Relationship of Production and Conformation to Lifetime Profit

Bennet G. Cassell

Dept of Dairy Science, Virginia Polytechnic Institute and State Univ, Blacksburg, VA, 24061-0315 USA
Email: bcassell@vt.edu

▪ Take Home Message

- Increased lifetime profit is a better selection goal than longer productive life. Living a long time doesn't guarantee that the cow was worth keeping.
- Select to improve protein if the market pays for it or if somebody else is willing to pay a premium for breeding stock bred for higher protein. Commercial herds in fluid milk markets don't need to pay premium prices for semen from the very best protein bulls.
- Type traits are useful for improving lifetime profit, but are less useful than most producers believe. Production traits, productive life, and SCS are much more valuable traits to change through selection.
- Just because somebody recorded data on 14 type traits and calculated genetic evaluations on them doesn't mean that all those traits should affect sire selection. Closer front teat placement has some value. Deep udders are harmful but shallow udders that don't milk are even worse. Genetic differences between bulls in foot angle doesn't affect lifetime profit very much.
- The best way to remember all the little rules is to let a computer calculate a selection index that keeps all the genetic correlations and economic weights in mind and lets the chips fall where they may in ranking bulls.

▪ Introduction

The goal for selection efforts among many dairy producers is to make genetic improvement for lifetime net economic merit. Lifetime performance traits are difficult to improve through direct selection because of generation intervals and the difficulty of measuring some lifetime performance traits. Indirect selection on traits related to lifetime performance has been the method of choice for most dairy producers. Such selection is based on traits like production and conformation readily measured early in life on many dairy cows. The question addressed in this presentation is how effective can indirect selection be to improve lifetime economic merit? One purpose in addressing this issue is to compare optimum indirect selection indices with those widely used in the dairy industry.

Many dairy farmers are interested in increasing herdlife among their cows. Increases in herdlife would reduce replacement costs per unit of product and allow cows to produce for a longer period of time at higher milk yields as mature animals. Management of older cows increases health and reproductive costs and may require changes in herd management that add to per unit production costs. Throughout this presentation, comparisons will be made of indices to improve herdlife to indices to change lifetime net economic merit. These are not the same breeding objectives and producers should be aware of the major differences in selection policies required to change these two distinctly different measures of lifetime performance.

▪ Lifetime Performance Traits

Herdlife can be measured in several different ways. Perhaps the most basic expression would be age at disposal or death of an animal. Such a measure would include rearing period, days in production, and dry days. Production data, at least as routinely reported in the United States, contain days in milk, but only for the first 305 days of production in any lactation. We can count days of productive life as long as we are willing to discard days in milk beyond 305. This is the information currently used in the United States to measure our lifetime performance trait, Productive Life. Productive life, or PL as it frequently appears in listings of genetic evaluations, measures months (not days) of production by 84 months of age. We limit genetic evaluations to the first five lactations by any cow, but very few cows would even have calved for the fifth time by 84 months of age. PL through 84 months of age, discarding days in milk beyond 305, is the measure of herdlife chosen for our genetic evaluations.

Another basic measure of herdlife is the percent of cows surviving to calve for the second, third, fourth, etc. time. This approach is easy to understand, but may oversimplify what is really happening. Survival is a “yes or no” trait, but the genes which control survival operate more like those for milk production which is expressed across a continuous range of possible values. Some precision may be lost in measuring herdlife by survival percentages and alternate measures like length of productive life or total days in the milking herd do use a continuous scale. However, much good research has been done with survival data and we will use some of it in this paper.

