilk	Lactation week during which **MaxMilk** was observed	4	5	8
Milk20wAfP	Raw milk production 20 weeks after **wMaxMilk** (kg)	15	17	19

NB: Quartiles have been rounded.

Some complementary tables and figures

Table 2

Dependent variables for the logistic regression procedures (2/2)

First quartile, median and third quartile

DifFat	**Fat1-MinFat**	5	9	13
DifProt	**Prot1-MinProt**	4	6	8
DifLac	**MaxLac-Lac1**	1.5	2.5	4
DifMilk1	**MaxMilk-Milk1**	3	6	8
DifMilk2	**MaxMilk-Milk20wAfP**	6	10	12
vFat	**DifFat/wMinFat**	0.3	0.6	1
vProt	**DifProt/wMinProt**	0.5	0.7	1
vLac	**DifLac/wMaxLac**	0.1	0.2	0.3
vMilk	**DifMilk1/wMaxMilk**	0.5	1	1.5

NB: Quartiles have been rounded.

Table 3

Independent variables used for the logistic regression procedures

DEL	Delay between date of calving (Cal) and date of first detected oestrus (Heat1)	**DEL** = 'short' if Heat1 - Cal ≤ 50 **DEL** = 'long' if Heat1 – Cal > 50
HEA	Regularity of first observed heats before first artificial insemination *This variable only concerns cows which were not inseminated on first observed heat after calving*	**HEA** = 'reg' if all intervals between first observed heats are between 19 and 25 days or between 36 and 48 days Else: **HEA** = 'irreg'
AI1	Success to first artificial insemination	**AI1** = 'ret' if **AI1** was followed by an observed heat Else: **AI1** = 'no_ret'
AI2	Success to second artificial insemination, when practiced *This variable only concerns cows which were inseminated twice or more*	**AI2** = 'ret' if **AI2** was followed by an observed heat Else: **AI2** = 'no_ret'
SUC	Success to last practiced artificial insemination	**SUC** = 1 if last practiced ultrasound scan was positive Else: **SUC** = 0
nAI	Total number of artificial inseminations during the breeding season	**nAI** = 'few' if less than 3 AI Else: **nAI** = 'many'

Some complementary tables and figures

Table 4

Adjustment variables used for the logistic regressions procedures

Breed	Binary	'HN' if Holstein; 'MO' if Montbéliarde
System	Binary	'GS' or 'MCDS'
Year	Binary	**Year**=1 if first year of running (GS 2005 or MCDS 2004-2005) **Year**=2 if second year of running (GS 2006 or MCDS 2005-2006)
Parity	Binary	'P' if primiparous; 'M' if multiparous
GenMilk	Quantitative	Genetic merit for milk yield **GenMilk**=0.5*(sire's index)+0.25*(maternal grand sire's index) First quartile: -200; Median: 0; Third quartile: 100
GenProt	Quantitative	Genetic merit for protein content **GenProt**=0.5*(sire's index)+0.25*(maternal grand sire's index) First quartile: 0; Median: 6; Third quartile: 10
GenFat	Quantitative	Genetic merit for fat content **GenFat**=0.5*(sire's index)+0.25*(maternal grand sire's index) First quartile: 0; Median: 5; Third quartile: 15
UroGen	Binary	**UroGen**=1 if urogenital health disorders were observed; else: **UroGen**=0

NB: Quartiles have been rounded.

Some complementary tables and figures

Table 5

Significant results of the logistic regression procedures (1/2)

