When Is the Best Time to Get Cows Pregnant

Kevin Dhuyvetter | Elanco | kevin.dhuyvetter@elancoah.com

Notes:

PowerPoint Slides on next page

When is the best time to get cows pregnant? A lactation curves analysis

Kevin Dhuyvetter, PhD
Technical Consultant, Elanco

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Issue (i.e., question that came to me)

- Given improved reproduction, should breeding of cows be delayed?
- What is purpose for delaying breeding?
  (longer lactation, lower milk at dry-off, improved first service conception, ???)
- Objective of analysis: Identify optimal DIM of conception
- Simplify problem for analysis to
  - account for herd-specific shape of lactation curves by parity group
  - account for impact pregnancy status has on lactation curves

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Data from an individual herd

- Data for analysis from Elanco DDAS
  - DC305 backup dated 10/13/2022
  - JMP Ready file dated 10/12/2022
- Filters used for analysis (to remove extreme outliers)
  - Fresh data = 8/1/2019 to 7/31/2022 (3-year period)
  - Test DIM = 7 – 400
  - Test Milk = 10 – 180
  - L1Age at fresh (days) = 575 – 850 (~19-28 months)
  - Weight at fresh (L1 only) = 900 – 1700
  - Days in close-up pen = 1 – 70
  - Days dry (L>1 only) = 20 – 100

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Test day data (all filters applied)

Lact = 1 Cows

	TestDIM				TestMilk			TestECM			
Test	N	Mean	Min	Max	Mean	Min	Max	N	Mean	Min	Max
1	6941	23.8	7	214	65.1	10	123	6610	71.6	11	141
2	6765	54.7	34	211	80.4	11	132	6679	83.8	12	173
3	6500	86.3	62	239	82.6	12	126	6442	85.5	20	143
4	6208	117.7	91	274	82.6	10	127	6149	86.5	27	160
5	5885	149.2	125	302	82.4	15	135	5863	87.1	15	140
6	5581	180.7	154	298	81.2	33	130	5562	86.6	34	140
7	5332	212.5	182	299	79.1	25	127	5310	85.3	29	157
8	5055	243.6	217	327	75.4	28	130	5036	82.7	35	139
9	4451	272.6	245	353	72.4	26	127	4442	80.6	34	147
10	2668	300.6	280	383	69.9	20	119	2665	78.7	23	130
11	1199	332.9	308	378	68.7	28	119	1199	78.0	35	137
12	536	364.6	337	400	68.7	28	107	535	78.6	31	123

Lact > 1 Cows

	TestDIM				TestMilk			TestECM			
Test	N	Mean	Min	Max	Mean	Min	Max	N	Mean	Min	Max
1	13890	22.9	7	236	93.9	11	174	13455	101.9	14	220
2	13808	53.8	34	264	114.0	13	179	13738	118.8	17	245
3	13509	85.3	62	299	113.0	15	179	13455	117.0	16	260
4	12888	116.6	91	327	107.6	14	177	12860	113.2	14	190
5	12321	148.2	125	355	102.6	19	166	12299	109.0	21	203
6	11657	180.1	154	277	96.5	12	165	11631	103.4	16	183
7	11090	211.8	182	305	89.6	18	160	11062	96.9	18	198
8	10417	243.2	217	286	81.3	11	153	10387	89.4	9	186
9	9159	273.2	245	315	74.3	11	152	9146	83.0	13	166
10	5683	301.6	280	343	69.7	10	125	5675	78.3	11	135
11	2810	333.6	308	378	66.3	11	121	2806	75.3	12	138
12	1386	364.8	336	400	63.7	10	112	1383	72.4	14	153

The number of observations drops considerably from the 9th test to 10th test and then considerably more from 10th to the 11th test and thus there is likely some "survivor bias" in these data that will impact results somewhat. Data from 10 tests were included to ensure cows with ~300 DIM existed for model estimation, however data from tests 11 and 12 are excluded due to survivor bias concerns.

