ANSWERS TO REVIEWER'S COMMENTS

Effects of feeding treatment on growth rate and performance of primiparous Holstein dairy heifers

Yannick Le Cozler, Julien Jurquet, Nicolas Bedere
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Effects of feeding treatment on growth rates and consequences on performance of primiparous Holstein dairy heifers

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Submitted by Nicolas Bedere 2019-09-09 09:22

Round #1

Author's Reply:

Decision

by Luis Tedeschi, 2019-10-29 14:07

Manuscript: https://doi.org/10.1101/760082

Revision Round #1

Dear authors; three reviewers have provided comments and suggestions on various aspects of your study. Before a final recommendation by the PCI ANSC can be made, I invite you to revise your manuscript based on reviewers' feedback. Please, read carefully the information provided for authors at https://animsci.peercommunityin.org/about/help_generic#For%20authors.

Author's Reply: are following the reviewers' comments and are indicated by the 'AU:' prefix and the font is red.

In this special part (answers to reviewer comments), we used references lines of 1st submitted paper and added the references in the new manuscript in red. We wish to thank the reviewer for his advice to improve the present paper and we are now looking forward to receiving the decision. English revisions have been performed by a specialised company (certificate of proofreading attached). We wish to thank in advance reviewers and editor for considering and correcting the present paper. We are now looking forward their decisions regarding the present publication.

Reviews

Round #1

Decision

by Luis Tedeschi, 2019-10-29 14:07

Manuscript: https://doi.org/10.1101/760082

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Dear authors; three reviewers have provided comments and suggestions on various aspects of your study. Before a final recommendation by the PCI ANSC can be made, I invite you to revise your manuscript based on reviewers' feedback. Please, read carefully the information provided for authors at https://animsci.peercommunityin.org/about/help_generic#For%20authors.

Reviews

Reviewed by anonymous reviewer, 2019-10-27 05:42

The study by Cozler et al. investigates the effects of feeding treatment on growth rates and consequences on performance in primiparous Holstein dairy heifers. Overall, the paper is well-written and the concept studied is very straightforward. The experiments are well-designed and the methodology appears to be appropriate. Findings presented in the manuscript contribute to a better understanding of the long-term effects of nutritional management on performance traits in Holstein dairy heifers. Some minor points need to be addressed prior to final publication.

Minor points:

Line 21: "… an experiment was performed…" AU: done line 21

Line 26: "… although they were still…" AU: done line 27

Line 46: ".. or older." AU: done line 49

Line 62: "…impact of accelerated growth" AU: done line 66

Line 66: "…designed and carried out an experiment…" AU: done line 70

Line 84: "…that, due to the fedding…" AU: done line 90

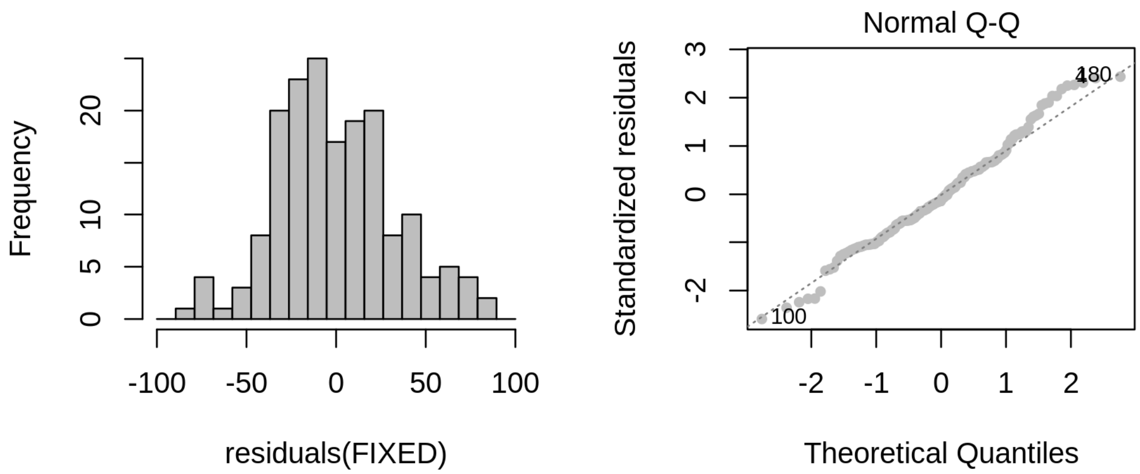
Line 139: "…grass, with the exception of…" AU: done line 166

Line 211: "2 consecutive values were not". Please state the interval between sample collection: AU: this information has been added on line 258-260

Line 211: "positive. Reductions in P4 milk…" AU: done line 260

Line 287: "…difference in the dam's BW…" AU: done line 330
Line 334: "AFS had minimal effects of fertility. Concerning ovarian…" AU: done line 381
Line 352: The present study indicates that …" AU: done line 400
Line 367: "in a study by Johnson et al…" AU: done line 414
Line 370: "…probably explains why no difference…" AU: done line 417
Line 371: "…the amount of milk offered until weaning…" AU: done line 425-426
Line 384: Define IGF1 AU: done line 437
Line 397: In the present study, a negative…" AU: done line 449-450
Line 415: "In the present study, fertility was…" AU: done line 465
Line 415: "…In a previous study on…" AU: done line 465
Line 434: "Collectively, these results indicate that…" AU: done line 483
Reviewed by anonymous reviewer, 2019-10-29 05:31
The objectives of the study were to assess the effects of feeding rearing programs on growth, reproduction and production performance of Holstein cows at nulliparous and primiparous stages. General comments The manuscript covers a relevant topic for dairy production. The material and methods section could be improved if it was more specific and improving the readability.
AU: Thanks to comments and suggestions of the reviewers, and the final language correction, we think that the readability has been improved now.
Materials and methods
L90-92: This sentence states that the expected average age at 1st AI was 15 mo. for SD and ID1 groups and 12 mo. what age for ID2. However, if ID1 groups are on an intensive plain diet wouldn't it be reasonable to expect they would reach the breeding age before the SD group?
AU: we agree, but as the experiment was performed in a seasonal calving herd, it was not possible to start breeding before 15 mo of age (in a non seasonal system, it would start earlier)
L92-93: When does the 1st season of grazing start and finish? When does pasture season 2 start and finish? Please, elaborate.
AU: the information has been added on lines 98-99
L94-95: Are you talking about only milk yield or also milk components? Please, specify.
AU: we specified that it was "yield" and added the information on line 102
L106-108: When did ID1 and 2 calves start to get 15% more since calving or after the pre-experimental phase (i.e., 10 d old)? Please, specify.
AU: this started on day 11 of live (added line 123)
L107: Table 1: In table 1: - Why is PDIE used as an acronym for metabolizable protein and not MP? I don't understand the term "rumen-degradable nitrogen", did you mean rumen-degradable protein? If so, why not us the RDP abbreviation? I don't understand the UFL concept, please explain.
AU: to explain more, we added information lines 109-115. Reference has been added in the list (558-560), and information also given in table 1.
L110: This sentence is confusing. Remove "(i.e. turning out to pasture)" since calves were housed during this period.
AU: this part has been deleted, line 119
L227: Where were you recording all the data before uploading it to the R software?
AU: we added information lines 274-276.
L235: Did you check if assumptions of ANOVA were not violated (e.g., normal distribution of residuals, homoscedasticity, etc.)?
AU: The 3 assumptions made when running an ANOVA are:
1. independent data
2. Normal distribution of the residuals
3. equal variance
We checked if these assumptions were respected, mainly through visualization techniques.
The independence of the data is inherent to the design.
The Normal distribution of the results can be checked by visualizing their distribution and QQplots (Quantile-Quantile Plots). Here is the example of body weight at first service:

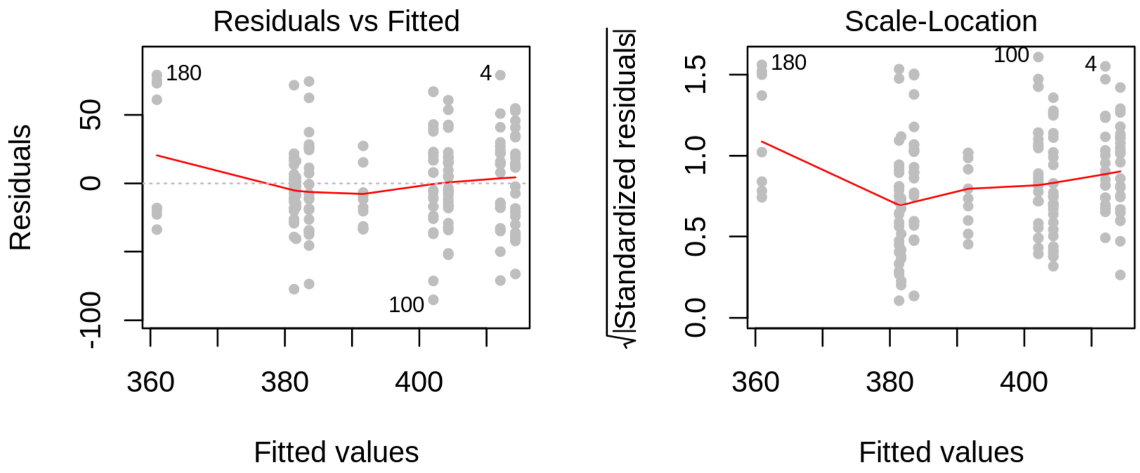
```
> FIXED<-lm(bw_ai1~year+feeding_system,data = data1)
> png("ANOVA_asumptions_normal.png",width=175,height=175/2,units="mm",point
size=12,res=250)
> par(mfrow=c(1,2))
> hist(residuals(FIXED),breaks = seq(-100,100,length.out=20),col = "grey",
main="")
> plot(FIXED,which=2,pch=20,col="grey")
> dev.off()
```



In this example, the residuals distribution (left panel) is very similar to a Normal distribution: e_i~N(0,32.9). The QQplot (right panel) show the quantiles of the standardized residuals in ordinates, against the quantiles of a simulated Normal distribution with the same mean and the same standard deviation. The regression is fairly similar to the dotted line which is y=x. This is another check that shows that the residuals follow a normal distribution.

The homoscedasticity of the variance can be checked by checking the absence of relationship between the residuals and the prediction of the model. With the same example:

```
> png("ANOVA_asumptions_homoscedasticity.png",width=175,height=175/2,units=
"mm",pointsize=12,res=250)
> par(mfrow=c(1,2))
> plot(FIXED,which=c(1,3),pch=20,col="grey")
> dev.off()
```



In this example, neither the residuals (left panel) nor the square root of the standardized residuals (right panel) show any pattern of relationship with the prediction of the model (x-axis). This means that the variance is constant among groups and that the homoscedasticity assumption is respected.
We checked all these for for all our models.
We decided to add few information (lines 278-279)

Results
Please correct the caption of Table 4 for "Association of age at first service with growth and reproductive performance of heifers during the rearing period"
AU: done line 335
Discussion
L389: remove "in"
AU: done line 377

Reviewed by Emilio Mauricio Ungerfeld, 2019-10-28 20:54
The manuscript by Le Cozler et al. tests the hypothesis that late born heifers can compensate growth and reproduce without any disadvantage in production or fertility compared to their earlier born pals. This is an important research that has relevant implications to dairy production.
The manuscript has a clear objective and the experiment and treatments are well designed to test the hypothesis. It is true that the treatments confound the effects of feeding regime and calving date. However, this is perfectly adequate for the objective of the study. Research seems to have been conducted with care and paying attention to details, but some aspects need to be clarified:
i) Did the authors conduct proximal analyses of the total mixed rations or feed components? If so, please add to the Materials and Methods and Results section
AU: For the analysis, we performed analysis on each feed components, at different stages of the experiment and then, recalculated for the mixed ration, using INRAtion Software. We detailed these aspects on lines 180-189
ii) Was pasture intake measured?
AU: Pasture intake was not measured. We added the information on line 190
iii) The statistical model should include year as a random, rather than as a fixed effect
AU: Year was considered in the models to take into account unknown environmental effects (e.g. drought) that might affect the average contemporary group in our analyses. We decided to include it as a fixed effect because there are only 3 levels (year1, year2, year3), which is the best option with this very limited number of levels. Indeed, if we would have include it as a random effect, the variance would have been estimated based on 3 levels only and would not be very accurate. Even with long lasting experiment (e.g. 10 years), the number of levels

in the factor “year” is rather small, this is the reason why considering year as a fixed effect is the statistical approach the most found in the literature (some examples: Dillon et al., 2003. Liv. Prod. Sci 83:21-33; Macdonald et al. 2005. J. Dairy Sci. 88:3363-3375; Horan et al., 2005. J. Dairy Sci. 88:1231-1243; Delaby et al. 2009. Animal 3:6:891-905; Cutullic et al. 2011. Animal 5:5:731-740; Berry at al. 2014. J. Dairy Sci 97:3894-3905, Hazel et al., 2014. J. Dairy Sci 97:2512-2525; Krpalkova et al. 2014. J. Dairy Sci. 97:6573-6582; Manzanilla-Pech. 2016. J. Dairy Sci. 99:443-457...).

We considered your suggestion, here is an example with body weight at first service (bw_ai1):

```
> FIXED<-lm(bw_ai1~year+feeding_system,data = data1)
> Anova(FIXED,type=3)
Anova Table (Type III tests)

Response: bw_ai1
               Sum Sq  Df    F value    Pr(>F)
(Intercept)  21880176   1 19741.4624 < 2.2e-16 ***
year            27148   2    12.2472 1.079e-05 ***
feeding_system  11051   2     4.9853  0.007877 **
Residuals      187309 169
---
Signif. Codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

> summary(FIXED)
Call:
lm(formula = bw_ai1 ~ year + feeding_system, data = data1)

Residuals:
    Min      1Q  Median      3Q     Max
-85.083 -20.578  -3.997  19.860  79.036

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    392.443      2.793 140.504  < 2e-16 ***
year1           13.551      3.665   3.698 0.000294 ***
year2            3.582      3.491   1.026 0.306252
feeding_system1  8.288      3.573   2.319 0.021576 *
feeding_system2  6.057      3.601   1.682 0.094401 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 33.29 on 169 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.1646,    Adjusted R-squared:  0.1448
F-statistic: 8.324 on 4 and 169 DF,  p-value: 3.75e-06

> RANDOM<-lmer(bw_ai1~feeding_system+(1|year),data = data1)
> Anova(RANDOM,type=3)
Analysis of Deviance Table (Type III Wald chisquare tests)

Response:  bw_ai1
                  Chisq Df Pr(>Chisq)
(Intercept)  1866.0475  1  < 2.2e-16 ***
feeding_system  9.8638  2   0.007213 **
```

```
---
Signif. Codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

> summary(RANDOM)
Linear mixed model fit by REML ['lmerMod']
Formula: bw_ai1 ~ feeding_system + (1 | year)
   Data: data1

REML criterion at convergence: 1703.3

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.5455 -0.6410 -0.1231  0.6058  2.4087

Random effects:
 Groups   Name        Variance Std.Dev.
 Year     (Intercept)  224.2   14.97
 Residual             1108.4   33.29
Number of obs: 174, groups:  annee, 3

Fixed effects:
                Estimate Std. Error t value
(Intercept)      392.450      9.085  43.198
feeding_system1    8.298      3.574   2.322
feeding_system2    5.955      3.600   1.654

Correlation of Fixed Effects:
                (Intr) feeding_system1
feeding_system1 -0.085
feeding_system2 -0.081 -0.183

> AIC(FIXED);AIC(RANDOM)
[1] 1720.564
[1] 1713.284
```

Considering year as random gives the same results as fixed in this case. The residual variance is the same, AIC are very similar, the effect sizes for feeding systems are similar between both approaches.
Given these elements, we intend to maintain year as a fixed effect, except if we misunderstood what you had in mind.
Done 272-275
In general, the document can be followed well. However, there are numerous writing and grammar mistakes that need to be fixed. I pointed out some of them under Specific comments. I recommend the authors to have the manuscript proofread by a native English speaker.
AU: Thanks to comments and suggestions of the reviewers, and the final language correction, we think that the readability has been improved now. English revisions have been performed by a specialised company (certificate of proofreading attached).
From their results, I disagree with the authors´ conclusion that using nutrition to help heifers born later in the season catch up in growth did not impair their productive performance. There was a tendency towards a 6 to 7% loss in milk production in the first lactation (lines 297-298), which is not negligible. To me, it is somewhat risky to conclude that there is no loss in milk production. Certainly, this practice will be profitable for some combinations of milk

prices and other costs such as labor and feeding. But while the study provides very useful knowledge, I recommend being more cautious about concluding that heifers born later in the season will not lose milk production if fed more.
AU: we temperate a bit our conclusion, and added "in the present study" (line 462), and added information (line 449 – 451).
Plus, there is no information about subsequent lactations in this study, which should constitute another note of caution.
AU: we added this point at the end of the conclusion (line 486-487)

Results of fat- and protein-corrected milk production need to be calculated and presented.
The Results section needs to be improved. I could not find Table 5. The same with the Feed intake result in the Appendix.
AU: Table 5 missed in this version. It was a mistake. Information regarding feed intake on a kg basis jas been added (figure 3)
In many instances results are presented in the text but the reader is not referred to a table. In other instances P values are not presented in the text.
AU: this has been corrected directly in the text (reference to the table or figure) and P values have been added.
In the Appendix, the curves either do not follow or do not overlap with the observations. Please correct or clarify.
AU: this was an error. No such a problem in the new supplementary figure.
Specific comments
Abstract
Line 30. "there were no differences"
AU: added on line 30
Lines 30, 36, and throughout. Recommend "milk composition" instead of "milk quality"
AU: added on line 30, 36… (please noticed
Line 32. Insert "or" i.e. "or 15.5"
AU: added on line 32
Line 35. "the whole lactation"
AU: added on line 35
Line 37. Suggest "with the growth of heifers born earlier in the season"
AU: added on line 38-39
Introduction
Line 52. "Increasing nutrient uptake"
AU: correction done on line 55
Lines 59-60. Unclear sentence, please re-write.
AU: we re-wrote lines 62-63
Line 62. Perhaps "too rapid growth" instead of "too high a growth"?
AU: added on line 65
Line 66. "conduct" instead of "led"
AU: we changed to "carried out" as proposed by referee 1 (line 70)
Lines 70-71. I do not understand "and results from autumn groups calving strategy could be used in a non-grouping strategy". Recommend re-writing or eliminating
AU: we re-wrote (lines 74-75)
Lines 71-73. Suggest re-writing as "We examined the possibility for late-born heifers to catch up with the rest of the heifers at 1st artificial insemination (AI) at a minimum BW of 370 to 380 kg, resulting in less than 22 mo at first calving."
AU: we re-wrote (lines 75-78)
Materials and Methods
Lines 77-81. It is not clear which 3 cohorts are the authors referring to. Is it the three treatments? Perhaps a simple table, including years, number of animals, breed and any other aspect the authors judge important could help the reader understand this aspect of the design better
AU: we re-wrote (lines 84-87)
Line 92. "the end"
AU: done line 99

Line 93. “in season 2” or “in the second season”
AU: we re-wrote line 100
Line 94 “milk production”
AU: we changed to yield, as proposed by referee 1 (in the final version, corrected by two natives, they proposed to write yield instead of production. We did so). Line 102
Line 95. “The experiment”
AU: we added “the” line 1903
Lines 98-100. Can be fused into one sentence
AU: done (line 106-108)
Line 101. Piled straw?
AU: (line 116): no, it was cumulated straw bedding (this sentence is also changed in the definitive text)
Line 104. What is the meaning of “dynamic groups”
AU: we added information (lines 119-120)
Line 112. “concentrate intake”
AU: we re-wrote line 130
Line 119. “the SD and ID1 groups”
AU: we added “the” (line 136)
Line 129. 80 feeders?
AU: No individual feeder. Each animal had its own place and had direct contact with his neighbours.
Lines 130-131. “competition for feed”
AU: we re-wrote line 148
Line 135. “mineral supplements”. Please specify composition, product, brand and origin. Same on lines 139-140 and lines 146 and 150.
AU: we added a section, lines 154-161 on minerals, and lines 180-190 for feed in general
Lines 155-156. Suggest “A classification based on age at first service (AFS) was created a posteriori in order to better understand which factors could lead to…”
AU: done lines 194-195.
Line 157. Suggest “Three groups were created with equal number of animals in each of them”.
AU: done line 196
Line 161. “would occur”
AU: done line 201
Line 172. I suggest “Sampling and measurements”
AU: done line 212
Line 213. “These”
AU: done lines 194-195
Lines 232 and 239. “overall mean”
AU: done lines 293
Results
Table 3 is not cited in the text for the growth results. Please correct
AU: done lines 194-195
Line 248. “animals”
AU: done lines 314, 316, 317
Lines 248-249. “did not get pregnant”
AU: done lines 301
Lines 252-253. Please indicate P value and “(result not shown)”
AU: Table 3 is now available
Line 262. Please indicate “(result not shown)” if not shown in any table
AU: Table 3 is now available
Lines 262-265. Please indicate significance and where are these results show, or otherwise “(result not shown)”
AU: as we wrote “significant” in the text (at least $P < 0.05$) , p value is not necessary. Table 3 is now available too
Lines 267. “services”
AU: Done line 319