Improved herdlife improves lifetime economic performance of dairy cows, but tells us less about which cows made money than a more direct measure of lifetime economic merit would. After all, herdlife only tells us how long a cow lasted in the herd, not how profitable she was in the interim. At Virginia Tech (the same place as Virginia Polytechnic Institute and State University listed on the title page), we have developed a measure of lifetime economic merit based on DHI records. We call this measure Lifetime Relative Net Income. A general description of how we calculate it is as follows:

Sources of Income:

- Value of milk minus production costs
- Value of fat minus production costs
- Value of protein minus production costs
- Number of calves born times net value of each calf
- Salvage value of the cow minus her value as a heifer calf

Sources of Expense:

- Rearing cost based on age at calving
- Charges for maintenance, labor, and facilities for each day in milk
- Similar charges for each day not in milk

Our studies have used cows from all over the country and certainly no single milk price or set of expenses would apply for such diverse conditions. We do use the same costs and values, however, which means that the absolute value of net income we estimate will not be perfect from herd to herd. However, the method RANKS cows very well within a herd and allows us to estimate the differences in net income between cows managed the same.

One other concept is necessary to understand what we have tried to do by estimating Lifetime Relative Net Income. We charge each cow “rent” on the stall she occupies for each day she is in the lactating herd. We do this because even an Angus cow would generate some income in a dairy herd if the farmer was willing to house, feed, and milk her. We call this rent “opportunity cost”, as the owner of each cow has the “opportunity” to replace her with some other heifer from the replacement herd at any time. The rent is different for each herd and for each year within each herd. Those replacement heifers get better because of genetic trend. “Rent” for old cows is higher per day than it was early in their life because the competition for stall space has gone up!

Adjusting our lifetime net income figures for opportunity costs lets us compare cows on the basis of their contribution to herd income above or below what would be generated by an average replacement heifer from the same herd.

Many of our studies have used Lifetime Relative Net Income adjusted for opportunity cost as the “ideal” or ultimate breeding objective which producers should wish to improve. What we have set out to do, and what I want to share in this article, is which traits tell us the most about lifetime net income and how we should combine PTA's on dairy bulls to make an ideal index to change it.

Note to readers: The author apologizes for some of the detail used in explaining lifetime performance traits and Lifetime Relative Net Income in particular. Producers tend to think of lifetime performance traits as simple concepts like milk production per day. Unfortunately, that is not correct. Changing genetic merit for lifetime performance of dairy cows is more complex than changing milk yield and my hope is that breeders will consider carefully what is involved in some of these issues as they critically evaluate their breeding programs.

▪ Trends in Herdlife

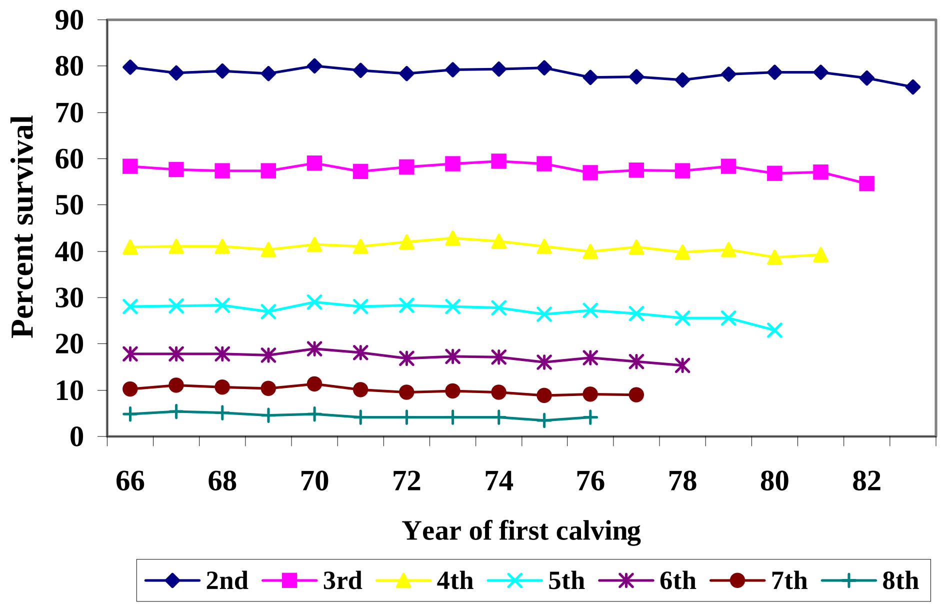
By the late 1980's, US dairy farmers had seen enough genetic progress in milk production to recognize that their cows were under greater stress than they had been years earlier. They began to question whether selection to increase milk yield had decreased herdlife. For an individual cow, higher yields are positively related to herdlife at the genetic level, but the relationship might not hold for entire populations.

