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Aligning Genetic Potential with Nutritional Requirements for Longevity and Sustainability

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Answers to Questions Asked, Courtesy of:

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Q: Why did the (National Research Council) NRC predictive equation drop off so dramatically at high milk yields?

José: I think this is just an artifact of fitting a nonlinear model to a data set in which very few cows - back in the 1980s and early 1990s - were producing at 4X or 5X maintenance. I don't think it's real. NRC in 2001 probably overestimated the real values for discounted digestibility as intake increased above 4X or 5X maintenance.

Q: How could energy metabolism affect residual feed intake (RFI) or feed efficiency?

José: We typically assume that every cow has the same maintenance requirement and that efficiency of nutrient utilization is the same. For instance, if a cow weighs 680 kg and the diet she consumes contains 1.65 Mcal/kg of DM, we assume that she will require 0.08 x 6800.75 Mcal for maintenance (10.7 Mcal/d) and each kg of 3.5% fat-corrected milk will require approximately 0.70 Mcal. If the cow eats 25 kg of DM, she is expected to produce 43.6 kg of 3.5% FCM. Obviously, some cows might digest feed better. They might have increased rumen digestion, which will increase the NE of the diet and the amount of microbial protein produced, she might have reduced maintenance needs because her post-absorptive metabolism is less wasteful, her tissues might have less futile biochemical reactions, she might demand less nutrients to maintain an immune system, etc., etc. There are numerous reasons why altered individual animal energy metabolism might affect RFI or feed efficiency.

Q: Would it not be more biologically relevant to use energy intake vs. dry matter intake to determine feed efficiency?

Kent: Yes, we typically do these calculations in MCal of energy. The figures in the presentation used kg for simplicity.

Q: What is your opinion regarding contribution of precision nutrition to RFI relative to other dairy herd and farm management practices?

Kent: I think it is critically important. If we are going to capture economic gains from knowing the genetic potential of each cow and meeting those needs as closely as possible, then we will need to divide animals into multiple groups and match rations accordingly.

Q: Is there a way to select for lifetime efficiency/sustainability?

Kent: Right now, we select animals for Lifetime Net Merit, a measure of net profit over the rearing, lactating, and dry periods, including all known costs and revenues. That's really the ultimate goal. That said, in the recent Jersey Performance Index update we used lifetime combined fat plus protein divided by lifetime (estimated) dry matter intake as the breeding objective, so it is a reasonable thing to do.

Q: Kent, I believe in a recent presentation Albert DeVries suggested 5th and 6th lactation cows were most profitable. How do you reconcile that with your suggestion to consider culling after the second lactation? P.S. I'm not saying you're wrong.

Kent: I wasn't saying we should necessarily cull all cows at the end of the second lactation, just that we should take a holistic look at such options and evaluate the pros and cons from an economic (including labor, vet costs), environmental, and consumer/social sustainability viewpoint. If we were to do such a thing, we would have to adjust our selection and nutrition programs so cows could calve younger, like 18 months of age, and produce at a level as close as possible to current mature equivalent levels in the first two lactations, and we would have to determine the optimal way to transition her to a beef feedlot afterwards.

Q: Why is liver amino acid flux positive in the control in that study? There is always a net uptake of AA by the liver.

José: The net flux of essential amino acids (AA) is negative because mammalian cells do not express genes for certain enzymes required to synthesize essential amino acids. Therefore, essential AA either have a 0 or a negative hepatic net flux (liver cannot synthesize them). On the other hand, nonessential AA can be synthesized by hepatocytes through transamination reactions. Many nonessential AA are synthesized in the liver either from intermediates of the TCA cycle through pathways that use pyruvate, α-ketoglutarate, and oxaloacetate. This is why the net flux for the animals not induced to have inflammation was positive. For animals with induced lung inflammation, it remained negative because disease (inflammation) causes anorexia and increases the use of nonessential AA (deamination and use of carbon for gluconeogenesis, or use of AA for synthesis of acute phase proteins).

Q: In the brown midrib corn (BMR) study, was there less bodyweight gain (BWG) to compensate for the higher production at same intake?

José: The experiment by Masahito Oba and Mike Allen on BMR corn showed increased yields of milk and 3.5% FCM with increased DM intake. Intake of DM increased 2 kg/d with the BMR silage and production increased 3 kg/d. The increased DMI explained the increase in milk yield. There was no difference in changes in bodyweight or body condition. Because the BMR corn silage had more digestible NDF, cows were able to consume more DM. The combined increased DMI and more digestible fiber allowed them to be more productive.

Q: Is feed efficiency consistent across life stages? E.g. are animals that are more feed efficient as calves also more efficient during lactation?