Independent variable	Dependent variable	Modalities	Adjusted odd-ratio [CI 95 %]	Adjustment variables
DEL (delayed recovery of cyclicity)	**Lac1**	< 46 [46 – 47[[47 – 48[≥ 48	1 0.691 [0.262 – 1.821] 0.423 [0.177 – 1.012] 0.316 [0.139 – 0.719]**	**GenFat, GenProt**
	Milk1	< 15 [15 – 20[[20 – 25[≥ 25	1 1.505 [0.568 – 3.985] 0.933 [0.347 – 2.505] 4.403 [1.479 – 13.104]**	**Breed, Parity, GenFat, GenProt**
	Milk20wAfP	< 15 [15 – 17[[17 – 19[≥ 19	1 1.636 [0.634 – 4.221] 0.771 [0.311 – 1.912] 2.909 [1.077 – 7.855]*	**Breed, Parity, System**
AI1 (heat observed after AI1)	**Milk1**	< 15 [15 – 20[[20 – 25[≥ 25	1 1.319 [0.529 – 3.291] 2.485 [1.012 – 6.105]* 2.469 [0.942 – 6.469]	**Year, Parity**
	vMilk	< 0.5 [0.5 – 1.0[[1.0 – 1.5[≥ 1.5	1 0.657 [0.266 – 1.622] 0.672 [0.251 – 1.797] 0.366 [0.140 – 0.958]*	**UroGen**
nAI (more than 2 artificial inseminations)	**MinBCS**	< 1.5 [1.5 – 2.0[≥ 2.5	1 0.696 [0.331 – 1.464] 0.276 [0.119 – 0.639]**	**UroGen**
	DifBW	< 20 [20 – 40[[40 – 75[≥ 75	1 2.205 [0.828 – 5.872] 2.947 [1.115 – 7.788]* 2.593 [0.968 – 6.818]	**Year, UroGen**

Table 5

Significant results of the logistic regression procedures (2/2)

Independent variable	Dependent variable	Modalities	Adjusted odd-ratio [CI 95 %]	Adjustment variables
SUC (last AI was successful)	**BW1**	< 600 [600 – 650[[650 – 700[≥ 700	1 0.828 [0.248 – 2.770] 0.420 [0.135 – 1.303] 0.145 [0.045 – 0.466]**	**Parity, GenMilk, GenProt, GenFat**
	MinBW	< 550 [550 – 600[[600 – 650[≥ 650	1 0.573 [0.181 – 1.819] 0.330 [0.098 – 1.114] 0.283 [0.083 – 0.967]*	**Parity, GenMilk, GenProt, GenFat, UroGen**
	DifBW	< 20 [20 – 40[[40 – 75[≥ 75	1 0.700 [0.269 – 1.818] 0.734 [0.280 – 1.926] 0.379 [0.151 – 0.950]*	**System, UroGen**
	Fat1	< 40 [40 – 45[[45 – 50[≥ 50	1 1.010 [0.362 – 2.817] 0.445 [0.168 – 1.180] 0.391 [0.157 – 0.971]*	**Parity**
	wMaxLac	< 7 [7 – 13[[13 – 26[≥ 26	1 1.734 [0.684 – 4.395] 1.479 [0.614 – 3.563] 6.735 [1.879 – 24.148]**	**System, GenMilk, GenProt, GenFat**
	DiffFat	< 5 [5 – 9[[9 – 13[≥ 13	1 0.405 [0.149 – 1.101] 0.536 [0.184 – 1.565] 0.310 [0.108 – 0.893]*	**Parity, GenMilk, GenProt, GenFat, UroGen**

Some complementary tables and figures

Table 6

Reproductive performance of GS dairy cows according to year, date of calving, parity and breed (1/2)

Year	Calving month	Parity	Breed	Number of cows	Number of pregnant cows	Success rate
2005	February	Primiparous	Holstein	8	7	88 %
2005	February	Primiparous	Montbéliarde	4	4	100 %
2005	February	Multiparous	Holstein	1	0	0 %
2005	February	Multiparous	Montbéliarde	4	3	75 %
2005	March	Primiparous	Holstein	2	2	100 %
2005	March	Primiparous	Montbéliarde	2	1	50 %
2005	March	Multiparous	Holstein	3	0	0 %
2005	March	Multiparous	Montbéliarde	3	2	67 %
2005	April	Primiparous	Holstein	1	0	0 %
2005	April	Primiparous	Montbéliarde	0	0	-
2005	April	Multiparous	Holstein	6	1	17 %
2005	April	Multiparous	Montbéliarde	1	1	100 %
2005	May	Primiparous	Holstein	0	0	-
2005	May	Primiparous	Montbéliarde	0	0	-
2005	May	Multiparous	Holstein	0	0	-
2005	May	Multiparous	Montbéliarde	2	1	50 %