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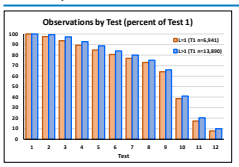
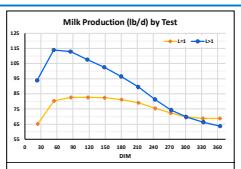
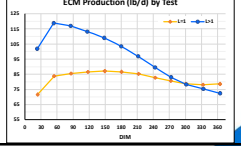
Test day data (all filters applied)







Data from Tests 11 and 12 (i.e., data points > 300 DIM on figures) are excluded from lactation curve analyses.

Number of L=1 cows drops faster over time compared to L>1 cows – this is not what would generally be expected or what has been observed in other herds.

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Estimating lactation curves

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An Economic Spreadsheet Model to Determine Optimal Breeding and Replacement Decisions for Dairy Cattle

H. Groenendaal,[1] D. T. Galligan,[1] and H. A. Mulder[2]
[1]New Bolton Center, Center of Animal Health and Productivity School of Veterinary Medicine, University of Pennsylvania, Kennett Square 19348
[2]Animal Breeding and Genetics Group, Wageningen University, The Netherlands

$$Y = A\,(DIM)^{b}\,e^{c\,DIM}\,e^{dDP}$$

Y = daily milk yield (kg),
A = f(GNRHA/100 – µ/2.96),
GNRHA = rolling lactation average (genetic rolling herd average) (kg/yr),
DIM = days in lactation (milk),
DP = days in gestation (days pregnant),
e = base of natural logarithm, and
a, b, c, g = constants that determine the shape of the lactation curves.

← Used this basic model as starting point (after transforming), and included some additional variables (did not explicitly include GNRHA)

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Multivariate statistical models estimated (by parity group)

- Dependent variables
  - Milk, ECM, Fat + Protein – LN of lb/day for all variables
- Independent (explanatory) variables
  - Month fresh and Year fresh (Year fresh is Aug of first year through Jul of following year)
  - Calf outcome (female, male, twin, other)
  - Calvings same week by parity (primiparous or multiparous)
  - Days in close-up pen (linear and squared terms)
  - Age at L1 fresh, days (linear and squared terms)
  - Weight at fresh (linear and squared terms) – L=1
  - Days dry (linear and squared terms) – L>1
  - PTA Milk
  - Previous lactation 305 ME – L>1
  - Disease in first 30 DIM (Y|N) – Mastitis, Metritis, and RP
  - DIM at transfer to Site2 (linear and squared terms)
  - DIM at test (linear and LN terms)
  - Days pregnant
  - Days pregnant x DIM interaction – allows slope to vary by pregnant status

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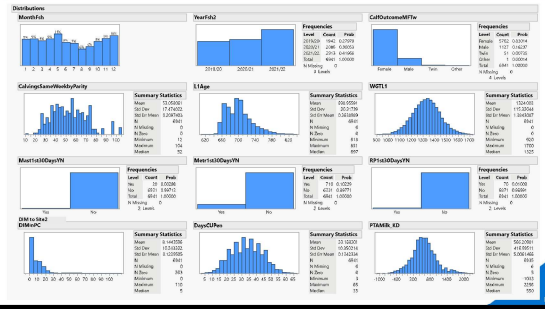
Summary statistics for various factors for Lact = 1



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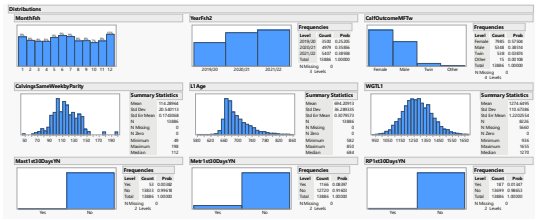
Summary statistics for various factors for Lact > 1



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Summary statistics for various factors for Lact > 1

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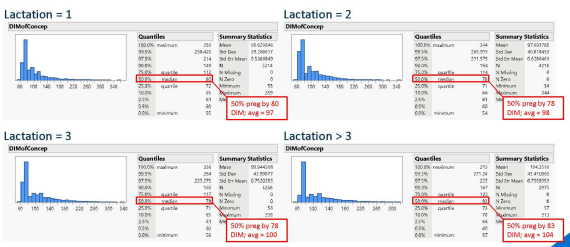
Distribution of DIM of conception (all filters applied, FDAT 8/1/19 – 4/30/22)