Line 297. Where is this result presented?
AU: Sorry, we forgot to include table 5.
Lines 303. Replace “was already shrunk” by “decreased”
AU: changed but rewrote according to referee 1 suggestion.
Line 309. “patterns”
AU: done line 356
Line 327. AFS12.5 and AFS14.0?
AU: done line 373
Line 329. “pic”? (do the authors mean peak?)
AU: done line 377 (referee was right, it was a mistake)
Discussion
Line 352. “The present experiment”. Delete “down”
AU: done 400
Line 354. Delete “down”
AU: done 402
Lines 366-367. Re-write as: “The differences in feed allowance resulted in differences in development and size at 6 and 12 mo of age, but had limited effect on BW at weaning”
AU: done line 413-414
Line 367. “by Johnson”
AU: done line 414
Line 368. Do not understand “in size in pre-weaning performance”
AU: we removed “in size”
Line 370. “total mixed ration”
AU: done line 413
Line 371. Please re-write “low in most practices”
AU: done line 425 “In most commercial…”
Line 374. “the present study” “was around”
AU: done line 427
Line 376. “recommendations”
AU: done line 429
Line 377. “by Ettema” “about the importance”
AU: done line 430
Line 378. “achieved the recommended targets weights, which led to economic losses”
AU: done line 431-432
Line 380. “the milking phase”
AU: done line 434
Line 387. Delete “presented and”
AU: done line 440
Line 388. Delete “achieve the recommended targets and, therefore, this leads to economic losses” and start a new sentence
AU: this was line 431 and changes have been done
Line 394. “effects”
AU: done line 447
Lines 395-396. Please re-write for better understanding
AU: for lines 395 to 405, this has been re-written (lines 446-456)
Line 397. But that was the only lactation evaluated
AU: for lines 395 to 405, this has been re-written (lines 446-456)
Line 398. “was associated” Also, please explain how it was associated i.e. positively associated
AU: for lines 395 to 405, this has been re-written (lines 446-456)
Line 400 seems to contradict what as been said in line 398
AU: for lines 395 to 405, this has been re-written (lines 446-456)
Line 405. Delete “is”
AU: for lines 395 to 405, this has been re-written (lines 446-456)
Lines 406-409. This is important, although I think that the direction and significance of the finding is what really matters, rather than absolute milk production with 24 mo calving
AU: we agree too

Line 409. “the present study” “younger heifers”
AU: done line 462
Lines 411-413. The difference with what? With the meta-analysis discussed above? Please clarify
AU: done line 463 (“in milk production”)
Line 415. “In the present study”
AU: done line 465
Line 418. Recommend repeating “Puberty was reached” instead of the more vague “It occurred”
AU: done line 468
Line 422. Delete “means that it”
AU: in this corrected version, we decided to keep it, and ask the English natives to correct (see final version)
Line 425. “future milk production”
AU: done line 475
Line 426. “by age”
AU: done line 476
Line 429. “years”
AU: done line 479
Line 432. “in the present study”
AU: done line 481
Line 434. Delete “All”
AU: we re-wrote “collectively, these…”(line 483)
Lines 435-437. Re-write for clarity and to eliminate redundancies
AU: done lines 483-487
Tables 3 and 4. Could it be “Conception rate at first service” instead of “Success at first service”?
AU: done
Tables 3 and 4. “Number of services”
AU: done

REVISED VERSION AFTER CONSIDERING ALL REVIEWERS' COMMENTS

Effects of feeding treatment on growth rate and performance of primiparous Holstein dairy heifers

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Effects of feeding treatment on growth rates and consequences on performance of primiparous Holstein dairy heifers

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Abstract

The objective of this study was to investigate the effects of feeding rearing programs aiming a first calving between 20 and 27 months (mo) of age on growth, reproduction and production performance of Holstein cows at nulliparous and primiparous stages. Our hypothesis was that, in a seasonal autumn calving strategy, it was possible for late-born heifers in the season to catch up with the growth of heifers born earlier and be inseminated at the same time-period, at a 370 kg body weight (BW) minimum. This would result a first calving age at about 21 to 22 mo, without impairing their later performance. To answer this question, an experiment was performed, involving a total of 217 heifers over 3 years. These heifers were split into 3 groups: the first group received a control feeding treatment (SD), the second one an intensive-plane diet (ID1) from birth to 6 mo, and the last group an intensive-plane diet until 1 year of age. Groups SD and ID1 comprised heifers born from September until end of November; ID2 was composed of heifers born later. The present study showed that late-born heifers (ID2) could catch up with the growth of the other thanks to feeding treatment, although they were still 42 kg lighter than both SD and ID1 ones at first calving. There was no difference in reproductive performance of the heifers between the groups. Once primiparous, the cows reared with the ID2 treatment tended to produce less milk than SD and ID1 (about -400 kg over the lactation), and there were no differences regarding milk composition, feed intake, body condition score, or BW. A classification on age at first service was created *a posteriori* leading to 3 classes with heifers first inseminated at about 12.5 mo ($AFS_{12.5}$), 14.0 mo ($AFS_{14.0}$) or 15.5 mo ($AFS_{15.5}$) of age. Heifers in $AFS_{12.5}$ had a faster growth than those in $AFS_{14.0}$ and $AFS_{15.5}$. Once primiparous, the $AFS_{12.5}$ cows tended to produce less milk at peak than $AFS_{14.0}$ and $AFS_{15.5}$ (about -1.5 kg/d) although there was no difference regarding total milk production in the whole lactation. There was no difference between these groups regarding milk composition, feed intake,

body condition score, or BW. All these results support the conclusion that it is possible, through feeding treatment, to help late-born heifers to catch up with the growth of heifers born earlier in the season. This leads to an earlier first calving but do not impair their reproductive performance but slightly decrease milk production during lactation 1 (- 400 kg) on a 305 d basis. Long-term effects of such strategy need to be investigated.

Key words: dairy cattle, heifer, growth, reproduction, feeding treatment

Implications

Increasing the growth rate of dairy heifers decreased their age at puberty, potentially reducing age at first calving, and ultimately shortening the non-productive rearing period. Heifers first calving at 22.5 months (mo) of age or less presented similar performances than those calving at 23.8 mo of age or older.

Introduction

In seasonal calving systems, heifers usually first calve at a young age (around 24 months(mo)) but 1st insemination may be delayed for those born at the end of the calving period if an adequate body weight (BW) is not reached (i.e. 360 to 380 kg for Holstein heifers in French dairy herds; Le Cozler *et al*., 2008). Increasing nutrient uptake and thus the growth rate for these late-born heifers is a solution to lower this risk. A high growth rate during rearing is associated with a decreased age at puberty and, consequently, 1st calving may occur as early as 20 to 21 mo of age. Tozer (2000) concluded that a higher plane of nutrition incurred higher daily feed costs, but these costs were recouped when heifers calved at a younger age through savings on labour, housing and overall feed costs. Regardless of the strategy of rearing (group-calving or not), it is, however, necessary for animals to have achieved an adequate body size before calving or milk production potential in the first lactation is compromised (Bach and Ahedo, 2008). Indeed, the use of accelerated growth program for dairy heifers cannot be resumed to early puberty attainment. Many authors have studied the impact of growth intensity on further performances (see the literature review of Le Cozler *et al*., 2008), but if most of them indicated negative impact of too rapid a growth, some authors indicated limited impact of accelerated growth. According to Pirlo *et al.* (1997), reducing age at first calving to 23 to 24 mo was the most profitable procedure, but not less than 22 mo (except in cases of low milk prices and high rearing costs). They concluded that reluctance to decrease age at first calving is generally attributable to the belief that early calving is detrimental to milk yield and longevity. Here, we designed and carried out an experiment to determine the effects of feeding treatments on growth parameters, reproduction and production performance of Holstein primiparous heifers first calving between 20 and 27 mo of age, in a seasonal calving system. We hypothesised that genetic improvement over the last decades in dairy production resulted in animals that could calved now at an earlier age than 24 mo of age. We also presumed that results from animals raised in a seasonal calving strategy could be used and generalized for non-grouping strategy. We examined the possibility for late-born heifers to catch up with the rest of the heifers at 1st artificial insemination (AI) at a minimum BW of 370 to 380 kg, resulting in less than 22 mo of age at first calving.

Material and Methods

General design

A total of 217 Holstein heifers, born during the 2009-10 (n = 65), 2010-11 (n = 73) and 2011-12 (n = 76) calving seasons (September to February), were reared and followed until oestrus synchronisation (12 to 15 mo of age) at the INRA experimental farm of Méjusseaume (Le Rheu, France). Another study based on the same experiment (heifers born 2011-12) was already published, where rearing procedures and strategies used in present study have been fully detailed for one of them (Abeni *et al.*, 2019). Briefly, calves born between 1st of September and 30th of November were alternately allocated to 1 of 2 nutritional treatments (according to birth order) and fed either a standard diet (SD) or an intensive-plane diet (ID1) from 0 to 6 mo of age. It was expected that, due to the feeding intensity chosen, heifers fed SD and ID1 diets would reach 190 to 200 and 220 to 230 kg at 6 mo of age, respectively. Heifers born after 1st of December (ID2) received the same intensive-plane diet as ID1 heifers from 0 to 6 mo of age, to limit the possible confusion effect between age and treatment during this period. Thereafter, a complementary diet was formulated for ID2 heifers in order to reach 380 kg at 1 year of age. The main objective of this latest procedure was to study the possibility for late-born heifers to catch up with the rest of the heifers at 1st artificial insemination (AI) at a minimum BW of 370 to 380 kg. It was expected that this corresponded to average ages of 15 and 12 mo for (SD and ID1) and for (ID2) heifers, respectively. During year 1, heifers grazed from mid-May until end of October. During year 2, grazing started in end of March until calving season (starting 1st September). From the end of 1st season of grazing, all heifers were grouped-housed until turning out to pasture in season 2. Three weeks before expecting date of calving, heifers entered cows herd and were fed individually a similar total mixed ration (TMR). During lactation, milk yield was recorded twice a day and animals were weighed every day. The experiment ended week 15 after calving.

Feeding management

Diets were formulated for the different stages of growth according to recommendations and procedures presented by Agabriel and Mechy (2007), to reach a targeted average daily gain (ADG) per period, with respect to the initial BW and feeding treatment used. Briefly, in this approach, energy is expressed per UFL (Forage Unit for lactation, g/kg), which correspond to net energy for lactation (g/kg) /1760. For protein, PDIN (protein digestible in the small intestine, g/kg) and PDIE (protein digestible in the small intestine) are used. PDIN correspond to protein digestible in the small intestine supplied by rumen-undegraded dietary protein + protein digestible in the small intestine supplied by microbial protein from rumen-degraded dietary protein. PDIE is the protein digestible in the small intestine supplied by rumen-undegraded dietary protein + protein digestible in the small intestine supplied by microbial protein from rumen-fermented organic matter (INRA, 2007). At the end of the pre-experimental phase (0-10 d), heifers were group-housed indoors on cumulated straw bedding. They were fed reconstituted milk replacer made of 135 g milk powder (23.9 % crude protein and 19.0 % fat content) with 865 g water per litre until weaning (about 77 to 84 d of age). They were reared in dynamic groups, meaning that calves entered the group every week while others left it at weaning (70 to 77 days). They were individually fed with automatic milk feeding systems (AMFS), with free access to fresh water, straw and hay. Group size varied from 8 to 24 calves per AMFS. From day 11, milk was distributed according to either the standard ration routinely used in the experimental

Table 1: Ingredients and chemical composition of the experimental diets

Item[1]	TMR1	TMR2	TMR3a	TMR3b	TMR4	TMR5	TMR6	TMR7
Stage of growth, age	(7d to 4 mo)	(4 to 6/8mo)	(9 to 11mo)	(6 to 11mo)	(11 to 15 mo) *(winter 1)*	(21 to 26 mo) *(- 21 d prior calving until calving)*	(21 to 26 mo) *Calving + 14 d*	(21 to 35 mo) *(15 d until end of lactation)*
Feeding Treatment group	All	All	SD, ID1	ID2	All	All		All
Ingredient, %								
Corn silage	47.5	72.0	80.0	80.0	79.0	84.5	52.5	65.0
Soybean meal	-	8.0	20.0	20.0	21.0	9.0	8.0	8.0
18% CP alfafa pellets	5						10	10
Straw						2.5	2.5	2.5
Urea								0.8
Minerals + vitamins								1.0
Concentrate 1[2]	47.5	20.0						
Concentrate 2[3] (kg/head/d)			1.0	2.0	1.0			
Concentrate 3[4] (%)						4.0	25	15.0
Estimated chemical composition								
DM, %	51.4	42.0	42.2	46.0	42.1	38.6	48.8	44.4
PDIE, g / kg DM	93.0	93.1	104.5	103.1	106.2	85.0	93.7	89.6
PDIN, g / kg DM	79.8	84.0	108.7	108.5	111.3	72.8	83.9	91.3
UFL / kg DM	0.96	0.96	0.98	1.00	0.99	0.93	0.93	0.92

[1] *abbreviations: TMR: Total Mixed Ration; SD, ID1, ID2: animals fed either on a standard (SD) or increased-plane (ID1 & ID2) feeding treatment; DM: dry mater; UFL (Forage Unit for lactation, g/kg); PDIN (protein digestible in the small intestine, g/kg); PDIE (protein digestible in the small intestine) (INRA, 2007).*
[2] *Chemical composition: DM 88.7%; PDIE 118 g; PDIN 114 g; UFL 1.05.*
[3] *Chemical composition: DM 87.9%; PDIE 81 g; PDIN 90 g; UFL 0.96.*
[4] *Chemical composition: DM 87.7; PDIE 101 g; PDIN 76 g; UFL 1.05.*

herd (SD) or an increased 15% milk ration (ID1 & ID2). All calves were fed *ad libitum* total mixed ration 1 (TMR1; Table 1).

From weaning to 6-8 mo of age, calves were housed on deep straw bedding with *ad libitum* access to fresh water and straw. Until 4 mo of age, the SD group received TMR1 *ad libitum* until the concentrate reached 2 kg DM/head/d. No restriction was applied to ID1 & ID2 heifers. From 4 to 6-8 mo of age, TMR2 was distributed *ad libitum* until the maximum daily allowance of concentrate intake reached 2 kg and 2.5 kg DM/head/d for SD and (ID1 & ID2) heifers, respectively, i.e. a total daily allowance of 10 and 12.5 kg DM/head/d of TMR2 for SD and (ID1 & ID2) heifers respectively. These amounts did not change until turning out to pasture.

Starting from mid-May and mid-June for (SD & ID1) and ID2 heifers, heifers were turned out to pasture and rotationally grazed on a perennial ryegrass sward. After a 5-d transition phase and throughout the pasture season, the SD and ID1 groups received a daily supplement of 1 kg DM/heifer of concentrate 2, whereas the ID2 group received 1 kg DM/heifer/d of corn silage and 2 kg DM/heifer/d of concentrate 2. Grass availability and/or quality were insufficient to maintain the desired growth rates during summer. SD and ID1 heifers then received up to 2.5 kg DM/heifer/d of additional TMR3a, plus 1 kg DM/heifer/d of concentrate 2; ID2 heifers received up to 3 kg DM/heifer/d of TMR3b, plus 2 kg DM/heifer/d of concentrate 2. To achieve 380 kg at the end of outdoor season (when oestrus synchronisation started), the expected ADG for SD and ID1 heifers was estimated to be around 600 g/d during this period, with a feeding regime based on pasture plus 1 kg DM/heifer/d of concentrate 2, and 800 g/d when receiving grass plus TMR3a. For ID2 heifers, it was estimated that grass alone was not sufficient to reach 900 g/d during the same period and TMR3b was used (Table 1). In the pasture area, a permanent headlock barrier (80 places on concrete floor) was used daily to feed SD and ID1 heifers with their concentrate. Heifers were locked for 1 hour while eating, to limit competition for feed intake between heifers. The SD2 group had free access to its ration, and so, heifers were not locked.

At the end of the first pasture season (1^{st} week of November), heifers were group-housed (8 heifers/pen) on deep straw bedding and received 3.8 kg DM/head/d of a diet containing 79% corn silage and 21% soybean meal. They had free access to fresh water, straw and mineral complements.

Minerals and vitamins, when not included in concentrate during rearing, were included in licking stones, containing for minerals per kg of DM, 2.5 % Ca, 2 % Mg and 32.5 % Na and per kg, 10 000 mg Zn, 8250 Mn, 1500 Cu, 200 Io, 20 Se and 13 Co. The concentrates during growth contained 4% P, 27% Ca and 5% Mg, plus vitamins per UI/kg, 1 000 000 A, 350 000 D3, 8 000 E. It also contained, per mg/kg, Cu (1500), Zn (10 000), Io (200), Co (100) and Se (10). During lactation, mineral complement contained 7% P, 22% Ca and 4% Mg, plus per UI/kg, 500 000 vit A, 100 000 vit D3, 1 500 vit E. It also contained, per mg/kg, Cu (1000), Mn (3500), Zn (4530), Io (80), Co (35) and Se (22).

After a 2-week adaptation period, oestrous cycles were synchronised in heifers (see below), and the same procedure of rearing was applied for all heifers. Depending on their date of successful insemination, heifers turned out to pasture (generally in March). They were them all reared in an unique group and received no additional feed but grass, with the exception a mineral and vitamins complementation.
Three weeks before the expected date of calving, all heifers were housed indoors, together with multiparous cows, in a cubicle barn with fresh straw bedding distributed daily. Heifers were fed individually and received a daily TMR5 composed of corn silage (84.5 %), soybean meal (9 %), concentrate (4 %) and straw.
From calving to 14 d post-calving, TMR6 was composed of corn silage (52.5 %), soya bean meal (8 %), concentrate (25 %), dehydrated lucerne (1 %), mineral/vitamin complement, urea and straw (Table 1).
From day 14 after calving, cows individually received TMR7, composed of corn silage (65 %), soybean meal (8 %), concentrate (15 %), dehydrated lucerne (1 %), urea and completed with mineral/vitamin complement (7% P; 22% Ca and 4% Mg). During lactation, all heifers were fed *ad libitum*, based on a 10% refusal at least per day. Feed was distributed twice a day (09.00 and 16.30), and refusals collected every morning, before distribution of fresh TMR.
Chemical composition of TMR components produced on-farm (corn silage, straw) was determined when harvested and analysis were performed on an average sample when changing storage silo or field-straw origin. This average sample originated from daily sample. However, dry matter was determined at least once a week on all TMR contents. A similar procedure was applied for concentrate feed. Analysis was performed by manufacturer before delivering (concentrate; soybean) and compared to the average sample when changing. The estimate chemical composition of TMR was then determined using INRAtion® Software (INRA, 2010), based on these analysis and the percentage of each ingredient in the TMR. Because of possible changes in composition (dry mater or grain content of corn silage for example), TMR composition was checked regularly and the amount of each ingredient was adapted accordingly.
Pasture intake was not measured in present study.
During the entire experiment, all heifers and cows housed indoor had free access to fresh water.

Age at first service

A classification based on age at first service (AFS) was created *a posteriori* in order to better understand which factors could lead to different AFS and how future performance can be related to AFS. Three groups were created with equal number of animals in each of them (Table 2).

Table 2: Description of the classes of age at first service

	$AFS_{12.5}$	$AFS_{14.0}$	$AFS_{15.5}$
AFS[1]	12.6 (0.73)	14.2 (0.36)	15.4 (0.65)
Total number	58	57	60
Number in SD	16	29	29
Number in ID1	15	27	30
Number in ID2	27	1	1

[1]*Mean age at first calving with standard deviations in parentheses*

Oestrus synchronisation

All heifers were inseminated after oestrus synchronization during winter 2 of rearing, so that calving would occur at around two years of age. At the end of November, for nearly half of the heifers, oestrus was synchronized using a progestin ear implant (Norgestomet®, Intervet, Angers, France) in conjunction with an intramuscular oestrogen injection (Crestar®, Intervet, Angers, France) without consideration of ovarian activity. A second synchronization was performed three weeks later for the rest of the heifers. After nine days of treatment, the ear implant was removed. Heifers generally exhibited signs of oestrus within 24 to 96 h and were then inseminated on detected oestrus. In case of failure to conceive, heifers exhibiting further signs of oestrus were inseminated until the end of the reproductive season (April). Ultrasonography was conducted 42 d after insemination on average in order to diagnose pregnancy. Non-gestating heifers were then removed from the rest of the experiment.

Sampling and measurements

Heifers were weighed every 14 d from birth to weaning, every 21 d from weaning until turning out to pasture, and every 28 d until the end of the experiment. Interpolations were performed in order to compare BW of heifers at similar stage of growth. Average daily gains were then calculated. Heifer health and care information was recorded during the experiment. Their body condition score (BCS) was recorded 3 weeks before the expected date of calving and then, once a month. The method and scale developed by Bazin *et al.* (1984) that ranged from 0 to 5, was used. BCS was scored by 3 trained technicians and their records were averaged.

To monitor morphological traits during rearing and first lactation, five measurements were recorded: heart girth (HG), chest depth (CD), wither height (WH), hip width (HW) and backside width (BaW). A tape measure was used to measure HG, while a height gauge was used for the other measurements. These measurements were recorded only for the 2 firsts cohorts (2009-10 and 2010-11), results are presented on complementary data 1 and figures 1 & 2. Presentations are based on a classification on age at first service (AFC), created *a posteriori* (not presented and discussed in present paper).

Daily feed intake was calculated individually as the difference between daily feed allowance and refusals. Refusals were collected every day at 7.00 and weighed. The composition of refusal and allowance were presumed to be the same. Dry matter (DM) for silage was determined 5 times per week, while DM of the pellets was determined once a week. Feed composition was estimated based on average samples for corn silage, straw, soybean, and concentrate. No such information was available for fresh grass (see Table 1).