Some complementary tables and figures

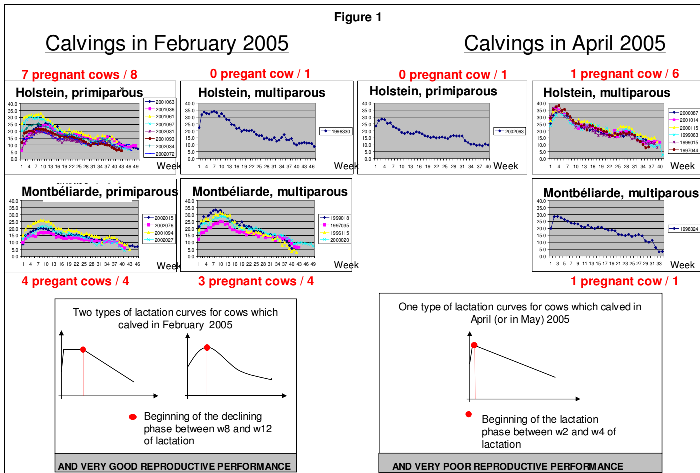
Table 6

Reproductive performance of GS dairy cows according to year, date of calving, parity and breed (2/2)

Year	Calving month	Parity	Breed	Number of cows	Number of pregnant cows	Success rate
2006	February	Primiparous	Holstein	2	1	50 %
2006	February	Primiparous	Montbéliarde	3	0	0 %
2006	February	Multiparous	Holstein	1	0	0 %
2006	February	Multiparous	Montbéliarde	4	2	50 %
2006	March	Primiparous	Holstein	2	0	0 %
2006	March	Primiparous	Montbéliarde	5	2	40 %
2006	March	Multiparous	Holstein	3	0	0 %
2006	March	Multiparous	Montbéliarde	2	0	0 %
2006	April	Primiparous	Holstein	0	0	-
2006	April	Primiparous	Montbéliarde	0	0	-
2006	April	Multiparous	Holstein	2	0	0 %
2006	April	Multiparous	Montbéliarde	2	2	100 %
2006	May	Primiparous	Holstein	0	0	-
2006	May	Primiparous	Montbéliarde	0	0	-
2006	May	Multiparous	Holstein	2	1	50 %
2006	May	Multiparous	Montbéliarde	2	0	0 %

Some complementary tables and figures

Figure 1



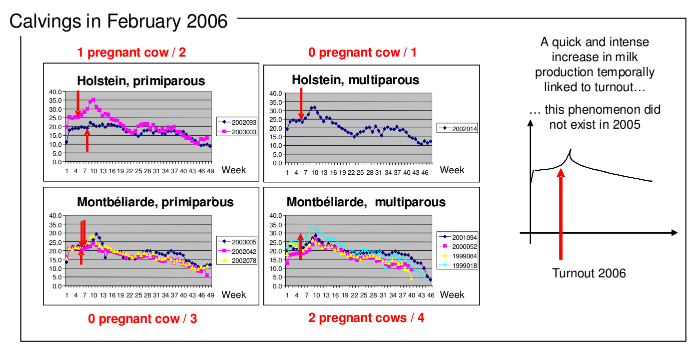
Hypothesis

In April, ingested grass very quickly stimulated milk production, which resulted in intense body fat mobilisation, low persistency, and poor reproductive performance.

Some complementary tables and figures

Figure 2

Differences between 2005 and 2006?



Hypothesis

In 2006, winter feeding quality and/or grazed grass quality were different in such a way that milk production was severely increased at tournout…

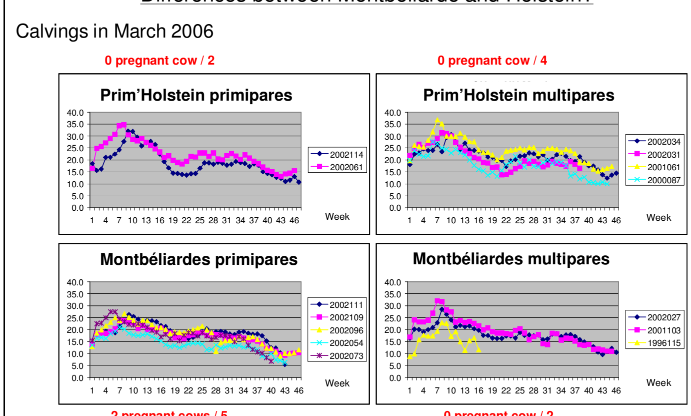
Which resulted in intense body fat mobilisation

And poor reproductive performance.

Some complementary tables and figures

Figure 3

Differences between Montbéliarde and Holstein?



Observation

Montbéliarde lactation curves were smoother than Holstein cows'…

… And their reproductive performance was better…