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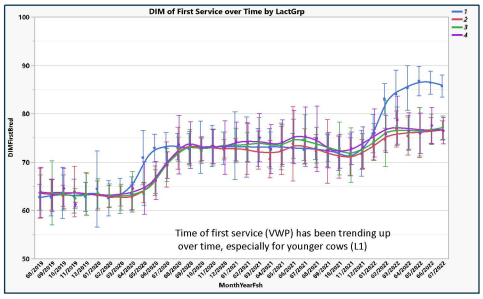
Average DIM of 1st service over time by LactGrp (all filters applied)



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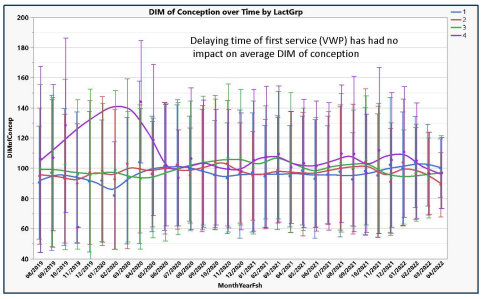
Average DIM of conception over time by LactGrp (all filters applied)



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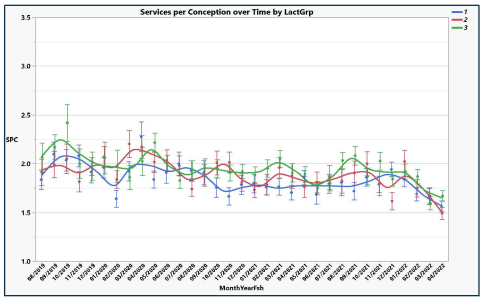
Average services/conception over time by LactGrp (all filters applied)



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Results

- Total of 12 models estimated:
  Three dependent variables (Milk, ECM, and Fat+Protein) x four lactation groups (L=1, L=2, L=3, and L>3) – only ECM curves shown below
- Focus of results here is on production over lactation curve (DIM 10-300) versus pregnancy status – Specifically, getting cow pregnant at 80, 110 or 140 days in milk (values can be changed)
- All variables other than day of conception are held constant at means by lactation group in figures that follow
- Models were estimated such that lactation curves are "forced" to be equal to conception and then they can "go where the data suggest" (still subject to functional form)…

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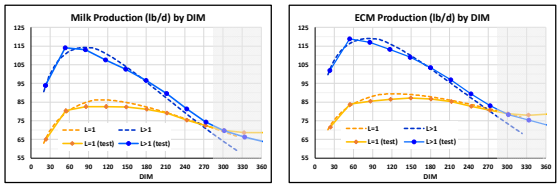
Test day average data vs Model estimated results



- Model results appear to match test day average data lactation curves quite well (remember that last two tests were not used for model estimation)
- Why go through all this hassle to estimate models?
- Having equation behind the line allows for additional analyses

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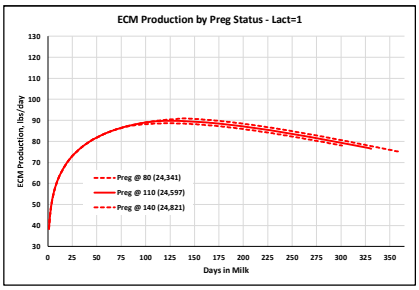
Results – ECM lactation curves for Lactation = 1*



Difference in cow becoming pregnant at 110 versus 140 DIM is 223 pounds less production from DIM 10-300 (256 lbs. less for 80 vs 110).

Time of conception dictates the length of lactation and to a lesser extent the persistency of the lactation curve.