Milk content analysis

Milk production was automatically recorded at each milking (i.e. twice daily). During 6 successive milkings (Tuesday to Thursday), milk samples were collected and analysed from each cow, to determine fat and protein contents (Milkoscan, Foss Electric, DK-3400 Hillerod, Denmark).). Fat and protein corrected milk was calculated with the following equation (INRA, 2018):

$$FPCM = MY \times \frac{[0.42 + 0.0053 \times (FC - 40) + 0.0032 \times (PC - 31)]}{0.42}$$

where FPCM stands for fat and protein corrected milk (kg), FC stands for milk fat content (g/kg) and PC for milk protein content (g/kg); and 0.42 is the UFL value for 1 kg of milk containing 40 g/kg of fat matter and 31 g/kg of protein matter.

Milk progesterone analysis

From calving to either 2 weeks after the service inducing pregnancy or to 5 weeks after the end of the breeding season (i.e. July), morning milk samples were collected on Monday, Wednesday and Friday, and stored at -20°C for progesterone determination by commercial ELISA kits (Milk Progesterone ELISA, Ridgeway Science Ltd., England). The coefficients of variation between assays for ELISA on 5 ng/ml control samples ranged between 8 % and 14 % among experimental years.

Determination of Luteal Activity

Two progesterone (P4) milk concentration thresholds were defined as in Petersson *et al.* (2006) adapted by Cutullic *et al.* (2011) to distinguish (i) the baseline P4 level in milk from the luteal phase level (threshold 1) and (ii) a low luteal phase level from a high luteal phase level (threshold 2). P4 values were qualified as follows: negative (< threshold 1), positive (> threshold 2) and intermediate. In short, rises of P4 milk concentrations were considered to be induced by corpus luteum activity if at least 2 consecutive values were not negative and at least one positive. Due to sampling collection procedure (Monday, Wednesday and Friday), the interval between sample collection was either 2 or 3 days. Reduction in P4 milk concentrations were considered to result from luteolysis of the corpus luteum when at least 1 value became negative. These definitions enabled to identify and distinguish luteal phases from inter-luteal phases.

Qualification of Progesterone Profiles

For each luteal phase, physiological intervals were computed: commencement of luteal activity (CLA), cycle length (IOI), luteal phase length (LUT) and inter-luteal interval (ILI; for details, see Cutullic *et al.*, 2011). Ovulation was considered to induce a prolonged luteal phase (PLP) if the luteal phase lasted longer than 25 days. Ovulation was considered to be delayed if inter luteal interval is longer than 12 days. Based on these definitions, P4 profiles were classified as (i) normal, (ii) PLP profile (if at least one PLP was observed), (iii) delayed (D; if CLA > 60 days), (iv) interrupted (I; if at least one ovulation of rank > 2 was delayed) or (v) disordered (Z; if luteal activity appeared irregular but could not be included in any abnormality class).

Calculations and statistical analysis

All information regarding dairy cow (reproduction production, feed intake…) were automatically stored on a dedicated registration chain. Other analysis, regarding heifer growth and performance, as well as information about progesterone, were recorded in Excel files. All data handling and statistical analyses were performed in R using either the *lm* procedure for ANOVA or the *glm* for logistic regressions (R Core Team, 2019). Normal distribution of the residuals, equality of the variance and non-dependant data were checked for all our models. Quantitative traits (i.e. growth, ages, live weight, milk production, body condition score, CLA and cycle lengths) were studied using the following ANOVA model :

$$y_{ij} = \mu + year_i + \left| \begin{matrix} AFS_j \\ T_j \end{matrix} \right| + e_{ij}$$

where y_{ij} is the variable of interest, μ was the overall mean of the variable of interest, $year_i$ was the fixed effect of the experimental year (i=1, 2 or 3), either AFS_j that was the fixed effect of age at first service (j= 12.5, 14.0 or 15.5 mo) or T_j that was the fixed effect of the feeding treatment (j= SD, ID1 or ID2) was included in the model, e_{ij} was the random residual effect. Year was included as a fixed effect because there were only 3 levels (year1, year2, year3), which we considered to be the right option with limited number of levels. If it was included as a random effect, the variance would have been estimated based on 3 levels only and would not be very accurate. Dichotomous traits (i.e. reproductive success and type of cyclicity pattern) were studied using the following logistic regression model :

$$log\left[\frac{P(y_{ij} = 1)}{1 - P(y_{ij} = 1)}\right] = \mu + year_i + \left| \begin{matrix} AFS_j \\ T_j \end{matrix} \right| + \beta \times PRI_{ij}$$

where y_{ij} is the variable of interest, μ is the overall mean and the fixed effects $year_i$, AFS_j or T_j are the same as described above. In the case of reproductive performance of heifers, the covariate PRI_{ij}

that describes the effect of the interval from the removal of the last progesterone-releasing implant to the insemination was included. This covariate was not needed for performance of cows because only heifers are synchronized.

Effects were declared highly significant at P<0.001, significant at P<0.05 and as a trend at P<0.10.

Results

There were initially 217 heifers enrolled in the experiment, out of which 175 successfully calved. The 42 remaining animals either died during rearing (7), were culled because of injuries (6), or did not get pregnant within the breeding period considered for the present study (29).

Growth and reproductive performance of heifers

The average BW at birth was 41.3 kg (±5.2) and was balanced across the groups (i.e. not associated to neither feeding treatment (P = 0.85) nor AFS(P = 0.15)) (Table 3; Table 4).

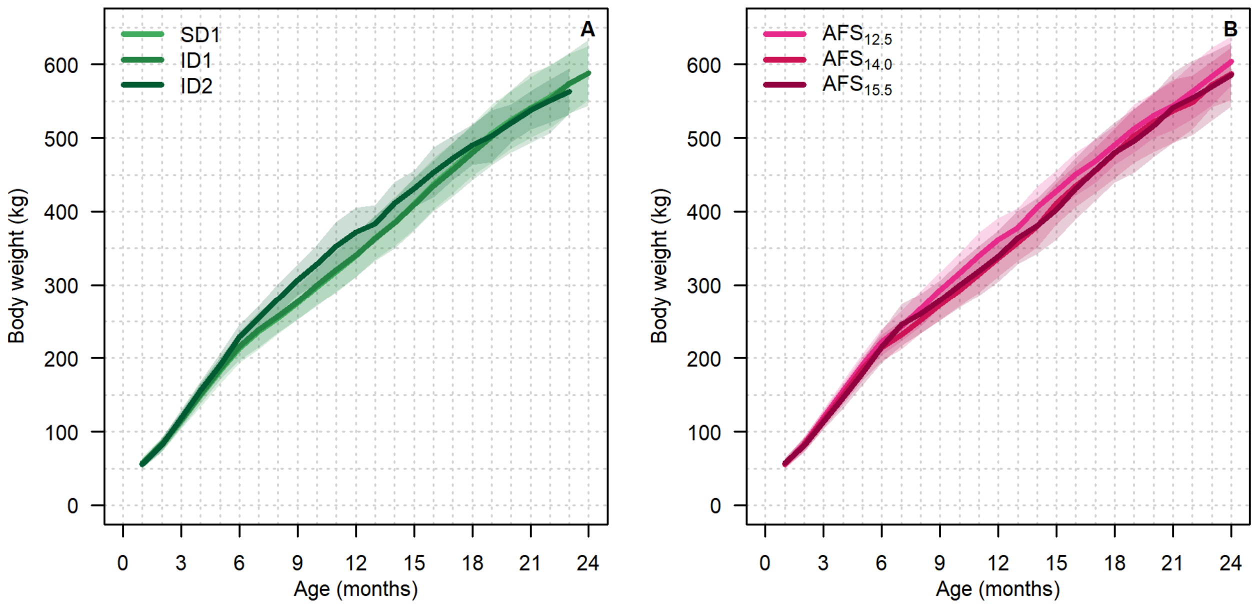


Figure 1: Body weight of the heifers during the rearing period, according to the feeding treatment (A) and classes of age at first service (AFS; B).

Feeding treatment had limited effect on growth during milking phase and heifers reached 117 kg (±11.8) at 3 mo of age (just after weaning). From weaning to 6 mo of age, heifers in the ID2 group were heavier than these in both the SD and ID1 treatments (229 kg *vs* 213 kg and 217 kg at 6 mo of age respectively; P < 0.001; Figure 1.A). The highest ADG was found for ID2 heifers from 0 to 6 mo (1042 *vs* 958 and 976 g/d for ID2, SD and ID1 respectively; P < 0.001, Table 3). This difference was still significant from 6 to 12 mo of age (789, 703 and 699 g/d for ID2, SD and ID1 heifers, respectively; Table 3). However, from 12 to 18 mo of age, ADG was significantly reduced for ID2 heifers in comparison of SD and ID1 heifers (660 *vs* 800 and 774 g/d respectively; Table 3).

Reproductive performance was not affected by the feeding treatment (Table 3), although the number of services tended to be lower for ID2 heifers than for SD and ID1 heifers (1.5 vs 1.9 and 1.8, respectively). Indeed, cows in the 3 feeding treatment showed a similar interval from the start of the breeding season to the 1st service (13.5 d), similar success at 1st service (about 62% of pregnant heifers) and similar pregnancy rate by the end of the breeding season (94%).
There was no difference in calf BW (37.9 kg) despite a difference in their dam's BW at both 1st service and 1st calving (ID2 heifers were lighter than both SD and ID1, Table 3 and Table 5). Heifers in the ID2 treatment calved at a younger age than those in the SD and ID1 treatments (about 2 months earlier, P<0.001; Table 3).
Heifers inseminated at a young age (12.5 mo of age on average; $AFS_{12.5}$) tended to have a higher growth rate than heifers inseminated at either 14.0 ($AFS_{14.0}$) or 15.5 ($AFS_{15.5}$) mo of age, from 0 to 6 mo of age (1001 *vs* 960 and 978 g/d; P 0<0.10; Table 4). This difference became more important from 6 to 12 mo of age (759 *vs* 688 and 698 for $AFS_{12.5}$, $AFS_{14.0}$ and $AFS_{15.5}$ respectively; P < 0.01

Table 3: Effect of the feeding treatment on the growth and reproductive performance of heifers during the rearing period

	Feeding Treatment			Model[1]		Significance levels[2]
	SD1	ID1	ID2	R^2_{adj}	RSE	
Number of records	74	72	29			
Growth						
BW at birth (kg)	41.2	41.7	41.1	0.00	5.19	0.85
BW at 1st AI (kg)	400.7[a]	398.5[a]	378.1[b]	0.14	33.29	★★
ADG 0-6 months (g/d)	958[a]	976[a]	1042[b]	0.09	97.7	★★★
ADG 6-12 months (g/d)	703[a]	699[a]	789[b]	0.31	116.8	★★
ADG 12-18 months (g/d)	800[a]	774[a]	660[b]	0.11	133.2	★★★
Reproduction						
Start of breeding season to1st service interval (d)	13.9	12.8	14.0	0.00	5.76	0.46
Conception rate at 1st service (%)	64	58	66	NA	NA	0.64
Number of services	1.9	1.8	1.5	0.21	0.78	●
Pregnant (%)	95	96	90	NA	NA	0.67
Age at 1st calving (months)	24.0[a]	23.9[a]	21.9[b]	0.32	1.26	★★★
Calf body weight (kg)	38.4	37.6	37.2	0.32	4.02	0.37

[1]*adjusted coefficient of determination: R^2_{adj}; and residual standard error: RSE.*
[2]*★★★ P<0.001; ★★ P<0.01; ★ P<0.05; ● P<0.1; the exact P-value otherwise*
[a-b] *Different superscripts point out adjusted means that are different between feeding treatments (P<0.05, Tukey's pairwise comparison)*

Table 4: Association of age at first service with growth and reproductive performance of heifers during the rearing period"

	Age at first service (AFS)			Model[1]		Significance levels[2]
	$AFS_{12.5}$	$AFS_{14.0}$	$AFS_{15.5}$	R^2_{adj}	RSE	
Number of records	58	57	60			
Growth						

BW at birth (kg)	41.5	42.0	40.2	0.02	5.13	0.15
BW at 1st AI (kg)	373.1[a]	394.3[b]	419.8[c]	0.37	28.49	★★★
ADG 0-6 months (g/d)	1001	960	978	0.03	100.8	●
ADG 6-12 months (g/d)	759[a]	688[b]	698[b]	0.30	117.5	★★
ADG 12-18 months (g/d)	712[a]	799[b]	790[b]	0.07	136.3	★★
Fertility						
Start of breeding season to1[st] service interval (d)	12.9	13.2	14.3	0.00	5.75	0.42
Conception rate at 1[st] service (%)	59	60	67	NA	NA	0.30
Number of services	1.7	1.7	1.9	0.20	0.78	0.25
Pregnant (%)	93	91	98	NA	NA	0.37
Age at 1[st] calving (months)	22.3[a]	23.8[b]	24.8[c]	0.52	1.06	★★★
Calf body weight (kg)	37.4	38.6	37.7	0.32	4.02	0.31

[1]*adjusted coefficient of determination: R^2_{adj}; and residual standard error: RSE.*
[2]★★★ *P<0.001;* ★★ *P<0.01;* ★ *P<0.05;* ● *P<0.1; the exact P-value otherwise*
[a-b] *Different superscripts point out adjusted means that are different between feeding treatments (P<0.05, Tukey's pairwise comparison)*

Table 4; Figure 1.B). Growth was reduced for $AFS_{12.5}$ animals from 12 to 18 mo of age, with an ADG of 712 g/d, compared to 799 and 790 g/d for $AFS_{14.0}$ and $AFS_{15.5}$ (P < 0.001; Table 4). This is consistent with the effects of feeding treatment observed, and with the distribution of animals among the classes of AFS and feeding treatments (Table 2).

Fertility was not affected by age at first service (Table 4): all heifers showed a similar interval from the start of the breeding season to the 1[st] service, a similar success rate at 1[st] service and pregnancy rate by the end of the breeding season, with a similar number of service per animal.

There was no difference in calf BW (37.9 kg) despite a difference in the dam's BW at 1[st] service and at 1[st] calving ($AFS_{12.5}$ heifers were lighter than the ones in $AFS_{14.0}$ themselves lighter than the one in $AFS_{15.5}$, Table 4 and Table 6). Consistent with the age at 1[st] service, heifers in the $AFS_{12.5}$ group calved younger than those in the $AFS_{14.0}$ who calved at a younger age than those in the $AFS_{15.5}$ group (Table 4).

Lactating performance of primiparous cows

BW recorded immediately after calving was lower for ID2 cows compared to SD and ID1 cows (501 *vs* 542 and 534 kg; P < 0.001; Table 5; Figure 2.A.), which is consistent with the fact that ID2 heifers first calved at a younger age than SD and ID1 heifers (Table 4). No difference between the feeding treatments was noticed in BCS during the first lactation (result not shown). On a 308 d basis, ID2 cows tended to produce less milk than SD and ID1 cows (6920 *vs* 7312 and 7370 kg; P < 0.10; Table 5; Figure 2.C.). There was no difference between feeding treatments regarding average fat and protein contents. However, cows that received the ID2 treatment when heifers produced less FPCM than cows that received either the SD or ID1 treatments (6482 *vs* 6983 and 6973 kg; P < 0.05). Milk yield peak was reduced for ID2 cows compared to both SD and ID1 ones (28.7 *vs* 31.3

and 31.9 kg; P < 0.001). During the first 7 weeks of lactation, ID2 cows were lighter (on average -38 kg compared to SD and -25 kg compared to ID1); and produced less milk (-3.1 kg/d compared to both SD and ID1). This difference decreased during the last part of the period (from 8 to 15 weeks), ID2 cows weighed 27 kg and 17 kg less than SD and HD1 cows respectively; and produced 2.2 kg/d and 2.9 kg/d of milk less than SD and HD1 cows respectively.

Table 5: Effect of the feeding treatment during the rearing period on the productive and reproductive performance of primiparous cows

	Feeding Treatment			Model[1]		Significance levels[2]
	SD1	ID1	ID2	R^2_{adj}	RSE	
Number of records	67	68	24			
Production						
Total milk yield over 308 d (kg)	7312	7370	6920	0.19	706.9	●
Peak milk yield (kg)	31.3^{a}	31.9^{a}	28.7^{b}	0.10	3.50	★★
Average Fat Content (g/kg)	37.0	36.5	36.2	0.10	3.66	0.75
Average Protein Content (g/kg)	30.2	29.7	29.4	0.02	1.53	0.17
Fat and Protein Corrected Milk (kg)	6983^{a}	6973^{a}	6138^{b}	0.26	668.5	★
Conformation						
BW at 1st calving (kg)	542^{a}	534^{a}	501^{b}	0.10	43.0	★★★
BCS at calving (0-5 scale)	2.45	2.40	2.30	0.33	0.296	0.11
BCS at nadir (0-5 scale)	1.85	1.80	1.75	0.43	0.267	0.47
BCS loss to nadir (0-5 scale)	-0.55	-0.60	-0.60	0.44	0.255	0.81
Cyclicity						
CLA (d)	20.9	24.8	20.1	0.00	0.56	0.23
IOI_1	20.7	23.8	24.9	0.04	14.01	0.47
LUT_1	13.3	13.9	14.9	0.18	10.77	0.88
ILI_1	9.6	11.2	7.7	0.04	11.29	0.55
IOI_{2-4}	23.3	23.6	21.2	0.00	5.91	0.42
LUT_{2-4}	13.8	13.7	12.5	0.39	5.79	0.77
ILI_{2-4}	9.0	10.2	9.0	0.45	4.76	0.54
Normal (%)	65%	59%	53%	NA	NA	0.52
PLP (%)	19%	18%	33%	NA	NA	0.44
Delayed (%)	10%	12%	7%	NA	NA	0.81
Fertility						
Number of service per cow	1.9^{a}	2.4^{b}	2.2^{ab}	0.10	1.27	★
Pregnant (%)	86%	85%	87%	NA	NA	0.92
Calf body weight (kg)	38.4	37.8	36.9	0.00	4.84	0.40

[1]*adjusted coefficient of determination:* R^2_{adj}*; and residual standard error: RSE.*

[2]*★★★ P<0.001; ★★ P<0.01; ★ P<0.05; ● P<0.1; the exact P-value otherwise*

[a-b] *Different superscripts point out adjusted means that are different between feeding treatments (P<0.05, Tukey's pairwise comparison)*

The feeding treatment of dairy cows during the rearing period did not affect ovarian cyclicity during the 1st lactation (Table 5). On average, the CLA was about 20.4 d, the first IOI was about 20.7 d with no difference among treatments concerning the LUT and the ILI. There was no difference concerning the subsequent cycles neither, with an IOI of 23.3 d on average. The distribution of abnormal patterns of ovarian activity was not significant, although the ID2 cows showed a lower proportion of normal profile than ID1 cows, that had themselves a lower proportion of normal profiles than SD cows (53% *vs* 59% *vs* 65% respectively; Table 5). ID2 cows had an incidence of 33% of PLP abnormalities, while the incidence in ID1 and SD cows were 18 and 19% respectively (Table 5). About 86% of the cows were pregnant at the end of the breeding season, with no relationship with feeding treatment. Although the difference in cyclicity between feeding treatment did not impair the re-calving rate, ID1 cows needed more inseminations to be pregnant than SD cows (2.4 *vs* 1.9; $P < 0.05$; Table 5). The number of services needed to achieve pregnancy was about 2.2 for the ID2 cows. Subsequent calf BW was not affected by the feeding treatment.