A study by Nieuwhof, et al. published in 1989 is the source of the figure that follows. The study was based on survival of cows first calving between 1966 and 1983. By their very nature, lifetime performance studies are based on "old" data because cows need time to express longevity. The USDA study tells us less than we might like about what has happened with 10 more years of selection, but it should give us confidence that nothing about herdlife is changing very fast. Survival in Holsteins is decreasing slightly over time. The data shown are from a fairly equal mix of registered and grade cows. Survival in registered Holsteins was slightly higher than for grades. Not shown are results for Jerseys where selection for higher production may have been even more intense than in Holsteins. However, survival for Jerseys was improving over the years in the study. The Jersey breed has enjoyed increasing popularity and some growth in the past 25 years.

Why is the trend in survival slightly negative? One reason is because the national herd of Holsteins in the US was contracting during the years shown, particularly in the 1980's when genetic progress for milk yield was more rapid than growth in demand for dairy products. That simple fact meant that fewer cows were needed to produce milk for the country. When a population is contracting for a number of years, herdlife and/or survival HAS to decline. The trend toward larger herds was beginning in earnest during the period involved in the study. Herd managers were beginning to demand that cows freshen young, milk at high levels quickly, and adapt to the rigors of confinement housing and high energy diets without disrupting daily procedures. As more such herds appear, will there be a place for the old cow which needs a little extra attention, and extra service or two to breed, and a few days in the hospital herd each year?

University research projects have shown that selection to improve milk production will increase health costs and somatic cell scores over time. It is less clear that longevity will suffer greatly. Most breeders and geneticists in the US would agree that the relative value of fitness traits has increased in recent years and that some selection pressure on traits like productive life and somatic cell count are justified.

Holstein Survival Rates to Different Parities



▪ Relationships Between Lifetime Performance and Other Traits

One basic rule of selection to change an animal is that while you are changing one trait through DIRECT selection, you also change other traits controlled by some of the same genes. Perhaps the best known such relationship in dairy cattle breeding is the **negative genetic correlation** between milk volume and fat percentage. Higher milk yield is negatively correlated with fat percentage. Because of this relationship, we have reduced the fat content PER UNIT of milk produced through genetic improvement in milk production. Cows today producer more total fat than they used to, but there is less fat per unit of milk than cows of 20 years ago produced. Of course, we enjoy the benefits of some fortunate positive relationships such as the improvement in feed efficiency that accompanies improved milk production.

The results that follow are driven by correlated responses. The two studies involved were made by Dr. Dan Weigel, a Ph.D student of mine and subsequent postdoctoral fellow at Virginia Tech a few years ago. Dan worked with data from Holstein herds in the US that had classified at least once between 1983 and the early 1990's. He had scores on those cows from Holstein Association, Inc. (HA) in Brattleboro, Vt. and lifetime production records from USDA files used for genetic evaluations. Dan calculated productive life and lifetime relative net income adjusted for opportunity costs on over 2 million cows. He used economic values for milk, fat, and protein that fit two milk market conditions: milk marketed for fluid consumption and milk used in the manufacture of cheese. For the final analysis, Dan used over 52,000 cows scored in special programs run by HA called SETs. SET stands for "special evaluation for type" and is a program designed to score daughters of AI young sires and an appropriate number of contemporaries to run genetic evaluations for type. We used these data because we felt they would be less affected by selection of better type animals by breeders prior to regularly scheduled HA classification programs. Dan's data included about 26% grade cows.

Table 1 shows heritabilities of different traits in the study and the genetic correlation of each trait with relative net income from the fluid or cheese market and PL. All the traits except the three lifetime traits were measured in the first lactation of the 52,000 cows in the study. The relationships in Table 1 are a simplistic interpretation of the real life situation. Fore udder attachment is moderately heritable – meaning a bit more difficult to change through selection than stature or milk production, but easier to change than somatic cell score. Improving fore udder attachment **reduces** both of the lifetime profit functions, but it improves PL. How can this be? Aren't better fore udders a good thing? "Better" as measured by today's standards for fore udder means that there is less fore udder and, thus, less secretory tissue to produce milk. If we just select for improved fore udder, we will reduce milk production enough to depress lifetime profit. Better fore udders don't improve productive life enough to offset the losses in productivity each day a cow is in the herd.