* Values in parenthesis represent the total production from DIM 10-300

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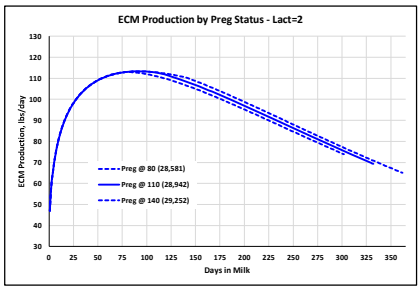
Results – ECM lactation curves for Lactation = 2*



Difference in cow becoming pregnant at 110 versus 140 DIM is 311 pounds less production from DIM 10-300 (360 lbs. less for 80 vs 110).

Time of conception dictates the length of lactation and to a lesser extent the persistency of the lactation curve.

* Values in parenthesis represent the total production from DIM 10-300

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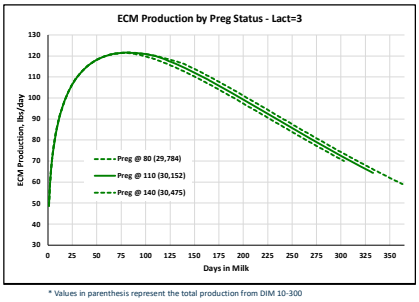
Results – ECM lactation curves for Lactation = 3*



Difference in cow becoming pregnant at 110 versus 140 DIM is 323 pounds less production from DIM 10-300 (367 lbs. less for 80 vs 110). Across 7 other herds with similar analysis, difference ranged from 137 – 590 pounds between 90 and 150 DIM).

Time of conception dictates the length of lactation and to a lesser extent the persistency of the lactation curve.

* Values in parenthesis represent the total production from DIM 10-300

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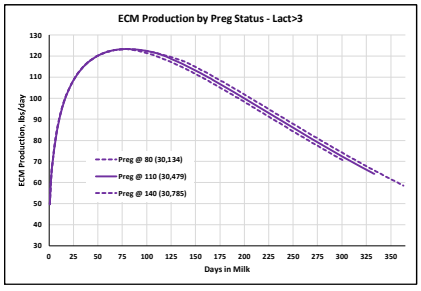
Results – ECM lactation curves for Lactation > 3*



Difference in cow becoming pregnant at 110 versus 140 DIM is 306 pounds less production from DIM 10-300 (345 lbs. less for 80 vs 110).

Time of conception dictates the length of lactation and to a lesser extent the persistency of the lactation curve.

* Values in parenthesis represent the total production from DIM 10-300

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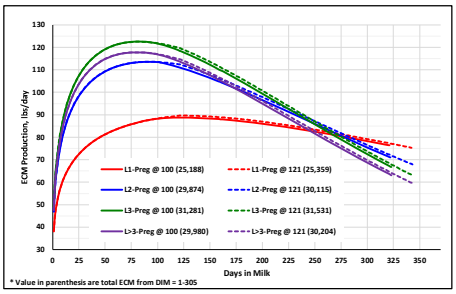
Results – ECM lactation curves by parity group



* Value in parenthesis are total ECM from DIM = 1-305

Cows conceiving 21 days later (121 DIM vs 100 DIM) will produce 171-250 pounds more milk in first 305 days due to slightly more persistent lactation curve.

Additionally, they will have a 21-day longer lactation curve.

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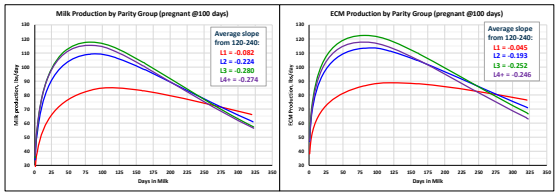
Persistency of lactation curves (conception @ 100 DIM)



- Lactation curves estimated with ECM are more persistent than those estimated with milk
- Lactations curves peak at roughly the same DIM (previous analyses of other herds has generally shown that ECM curves peak quicker than milk curves)
- This would suggest that optimal time to get cow pregnant based on MILK lactation curves likely would be equal or earlier than optimal time based on ECM lactation curves

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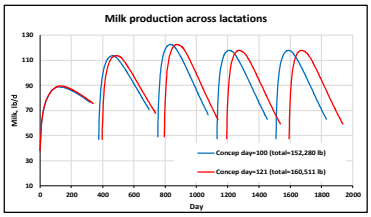
Lactation curves with different DIM of conception

- Getting a cow pregnant later in lactation will always result in more lifetime milk for that cow (all else equal), but milk/day of productive life is slightly lower. Does this comparison have any meaning/value?