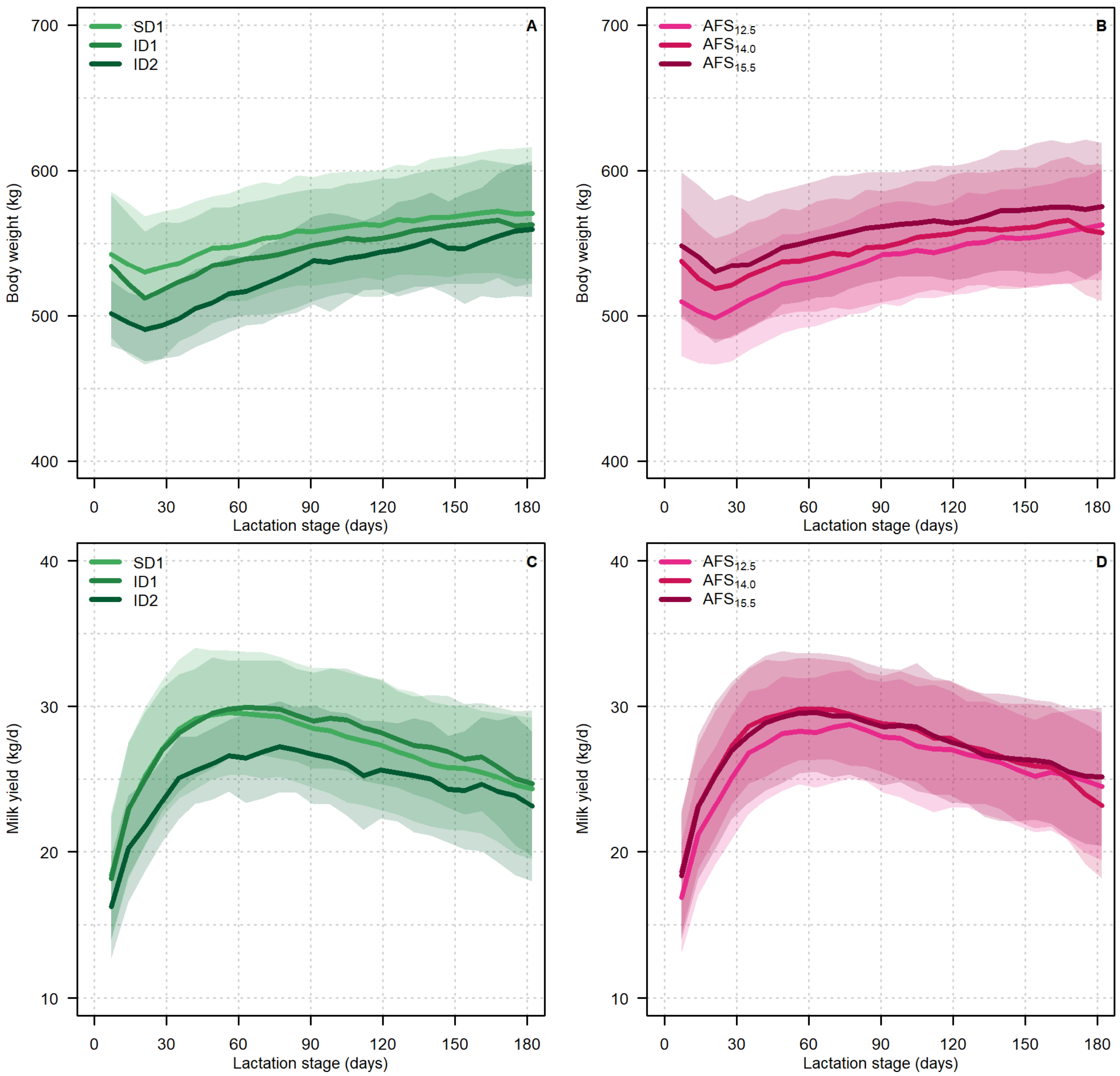


Figure 2: Body weight of the primiparous cows during lactation, according to the feeding treatment (A) and classes of age at first service (B); and milk yield of the primiparous cows during lactation, according to the feeding treatment (C) and classes of age at first service (D).

BW at calving was affected by AFS and was lower for $AFS_{12.5}$ than for $AFS_{14.0}$ and for $AFS_{15.5}$ cows (509 kg *vs* 539 kg and 549 kg respectively, P< 0.001; Table 6; Figure 2.B.). BCS at calving was significantly higher for $AFS_{15.5}$ heifers in comparison of BCS of $AFS_{12.5}$ and $AFS_{14.0}$ (2.45 *vs* 2.35, respectively; P<0.05). After calving, BCS did not differ between groups of heifers. On a 308 d basis, there was no difference in milk yield, composition or FPCM. Only milk yield peak tended to be reduced for $AFS_{12.5}$ (30.2 kg), in comparison of milk yield of $AFS_{14.0}$ and $AFS_{15.5}$ (31.6 and 31.7 respectively; Figure 2.D.; Table 6).

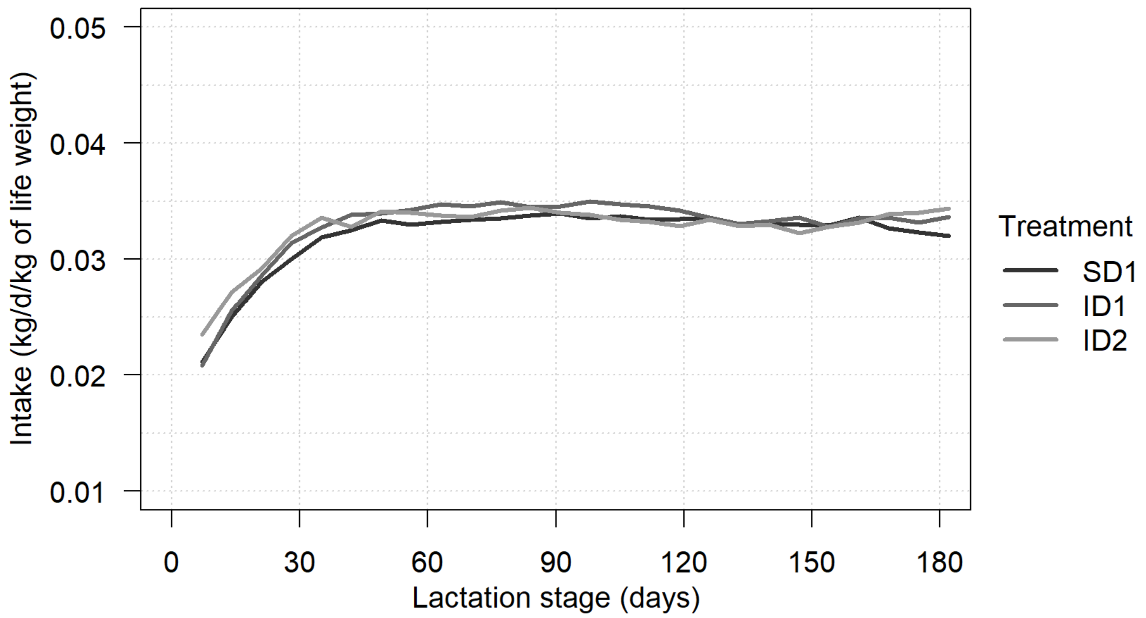
Table 6: Effect of the class of age at first calving on the productive and reproductive performance of primiparous cows

	Age at first service (AFS)			Model[1]		Significance levels[2]
	$AFS_{12.5}$	$AFS_{14.0}$	$AFS_{15.5}$	R^2_{adj}	RSE	
Number of records	51	50	58			
Production						
Total milk yield over 308 d (kg)	7229	7236	7370	0.15	721.7	0.68
Peak milk yield (kg)	30.2	31.6	31.7	0.04	3.59	●
Average Fat Content (g/kg)	36.2	36.9	36.8	0.10	3.65	0.66
Average Protein Content (g/kg)	29.8	29.9	29.9	0.00	1.56	0.93
Fat and Protein Corrected Milk (kg)	6800	6891	7000	0.26	688.4	0.51
Conformation						
BW at 1st calving (kg)	509a	539b	549b	0.14	41.9	★★★
BCS at calving (0-5 scale)	2.35a	2.35a	2.45b	0.34	0.295	0.05
BCS at nadir (0-5 scale)	1.75	1.8	1.85	0.44	0.264	0.13
BCS loss to nadir (0-5 scale)	-0.60	-0.60	-0.55	0.44	0.254	0.41
Cyclicity						
CLA (d)	20.2	23.6	23.7	0.00	0.56	0.39
IOI_1	25.0	19.8	23.2	0.04	13.96	0.31
LUT_1	13.9	12.3	14.9	0.19	10.73	0.57
ILI_1	10.7	8.7	10.7	0.04	11.32	0.68
IOI_{2-4}	23.0	22.3	24.1	0.00	5.92	0.45
LUT_{2-4}	14.5	13.6	12.7	0.39	5.75	0.44
ILI_{2-4}	8.8	8.8	11.1	0.48	4.67	●
Normal (%)	58%	68%	56%	NA	NA	0.55
PLP (%)	29%	8%	23%	NA	NA	★
Delayed (%)	5%	13%	14%	NA	NA	0.23
Fertility						
Number of service per cow	1.9	2.4	2.2	0.08	1.28	0.16
Pregnant (%)	86%	88%	84%	NA	NA	0.90
Calf body weight (kg)	37.2a	39.3b	37.3a	0.04	4.77	★

[1]*adjusted coefficient of determination:* R^2_{adj}*; and residual standard error: RSE.*
[2]★★★ *P<0.001;* ★★ *P<0.01;* ★ *P<0.05;* ● *P<0.1; the exact P-value otherwise*
[a-b] *Different superscripts point out adjusted means that are different between feeding treatments (P<0.05, Tukey's pairwise comparison)*

AFS had minimal effects on fertility. Concerning ovarian cyclicity, all 3 groups of AFS showed a similar CLA, with similar cycles length, except for cows in $AFS_{15.5}$ that tended to show longer ILI between the 2nd to 4th cycle, than cows in $AFS_{12.5}$ and $AFS_{14.0}$ (Table 6) Cows in the $AFS_{14.0}$ group showed a lower incidence of PLP than cows in $AFS_{12.5}$ and $AFS_{15.5}$ (8% *vs* 29% and 23% respectively; $P < 0.05$; Table 6). Fertility was not affected by AFS neither: all groups showed a similar number of inseminations (2.2 on average) and 86% of the cows were pregnant at the end of the breeding season. Subsequent calf BW was heavier for cows in the $AFS_{14.0}$ group compared to cows in $AFS_{12.5}$ and $AFS_{15.5}$ (+2kg; $P < 0.05$; Table 6).

Feed intake was not different neither between feeding treatment, nor between AFS groups (17 kg DM/d), even when it was corrected on the basis of kg of live cow (figure 3).



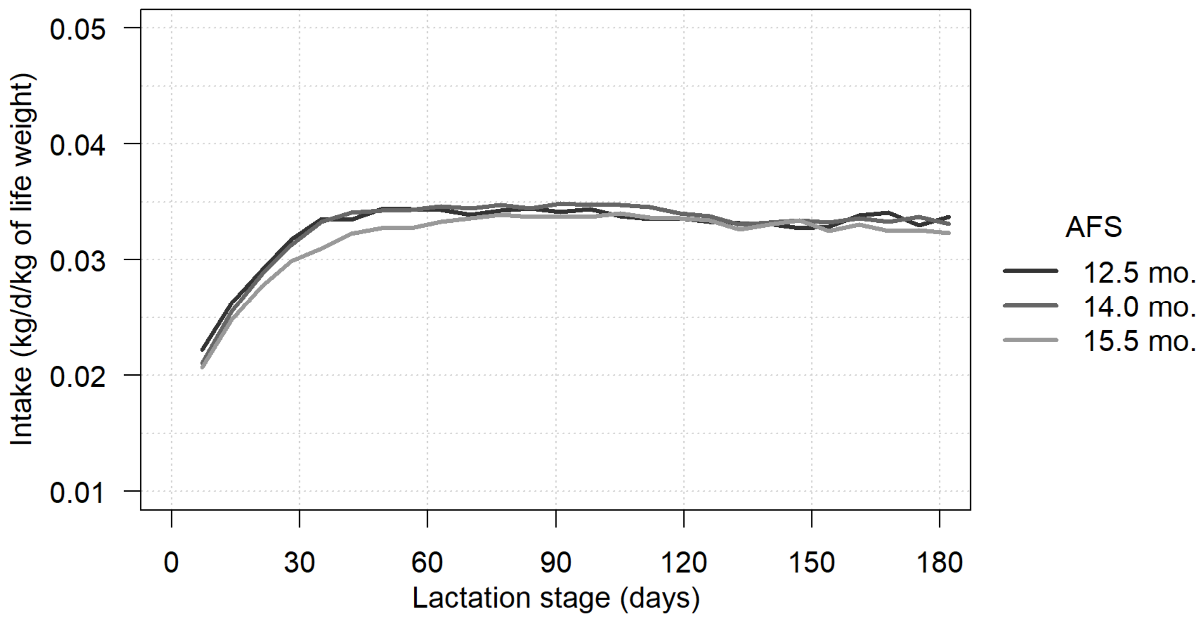


Figure 3: Daily dry matter intake of total Mixed ration per kg of cow during lactation 1, according to the feeding treatment (top) and classes of age at first service (down) of the primiparous cows during lactation.

Morphological traits analysis based on age at first calving cohorts 2009-10 and 2010-11 (supplementary files 1) indicated that young cows at first calving (21 mo of age on average, n= 30; AFC_{21}) were not only lighter compared to heifers first calving at average age of 23.5 (n = 39; $AFC_{23.5}$) or 25 (n = 36; AFC_{25}) mo of age (498 vs 528 and 563 kg respectively, $P < 0.05$) but they also presented reduced morphological traits. For example, HW was 137.4, 139.1 and 140.4 cm for AFC_{21}; $AFC_{23.5}$ and AFC_{25} respectively; $P < 0.05$). However, at a similar age (25 mo for example), no such difference was noticed between treatments (140.7, 140.4 and 142 mm).

Discussion

The present study indicates that reducing age at first service to around 1 year of age, and consequently, age at first calving at 22 mo of age or less had limited impact on performance of Holstein primiparous cows. Several authors have shown that calving down heifers between 23-26 months of age increases longevity and maximises economic returns (Bach 2011; Wathes *et al.,* 2014; Boulton *et al.,* 2017). The early rearing period is a key period to achieve this target, as sub-optimal nutrition delays the onset of puberty and adversely affects skeletal growth and increases the risk of dystocia at first calving (Ettema and Santos 2004). Poor growth is also one of the main reasons for culling heifers prior to calving (Esslemont and Kossaibati 1997). Pre-weaning growth in dairy heifers has generally been associated with performance in first lactation (Khan *et al.* 2011; Soberon *et al.,* 2012). Some studies reported, however, that pre-weaning differences associated with different feeding regimes were no longer statistically significant as calves aged (Morrison *et al.*

2009; Quigley *et al.* 2006). This may in part be explained by compensatory increase in growth for animals when feed allowance (level, energy, protein) is not limited after a period of restriction.

The differences in feed allowance resulted in differences in development and size at 6 and 12 mo of age, but had limited effect on BW at weaning. In a study by Johnson et al (2019), the two treatment groups before weaning induced significant differences in pre-weaning performance and this persisted until six months. In our case, the high level of feed allowance before weaning, without restriction of total mixed ration for control heifers, probably explain why no difference on BW at weaning was observed. In most commercial practices, the amount of milk offered until weaning is low: about 4 to 6 L/day of whole milk, or 400 to 600 g of milk replacer (MR) until weaning at 42-56 days of age (Morrison *et al.* 2009). According to Jasper and Weary (2002), *ad libitum milk* intake is around 12 L/day of whole milk, and in the present study, it was around 9 L/d per heifer until 11 weeks of age. The development and BW of animals at 6 mo of age were high (111 cm heart girth and 220 kg body weight, for example), which fits well with recommendations for optimal age at first calving at 24 mo of age or less. In a study by Ettema and Santos (2004) about the importance of age and BW at first calving for Holstein heifers, only 2.7% of dairy farms achieved the recommended targets weights, which led to economic losses. Total nutrient intake, source of energy and protein content of the diet have additive effects on how calves partition nutrients into tissue (Van Amburgh and Drackley 2005). During the milking phase, calves benefit when MRs contain more protein and less fat, achieving higher levels of skeletal growth (Hill *et al.,* 2010). Providing greater quantities of MR therefore improves both growth and feed efficiency (Bartlett *et al.,* 2006). Increased nutrient intake is also associated with increased plasma level of insulin-like growth factor-1 (IGF1; Smith *et al.,* 2002; Bartlett *et al.,* 2006) which in part regulates the subsequent growth rate (Hammon *et al.,* 2002; Brickell *et al.,* 2009a).

The effect of intensive growth during rearing have been discussed in several papers (Le Cozler et al. 2008), and as already presented in these papers, increasing growth rate resulted in earlier puberty (Abeni *et al.*, 2019). However, authors do not agree on the impact on milk performance. Indeed, while some authors noticed a negative impact on milk production, other did not. Abeni *et al.* (2000) and Van Amburgh *et al.* (1998) concluded that calving earlier than 23 mo of age is associated with lower milk yields and lower milk fat content, although, it also leads to a higher milk protein content. They concluded as well that earlier calving leads to reduced reproduction performance. In a more recent study, Krpálková *et al.* (2014) did not observe effects of age at first calving on milk yields in primiparous cows, except on milk yield during the 100 d of lactation. Authors also noticed the highest milk yield in the second and third lactation for heifers first calving at an age lower than 699 days. In the present study, a negative impact was also noticed only at the start of lactation, but not on overall lactation 1. No information is available on further lactations. In their study, Van De Stroet *et al.* (2016) noticed a tendency to produce more milk during the peak of lactation in primiparous cows which had a high intake of starter feed as calves, compared to first lactation cows which had low intake. However, higher calf growth rates were not significantly associated with future milk yield but were associated with higher BW in lactating cows and higher odds of survival to first lactation. When milk lactation was corrected to BW, no difference was found in milk yield or composition, regardless of rearing treatment.

Decreasing age at first calving is an effective way to decrease the length of non-productive days during rearing and first calving at around 24 months of age appears to be optimal for profitable production (Mourits *et al.,* 1999b; Ettema and Santos; 2004; Shamay *et al.*, 2005). In a metanalysis based on results from 100 herds, Mohd Nor *et al.* (2013) estimated that heifers having a first calving age of 24 mo produced, on average, 7 164 kg of milk per 305 d, and calving 1 mo earlier gave 143 kg less milk on a 305 d lactation length basis. In the present study, we also noticed that younger heifers produced less milk during the first part of lactation, but the total milk yield over 305 d was not different. However, it could be noticed that despite no difference from the statistical point of view, the difference in milk production was very similar when age at first calving decreased from 24.8 to 23.8 mo of age: 134 kg less on a 305 d basis.

In the present study, fertility was not affected by age at first service. In a previous study on puberty attainment based on 2011-12 cohort, we noticed that most heifers reached puberty before oestrus synchronisation, at an average age of 10.3 ± 2.2 mo (6.2 to 14.4 mo), averaging 296 ± 40 kg (224 to 369 kg) BW (Abeni *et al.*, 2019). Puberty was reached one mo earlier for ID2 heifers than in SD and ID1 heifers. Puberty onset at 9 to 10 mo of age or less meant that 3 or 4 oestrous cycles occurred before insemination, which is generally consistent with good fertility results in many species (Lin *et al.*, 1986; Byerley *et al.*, 1987; Robinson, 1990; Le Cozler *et al.*, 1999). Regardless of calving strategy, lowering the age at puberty and, consequently, the age at first insemination, is an efficient way to shorten the non-productive period before calving. However, as suggested by Meyer *et al.* (2006), it might reduce pre-pubertal mammary gland development by shortening the allometric phase of mammary gland growth and, in some cases, impair future milk production. Similar to fertility in heifers, fertility in primiparous cows during first lactation was not affected by age at first calving. Wathes *et al.* (2008) reported that optimal fertility and maintenance of maximum performance in the first lactation were reached at the calving age of 24 to 25 mo, although heifers that calved at the age of 22 to 23 mo were the best in overall performance and longevity over 5 years, partly because heifers with good fertility also had a high level of fertility as cows.

Finally, in the present study, we also noticed that for a similar feed allowance, early calving heifers ate a similar amount of feed, produced less milk and at the end, were able to catch the difference in

BW and development. Collectively, these results indicate that, as already reported by Krpalkova *et al*. (2014), the objective of a rearing period leading to an age at first calving less than 23 mo of age in Holstein heifers proves to be a suitable option for successful rearing of heifers with optimal subsequent production and reproduction in a herd with suitable management. However, performances during lactation 2 and further, as well as longevity of animal, need to be investigated.

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Declaration of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethics statement

Experimental work has been conducted in accordance with French national legislation on the use of animals for research. Protocol received agreement (00944-02) from French Ethical Committee n°7.

Software and data repository resources

None of the data were deposited in an official repository.

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REVISED VERSION AFTER ENGLISH CORRECTION

Effects of feeding treatment on growth rate and performance of primiparous Holstein dairy heifers

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Effects of feeding treatment on growth rates and ~~consequences on~~ performance of primiparous Holstein dairy heifers

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Abstract

The objective of this study was to investigate ~~the~~ effects of feeding~~-~~rearing programs that aim~~ing a~~ for first calving ~~between~~ at 20~~- and~~ 27 months (mo) of age on growth, reproduction and production performance of Holstein cows at nulliparous and primiparous stages. ~~Our~~ We hypothesised ~~was~~ that, in a seasonal autumn~~-~~calving strategy, ~~it was possible for late-born~~ heifers born late in the season ~~to~~ could catch up ~~with~~ to the growth of heifers born earlier and be inseminated ~~at~~ during the same ~~time~~ period, at a ~~370 kg~~ body weight (BW) of at least 370 kg ~~minimum~~. This approach would result in ~~a~~ first calving age at ~~about~~ 21~~- to~~ 22 mo of age~~,~~ without impairing their later performance. To test this hypothesis~~answer this question, an experiment was performed, involving~~, we studied ~~a total of~~ 217 heifers over 3 years. They~~se~~ ~~heifers~~ were split into ~~3~~ three treatment groups: ~~the first group received a~~ control feeding ~~treatment~~ (SD), ~~the second one~~ an intensive-plane diet (ID1) from birth to 6 mo of age~~,~~ ~~and~~ or ~~the last group~~ an intensive-plane diet from birth to~~until~~ ~~1~~ one year of age. Heifers in g~~G~~roups SD and ID1 ~~comprised heifers~~ were born from September until the end of November, while~~;~~ those in ID2 ~~was composed of heifers~~ were born later. The present study showed that late-born heifers (ID2) could catch up with the growth of the others ~~thanks~~ due to the feeding treatment, although they were still 42 kg lighter than ~~both~~ the SD and ID1 ~~ones~~ heifers at first calving. ~~There was~~ N~~n~~o difference in reproductive performance was observed ~~of the heifers between~~ among ~~the~~ groups. Once primiparous, the cows reared with the ID2 treatment tended to produce less milk than SD and ID1 cows (ca.~~about~~ ~~-~~400 kg less ~~over~~ throughout ~~the~~ lactation), and ~~there were~~ no differences in ~~regarding~~ milk composition, feed intake, body condition score~~,~~ or BW were observed among groups. ~~A classification on~~ a~~A~~ge at first service (AFS) was ~~created~~ classified *a posteriori* ~~leading~~ into three~~3~~ classes: ~~with heifers first inseminated at about~~ 12.5 ~~mo~~ ($AFS_{12.5}$), 14.0 ~~mo~~ ($AFS_{14.0}$) ~~or~~ and 15.5 mo ($AFS_{15.5}$) of age. Heifers in $AFS_{12.5}$ ~~had a~~ grew faster ~~growth~~ than those in $AFS_{14.0}$ and $AFS_{15.5}$. Once primiparous, the $AFS_{12.5}$ cows tended to produce less milk at

Mis en forme : Interligne : 1,5 ligne

Commenté [MSC1]: Ou bien "at the same time"

Commenté [MSC2]: Pour préciser "This"; ça va?