Table 1. Heritabilities and genetic correlations of traits measured early in a dairy cow's life with lifetime performance traits.

		Genetic correlation with		
Trait	**h^2**	**RNI, fluid**	**RNI, cheese**	**PL**
RNI, fluid	0.18	1.00	0.92	0.59
RNI, cheese	0.14	0.92	1.00	0.72
Productive life (PL)	0.06	0.59	0.72	1.00
Milk	0.35	0.85	0.73	0.37
Fat	0.29	0.42	0.54	0.38
Protein	0.31	0.68	0.73	0.37
Somatic cell score	0.11	0.04	-0.14	-0.25
Stature	0.37	-0.06	-0.04	0.17
Strength	0.28	-0.18	-0.15	-0.05
Body depth	0.33	-0.12	-0.08	0.02
Dairy form	0.30	0.47	0.48	0.32
Rump angle	0.34	0.08	0.07	0.02
Thurl width	0.24	-0.08	-0.06	0.02
Rear legs, side view	0.16	0.09	0.11	0.02
Foot angle	0.14	0.01	0.09	0.29
Fore udder attachment	0.20	-0.21	-0.12	0.24
Rear udder height	0.18	0.00	0.07	0.22
Rear udder width	0.15	0.08	0.14	0.18
Udder cleft	0.14	0.04	0.06	0.16
Udder depth	0.28	-0.27	-0.18	0.21
Teat placement	0.22	-0.04	-0.01	0.09

h^2 = heritabilities; RNI = Relative Net Income; PL = Productive Life

Good selection policy must consider all the major genetic correlations between economically important traits and "indicator" traits. Leaving out an important relationship could cause us to change the wrong trait, change it in the wrong direction, change it too much, or give it too much value relative to other traits. With that word of warning, let's make some interpretations of Table 1.

Both the fluid and cheese profit functions are more heritable than PL. That's because they include a heavy dose of production traits in how they are calculated. The genetic correlation between the two functions is high at .92. If you build selection index values around the two, the same bulls would tend to rank high on both indexes. Both profit functions are positively correlated with PL at .59 for fluid and .72 for the cheese market prices. Cheese market prices are lower than fluid market prices. This makes the traits in RNI which affect turnover rates, rearing costs, days in milk, and overall length of productive life more important for the cheese market than they are for the fluid market. The relationships between other traits and fluid or cheese RNI should not be expected to be the same, since somewhat different groups of genes affect the two functions.

The production traits are positively correlated with PL. Higher producing cows live longer. Notice that the genetic correlations are higher between production traits and the RNI functions than between production and PL, however. Production affects profit directly since more milk means more income to offset rearing costs. Milk is more important in fluid RNI than it is in cheese RNI, whereas the reverse is true for fat and protein. Fat and protein have more value in cheese RNI than in fluid RNI. This means that the milk market can affect the optimum selection index used by producers to select service sires. In the milk manufacturing areas, milk components and those traits, which improve PL have higher economic value than they do in fluid milk market areas.

Genetic correlations between individual type traits and the profit functions tend to be fairly close to zero with some positive and some negative relationships. The exception is dairy form, which is really another measure of milk production. Cows with higher milk production tend to score better for dairy form, which explains the relatively high positive genetic correlations between dairy form and PL or the profit functions. The body traits – stature, strength, and body depth – as a group are negatively related to lifetime profit. Stature has a small positive relationship with productive life. Farmers tend (but not strongly) to keep big cows longer. Maybe they cull the runts earlier. The relationship between PL and body depth or strength is nearly zero.