Kent: It appears that the correlation between feed efficiency as a growing heifer and feed efficiency as a first lactation cow is slightly positive, around 0.25 or 0.30, from an Australian study, whereas the correlation between growing heifer efficiency and efficiency as a second or third lactation cow is lower, like 0.05 or 0.10. Still, at least it is a positive correlation, which is good.

Q: How was DMI measured in Marinho's study?

José: In Marinho's study, there were 399 cows from 4 experiments in which DMI was measured for individual cows daily from calving to 105 days in milk.

Q: Low intake in early lactation may not affect total milk production, but what about the incidence of metabolic disorders and the associated costs?

José: In general, there is an association between disease and DMI. Cows that develop disease have reduced DMI. In some studies, cows with less DMI prepartum are more likely to develop disease postpartum. The challenge in those studies is to establish cause-effect because they are all of epidemiological nature (association). In Marinho's data, we are looking at the risk of disease, but we do not have it analyzed yet. In any case, remember that most diseases in dairy cows occur in the first 4 to 8 weeks in lactation, which makes it difficult to sort out if less intake resulted in more disease, or if disease resulted in less intake.

Q: Is there a risk to increase health disorder and involuntary culling rate when we select cows based on RFI? Do we know the difference in survival rate to the next lactation between low RFI and high RFI cows?

Kent: Yes, there is a significant risk. Based on preliminary data it appears that feed efficiency in mid lactation is relatively uncorrelated with female fertility and early postpartum health traits, but we will need to monitor such traits closely so we don't get an undesirable correlated response to selection for efficiency.

Q: Kent, you showed that body protein turnover was a significant part of maintenance (energy?) cost in non-lactating animals. Is this true to this extent in lactating cows?

Kent: The data I showed were from beef cattle, but it was consistent with mice and other non-cattle species in which people have made selection lines for low and high efficiency. So, I believe it's probably true but don't have solid data yet to support that belief.

Q: Can increasing MP in early lactation induce greater body fat mobilization (to support the increase in milk production induced by MP) and potentially increase the risk of metabolic health disorder?

José: There are some suggestions in the literature for that. Early work by Bob Ørskov in Scotland showed that increased dietary crude protein by supplementing fishmeal to cows in the first weeks of lactation stimulated milk yield without a concurrent increase in DMI, which resulted in increased fat mobilization. More recent work from Bill Weiss at the Ohio State University did not corroborate those data. Weiss work showed that increasing MP supply improved milk yield without a concurrent increase in lipomobilization. Perhaps, the best way to look at this is: In herds with poor postpartum management, it is possible that supplying more MP might increase milk yield at the expense of body reserves. On the other hand, in herds in which cows are well fed, housed, and managed, supplying more MP will increase milk yield in early lactation without a negative impact on body reserves because cows will soon be able to compensate with additional intake.

Q: Should we make energy maintenance requirement partly dependent on feed intake level?

José: The data I showed in the presentation from Alex Bach in Spain indicates that as milk yield increases, the efficiency of use of NEL, after accounting for maintenance and body energy changes, decreases (it was not constant at all levels of energy intake or at all levels of milk yield). At this point, it is unclear if maintenance requirements explain the reduced efficiency of NEL use in high-producing cows. It is possible that a combination of factors such as:

- increased maintenance requirements
- reduced rumen digestibility at very high intakes (so the NEL we use for the diet is less than estimated)
- Incorrect assumptions of body energy change (either incorrect assumptions used to account for energy release from loss of BW or for energy required for gain of BW).
- Lack of data for body composition when dairy cows gain or lose body weight (incorrect quantification of the energy released/required to lose/accrete tissue if it is gut fill, body fat, or body protein.

Q: Jose, if we supply more MP to fresh cows and drive milk, are we at higher risk for fatty liver and ketosis?

José: See my response, above, on the same topic. Remember, producers select cows to produce more milk components. We do not want to antagonize or work against that. What we need to figure out is how to provide the key nutrients and remove the hurdles that prevent cows from consuming adequate amounts of DM in early lactation for their own needs. My impression (remember that the world is full of impressions and opinions whenever we do not have the real data!) is that in poorly managed herds there might be a risk as suggested in your question. On the other hand, in well managed herds the risk is probably nonexistent.

Q: In autumn, a huge test will occur in the Netherlands due to new maximum crude protein legislation!

José: Jose: I am assuming the point here is that you will have more limitation on how much protein you can feed. Perhaps, the key here is to group cows such that you can better utilize the total amount of N you can feed a cow during a lactation to optimize the efficiency of N utilization.

Q: RFI started with beef. Now it is coming to dairy. How can we use this concept if measuring DMI is not easy?