Commenté [MSC3]: Suggestion de ne pas utiliser "about" avec une gamme (car elle devrait contenir la variabilité).

peak than AFS$_{14.0}$ and AFS$_{15.5}$ cows (about ca. -1.5 kg/d less), although there was no difference in regarding total milk production yield in the wholeduring lactation was observed. There was Nno differences between these groups regarding in milk composition, feed intake, body condition score, or BW were observed among groups. TAll these results support the conclusion that the feeding treatment it is possible, through feeding treatment, to help can enable late-born heifers to catch up with to the growth of heifers born earlier in the season. This strategy leads toresults in an earlier first calving but that does not impair their reproductive performance but does slightly decrease milk production yield slightly (by 400 kg) during first lactation 1 (- 400 kg) on a 305 d basis. Future studies should investigate lLong-term effects of such this strategy need to be investigated.

Key words: dairy cattle, heifer, growth, reproduction, feeding treatment

Implications

Increasing the growth rate of dairy heifers decreased their age at puberty, potentially reducing age at first calving, and ultimately shortening the non-productive rearing period. Heifers first calveding at 22.5 months (mo) of age or less presented had similar performances similar than to those heifers that first calveding at 23.8 mo of age or older.

Introduction

In seasonal calving systems, heifers usually first calve at a young age (around ca. 24 months (mo)). but The first1st insemination (i.e. service) may be delayed, however, for those heifers born at the end of the calving period if an adequate body weight (BW) is not reached (i.e. 360- to 380 kg for Holstein heifers in French dairy herds; Le Cozler *et al.*, 2008). Increasing nutrient uptake and thus the growth rate for of these late-born heifers is onea solution to lower this risk. A hHigh growth rate during rearing is associated with a decreased age at puberty and;, consequently, 1st first calving may occur as early as 20- to 21 mo of age. Tozer (2000) concluded that a higher plane of nutrition incurred higher daily feed costs, but these costs were recouped when heifers calved at a younger age through savings on labour, housing and overall feed costs. Regardless of the rearing strategy of rearing (group -calving or not), it is, however, necessary for animals need to have reach achieved an adequate body size before calving or to avoid compromising milk production potential induring the first lactation is compromised (Bach and Ahedo, 2008). Indeed, the use ofan accelerated growth program for dairy heifers cannot be resumed tofocus only on early puberty attainmentonset of puberty. Many authors have studied the impact influence of growth intensity on further future performances (see the literature review of Le Cozler *et al.*, 2008)., but if Mmost studies of them indicated that a too--rapid growth rate had a negative impactinfluence of too rapid a growth, while s, some authors indicated that accelerated growth had limited little impact of accelerated growth. According to Pirlo *et al.* (1997), reducing the age at of first calving to 23 to 24 mo was the most

Commenté [MSC4]: Pour cohérence du terme utilisé le plus souvent dans le manuscrit

Commenté [MSC5]: Ajouté pour préciser « This ».

Commenté [MSC6]: J'aurais tendance de ne pas répéter le même résultat deux fois dans le même résumé. Je supprimerais cette instance-ci.

Commenté [MSC7]: Je déplacerais ce détail avec la première mention de "400 kg de moins" plus tôt dans le résumé.

Commenté [MSC8]: Pour cohérence de votre utilisation de ce terme dans l'Introduction

Commenté [MSC9]: Suggestion d'ajout pour lier « first insemination » à « first service », qui est le terme utilisé après dans le manuscrit.

Commenté [MSC10]: Vous parlez de « body weight » après. Serait-il plus cohérent de l'utiliser ici, aussi ?

Commenté [MSC11]: Est-ce que c'est ça que vous vouliez dire ?

profitable procedure, but no~~t~~ less than 22 mo (except in cases of low milk prices and high rearing costs). They concluded that the reluctance to decrease the age ~~at~~ of first calving is generally attributed~~able~~ to the belief that early calving is detrimental to milk yield and longevity. ~~Here,~~ W~~w~~e designed and ~~carried out~~conducted an experiment to determine the ~~effects~~ influence of feeding treatments on growth parameters, reproduction and the production performance of Holstein primiparous heifers that first calved~~ing~~ ~~between~~ from 20-~~ and~~ 27 mo of age~~,~~ in a seasonal calving system. We ~~hypothesised~~ assumed that genetic improvements ~~over the last decades~~ in dairy production over the past few decades had yielded~~resulted in~~ animals that could calve~~d~~ ~~now at an~~ earlier ~~age~~ than 24 mo of age. We also ~~presumed~~ assumed that results ~~from~~ for animals ~~raised~~ reared ~~in~~ in a seasonal calving strategy could be used and generalis~~z~~ed for those in a non-grouped~~ing~~ strategy. We examined the ~~possibility~~ potential for late-born heifers to catch up ~~with~~ to the rest of the heifers ~~at~~ by the ~~1st~~ first artificial insemination (AI) at a minimum BW of 370-~~ to~~ 380 kg, resulting in a first calving at less than 22 mo of age ~~at first calving~~.

Material**s** and methods

General design

A total of 217 Holstein heifers, born during the calving season in 2009-10 (n = 65), 2010-11 (n = 73~~)~~) and 2011-12 (n = 76) ~~calving seasons~~ (September to February), were reared and followed until oestrus synchronisation (12-~~ to~~ 15 mo of age) at the INRA experimental farm of Méjusseaume (Le Rheu, France). ~~Another study based on the same experiment (heifers born 2011-12) was already published, where~~ For details of the rearing procedures and strategies used in the present study, see~~have been fully detailed for one of them (~~Abeni *et al.*~~,~~ (2019), who studied heifers in this experiment born in 2011-12. ~~Briefly, C~~Calves born ~~between~~ from 1st ~~of~~ September ~~and~~ to 30th ~~of~~ November were alternately ~~allocated~~ assigned to 1 of two~~2~~ nutritional treatments (according to birth order) and fed either a standard diet (SD) or an intensive-plane diet (ID1) from 0-~~ to~~ 6 mo of age. It was expected that heifers fed ~~, due to~~ the~~ feeding intensity chosen, heifers fed~~ SD and ID1 diets would reach 190-~~ to~~ 200 and 220-~~ to~~ 230 kg at 6 mo of age, respectively. Heifers born after 1st ~~of~~ December (ID2) received the same intensive-plane diet as ID1 heifers from 0-~~ to~~ 6 mo of age~~,~~ to ~~limit~~ a decrease ~~the possible~~potential ~~confusion~~ interaction ~~effect~~ between age and treatment during this period. Thereafter, a ~~complementary~~ supplemental diet was formulated for ID2 heifers ~~in order~~ to enable them to reach 380 kg at 12 mo~~1 year~~ of age. The main objective of ~~this latest latter procedure~~the ID2 diet was to study the ~~possibility~~ potential for late-born heifers to catch up ~~with~~ to the rest of the heifers by the first~~s at 1st artificial insemination (~~AI~~)~~ at a minimum BW of 370~~ to~~ -380 kg. It was expected that this strategy would correspond~~ed~~ to a mean ~~average~~ age~~s~~ of 15 ~~and~~ mo ~~12 mo~~ for ~~(~~SD and ID1 heifers~~)~~ and 12 mo for ~~(~~ID2~~)~~ heifers~~, respectively~~. ~~During~~ In year ~~1~~one, heifers grazed from mid-May until the end of October. ~~During~~ In year ~~2~~two, heifers grazed~~ing~~ ~~started~~ from the ~~in~~ end of March until calving season (starting 1st September). ~~From~~ At the end ~~of~~of the first ~~1st~~

Commenté [MSC12]: Pour cohérence avec l'anglais britannique choisi

Commenté [MSC13]: Suggestion pour faire plus concis et direct

Commenté [MSC14]: Suggestion pour cohérence du terme (et l'unité) utilisé le plus souvent

Commenté [MSC15]: Suggestion pour précision

Commenté [MSC16]: Maintenant assez redondant avec la nouvelle phrase ajoutée à la fin de l'Introduction

Commenté [MSC17]: Suggestion pour préciser « this ». Correct ?

grazing season~~ of grazing~~, all heifers were group~~ed~~-housed until being turn~~ed~~~~ing~~ out to pasture in the second season~~ 2~~. Three weeks before the expect~~ed~~~~ing~~ date of calving, heifers ~~entered~~ were placed in cow~~s~~ herd~~s~~ and ~~were~~ individually fed ~~individually~~ a similar total mixed ration (TMR). During lactation, milk yield was recorded twice per~~a~~ day, and animals were weighed ~~every~~ once per day. The experiment ended ~~week~~ 15 weeks after calving.

Feeding management

Diets were formulated for ~~the different~~each growth stage~~s of growth~~ according to recommendations and procedures ~~presented~~ developed by Agabriel and Mechy (2007)~~,~~ to reach a targeted average daily gain (ADG) per period, ~~with respect to~~as a function of the initial BW and feeding treatment used. ~~Briefly, I~~in this approach, energy is expressed per UFL (~~f~~Forage ~~u~~Unit for lactation, g/kg), which ~~correspond to~~is the net energy required for lactation (g/kg)~~-~~/1760. For protein, PDIN (protein digestible in the small intestine, g/kg) and PDIE (protein digestible in the small intestine, g/kg) are used. PDIN ~~correspond to~~is the protein ~~digestible in the small intestine~~ supplied by rumen-undegrad~~able~~eed dietary protein (PDIA) ~~+~~ plus that~~protein digestible in the small intestine~~ supplied by microbial protein from rumen-degrad~~able~~eed dietary protein. In comparison, PDIE is ~~the protein digestible in the small intestine supplied by rumen-undegraded dietary protein~~PDIA ~~+~~ plus the ~~protein digestible in the small intestine supplied by~~ microbial protein from rumen-fermented organic matter (INRA, 2007). At the end of the pre-experimental phase (0-10 d), heifers were group-housed indoors on ~~cumulated~~ straw bedding. They were fed a reconstituted milk replacer (MR) made ~~of~~ from 135 g milk powder (23.9~~-~~% crude protein and 19.0~~-~~% ~~-~~fat content) ~~with~~ and 865 g water per ~~litre~~ L until weaning (~~about~~ ca. 77~~- to~~ 84 d of age). They were reared in dynamic groups~~:~~, ~~meaning that~~ calves entered the group ~~every~~ each week, while others left it at weaning (70~~- to~~ 77 days). They were individually fed with automatic milk feeding systems (AMFS), with ~~*free*~~ *ad libitum* access to fresh water, straw and hay. Group size ~~varied~~ ranged from 8~~- to~~ 24 calves per AMFS. From day 11, milk was distributed according to ~~either~~ the standard ration routinely used in the experimental herd (SD) or ~~an~~ the standard ration increased by 15% ~~milk ration~~ (ID1 & ID2). All calves were fed ~~ad libitum total mixed ration~~TMR no. 1 (TMR1) *ad libitum* (~~TMR1;~~ Table 1).

Table 1: Ingredients and chemical composition of the experimental diets

Item[1]	TMR1	TMR2	TMR3a	TMR3b	TMR4	TMR5	TMR6	TMR7
Stage of growth, age	(7 d to 4 mo)	(4 to 6-~~/~~8 mo)	(9-~~ to~~ 11 mo)	(6-~~ to~~ 11 mo)	(11-~~ to~~ 15 mo) *(winter 1)*	(21-~~ to~~ 26 mo) *(~~-~~21 d ~~prior~~ before*	(21-~~ to~~ 26 mo) *Calving + 14 d*	(21-~~ to~~ 35 mo) *(15 d after calving until end of*

Commenté [MSC18]: Cette courte définition est la même que celle pour PDIN. Possible d'ajouter un mot à chacune pour les rendre différentes ?

Commenté [MSC19]: Ajouté pour donner les unités, comme pour PDIN ; correct ?

Commenté [MSC20]: Pour cohérence du terme vu plus souvent sur Google Scholar

Commenté [MSC21]: J'ai suggéré de définir un sigle ici pour pouvoir l'utiliser dans la phrase suivante, car les deux phrases sont tellement longues et répétitives. Est-ce que PDIA marche, ou faudrait-il utiliser un autre ?

Commenté [MSC22]: Suggestion pour faire plus court ; est-ce que ça marche ?

Commenté [MSC23]: « cumulated » ne marchait pas avec « straw bedding ». Voulez-vous utiliser « deep straw bedding », comme vous le faites plus tard ?

Commenté [MSC24]: Pour définir le sigle à la première instance du terme

Commenté [MSC25]: Pour cohérence de terme ; correct ?

Mis en forme : Police :Italique

Mis en forme : Police :Non Italique

Mis en forme : Police :Non Italique

Tableau mis en forme

Commenté [MSC26]: Ajouté pour précision ; correct ?

						calving until calving)		*lactation)*
Feeding ~~T~~treatment ~~group~~	All	All	SD, ID1	ID2	All	All		All
Ingredient, %								
~~Corn~~ Maize silage	47.5	72.0	80.0	80.0	79.0	84.5	52.5	65.0
Soya bean meal	-	8.0	20.0	20.0	21.0	9.0	8.0	8.0
18% CP ~~alfafa~~ lucerne pellets	5.0						10.0	10.0
Straw						2.5	2.5	2.5
Urea								0.8
Vitamins & ~~m~~Minerals ~~+ vitamins~~								1.0
Concentrate 1[2]	47.5	20.0						
Concentrate 2[3] (kg/head/d)			1.0	2.0	1.0			
Concentrate 3[4] (%)						4.0	25	15.0
Estimated chemical composition								
DM, %	51.4	42.0	42.2	46.0	42.1	38.6	48.8	44.4
PDIE, g / kg DM	93.0	93.1	104.5	103.1	106.2	85.0	93.7	89.6
PDIN, g / kg DM	79.8	84.0	108.7	108.5	111.3	72.8	83.9	91.3
UFL / kg DM	0.96	0.96	0.98	1.00	0.99	0.93	0.93	0.92

[1] abbreviations: TMR: ~~T~~total ~~M~~mixed ~~R~~ration; SD, ID1, ID2: animals fed ~~either on~~ a standard (SD) or increased-plane (ID1 & ID2) feeding treatment; DM: dry matter; ~~UFL (Forage Unit for lactation, g/kg); PDIN (protein digestible in the small intestine, g/kg);~~ PDIE (protein digestible in the small intestine, g/kg); PDIN (protein digestible in the small intestine, g/kg); UFL (forage unit for lactation, g/kg) (INRA, 2007).

[2] Chemical composition: DM 88.7%; PDIE 118 g; PDIN 114 g; UFL 1.05.

[3] Chemical composition: DM 87.9%; PDIE 81 g; PDIN 90 g; UFL 0.96.

[4] Chemical composition: DM 87.7%; PDIE 101 g; PDIN 76 g; UFL 1.05.

From weaning to 6-8 mo of age, calves were housed on deep straw bedding with *ad libitum* access to fresh water and straw. Until 4 mo of age, the SD group received TMR1 *ad libitum* until the maximum daily allowance of concentrate intake reached 2 kg dry matter (DM)/head/d. No restriction was applied ~~to~~ for ID1 ~~&~~ or ID2 heifers. From 4 to 6-8 mo of age, TMR2 was distributed *ad libitum* until ~~the maximum daily allowance of~~ concentrate intake reached 2.0 ~~kg~~, 2.5 and 2.5 kg DM/head/d for SD, ~~and (~~ID1 and~~&~~ ID2~~)~~ heifers, respectively~~,~~ (i.e. ~~a~~ total daily allowance of 10.0, ~~and~~ 12.5 and 12.5 kg DM/head/d ~~of TMR2 for SD and (ID1 & ID2) heifers~~, respectively). These amounts did not change until being turned~~ing~~ out to pasture.

~~Starting from mid-May and mid-June for (~~SD, ~~&~~ ID1~~)~~ and ID2 heifers, ~~heifers~~ were turned out to pasture from mid-May, mid-May and mid-June, respectively, and rotationally grazed on a perennial ryegrass sward. After a 5-d transition phase and throughout the ~~pasture~~ grazing season, the SD and ID1 groups received a ~~daily~~ supplement of 1 kg DM/heifer/d of concentrate 2.~~,~~ ~~whereas~~ ~~t~~The ID2 group received 1 kg DM/heifer/d of ~~corn~~maize silage and 2 kg DM/heifer/d of concentrate 2. Grass availability and/or quality were insufficient to maintain the desired growth rates during summer. SD and ID1 heifers then received up to 2.5 kg DM/heifer/d of additional TMR3a, plus 1 kg DM/heifer/d

Commenté [MSC27]: Pour cohérence avec l'anglais britannique

Commenté [MSC28]: Normalement dans cet ordre en anglais

Commenté [MSC29]: Comme avant, possible d'ajouter 1-2 mots aux deux courtes définitions pour les distinguer ?

Commenté [MSC30]: Ajouté pour clarté et cohérence ; correct ?

Commenté [MSC31]: Mis dans l'ordre affiché dans le tableau

Commenté [MSC32]: Suggestion de mettre les détails de la formulation ici, dans la première phrase de cette description. Est-ce que ça marche ?

Commenté [MSC33]: Pour définir le sigle DM pour la première instance de « dry matter » dans le corps du texte.

Commenté [MSC34]: Me semblait plus compréhensible comme ceci, sans les parenthèses

Commenté [MSC35]: Pour cohérence d'unité utilisé après of concentrate 2.~~;~~ ID2 heifers received up to 3 kg DM/heifer/d of TMR3b, plus 2 kg DM/heifer/d of concentrate 2. To ~~achieve~~ reach 380 kg at the end of the outdoor season (when oestrus synchronisation started), the expected ADG for SD and ID1 heifers was ~~estimated to be around~~ca. 600 g/d during this period, with a feeding regime based on ~~pasture~~ grass plus 1 kg DM/heifer/d of concentrate 2, and 800 g/d when receiving grass plus TMR3a. For ID2 heifers, it was estimated that grass alone was not sufficient to reach 900 g/d during the same period, so~~and~~ TMR3b was used (Table 1). In the pasture area, a permanent headlock barrier (80 places on a concrete floor) was used daily to feed concentrate to SD and ID1 heifers ~~with their concentrate~~. Heifers were locked in for 1 hour while eating~~,~~ to ~~limit~~ decrease competition between heifers for feed ~~intake between heifers~~. Since t~~T~~he I~~S~~D2 group had *~~free~~ ad libitum* access to ~~its~~ the ration, ~~and so,~~its heifers were not locked in.

At the end of the first ~~pasture~~ grazing season (~~1st~~ the first week of November), heifers were group-housed (8 heifers/pen) on deep straw bedding and received 3.8 kg DM/head/d of a diet containing 79% ~~corn~~ maize silage and 21% soya bean meal. They had *~~free~~ ad libitum* access to fresh water, straw and mineral ~~complements~~supplements.

Vitamins and m~~M~~inerals ~~and vitamins~~, when not included in the concentrate during rearing, were included in ~~licking stones~~mineral blocks~~,~~ that containeding ~~for minerals per kg of DM:~~, 2.5 % Ca, 2.0 % Mg and 32.5 % Na per kg of DM, as well as ~~and~~ (in mg/~~per~~ kg)~~,~~ Zn (10 000) ~~mg Zn~~, Mn (8250) ~~Mn~~, Cu (1500) ~~Cu~~, I (200) ~~Io~~, Se (20) ~~Se~~ and Co (13) ~~Co~~. The concentrates during growth contained 4% P, 27% Ca, ~~and~~ 5% Mg, plus vitamins (in~~per~~ UI/kg)~~,~~ (1 000 000 vitamin A, 350 000 vitamin D3~~,~~ and 8 000 vitamin E). ~~It~~ They also contained~~,~~ (in ~~per~~ mg/kg)~~,~~ Cu (1500), Zn (10 000), I~~o~~ (200), Co (100) and Se (10). During lactation, the mineral ~~complement~~ supplement contained 7% P, 22% Ca and 4% Mg, plus vitamins ~~per~~ (in UI/kg)~~,~~ (500 000 vitamin A, 100 000 vitamin D3 and~~,~~ 1 500 vitamin E). It also contained~~,~~ (in ~~per~~ mg/kg)~~,~~ Cu (1000), Mn (3500), Zn (4530), I~~o~~ (80), Co (35) and Se (22).

After a 2-week adaptation period, heifers' oestrous cycles were synchronised ~~in heifers~~ (see below), and the same rearing procedure ~~of rearing~~ was applied ~~for~~ to all heifers. Heifers were turned out to pasture (generally in March) ~~Depending~~ based on their~~r~~ date of successful insemination. ~~, heifers turned out to pasture (generally in March).~~ They were ~~them all~~ reared in an~~n~~ ~~unique~~ single group and received no additional feed ~~but~~ except for grass, ~~with~~ along with the ~~exception a~~ supplemental vitamins and minerals ~~and vitamins complementation~~.