If a cow makes it through 5 lactations, getting her pregnant, on average, at 121 DIM every time versus at 100 DIM would result in 8,231 additional pounds of production over her lifetime (1,941 total days vs 1,836 days). Milk/day of productive life = 82.7 for 121 DIM vs 82.9 for 100 DIM.

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Production and economic assumptions

- Production
  - Voluntary waiting period = 70
  - Gestation length = 275-278 (L1 = 275, L2 = 277, L>2 = 278)
  - Dry period = 55 days
  - Max DIM at dry off = 400
- Economic
  - Maintenance and marginal feed = 20 lb/day and 0.444 lb DM/lb of milk
  - Feed cost = $0.135/lb DM for lactating cows and $3.50/day for dry cows
  - Milk price = $18.00/cwt
  - Springer value = $2,000
  - Average calf value = $175
  - Price of cull cow = $0.60/lb
  - Fixed cost = $7.00/hd/day for lactating cow and $4.00 for dry cow
  - Interest rate = 8.0%

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What metric should be used to determine what is optimal?

- Total lifetime milk
- Milk production per day of productive life
- Income over feed costs (IOFC) – milk income minus feed costs
- Income over total costs (IOTC) – milk income minus total costs
- Net cash flow (IOTC plus include cost of springer, calf and salvage value)

- Do we need to account for the time value of money?
- Do we need to account for repeating the entire process?

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Economic model

- Calculate IOFC, IOTC, and Net cash flow for each day of 5 full lactations (including dry days)
  - Milk production is based on estimated ECM lactation curves (L4=L5=L>3 model)
  - Cow is sold for salvage value at end of fifth lactation
  - Net Present Value (NPV) is calculated for stream of income and expenses*
  - NPV for 5 lactations is then repeated into infinity

* NPV simply accounts for the "time value of money" (i.e., a dollar today is worth more than a dollar tomorrow)

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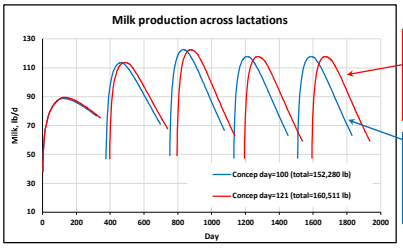
Lactation curves and economic returns versus DIM of conception



Net cash flow of 5-lactation series = $734. NPV = $96, interpretation of NPV is that you could pay $2,096 ($2000 + $96) for springer and realize an 8% rate of return (i.e., discount factor used). Repeating NPV every 1,941 days into infinity = $286.

Net cash flow of 5-lactation series = $764. NPV = $139, interpretation of NPV is that you could pay $2,139 ($2000 + $139) for springer and realize an 8% rate of return (i.e., discount factor used). Repeating NPV every 1,836 days into infinity = $433.

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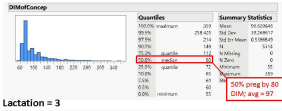
Various economic metrics based on current conception DIM

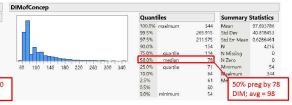
Lactation =>	1	2	3	4	5		Discount		Discount	Net		Repeat	5-lact	5-lact	Milk/day
	Optimal DIM of conception					IOFC	IOFC	IOTC	IOTC	cash flow	NPV	NPV	ECM, lbs	total days	prod life
Current average	97	98	100	104	104	$13,149	$10,863	$951	$750	$756	$133	$415	152,452	1,839	82.90
Average +21 days	118	119	121	125	125	$13,851	$11,338	$918	$726	$723	$89	$265	160,664	1,944	82.65
Current median	80	78	78	83	83	$12,440	$10,371	$949	$748	$754	$150	$490	144,274	1,738	83.01