Cows with better feet and udder traits tend to live longer, based on the genetic correlation between several of those traits and PL. The relationships with the profit functions are less clear (closer to zero) expect for udder depth. Cows with deeper udders tend to be more profitable. This is another case of a hidden relationship responsible for an observed result. Deeper udders are a natural consequence of selecting for higher milk yield. That milk has to come from somewhere, just like the case with fore udder attachment. Just as with fore udder, udder depth is positively related to how long cows live, but negatively related to how profitable those cows are. That's part of why I say that selection to improve lifetime performance requires a breeder to figure out just what it is that needs to change about lifetime performance. Longer life won't pay the mortgage if the cow doesn't milk in the meantime.

▪ Accuracy of Prediction of Lifetime Performance

Our purpose in the work that created Table 1 was to learn more about how accurately we could predict the lifetime economic traits and productive life. Remember that we need to predict these traits on daughters of a bull way before we could measure them directly. Bulls that have seven year old daughters have to be at least nine years old themselves. We get progeny tests for milk and type when the bulls are five years old. We are within a year or so of proven sons of a bull before we can measure 84-month survival on his daughters. Decisions about which proven bulls to use heavily must be made earlier.

Fortunately, we can use daughter information for production, conformation, somatic cell score, survival to have a second or third calf, and pedigree merit of bulls for PL or lifetime profit to predict what the genetic evaluations would be if daughters were allowed to become old enough to express lifetime traits. Such predictions depend on genetic correlations between the traits measured and the traits being predicted. Just how much do you know about a bull's breeding value from a "predicted" evaluation? The accuracy of predicted evaluations can be measured by Reliability, just as we measure accuracy of production or type evaluations. Accuracy of an evaluation will depend on the amount of genetic control of the trait (heritability) and the number of daughters evaluated. Table 2 shows the Reliability associated with sire PTA's for PL and lifetime profit when different combinations of traits are used.

Table 2. Reliability of predicted productive life (PL), and relative net income (RNI) from fluid and cheese markets using production traits, somatic cell score (SCS), and different combinations of type traits. All reliabilities are based on 80 "effective daughters" for direct measurements of traits.

Traits used for prediction	**Trait being predicted**		
	RNI, fluid	**RNI, cheese**	**Productive Life**
Production traits	0.65	0.51	0.16
- add SCS	0.66	0.56	0.22
- add foot angle, udder depth, and teat placement	0.66	0.57	0.35
- add dairy form and rear udder width	0.67	0.58	0.36
- add stature, body depth, rump angle, thurl width, rear legs side view, and udder cleft	0.68	0.60	0.38
- add strength, fore udder attachment, and rear udder height	0.68	0.60	0.39

Table 2 assumes that bulls have 80 daughters distributed one per herd with all the correlated traits measured on each daughter. In reality, many bulls would have 50 to 60 daughters or even less and almost never would all the type and production traits be available on every daughter.

Let's start with the best case situation. If we used all the correlated traits to predict evaluations for profit, maximum Reliability would be 68% for fluid market conditions and 60% for the cheese market conditions. Maximum Reliability would be quite a bit lower, 39%, for PL. These values line up about like you would expect with the heritabilities for RNI and PL in Table 1. There is less genetic control of PL, and 80 daughters just won't tell us as much about genetic ability for that trait as they will about genetic ability for the profit functions.

Traits are added in groups in Table 2 – except for SCS which measures something quite a bit different from production or type information. SCS increases Reliability for PL quite a bit, from 16 to 22%. It adds less to what we know about the RNI values. The most useful type traits, foot angle, udder depth, and teat placement, boost Reliability for PL from 22 to 35%, a substantial increase. However, those traits don't do much for the lifetime profit functions. The other type traits tell us a little bit more about PL but very little about the profit functions. Bottom line: type data are useful for predicting how long a cow will live, but considerably less useful in telling us how profitable she will be in the meantime.

▪ Relative Value of Type and Production Traits

Table 2 gives some insight into how useful production and type traits are in predicting lifetime profit or PL, but many producers would be interested in how to combine those traits in a selection index if they were actually trying to change lifetime profit. PL can be selected for directly, and genetic evaluations for PL in Holsteins actually include information from all of the traits in Table 2 except SCS. Table 3 shows standardized weights for the most important type and production variables to predict profit or PL. A brief explanation of "standardized weights" may be helpful.