All heifers were housed indoors t~~T~~hree weeks before the expected date of calving, ~~all heifers were housed indoors, together~~ along with multiparous cows, in a cubicle barn with fresh straw bedding that was distributed daily. Heifers were fed individually and received ~~a daily~~ TMR5 daily, composed of ~~corn~~maize silage (84.5 %), soya bean meal (9 %), concentrate (4 %) and straw.

Commenté [MSC36]: « grazing », pour cohérence ?

Commenté [MSC37]: Pour cohérence de terme

Commenté [MSC38]: Correct que c'est ceci et pas le « SD2 » que vous aviez ?

Mis en forme : Police :Italique

Commenté [MSC39]: Pour cohérence avec l'anglais britannique

Mis en forme : Police :Italique

Commenté [MSC40]: Je pense qu'un terme plus commun est celui-ci. Sinon, il y a « salt licks ».

Commenté [MSC41]: J'ai tenté de rendre ces listes plus claires et cohérentes.

From calving to 14 d post-calving, cows individually received TMR6, which ~~was composed of~~contained ~~corn~~maize silage (52.5 %), soya ~~a~~ bean meal (8 %), concentrate (25 %), dehydrated lucerne (1 %), ~~mineral/~~vitamin/mineral ~~complement~~supplements, urea and straw (Table 1).
From day 14 after calving, cows individually received TMR7, which contained~~composed of~~ ~~corn~~maize silage (65 %), soya bean meal (8 %), concentrate (15 %), dehydrated lucerne (1 %), urea and vitamin/~~completed with~~ mineral~~/vitamin~~ supplements ~~complement~~ (7% P, 22% Ca and 4% Mg). ~~During lactation, A~~All ~~heifers~~ cows were fed *ad libitum* during lactation~~,~~ ~~based on~~assuming ~~a~~ at least 10% refusal ~~at least~~ per day. Feed was distributed twice ~~a~~ per day (09:00 and 16:30), and refusals were collected ~~every~~ each morning~~,~~ (7:00) before fresh TMR was distribute~~d~~~~ion of fresh TMR~~.
The ~~c~~Chemical composition of TMR ~~components~~ ingredients produced on-farm (~~corn~~maize silage, straw) was determined ~~when~~ at harvest~~ed~~, and ~~analysis were was performed on~~ an average sample of each was analysed when the ~~changing~~ storage silo or, for straw, field of ~~-straw~~ origin changed. This average sample ~~originated~~ came from daily sample. However, ~~dry matter~~DM was determined at least once a week ~~on~~ for all TMR ~~contents~~ingredients. A similar procedure was applied ~~for~~ to concentrate feed. The manufacturer ~~a~~Analys~~ed~~is ~~was performed by manufacturer~~ the feed ~~before delivering~~ (e.g. concentrate~~;~~, soya bean) before delivering it, and we compared it to the average sample when changing feed. The estimated chemical composition of TMR was then determined using INRAtion® ~~s~~Software (INRA, 2010)~~,~~ based on these analys~~e~~is and the percentage of each ingredient in the TMR. ~~Because of~~Due to ~~possible~~ potential changes in composition (e.g. ~~dry mater~~DM or grain content of ~~corn~~maize silage~~, for example~~), TMR composition was checked regularly, and the amount of each ingredient was adapted accordingly.
~~Pasture~~Grass intake was not measured ~~in present study~~.
~~During the entire experiment, a~~All heifers and cows housed indoors had ~~free~~ *ad libitum* access to fresh water during the entire experiment.

Age at first service

~~A classification based on a~~Age at first service (AFS) was then ~~created~~ classified *a posteriori* ~~in order~~ to ~~better~~ understand better which factors could ~~lead to different~~influence AFS and how future performance ~~can~~ may be related to AFS. Three ~~groups~~ classes were created, with nearly an equal number of animals in each ~~of them~~ (Table 2).

Table 2~~.~~: Description of the classes of age (in mo) at first service (AFS)

Characteristic	$AFS_{12.5}$	$AFS_{14.0}$	$AFS_{15.5}$
AFCS[1]	12.6 (0.73)	14.2 (0.36)	15.4 (0.65)
Total ~~number~~heifers	58	57	60
~~Number~~ Heifers in SD	16	29	29
~~Number~~ Heifers in ID1	15	27	30

Commenté [MSC42]: Ajouté pour précision et cohérence ; correct ? Aussi correct de les appeler « cows » au lieu de « heifers » une fois qu'elles ont eu des veaux ?

Commenté [MSC43]: Pour cohérence du terme utilisé avant ; correct ?

Commenté [MSC44]: Suggestion de remonter cette information ici, pour cohérence au sein de la phrase.

Commenté [MSC45]: Pour précision ; correct ?

Commenté [MSC46]: Pour précision et cohérence ; corect ?

Commenté [MSC47]: Pour précision

Commenté [MSC48]: Pour cohérence de terme

Mis en forme : Police :Italique

Commenté [MSC49]: Suggestion d'ajout pour précision

Tableau mis en forme

Commenté [MSC50]: Ajouté pour avoir un en-tête dans chaque colonne ; ça va ?

Commenté [MSC51]: Correct ?

Commenté [MSC52]: Suggestion pour précision

~~Number~~ Heifers in ID2	27	1	1

[1]*Mean (and standard deviation) of age at first calving (AFC) ~~with standard deviations in parentheses~~*

Oestrus synchronisation

All heifers were inseminated after oestrus synchroni~~s~~zation during the second winter ~~2~~ of rearing~~,~~ so that calving would occur at ~~around~~ca. ~~two years~~24 mo of age. At the end of November, oestrus was synchronised for nearly half of the heifers~~, oestrus was synchronized~~ using a progestin ear implant (Norgestomet®, Intervet, Angers, France), ~~in conjunction~~ along with an intramuscular injection of oestrogen ~~injection~~ (Crestar®, Intervet, Angers, France), without consider~~ingation of~~ ovarian activity. A second synchroni~~s~~zation was performed three weeks later for the ~~rest~~ remaining ~~of the~~ heifers. The ear implant was removed aAfter ~~nine days~~9 d of treatment~~, the ear implant was removed~~. Heifers generally ~~exhibited~~ showed signs of oestrus within 24~~- to~~ 96 h and were ~~then~~ inseminated ~~on~~ when oestrus was detected ~~oestrus~~. ~~In case of~~Heifers that fail~~edure~~ to conceive but~~,~~ ~~heifers~~ exhibit~~eding~~ further signs of oestrus were inseminated ~~until~~ at the end of the reproductive season (April). Ultrasonography was conducted an average of 42 d after insemination~~, on average,~~ ~~in order~~ to ~~diagnose~~ determine pregnancy. Non-gestating heifers were ~~then removed~~excluded from the rest of the experiment.

Sampling and measurements

Heifers were weighed every 14 d from birth to weaning, every 21 d from weaning until being turn~~ed~~ing out to pasture~~,~~ and every 28 d until the end of the experiment. BW was i~~I~~nterpolat~~ed~~ions ~~were performed~~ ~~in order~~ to compare the BW of heifers at similar stages of growth. ADGs ~~verage daily gains~~ were then calculated. Heifer health and care information was recorded ~~during~~ throughout the experiment. The~~ir~~ body condition score (BCS) was recorded ~~3~~ three weeks before the expected date of calving and then~~,~~ once a month. The method and scale (ranging from 0~~- to~~ 5) developed by Bazin *et al.* (1984) ~~that ranged from 0 to 5,~~ was used. BCS was scored by ~~3~~ three trained technicians, whose ~~and their records~~ scores were averaged.

Five measurements were recorded t~~T~~o monitor morphological traits during rearing and first lactation~~, five measurements were recorded~~: heart girth (HG), chest depth ~~(CD)~~, wither height (WH), hip width ~~(HW)~~ and backside width ~~(BaW)~~. A tape measure was used to measure HG, while a height gauge was used for the other measurements. The~~se~~ measurements were recorded only for the ~~2~~ two first~~s~~ cohorts (2009-10 and 2010-11)~~;~~. ~~S~~results ~~are presented~~ ~~shown on~~ ~~in the~~ ~~complementary~~ ~~s~~supplementary data 1 and F~~f~~ig~~uress~~. 1 and~~&~~ 2). ~~Presentations are~~Results were interpreted by ~~based on a~~ classi~~fication~~ o~~f~~n age at first service (AFC), which was created ~~a posteriori~~later (not ~~presented~~ shown ~~and~~ or discussed in the present ~~paper~~article).

Daily feed intake was calculated individually as the ~~difference between~~ daily feed allowance and minus refusals, which~~.~~ ~~Refusals were collected every~~ each day at 7.00 and were weighed. The

Commenté [MSC53]: Ça va comme ça ?

Mis en forme : Police :11 pt, Non Gras, Non Italique

Mis en forme : Paragraphes solidaires

Commenté [MSC54]: Suggestion pour cohérence d'unité utilisée le plus souvent

Commenté [MSC55]: Pour cohérence de format et d'unité

Commenté [MSC56]: J'ai suggéré de supprimer les sigles pas utilisés après dans le corps du texte.

Commenté [MSC57]: Serait-il « Supplementary Materials » ?

Commenté [MSC58]: Voulez-vous dire « age at first calving » ici ? Sinon, je mettrais « AFS », car le sigle AFS est déjà défini.

allowance and ~~composition of the~~ refusals ~~and allowance~~ were ~~presumed~~ assumed to have ~~be~~ the same composition. ~~Dry matter (~~DM~~)~~ ~~for~~ of silage was determined ~~5~~ five times per week, while the DM of the pellets was determined once ~~a~~ per week. Feed composition was estimated ~~based on~~from average samples for ~~corn~~ maize silage, straw, soya bean~~,~~ and concentrate. ~~No such This information~~Composition was not available for fresh grass (~~see~~ Table 1).

Commenté [MSC59]: Pour cohérence avec l'anglais britannique

Commenté [MSC60]: Pour précision ; correct ? (Vous avez déjà dit que « grass intake » n'était pas mesuré.)

Milk content analysis

Mis en forme : Paragraphes solidaires

Milk ~~production~~ yield was automatically recorded at each milking (i.e. twice per day~~daily~~). During ~~6~~ six successive milkings (Tuesday~~-~~ ~~to~~ Thursday), milk samples were collected and analysed ~~from~~ for each cow~~,~~ to determine the fat and protein contents (Milkoscan, Foss Electric, ~~DK-3400~~ Hillerod, Denmark). ~~).~~ Fat~~-~~ and~~-~~ protein~~-~~ corrected milk (FPCM, kg) was calculated ~~with~~ using the following equation (INRA, 2018):

Commenté [MSC61]: Pour cohérence du terme utilisé le plus souvent dans le texte

Commenté [MSC62]: J'ai suggéré de supprimer le code postale, qui ne me semblait pas nécessaire dans le manuscrit.

$$FPCM = MY \times \frac{[0.42 + 0.0053 \times (FC - 40) + 0.0032 \times (PC - 31)]}{0.42}$$

where ~~FPCM stands for~~is ~~fat and protein corrected milk (kg),~~ FC ~~stands for~~ is milk fat content (g/kg), ~~and~~ PC ~~for~~ is milk protein content (g/kg)~~;~~ and 0.42 is the UFL value for 1 kg of milk containing 40 g/kg of fat ~~matter~~ and 31 g/kg of protein ~~matter~~.

Milk progesterone analysis

Morning milk samples were collected Monday, Wednesday~~,~~ and Friday f~~F~~rom calving to ~~either 2~~ two weeks after the service that induc~~ed~~ing pregnancy, or ~~to 5~~five weeks after the end of the breeding season (i.e. July), ~~morning milk samples were collected on Monday, Wednesday and Friday,~~ and ~~then~~ were then stored at -20°C ~~for~~ to determine progesterone ~~determination by~~using commercial ELISA kits (Milk Progesterone ELISA, Ridgeway Science Ltd., England). ~~The c~~Coefficients of variation ~~between~~ among assays for ELISA on 5 ng/ml control samples ranged ~~between~~ from 8~~-%~~ ~~and~~ 14-% among experimental years.

Determin~~ing~~ation ~~of~~ Luteal Activity

Two progesterone (P4) milk concentration thresholds were defined, ~~as in~~following Petersson *et al.* (2006) and adapted by Cutullic *et al.* (2011), to distinguish (i) the baseline P4 level in milk from the luteal phase level (threshold 1) and (ii) a low luteal phase level from a high luteal phase level (threshold 2). P4 values were ~~qualified~~ classified as ~~follows:~~ negative (< threshold 1), positive (> threshold 2) ~~and~~ or intermediate. ~~In short, rises of~~An increase in P4 milk concentrations ~~were~~ was considered to be induced by corpus luteum activity ~~if~~ when at least ~~2~~ two consecutive values were not negative and at least one was positive. Due to the sampling ~~collection procedure~~schedule (Monday, Wednesday and Friday), the interval between samples ~~collection~~ was ~~either~~ 2 d or 3 da~~ys~~. ~~Reduction~~ A decrease in P4 milk concentrations ~~were~~ was considered to result from luteolysis of the corpus luteum when at least ~~1~~ one value became negative. These definitions ~~enabled~~ helped to identify and distinguish luteal phases from inter-luteal phases.

Qualifying~~ication~~ ~~of~~ Progesterone Profiles

Physiological intervals were calculated f~~F~~or each luteal phase~~, physiological intervals were computed~~: commencement of luteal activity (CLA), cycle length (IOI), luteal phase length (LUT) and inter-luteal interval (ILI)~~;~~ (for details, see Cutullic *et al.*, 2011). Ovulation was considered to induce a prolonged luteal phase (PLP) if the luteal phase ~~lasted longer than~~exceeded 25 d~~ays~~. Ovulation was considered to be delayed if the inter~~-~~luteal interval ~~is was longer than~~exceeded 12 d~~ays~~. Based on these definitions, P4 profiles were classified as (i) normal, (ii) PLP profile (~~if~~ when at least one PLP was observed), (iii) delayed (D; if CLA > 60 d~~ays~~), (iv) interrupted (I; ~~if~~ when at least one ovulation ~~of rank~~ > 2 was delayed) ~~or~~ and (v) disordered (Z; ~~if~~ when luteal activity appeared irregular but could not be ~~included in~~assigned to another~~y~~ abnormality class).

Commenté [MSC63]: Correct ?

Calculations and statistical analysis

All ~~information~~ data ~~regarding~~ on dairy cows (e.g. reproduction~~-production~~, feed intake~~…~~) ~~were~~ was automatically stored ~~i~~on a dedicated registration chain. ~~Other~~ ~~A~~analys~~e~~is~~,~~ ~~regarding~~ of heifer growth and performance, as well as ~~information~~ data ~~about~~ on progesterone, were recorded in Microsoft Excel files. All data ~~handling~~ manipulation and statistical analyses were performed in R software using ~~either~~ the *lm* procedure for ANOVA or ~~the~~ *glm* for logistic regressions (R Core Team, 2019). Normal distribution of the residuals, equality of the variance and non-depende~~a~~nt data were checked for all ~~our~~ models. Quantitative traits (i.e. growth, age~~s~~, ~~live weight~~BW, milk ~~production~~yield, ~~body condition score~~BCS, CLA, ~~and~~ cycle lengths) were studied using the following ANOVA model~~.~~:

Commenté [MSC64]: C'est bien le bon terme dans le domaine en anglais ? Juste pour vérifier. Sinon, j'aurais utilisé qqc comme « dedicated data platform » ou « dedicated recording system », surtout si le terme en français contient le mot « enregistrement ».

Commenté [MSC65]: Pour cohérence de terme

$$y_{ij} = \mu + year_i + \left|\begin{matrix}AFS_j\\ T_j\end{matrix}\right| + e_{ij}$$

where y_{ij} is the variable of interest, μ ~~was~~ is the overall mean of the variable of interest, $year_i$ ~~was~~ is the fixed effect of the experimental year (i=1, 2 or 3), ~~either~~ AFS_j ~~that~~ is ~~was~~ the fixed effect of ~~age at first service~~AFS (j= 12.5, 14.0 or 15.5 mo) or T_j ~~that was~~is the fixed effect of ~~the~~ feeding treatment (j= SD, ID1 or ID2) ~~was~~ included in the model, and e_{ij} ~~was~~ is the random residual effect.

Year was included as a fixed effect because there were only ~~3~~ three levels (year1, year2, year3).~~,~~ ~~which~~ and this approach ~~we considered to be~~seemed the ~~right~~ most appropriate option ~~with~~ ~~for~~given the ~~limited~~ small number of levels. ~~If it was~~Had year been included as a random effect, ~~the~~ variance would have been estimated ~~based on~~from only ~~3~~ three levels, ~~only and would not be~~rendering it in~~very~~ accurate.

Commenté [MSC66]: Est-ce que ça marche ?

Dichotomous traits (i.e. reproductive success and type of cyclicity pattern) were studied using the following logistic regression model~~.~~:

$$log\left[\frac{P(y_{ij}=1)}{1-P(y_{ij}=1)}\right] = \mu + year_i + \left|\frac{AFS_j}{T_j}\right| + \beta \times PRI_{ij}$$

where y_{ij} is the variable of interest, µ is the overall mean and the fixed effects (year$_i$, AFS$_j$ or T$_j$~~)~~) are the same as previously described ~~above~~.

~~In the case of~~For the reproductive performance of heifers, the covariate PRI_{ij} was added; it ~~that~~ describes the effect of the interval from the removal of the last progesterone-releasing implant ~~to~~ until ~~the~~ insemination ~~was included~~. This covariate was not ~~needed~~ required for the performance of cows because only heifers ~~are~~ were synchronis~~z~~ed.

Effects were considered ~~declared~~ highly significant at P<0.001, significant at P<0.05 and ~~as~~ a trend at P<0.10.

Results

~~There were initially~~Of the 217 heifers ~~enrolled~~ in the experiment, ~~out of which~~ 175 successfully calved. The 42 ~~remaining animals~~that did not either ~~-~~died during rearing (7), were culled ~~because of~~due to injuries (6)~~,~~ or ~~did~~ were not ~~get~~ pregnant within the breeding period considered for the present study (29).

Growth and reproductive performance of heifers

~~The average~~Mean BW at birth was 41.3 kg (± 5.2) and ~~was~~ did not differ significantly ~~balanced~~ ~~across~~ among ~~the~~ all groups (i.e. not associated ~~to~~ with ~~neither~~ the feeding treatment (P = 0.85) ~~n~~or AFS (P = 0.15)) (Table 3; Table 4).

Mis en forme : Normal, Taquets de tabulation : Pas à 5,75 cm

Commenté [MSC67]: Pas forcément besoin de redéfinir des variables qui ont déjà été définies dans une équation précédente. Moi, j'aurais tendance de supprimer cette information ici.

Mis en forme : Non Surlignage

Mis en forme : Non Surlignage

Mis en forme : Non Surlignage

Mis en forme : Normal, Taquets de tabulation : Pas à 5,75 cm

Commenté [MSC68]: Reformulé, car le nombre 217 déjà donné dans les Méthodes

Mis en forme : Paragraphes solidaires

Commenté [MSC69]: Pour précision ; correct ?

Mis en forme : Police :12 pt

Mis en forme : ANM main text, Gauche, Interligne : simple

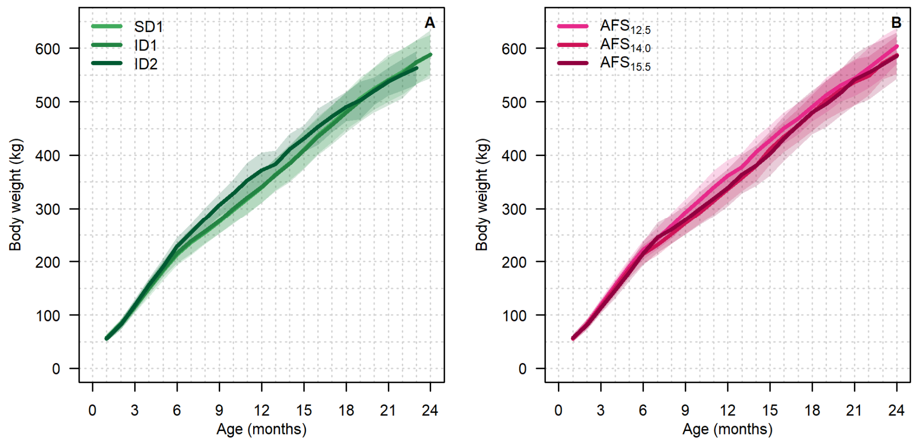


Figure 1.~~:~~ Mean b~~B~~ody weight of ~~the~~ heifers during the rearing period~~,~~ ~~according to~~by (A) ~~the~~ feeding treatment ~~(A)~~ and (B) class~~es~~ of age at first service (AFS~~; B~~). Shaded areas are 95% confidence intervals.

The f~~F~~eeding treatment had ~~limited~~ little effect on growth during the milking phase, and heifers reached 117 kg (± 11.8) at 3 mo of age (~~just~~ immediately after weaning). From weaning to 6 mo, ~~of age,~~ heifers in the ID2 ~~group~~ treatment were heavier than th~~o~~ese in ~~both~~ the SD and ID1 ~~treatments~~ treatments (229 kg *vs* 213 kg and 217 kg at 6 mo, ~~of age~~ respectively; P < 0.001; Fig~~ure~~. 1~~.~~A). The highest ADG was ~~found~~ observed for ID2 heifers from 0-~~ to~~ 6 mo (1042 *vs* 958 and 976 g/d for ID2, SD and ID1, respectively; P < 0.001, Table 3). This difference ~~was still~~remained significant from 6-~~to~~ 12 mo of age (789, 703 and 699 g/d for ID2, SD and ID1 heifers, respectively; P < X; Table 3). However, from 12-~~ to~~ 18 mo~~ of age~~, ADG was significantly ~~reduced~~ lower for ID2 heifers ~~in comparison of~~than for SD and ID1 heifers (660 *vs* 800 and 774 g/d, respectively; P < X; Table 3).