Lactation = 1



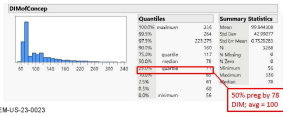
50% preg by 80 DIM; avg = 97

Lactation = 2



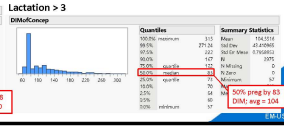
50% preg by 78 DIM; avg = 98

Lactation = 3



50% preg by 78 DIM; avg = 100

Lactation > 3



50% preg by 83 DIM; avg = 104

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Economic model

- Calculate IOFC, IOTC, and Net cash flow for each day of 5 full lactations (including dry days)
  - Milk production is based on estimated ECM lactation curves (L4=L5=L>3 model)
  - Cow is sold for salvage value at end of fifth lactation
  - Net Present Value (NPV) is calculated for stream of income and expenses*
  - NPV for 5 lactations is then repeated into infinity
- Various economic metrics are "maximized" using Solver by choosing conception DIM (i.e., this assumes a cow becomes pregnant when she is bred)
- Constraints for Solver (by lactation)
  - Conception DIM <= Latest DIM of conception (Latest DIM at dry off – (Gestation length – Dry period))
  - Conception DIM = Integer
  - Conception DIM >= VWP
- Solver gets "close" but isn't perfect (manually iterated to find max value)

* NPV simply accounts for the "time value of money" (i.e., a dollar today is worth more than a dollar tomorrow)

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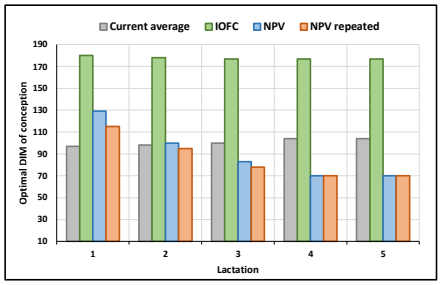
Summary of optimal DIM of conception vs economic metric



When total costs and income (value of springer, calf and cull cow) are included, along with the time value of money, what is optimal changes considerably. In a "perfect world" dairy could delay breeding slightly on first lactation cows, but they should get mature cows (L3+) pregnant faster.

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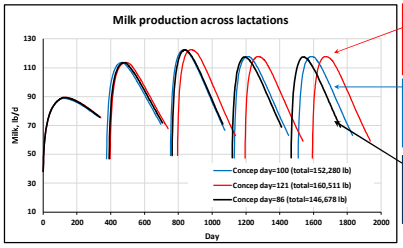
Economics of optimal breeding day in milk



Net cash flow of 5-lactation series = $734. NPV = $96, interpretation of NPV is that you could pay $2,096 ($2000 + $96) for springer and realize an 8% rate of return (i.e., discount factor used). Repeating NPV every 1,941 days into infinity = $286.

Net cash flow of 5-lactation series = $764. NPV = $139, interpretation of NPV is that you could pay $2,139 ($2000 + $139) for springer and realize an 8% rate of return (i.e., discount factor used). Repeating NPV every 1,836 days into infinity = $433.

Net cash flow of 5-lactation series = $791. NPV = $167 with Conception days of 115 for L1, 95 for L2, 78 for L3 and 70 for L4-L5. Repeating NPV every 1,764 days into infinity = $539.

Delaying when cows get pregnant increases milk, but makes all economic measures shown here (net cash flow, NPV, and repeated NPV) worse.