Milk production in the US is measured in pounds and varies a lot more than a type score for teat placement which is measured on a 50 point scale. A standardized weight accounts for differences in variation from one trait to another. For interpretation, the weights in Table 3 would be appropriate for genetic evaluations that were expressed in units of genetic standard deviations. Suppose a genetic standard deviation unit for milk is 600 lbs. (which is pretty close) and that a bull had a PTA for milk that was 1800 lbs. above the genetic base. That bull's standardized PTA would be 1800/600 or 3 standardized units. Three units of milk production would require the same selection effort to achieve as 3 units of teat placement. That means that the weights in Table 3 can be compared across traits to see which trait is the most valuable in improving profit in a fluid milk market. Similar comparisons can be made in the cheese market. PL is expressed in months instead of dollars, so the coefficients have a different scale.

Table 3. Standardized coefficients for prediction of relative net income in fluid or cheese milk markets or productive life using production traits, somatic cell score, and three type traits.

Trait	**Relative Net Income**		
	Fluid	**Cheese**	**Productive Life**
Milk production	189.04	65.50	0.54
Fat production	1.00	13.47	0.34
Protein production	-30.29	50.95	0.16
Somatic cell score	-25.99	-41.29	-0.36
Foot angle	2.85	7.64	0.38
Udder depth	-3.75	-2.88	-0.05
Teat placement	10.44	13.80	0.63

Interpretation of results in Table 3 is as follows: if you change milk production by one genetic standard deviation unit (about 600 lbs.), you will increase predicted RNI in a fluid market by $189.04. The same change will increase RNI in the cheese market by much less, only $65.50. PL would increase by 0.54 months with the same change. If you were comparing two bulls who differed by one genetic standard deviation unit in milk and were exactly the same in all those other traits, the predicted difference in the two bulls' genetic evaluations for profit or PL would differ by the amount in Table 3.

Here some other interpretations of results in Table 3.

- Somatic cell score decreases all three measures of lifetime performance as it increases. Higher cell counts are bad, lower cell counts are good. Compared to the other traits in Table 3, SCS is about as important as any of them except for milk production in the fluid market profit function.
- The relative value of fat and protein is not the same in the fluid and cheese markets. This means that where a farmer markets his milk affects sire selection if the relative values of milk, fat, and protein change substantially between markets.
- Protein has a negative value in the economic assumptions we used in the fluid market. Protein is fairly expensive to produce and it had no value in our fluid market.
- Udder depth has negative value for both profit functions and for PL. This means that bulls with LOWER evaluations for udder depth sire more profitable daughters and daughters with longer productive lives. Notice that the weights for udder depth are close to zero, however. The genetic correlation between udder depth and production is considered in Table 3, so udder depth doesn't mean very much in prediction of profit or PL.
- Teat placement does matter, even after the tendency for high producers to have wide teats is accounted for. Results show that bulls whose daughter

milk well AND have reasonable close teat placement are more profitable. Teat placement was the single most influential variable in predicting PL.

- In general, type information is more useful for predicting how long cows live than it is for predicting their economic contribution to the herd. The generally accepted dogma is that better type = longer life = more profit. The situation in real life is not that simple as that last equality doesn't hold.

Conclusions

The most profitable cows in dairy herds have to produce a lot of milk. Contrary to the beliefs of some, those cows that are most profitable come in many shapes and sizes. There is no "ideal type" that all breeders should strive to achieve **if** high lifetime profit is the ultimate objective. On the other hand, length of productive life has a clear, positive value to all dairy producers. Fitness traits will likely become more important in selections in the years to come.

Lifetime profit appears to be the preferred breeding objective for commercial breeding programs. Productive life is part of improved lifetime profit, but it must be combined with milk production and increased attention to fitness traits like somatic cell score if overall profitability across the lifetime of a cow is the desired breeding goal. In the years to come, additional fitness traits like disease resistance and reproductive performance may be included in commercial breeding objectives.

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