The feeding treatment had no effect on r~~R~~eproductive performance ~~was not affected by the feeding treatment~~ (Table 3), although ~~the number of services tended to be lower for~~ ID2 heifers tended to have fewer services than ~~for~~ SD ~~and~~ or ID1 heifers (1.5 vs 1.9 ~~and~~ or 1.8, respectively). ~~Indeed,~~ C~~c~~ows in the ~~3~~ three feeding treatments ~~showed~~ had a similar interval from the start of the breeding season to the first ~~1st~~ service (13.5 d), similar success at the first ~~1st~~ service (~~about~~ ca. 62% of heifers pregnant ~~heifers~~) and a similar pregnancy rate by the end of the breeding season (94%).

~~There was~~ N~~n~~o difference in calf BW (37.9 kg) was observed, despite a difference in their dam's BW at ~~both~~ the first ~~1st~~ service and first ~~1st~~ calving (ID2 heifers were lighter than ~~both~~ SD and ID1 heifers;~~,~~ Tables 3 and ~~Table~~ 5). ~~Heifers in the~~ ID2 ~~treatment~~ heifers calved at a younger age than ~~those in the~~ SD ~~and~~ or ID1 ~~treatments~~ heifers (~~about~~ca. 2 months earlier, P < 0.001; Table 3).

Heifers inseminated at the~~a~~ youngest age (a mean of 12.5 mo~~, of age on average~~; $AFS_{12.5}$) tended to have a higher growth rate from 0-6 mo of age than ~~heifers~~ those inseminated at ~~either~~ 14.0

Commenté [MSC70]: Ajouté pour précision ; correct ?

Commenté [MSC71]: Ajouté pour clarté ; correct ?

Commenté [MSC72]: Pour cohérence avec le précédent, il faudrait donner la valeur P.

Commenté [MSC73]: Pour cohérence avec le précédent, il faudrait donner la valeur P.

Commenté [MSC74]: Pour cohérence de formulation

($AFS_{14.0}$) or 15.5 ($AFS_{15.5}$) mo of age~~,~~ ~~from 0 to 6 mo of age~~ (1001 *vs* 960 ~~and~~ or 978 g/d, respectively; P ~~0~~< 0.10; Table 4). This difference ~~became more important~~ increased from 6- ~~to~~ 12 mo of age (759 *vs* 688 and 698 for $AFS_{12.5}$, $AFS_{14.0}$ and $AFS_{15.5}$~~-~~, respectively; P < 0.01; Table 4; Fig~~ure~~. 1~~-~~B).

Table 3.~~:~~ Effects of ~~the~~ feeding treatment on the growth and reproductive performance of heifers during the rearing period

	Feeding Treatment			Model[1]		Significance levels[2]
	SD1	ID1	ID2	R^2_{adj}	RSE	
Number of ~~records~~heifers	74	72	29			
Growth						
BW at birth (kg)	41.2	41.7	41.1	0.00	5.19	0.85
BW at ~~1st~~ first AI (kg)	400.7[a]	398.5[a]	378.1[b]	0.14	33.29	★★
ADG 0-6 months (g/d)	958[a]	976[a]	1042[b]	0.09	97.7	★★★
ADG 6-12 months (g/d)	703[a]	699[a]	789[b]	0.31	116.8	★★
ADG 12-18 months (g/d)	800[a]	774[a]	660[b]	0.11	133.2	★★★
Reproduction						
Start of breeding season to first ~~1st~~ service interval (d)	13.9	12.8	14.0	0.00	5.76	0.46
~~Conception~~ Pregnancy rate at ~~1st~~ first service (%)	64	58	66	NA	NA	0.64
Number of services	1.9	1.8	1.5	0.21	0.78	●
Pregnant (%)	95	96	90	NA	NA	0.67
Age at first ~~1st~~ calving (months)	24.0[a]	23.9[a]	21.9[b]	0.32	1.26	★★★
Calf body weight (kg)	38.4	37.6	37.2	0.32	4.02	0.37

[1]*adjusted coefficient of determination: R^2_{adj}; ~~and~~ residual standard error: RSE.*
[2]*★★★ P ≤ 0.001; ★★ P ≤ 0.01; ★ P ≤ 0.05; ● P ≤ 0.1; otherwise, the exact P-value ~~otherwise~~*
[a-b] *Different superscripts ~~point out~~indicate adjusted means that ~~are~~ differ~~ent~~ between feeding treatments (P ≤ 0.05, Tukey's pairwise comparison)*

Tableau mis en forme

Commenté [MSC75]: Idéalement, pour comprendre les sigles à part du corps du texte, il faudrait définir les sigles du table dans son titre ou sous le tableau.

Commenté [MSC76]: Pour cohérence avec le terme dans le corps du texte

Table 4~~.~~: ~~Association~~ Relations ~~of~~ between age at first service ~~with~~ and growth and reproductive performance of heifers during the rearing period~~"~~

	Age at first service (AFS)			Model[1]		Significance levels[2]
	AFS$_{12.5}$	AFS$_{14.0}$	AFS$_{15.5}$	R^2_{adj}	RSE	
Number of ~~records~~heifers	58	57	60			
Growth						
BW at birth (kg)	41.5	42.0	40.2	0.02	5.13	0.15
BW at ~~1st~~ first AI (kg)	373.1[a]	394.3[b]	419.8[c]	0.37	28.49	★★★
ADG 0-6 months (g/d)	1001	960	978	0.03	100.8	●
ADG 6-12 months (g/d)	759[a]	688[b]	698[b]	0.30	117.5	★★
ADG 12-18 months (g/d)	712[a]	799[b]	790[b]	0.07	136.3	★★
Fertility						
Start of breeding season to first ~~1st~~ service interval (d)	12.9	13.2	14.3	0.00	5.75	0.42
~~Conception~~ Pregnancy rate at first ~~1st~~ service (%)	59	60	67	NA	NA	0.30
Number of services	1.7	1.7	1.9	0.20	0.78	0.25
Pregnant (%)	93	91	98	NA	NA	0.37
Age at first ~~1st~~ calving (months)	22.3[a]	23.8[b]	24.8[c]	0.52	1.06	★★★
Calf body weight (kg)	37.4	38.6	37.7	0.32	4.02	0.31

[1]*adjusted coefficient of determination: R^2_{adj}; ~~and~~ residual standard error: RSE.*
[2]★★★ *$P < 0.001$; ★★ $P < 0.01$; ★ $P < 0.05$; ● $P < 0.1$; otherwise, the exact P-value ~~otherwise~~*
[a-b] *Different superscripts ~~point out~~indicate adjusted means that ~~are~~ differ~~ent~~ between feeding treatments ($P < 0.05$, Tukey's pairwise comparison)*

F~~Growth was reduced for AFS$_{12.5}$ animals f~~rom 12~~-~~ to 18 mo of age, AFS$_{12.5}$ heifers had a lower growth rate than AFS$_{14.0}$ and AFS$_{15.5}$ heifers ~~with an~~ (ADG of 712 ~~*g/d, compared to*~~ *vs* 799 and 790 g/d ~~for AFS$_{14.0}$ and AFS$_{15.5}$~~, respectively; ~~(~~P < 0.001; Table 4). This is consistent with the effects of the feeding treatment ~~observed,~~ and ~~with~~ the distribution of animals among the AFS classes ~~of AFS~~ and feeding treatments (Table 2).

AFS~~ge at first service~~ had no influence on f~~F~~ertility ~~was not affected by age at first service~~ (Table 4)~~.~~: A~~a~~ll heifers ~~showed~~ had a similar interval from the start of the breeding season to the first ~~1st~~ service, ~~a~~ similar success ~~rate~~ at the first ~~1st~~ service and a similar pregnancy rate by the end of the breeding season, with a similar number of services per animal.

~~There was~~ N~~n~~o difference in calf BW (37.9 kg) was observed, despite a difference in the dam's BW at first ~~1st~~ service and at first ~~1st~~ calving (AFS$_{12.5}$ heifers were lighter than ~~the ones~~those in AFS$_{14.0}$~~-~~, which were ~~themselves~~ lighter than ~~the one~~ those in AFS$_{15.5}$, Tables 4 and ~~Table~~ 6). Consistent with the ~~age at~~ first ~~1st service~~AFS, ~~heifers in the~~ AFS$_{12.5}$ ~~group~~ heifers calved younger than ~~those in the~~ AFS$_{14.0}$~~-~~, heifers, ~~who~~ which calved ~~at a~~ younger ~~age~~ than ~~those in the~~ AFS$_{15.5}$ heifers ~~group~~ (Table 4).

Lactating performance of primiparous cows

Tableau mis en forme

Mis en forme : Non Exposant/ Indice

Mis en forme : Police :Italique

Commenté [MSC77]: Pour cohérence du format utilisé avant ; correct ?

BW recorded immediately after calving was lower for ID2 cows ~~compared to~~than for SD and ID1 cows (501 *vs* 542 and 534 kg, respectively; P < 0.001; Table 5; Fig.~~ure~~ 2~~.~~A.), which is consistent with the ~~fact~~ observation that ID2 heifers first calved ~~at a~~ younger ~~age~~ than SD and ID1 heifers (Table 4). No difference in BCS was observed ~~between~~ among the feeding treatments ~~was noticed in BCS~~ during the first lactation (result not shown). On a 308 d basis, ID2 cows tended to produce less milk than SD and ID1 cows (6920 *vs* 7312 and 7370 kg, respectively; P < 0.10; Table 5; Fig~~ure~~. 2~~.~~C~~.~~). ~~There was~~ N~~n~~o difference ~~was observed~~ in mean fat and protein contents was observed ~~between~~ among feeding treatments ~~regarding average fat and protein contents~~. However, cows that received the ID2 treatment when heifers produced less FPCM than cows that received ~~either~~ the SD or ID1 treatments (6482 *vs* 6983 and 6973 kg, respectively; P < 0.05). ~~Milk yield peak was reduced for~~ ID2 cows ~~compared~~ had a lower peak milk yield than~~to~~ ~~both~~ SD and ID1 ~~ones~~ cows (28.7 *vs* 31.3 and 31.9 kg/d, respectively; P < 0.001). During the first ~~7~~ seven weeks of lactation, ID2 cows were lighter (on average, ~~-~~38 and 25 kg less than ~~compared to~~ SD and ~~-25 kg compared to~~ ID1 cows, respectively),~~;~~ and produced less milk (~~-~~3.1 kg/d less than ~~compared to both~~ SD and ID1). This difference decreased during the last part of the period (~~from~~ 8 ~~to~~ -15 weeks);~~,~~ ID2 cows weighed 27 ~~kg~~ and 17 kg less than SD and I~~I~~D1 cows, respectively,~~;~~ and produced 2.2 ~~kg/d~~ and 2.9 kg/d ~~of~~ less milk ~~less~~ than SD and I~~I~~D1 cows, respectively.

Commenté [MSC78]: Pour cohérence d'unité utilisé avant ; correct ?

Table 5~~.~~: Effects of ~~the~~ feeding treatment ~~during the rearing period~~ on ~~the~~ productive and reproductive performances of primiparous cows during the rearing period

	Feeding Treatment			Model[1]		Significance levels[2]
	SD1	ID1	ID2	R^2_{adj}	RSE	
Number of ~~records~~cows	67	68	24			
Production						
Total milk yield ~~over~~ per 308 d (kg)	7312	7370	6920	0.19	706.9	●
Peak milk yield (kg/d)	31.3[a]	31.9[a]	28.7[b]	0.10	3.50	★★
~~Average~~ Mean ~~f~~Fat ~~c~~Content (g/kg)	37.0	36.5	36.2	0.10	3.66	0.75
~~Average~~ Mean ~~p~~Protein ~~c~~Content (g/kg)	30.2	29.7	29.4	0.02	1.53	0.17
Fat~~-~~ and~~-~~ ~~p~~ Protein~~-~~ ~~c~~ Corrected ~~m~~Milk (kg)	6983[a]	6973[a]	6138[b]	0.26	668.5	★
Conformation						
BW at first~~1st~~ calving (kg)	542[a]	534[a]	501[b]	0.10	43.0	★★★
BCS at calving (0-5 scale)	2.45	2.40	2.30	0.33	0.296	0.11
BCS at nadir (0-5 scale)	1.85	1.80	1.75	0.43	0.267	0.47
BCS loss to nadir (0-5 scale)	-0.55	-0.60	-0.60	0.44	0.255	0.81
Cyclicity						
CLA (d)	20.9	24.8	20.1	0.00	0.56	0.23
IOI_1	20.7	23.8	24.9	0.04	14.01	0.47
LUT_1	13.3	13.9	14.9	0.18	10.77	0.88
ILI_1	9.6	11.2	7.7	0.04	11.29	0.55
IOI_{2-4}	23.3	23.6	21.2	0.00	5.91	0.42
LUT_{2-4}	13.8	13.7	12.5	0.39	5.79	0.77
ILI_{2-4}	9.0	10.2	9.0	0.45	4.76	0.54
Normal (%)	65%	59%	53%	NA	NA	0.52
PLP (%)	19%	18%	33%	NA	NA	0.44
Delayed (%)	10%	12%	7%	NA	NA	0.81
Fertility						
Number of services per cow	1.9[a]	2.4[b]	2.2[ab]	0.10	1.27	★
Pregnant (%)	86%	85%	87%	NA	NA	0.92
Calf ~~body weight~~BW (kg)	38.4	37.8	36.9	0.00	4.84	0.40

[1] *adjusted coefficient of determination: R^2_{adj}; ~~and~~ residual standard error: RSE.*
[2] *★★★ $P < 0.001$; ★★ $P < 0.01$; ★ $P < 0.05$; ● $P < 0.1$; otherwise, the exact P-value ~~otherwise~~*
[a-b] *Different superscripts ~~point out~~indicate adjusted means that ~~are~~ differ~~ent~~ between feeding treatments ($P < 0.05$, Tukey's pairwise comparison)*

The feeding treatment of dairy cows during the rearing period did not affect ovarian cyclicity during the first ~~1st~~ lactation (Table 5). ~~On average, the~~Mean CLA was ~~about~~ 20.4 d, and the first IOI was ~~about~~ 20.7 d, with no difference ~~among treatments concerning~~ ~~for~~in ~~the~~ LUT ~~and the~~or ILI among treatments. ~~There was~~ ~~N~~no difference ~~concerning~~ in the subsequent cycles was observed ~~neither~~, with a mean IOI of 23.3 d~~, on average~~. The distribution of abnormal patterns of ovarian activity was not significant, although ~~the~~ ID2 cows ~~showed~~ had a lower ~~proportion of~~ normal profile rate than ID1 cows, ~~that~~ which had ~~themselves~~ a lower ~~proportion of~~ normal profiles rate than SD cows (53% *vs*

Commenté [MSC79]: Pour cohérence du terme utilisé dans le corps du texte

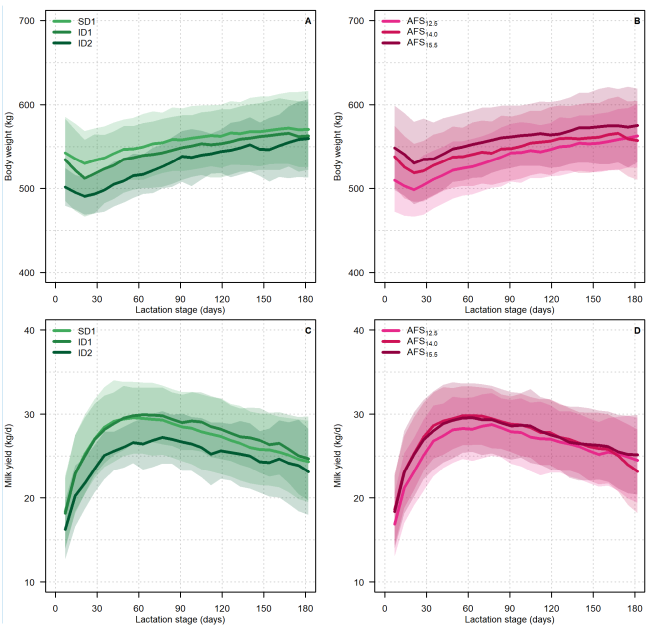
Commenté [MSC80]: Pour cohérence d'unité utilisé avant ; correct ?

Commenté [MSC81]: « Pregnancy rate », pour cohérence avec le corps du texte et des tableaux précédents ?

Commenté [MSC82]: Suggestion de ne pas utiliser "about" si les valeurs sont arrondies à des chiffres après la virgule.

59% *vs* 65%, respectively; Table 5). ID2 cows had an incidence ~~of 33%~~ of PLP abnormalities of 33%, while ~~the incidence in~~that for ID1 and SD cows ~~were~~ was 18% and 19%, respectively (Table 5). ~~About~~ Ca. 86% of ~~the~~ cows were pregnant at the end of the breeding season, ~~with~~ which had no relationship with feeding treatment. Although the difference in cyclicity ~~between~~ among feeding treatments did not ~~impair~~ influence the re-calving rate, ID1 cows ~~needed~~ required more ~~inseminations~~ services ~~to be~~for pregnancy to occur~~nt~~ than SD cows (2.4 *vs* 1.9, respectively; P < 0.05; Table 5). The number of services ~~needed~~ required to achieve pregnancy was ~~about~~ca. 2.2 for ~~the~~ ID2 cows. Feeding treatment had no influence on ~~S~~subsequent calf BW ~~was not affected by the feeding treatment~~.

Commenté [MSC83]: Pour cohérence de terme ; correct ?



Commenté [MSC84]: Pour mieux distinguer les lignes, je mettrais les fins des axes Y à 650 kg et 35 kg/d, et mettre les légendes sous les lignes.

Figure 2.~~:~~ (A and B) Body weight and (C and D) milk yield of ~~the~~ primiparous cows during lactation by~~,~~ ~~according to the~~ (A and C) feeding treatment ~~(A)~~ and (B and D) class~~es~~ of age at first service (AFS)~~ (B); and milk yield of the primiparous cows during lactation, according to the feeding treatment (C) and classes of age at first service (D)~~.

Commenté [MSC85]: Suggestion pour faire plus court

AFS influenced BW at calving, ~~was affected by AFS~~ and was lower for $AFS_{12.5}$ than for $AFS_{14.0}$ and ~~for~~ $AFS_{15.5}$ cows (509 ~~kg~~ *vs* 539 ~~kg~~ and 549 kg, respectively, P < 0.001; Table 6; Fig~~ure~~. 2~~.~~B.). BCS at calving was ~~significantly~~ higher for $AFS_{15.5}$ ~~heifers in comparison of BCS of~~than for $AFS_{12.5}$ and $AFS_{14.0}$ cows (2.45 *vs* 2.35 and 2.35, respectively; P < 0.05). After calving, BCS did not differ between ~~groups of heifers~~AFS classes. On a 308 d basis, ~~there was~~ no difference in milk yield,

Commenté [MSC86]: Modifié pour cohérence de la non utilisation de « significantly » avec des comparaisons qui sont significatives Ailleurs, vous écrivez simplement qu'il y a eu une différence et montrez la valeur P après.

Commenté [MSC87]: Pour précision ; correct ?

composition or FPCM was observed. Only peak milk yield ~~peak~~ tended to be ~~reduced~~ lower for $AFS_{12.5}$ cows (30.2 kg/d)~~,~~ ~~in comparedison of milk yield~~than ~~of~~ for $AFS_{14.0}$ and $AFS_{15.5}$ cows (31.6 and 31.7 kg/d, respectively; Fig~~ure.~~ 2~~.~~D.; Table 6).