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Optimal conception DIM depends upon economic metric used

Lactation =>	1	2	3	4	5		Discount		Discount	Net		Repeat	5-lact	5-lact	Milk/day
	Optimal DIM of conception					IOFC	IOFC	IOTC	IOTC	cash flow	NPV	NPV	ECM, lbs	total days	prod life
Current average	97	98	100	104	104	$13,149	$10,863	$951	$750	$756	$133	$415	152,452	1,839	82.90
Average +21 days	118	119	121	125	125	$13,851	$11,338	$918	$726	$723	$89	$265	160,664	1,944	82.65
Current median	80	78	78	83	83	$12,440	$10,371	$949	$748	$754	$150	$490	144,274	1,738	83.01
Objective to Maximize															
IOFC	180	178	177	177	177	$15,564	$12,437	$664	$541	$469	-$148	-$396	181,264	2,225	81.47
Discounted IOFC	180	178	177	177	177	$15,564	$12,437	$664	$541	$469	-$148	-$396	181,264	2,225	81.47
IOTC	180	119	96	70	70	$13,436	$11,063	$1,014	$789	$819	$157	$482	155,563	1,871	83.14
Discounted IOTC	174	115	94	70	70	$13,351	$11,006	$1,013	$789	$818	$160	$494	154,585	1,859	83.15
Net cash flow (NCF)	180	119	96	70	70	$13,436	$11,063	$1,014	$789	$819	$157	$482	155,563	1,871	83.14
Net Present Value*	129	100	83	70	70	$12,837	$10,652	$996	$781	$801	$168	$536	148,701	1,788	83.17
NPV repeated	115	95	78	70	70	$12,659	$10,527	$986	$774	$791	$167	$539	146,678	1,764	83.15

* As defined here, Net Present Value (NPV) is the same as Discounted NCF

- IOFC – poorest metric as it ignores opportunity value of stall (delay breeding)
- IOTC and Net cash flow – better than IOFC, but does not account for time value of money
- Discounted Net CF (NPV) – good metric, but ignores that process can be repeated
- NPV repeated – most appropriate metric for an on-going business – max returns to stall vs cow
- With exception of IOFC, early conception for L>1 is generally better

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Summary

- Determining the optimal time to breed cows is complex and depends upon many factors
  - Reproductive efficiency
  - Injury risk
  - Transition risk
  - Shape of lactation curves by parity – peak and persistency
  - Economic factors (prices, costs)
- Given shape of lactation curves estimated here (energy-corrected milk), it appears that delaying breeding is not warranted (with exception of primiparous cows) as optimal DIM was generally earlier than current average. However, it does depend upon which metric is used.

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Transition Risk (only filter applied is fresh date)

Early Removals by Lactation Group (FDAT 8/1/2019 - 7/31/2022)

	Removed in first 30 DIM*				Removed in first 60 DIM*			
Lact Grp	Yes	No	Total	% Yes	Yes	No	Total	% Yes
1	56	6,969	7,025	0.8%	142	6,883	7,025	2.0%
2	24	5,589	5,613	0.4%	79	5,534	5,613	1.4%
3	43	4,350	4,393	1.0%	108	4,285	4,393	2.5%
4	72	5,459	5,531	1.3%	173	5,358	5,531	3.1%

* Excludes Sold for Dairy

Is this risk high enough to impact breeding decisions?

	Conception DIM by Lactation						Discount		Discount	Net	Disc (NPV)	Repeat	5-lact	5-lact	Milk/day
	1	2	3	4	5	IOFC	IOFC	IOTC	IOTC	cashflow	Net CF	NPV	ECM, lbs	total days	prod life
Net cashflow	176	113	92	86	86	$13,978	$11,468	$1,398	$1,078	$1,198	$444	$1,354	160,439	1,890	84.89
Discounted Net CF*	128	91	76	75	79	$13,225	$10,956	$1,368	$1,069	$1,173	$458	$1,462	151,828	1,786	85.01
NPV repeated	85	77	70	70	70	$12,647	$10,552	$1,329	$1,044	$1,134	$451	$1,492	145,277	1,709	85.01
Optimal including transition risk															
Net cashflow	176	113	92	86	86					$882	$213	$389	160,439	1,890	84.89
Discounted Net CF*	135	93	78	75	79					$862	$224	$442	152,755	1,797	85.01
NPV repeated	118	87	72	70	71					$847	$222	$447	149,224	1,755	85.03

* Also referred to as NPV (Net Present Value)

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Thank You

Kevin Dhuyvetter, Ph.D.

(785) 410-3244

kdhuyvetter@elanco.com

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