Table 6~~.:~~ Effects of the class of age at first ~~calving~~ service (AFS) on the productive and reproductive performance of primiparous cows

	Age at first service (AFS)			Model[1]		Significance levels[2]
	$AFS_{12.5}$	$AFS_{14.0}$	$AFS_{15.5}$	R^2_{adj}	RSE	
Number of ~~records~~cows	51	50	58			
Production						
Total milk yield ~~over~~ per 308 d (kg)	7229	7236	7370	0.15	721.7	0.68
Peak milk yield (kg/d)	30.2	31.6	31.7	0.04	3.59	●
~~Average~~ Mean ~~F~~fat ~~C~~content (g/kg)	36.2	36.9	36.8	0.10	3.65	0.66
~~Average~~ Mean ~~P~~protein ~~C~~content (g/kg)	29.8	29.9	29.9	0.00	1.56	0.93
Fat~~-~~ and~~-p~~ ~~P~~protein~~-c~~ ~~C~~corrected ~~M~~milk (kg)	6800	6891	7000	0.26	688.4	0.51
Conformation						
BW at first ~~1st~~ calving (kg)	509[a]	539[b]	549[b]	0.14	41.9	★★★
BCS at calving (0-5 scale)	2.35[a]	2.35[a]	2.45[b]	0.34	0.295	0.05
BCS at nadir (0-5 scale)	1.75	1.8	1.85	0.44	0.264	0.13
BCS loss to nadir (0-5 scale)	-0.60	-0.60	-0.55	0.44	0.254	0.41
Cyclicity						
CLA (d)	20.2	23.6	23.7	0.00	0.56	0.39
IOI_1	25.0	19.8	23.2	0.04	13.96	0.31
LUT_1	13.9	12.3	14.9	0.19	10.73	0.57
ILI_1	10.7	8.7	10.7	0.04	11.32	0.68
IOI_{2-4}	23.0	22.3	24.1	0.00	5.92	0.45
LUT_{2-4}	14.5	13.6	12.7	0.39	5.75	0.44
ILI_{2-4}	8.8	8.8	11.1	0.48	4.67	●
Normal (%)	58%	68%	56%	NA	NA	0.55
PLP (%)	29%	8%	23%	NA	NA	★
Delayed (%)	5%	13%	14%	NA	NA	0.23
Fertility						
Number of services per cow	1.9	2.4	2.2	0.08	1.28	0.16
Pregnant (%)	86%	88%	84%	NA	NA	0.90
Calf ~~body weight~~BW (kg)	37.2[a]	39.3[b]	37.3[a]	0.04	4.77	★

[1]adjusted coefficient of determination: R^2_{adj}; ~~and~~ residual standard error: RSE.
[2]★★★ $P < 0.001$; ★★ $P < 0.01$; ★ $P < 0.05$; ● $P < 0.1$; otherwise, the exact P-value ~~otherwise~~
[a-b] Different superscripts ~~point out~~indicate adjusted means that ~~are~~ different between feeding treatments ($P < 0.05$, Tukey's pairwise comparison)

AFS ~~had minimal effects~~ influenced ~~on~~ fertility characteristics little. ~~Concerning~~ For ovarian cyclicity, all ~~3~~ three AFS ~~groups~~ classes ~~of AFS showed~~had ~~a~~ similar CLA, with similar cycle~~s~~ lengths, except for ~~cows in~~ $AFS_{15.5}$ cows, which ~~that~~ tended to ~~show~~ have longer ILI ~~between~~ from the ~~2nd~~ second to

Commenté [MSC88]: Pour cohérence d'unité utilisé avant ; correct ?
Commenté [MSC89]: Pour cohérence d'unité utilisé avant ; correct ?
Commenté [MSC90]: Pour cohérence avec le tableau 4 ; correct ?
Commenté [MSC91]: Pour cohérence d'unité utilisé avant ; correct ?
Mis en forme : Exposant
Mis en forme : Exposant
Mis en forme : Exposant
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Mis en forme : Exposant
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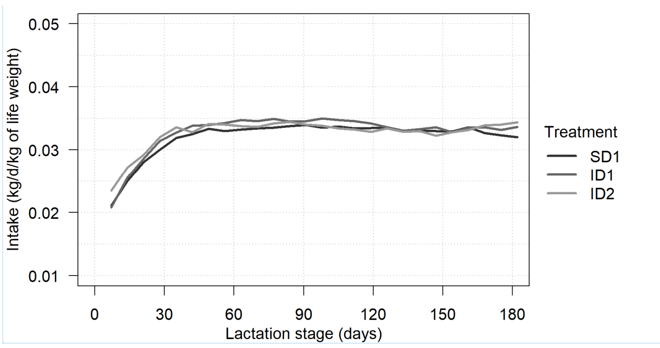
Commenté [MSC92]: « Pregnancy rate » ?, pour cohérence
Mis en forme : Exposant
Mis en forme : Exposant
Mis en forme : Exposant
Commenté [MSC93]: Suggestion d'ajout pour différencier cette phrase de la phrase plus tard and ce paragraphe qui dit qu'il n'y avait pas d'influence.
Commenté [MSC94]: Pour cohérence de terme

4^th^ ~~4th~~ fourth cycle~~,~~ than ~~cows in~~ $AFS_{12.5}$ and $AFS_{14.0}$ cows (Table 6). ~~Cows in the~~ $AFS_{14.0}$ ~~group~~ cows ~~showed~~ had a lower incidence of PLP than ~~cows in~~ $AFS_{12.5}$ and $AFS_{15.5}$ cows (8% *vs* 29% and 23%, respectively; P < 0.05; Table 6). AFS did not influence f~~F~~ertility ~~was not affected by AFS neither~~: all ~~groups~~ classes ~~showed~~ had a similar number of ~~inseminations~~ services (2.2, on average), and an average of 86% of the cows in each class were pregnant at the end of the breeding season. Subsequent calf BW was heavier for ~~cows in the~~ $AFS_{14.0}$ ~~group~~ cows ~~compared to~~than for cows in $AFS_{12.5}$ and $AFS_{15.5}$ cows (+2 kg; P < 0.05; Table 6).

Feed intake ~~was~~ did not different ~~neither between~~among feeding treatments~~,~~ ~~n~~or ~~between~~ among AFS ~~groups~~ classes (17 kg DM/d), even when it was corrected ~~on~~ per ~~the basis of~~ kg of body ~~live~~weight ~~cow~~ (F~~f~~ig~~ure~~. 3).



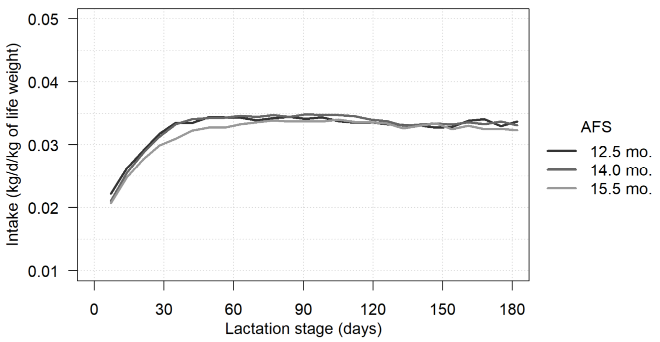


Figure 3.~~:~~ Daily dry matter intake of total m~~M~~ixed ration per kg of cow body weight during first lactation ~~1,~~ ~~according to~~ by (top) ~~the~~ feeding treatment ~~(top)~~ and (bottom) class~~es~~ of age at first service ~~(down)~~ (AFS) of ~~the~~ primiparous cows ~~during lactation~~.

Morphological trait~~s~~ analysis based on age at first calving (AFC) cohorts 2009-10 and 2010-11 (S~~s~~upplementary data~~files~~ 1) indicated that young cows at first calving (mean age of 21 mo ~~of age on average~~, n = 30; AFC_{21}) were ~~not only~~ lighter ~~compared to~~than ~~heifers~~ those that first calved~~ing~~

Commenté [MSC95]: Pour cohérence de terme utilisé avant ; correct ?

Commenté [MSC96]: Pour cohérence du terme utilisé dans le corps du texte

Commenté [MSC97]: Sur les axes Y, je changerais « life weight » à « body weight », pour cohérence.
Et je mettrais la fin des axes Y à 0,04 au lieu de 0,05, pour mieux distinguer les lignes.
Et pour cohérence avec les autres figures, je mettrais les légendes sur les graphiques.

Mis en forme : Paragraphes solidaires

Commenté [MSC98]: Pour cohérence de terme

Commenté [MSC99]: J'utiliserais A et B, comme dans les autres figures. Pour faire ça, il faudrait ajouter A et B à ces figures-ci.

Commenté [MSC100]: Idéalement, pour comprendre la figure à part du corps du texte, il faudrait expliquer que veulent dire les sigles pour les traitements d'alimentation dans le titre de la figure.

Commenté [MSC101]: Pour cohérence du terme utilisé avant. Serait-il « Supplementary Materials » ?

at a ~~average~~ mean age of 23.5 mo (n = 39; $AFC_{23.5}$) or 25 mo (n = 36; AFC_{25}) ~~mo of age~~ (498 , *vs* 528 and 563 kg, respectively; ~~,~~ P < 0.05), ~~but~~ and ~~they~~ also ~~presented~~ had ~~reduced~~ smaller morphological traits. For example, WH~~W~~ was 137.4, 139.1 and 140.4 cm for AFC_{21}~~;~~, $AFC_{23.5}$ and AFC_{25}~~,~~, respectively; P < 0.05). However, at a ~~similar~~ given age (e.g. 25 mo~~, for example~~), no ~~such~~ difference ~~was noticed~~ ~~observed between~~among the three treatments was observed (140.7, 140.4 and 142.0 mm, respectively).

Discussion

The present study indicates that reducing the age ~~at~~ of first service to ~~around~~ca. 12 mo~~1 year of age~~, and, consequently, age at first calving ~~at~~ to 22 mo ~~of age~~ or less, ~~had limited impact~~ influenced ~~on~~ the performance of ~~Holstein~~ primiparous Holstein cows little. Several authors have shown that calving down heifers ~~between~~ at 23-26 mo~~nths~~ ~~of age~~ increases longevity and maximises economic returns (Bach 2011; Wathes *et al.*, 2014; Boulton *et al.*, 2017). The early rearing period is ~~a~~ key ~~period~~ to ~~achieve~~ reaching this target, as sub-optimal nutrition delays the onset of puberty, ~~and~~ adversely affects skeletal growth and increases the risk of dystocia at first calving (Ettema and Santos 2004). Poor growth is ~~also one of the~~the main reason~~s~~ for culling heifers prior to calving (Esslemont and Kossaibati 1997). Pre-weaning growth in dairy heifers ~~has~~ is generally ~~been~~ associated with the performance ~~in~~ of first lactation (Khan *et al.* 2011; Soberon *et al.*, 2012). Some studies reported ~~, however,~~ that pre-weaning differences ~~associated with~~caused by different feeding regimes were not ~~longer~~ statistically significant as calves aged (Morrison *et al.* 2009; Quigley *et al.* 2006). This may ~~in part~~ be explained in part by a compensatory increase in growth ~~for animals~~ when the feed allowance (e.g. level, energy, protein) is no longer~~t~~ limited after a period of restriction.

The differences in feed allowance resulted in differences in development and size at 6 and 12 mo of age~~,~~ but had ~~limited~~ little effect on BW at weaning. In a study by Johnson et al (2019), ~~the~~ two treatment groups before weaning ~~induced~~ had significant differences in pre-weaning performance ~~and this~~that persisted up to~~ntil~~ ~~six months~~6 mo. In our ~~case~~study, the high ~~level of~~ feed allowance before weaning, without restricting~~ion~~ ~~of~~ the ~~total mixed ration~~TMR for control heifers, probably explains the lack of~~why no~~ difference ~~on~~ in BW ~~at weaning was~~ observed at weaning. ~~In~~ On most commercial ~~practices~~farms, ~~the~~ a small amount of milk ~~(is offered until weaning is low: about~~ 4- to 6 L/day of whole milk~~,~~ or 400- to 600 g of ~~milk replacer (~~MR~~)~~ is offered until weaning at 42-56 days of age (Morrison *et al.* 2009). According to Jasper and Weary (2002), *ad libitum* milk intake is ~~around~~ca. 12 L/day of whole milk, and intake in the present study~~, it~~ was ~~around~~ca. 9 L/d per heifer until 11 weeks of age. The development and BW of animals at 6 mo ~~of age~~ were high (e.g. 111 cm ~~heart girth~~HG and 220 kg ~~body weight~~BW~~, for example~~), which fits well with recommendations for an optimal age at first calving at 24 mo of age or less. ~~.~~ In a study by Ettema and Santos (2004) ~~about~~ on the importance of age and BW at first calving for Holstein heifers, only 2.7% of dairy farms

Mis en forme : Police :Italique

Commenté [MSC102]: Correct que vous vouliez dire ceci (le sigle pour wither height) ?

Commenté [MSC103]: Un peu vague. « feeding treatments » ou bien « AFC » ?

Commenté [MSC104]: C'est bien le bon terme dans le domaine en anglais ? Sinon, j'aurais utilisé qqc comme « setting age at first calving of heifers »

Commenté [MSC105]: Pour cohérence de format

Commenté [MSC106]: Est-ce que ça marche ?

Commenté [MSC107]: Est-ce que ça marche ?

~~achieved~~ reached the recommended target~~s~~ ~~weights~~BW, which ~~led to~~resulted in economic losses. Total nutrient intake, energy source ~~of energy~~ and protein content ~~of~~ in the diet have a ~~additive~~ cumulative effect~~s~~ on how calves partition nutrients into tissue (Van Amburgh and Drackley 2005). During the milking phase, calves benefit when MRs contain more protein and less fat, ~~achieving~~ and reach higher levels of skeletal growth (Hill *et al.,* 2010). Therefore, p~~P~~roviding ~~greater quantities of~~more MR ~~therefore~~ improves ~~both~~ growth and feed efficiency (Bartlett *et al.,* 2006). Increased nutrient intake is also associated with increased plasma levels of insulin-like growth factor-1 (~~IGF1;~~ Smith *et al.,* 2002; Bartlett *et al.,* 2006), which in part regulates the subsequent growth rate (Hammon *et al.,* 2002; Brickell *et al.,* 2009a).

Several studies discuss ~~tThe~~ effects of intensive growth during rearing ~~have been discussed in several papers~~ (Le Cozler et al. 2008)~~.,~~ and ~~as already presented in these papers,~~that an increase~~ing~~ growth rate resulted in earlier puberty (Abeni *et al*., 2019). However, authors do not agree on the ~~impact~~ influence of earlier puberty on milk performance:~~. Indeed, while~~ some ~~authors noticed~~ observed a negative ~~impact~~ influence ~~on milk production~~, while others did not. Abeni *et al.* (2000) and Van Amburgh *et al.* (1998) concluded that calving earlier than 23 mo ~~of age~~ is associated with lower milk yields and lower milk fat content; however~~, although~~, it also ~~leads to~~results in a higher milk protein content. They also concluded ~~as well~~ that earlier calving ~~leads to~~results in ~~reduced~~ a decrease in reproducti~~ve~~on performance. In a more recent study, Krpálková et al. (2014) observed ~~did not observe~~ that ~~effects of~~ age at first calving had no influence on ~~on~~ milk yields ~~in~~ of primiparous cows, except ~~on~~ for ~~milk yield~~those during the first 100 d of lactation. ~~Authors~~ They also ~~noticed~~ observed the highest milk yield ~~in~~ for the second and third lactation ~~for~~ of heifers that first calv~~ed~~ing at ~~an age lower~~ less than 699 days of age. In the present study, a negative ~~impact~~ influence was ~~also noticed~~ observed only at the start of the first lactation, but not ~~on overall~~for all of it ~~lactation 1~~. No ~~information is~~ data were available ~~on~~ for ~~further~~ later lactations. ~~In their study,~~ Van De Stroet *et al.* (2016) ~~noticed~~ observed that primiparous cows that had consumed more starter feed as calves ~~a~~ tended~~ncy~~ to ~~produce more~~ have higher peak milk ~~during the peak of lactation~~yields during first lactation ~~in primiparous cows which had a high intake of starter feed as calves, compared to~~than ~~first lactation cows~~those ~~which~~ that had ~~a low intake~~consumed less. However, higher calf growth rates were not significantly ~~associated with~~related to future milk yield, but were ~~associated with~~related to higher BW ~~in~~ of lactating cows and higher odds of surviv~~al~~ing to first lactation. When ~~milk~~ lactation was corrected ~~to~~ for BW, no difference ~~was found~~ in milk yield or composition was observed, regardless of the rearing treatment.

Decreasing the age ~~at~~ of first calving is an effective way to decrease the length of the non-productive ~~days~~ period during rearing. ~~and F~~first calving at ~~around~~ca. 24 ~~months~~ mo ~~of age~~ appears ~~to be~~ optimal for profitable production (Mourits *et al.,* 1999b; Ettema and Santos; 2004; Shamay *et*

Commenté [MSC108]: Suggestion de supprimer le sigle IGF1, qui n'est pas utilisé après.

Commenté [MSC109]: Ajouté pour clarté ; correct ?

Commenté [MSC110]: Pour cohérence de terme

Commenté [MSC111]: Ajouté pour clarté ; correct ?

Commenté [MSC112]: Possible de convertir en mois (« mo ») pour cohérence d'unité ?

Commenté [MSC113]: Correct ?

Commenté [MSC114]: Pour cohérence de terme utilisé avant

Commenté [MSC115]: Pour tenter d'augmenter la compréhension ; est-ce que ça marche ?

Commenté [MSC116]: Un peu vague, car terme pas utilisé avant. C'est le « feeding treatment » ou « AFS class » ? Si les deux, je préciserais « ...regardless of the feeding treatment or AFS class. »

Commenté [MSC117]: Pour cohérence du terme utilisé ailleurs dans le texte *al.*, 2005). In a meta-analysis ~~based on~~of results ~~from~~ of 100 herds, Mohd Nor *et al.* (2013) estimated that heifers ~~having a~~that first calved~~ing~~ ~~age of~~at 24 mo produced~~,~~ a mean of ~~on average,~~ 7~~-~~164 kg of milk per 305 d, and calving ~~1~~ one mo earlier resulted in ~~gave~~ 143 kg less milk ~~on a~~per 305 d ~~of lactation length basis~~. In the present study, ~~we also noticed~~ observed ~~that~~ younger heifers produced less milk during the first part of lactation, but the total milk yield ~~over~~ per 305 d ~~was~~ did not differ~~ent~~. ~~However, it could be noticed that despite no difference from the statistical point of view,~~ ~~t~~The ~~difference~~ decrease in milk ~~production~~ yield was ~~very~~ similar (134 kg less per 305 d), albeit not significantly different, when age at first calving decreased from 24.8 to 23.8 mo of age~~: 134 kg less on a 305 d basis~~.

Commenté [MSC118]: Toujours correct ?

Age at first service had no effect on ~~In the present study,~~ fertility ~~was not affected by age at first service~~. In a previous study on puberty attainment ~~based on~~in the 2011-12 cohort, we ~~noticed~~ observed that most heifers reached puberty before oestrus synchronisation, at a~~n~~ ~~average~~ mean age of 10.3 ± 2.2 mo (6.2-~~to~~14.4 mo)~~,~~ and a mean~~n average~~ ~~ing~~ BW of 296 ± 40 kg (224-~~to~~369 kg) ~~BW~~ (Abeni *et al.*, 2019). ID2 heifers reached p~~P~~uberty ~~was reached~~ one month earlier ~~for ID2 heifers~~ than ~~in~~ SD and ID1 heifers. The onset of p~~P~~uberty ~~onset~~ at 9-~~to~~10 mo ~~of age~~ or less meant that 3 or 4 oestrous cycles occurred before insemination, which is generally consistent with ~~good~~ acceptable fertility results in many species (Lin *et al.*, 1986; Byerley *et al.*, 1987; Robinson, 1990; Le Cozler *et al.*, 1999). Regardless of calving strategy, ~~lowering~~ decreasing the age ~~at~~ of puberty and, consequently, the age ~~at~~ of first ~~insemination~~service, is an effective~~icient~~ way to shorten the non-productive period before calving. ~~However,~~ A~~a~~s ~~suggested by~~ Meyer *et al.* (2006)~~,~~ suggested, however, ~~it~~ this ~~might~~ could reduce pre-pubertal mammary gland development by shortening the allometric phase of mammary gland growth and, in some cases, impair future milk production. ~~Similar to~~Like its lack of effect on fertility in heifers, age at first calving did not influence fertility ~~in~~ of primiparous cows during first lactation ~~was not affected by age at first calving~~. Wathes *et al.* (2008) reported that ~~optimal~~ fertility was optimised and ~~maintenance of~~ maximum performance was maintained ~~in the~~during first lactation ~~were reached at the~~when heifers first calved~~ing~~ ~~age of~~ at 24-~~to~~25 mo, although ~~heifers~~ those that first calved at ~~the age of~~ 22-~~to~~23 mo ~~were~~ had the best ~~in~~ overall performance and longevity over 5 years, in part~~ly~~ because heifers with ~~good~~ high fertility ~~also~~ maintained ~~had a~~ high ~~level of~~ fertility as cows.

Commenté [MSC119]: Un peu vague. Des espèces domestiques, comme des chèvres, agneaux, et cochons ? Ou bien des races bovines (« cattle breeds ») ?

Commenté [MSC120]: Pour cohérence du terme utilisé dans le manuscrit

Commenté [MSC121]: Toujours correct ?

~~Finally, in the present study,~~ W~~w~~e also ~~noticed~~ observed that ~~for~~ at a similar feed allowance, early-calving heifers ate a similar amount of feed, produced less milk and ~~at the end,~~ultimately were able to catch up ~~the difference~~ in BW and development. As Krpalkova *et al.* (2014) reported, ~~Collectively, these~~our results indicate that~~,~~ ~~as already reported by Krpalkova *et al.* (2014), the objective of~~ a feeding-rearing ~~period~~ program that aims for~~leading to~~ ~~an age at~~ first calving at less than 23 mo of age ~~in Holstein heifers proves to be~~is a suitable option for successfully rearing Holstein ~~of~~ heifers

Commenté [MSC122]: Pour cohérence avec la première phrase du résumé ; ça va ?

with optimal subsequent production and reproduction in a herd with suitable management. However, future studies are required to explore performances during the second and later lactations ~~2 and further~~, as well as animal longevity ~~of animal, need to be investigated~~.

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Declaration of interest

The authors declare that the research was conducted in the absence of ~~any~~ commercial or financial relationships that could be construed as a potential conflict of interest.

Ethics statement

Experimental work ~~has been~~was conducted in accordance with French national legislation on the use of animals for research. Protocol ~~received~~ agreement no. ~~(~~00944-02~~)~~ was received from French Ethical Committee no. °7.

Software and data repository resources

None of the data were deposited in an official repository.

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