Kent: It is definitely harder to measure RFI with the extra energy sink of secreted milk energy and, especially, the need to make sure we don't affect health, fertility, and other important traits adversely, so the cow can return and be profitable again in the next lactation. On the other hand, we don't have a better option. If we could get enough data, what I'd really like to do is estimate the regression coefficient for each energy sink (milk energy, metabolic body weight, and bodyweight change) for each cow using a random regression approach. This should be possible, but standard errors would probably be large.

Q: If we consider that cows are capital breeders, should we include feed/energy intake during the previous dry period when estimating feed efficiency to account for where the body reserve energy is coming from?

Kent: I don't understand the term capital breeders, but anyway we haven't done any work on feed efficiency in the dry period. We have mostly focused on mid lactation (50 to 200 days postpartum), so the cows are not losing or gaining significant amounts of weight at this point.

Q: Are farmers raising too many heifers and as a result being forced to cull more cows and, therefore, keeping culling rate high?

Kent: Well, they're not being forced, but some are doing it so it's a legitimate concern. But I think most have adjusted to the fact that we can now produce exactly has many heifers as we need using sexed semen, and they are using beef semen to breed the remaining cows. We probably won't see the big gluts in extra heifers as much in the future.

Q: Why does the digestibility discount fall off a cliff at five times maintenance?

Kent: See Jose's first answer on page 2.

Q: Kent, with genomics and better understanding of the genetic make-up of cattle, can we disentangle inbreeding from the deleterious impacts it causes on health and fertility?

Kent: Yes. At least for lethal conditions, we can identify haplotypes that are common in the population but never show up in homozygous form, which means they are likely lethal recessives. Sub-lethal conditions that just reduce performance, health, or fertility are more tricky.

Q: Could we select for a lower maintenance requirement? Would it make any sense?

Kent: Yes. Absolutely. We can select for smaller body (frame) size, and we should do so. Holstein cows have been getting larger and larger over time, so maintenance costs have increased significantly.

Q: Kent, you showed a slide in which selection for RFI results in leaner cattle. If that is the case for dairy cows, it means that they would have less BCS. Would that affect reproduction in the long run? Do you know what is the genetic correlation between RFI and DPR or fertility index in dairy cattle?

Kent: See the 3rd question on page 4.

Q: Do they use sexed semen (male) for the beef bulls they use on dairy cows?

Kent: Maybe a little bit, but I don't think it's too common because of the extra cost of sexed semen.

Q: What in the Holstein population is the average genetic potential for Energy Corrected Milk?

Kent: Milk-recorded, sire-identified U.S. Holstein cows born in 2015 (the genetic base year) have average mature equivalent 305-day yield of 28,072 milk, 1077 fat, and 871 protein, so that's probably the best answer I can give.

Q: Do we have statistics on how accurate we could be selecting cows for feed efficiency?

Kent: Unfortunately, not nearly as accurate as we would like. Reliabilities of genomic predictions for residual feed intake are around 0.20 for young selection candidates, and for feed saved (combination of RFI and excess maintenance costs) it's around 0.35 to 0.40, so we will make some mistakes. We are trying our best to keep building a larger genomic reference population, but we can only add 800 to 900 new cows per year unless we form some international collaborations with other countries who are trying to do the same thing.

Q: José, do you think the 12 nutritionists are focusing on the three most important factors?

José: I believe they are working with their clients to achieve those goals:

- have better quality forages
- have fewer sick cows
- improving postpartum cow care and the environment (housing, control of heat stress, feed bunk management, etc.) to improve early postpartum intake.

One area where the U.S. dairy industry has made huge improvements is on cow comfort and addressing fresh cow problems. The majority of producers today clearly understand that for cows to perform they need to be properly cared for. Facilities are better designed to the needs of the cows. Fresh cow programs (detection and intervention) are now based on better science. I believe most nutritionists aim for those three aspects, as well as others.

Q: Do the commonly used models to formulate diets for dairy cows capture the recent advances in the genetic potential for increased milk production of the modern cows? If not, do we need to make "adjustments"?

José: The challenges with any mathematical model used to predict nutrient needs is that it targets the average cow and the errors are substantial. On average, the new models (the upcoming NRC, for instance) will be quite good for the average cow, but there is substantial drift from the average cow. Let me give an example. We want to predict DMI of cows during late gestation or early lactation. The models used to predict that take into account animal characteristics (bodyweight, body condition, day relative to calving, milk yield if lactating), diet characteristics (NDF, forage NDF, starch, degradable starch, rumen-degradable protein, etc.), and some environmental factors. When we use those predictors, we account for some of the variance in DMI but, unfortunately, most of variance is explained by the experiment that originated the data (the farm) and the cow itself. In other words, because we do not have more information about the experiment that originated the data and the cow itself, we cannot explain more than half of the variance in DMI. As the famous British statistician Dr. George Box said, "all models are wrong, but some are useful." This applies to nutrition models.

Q: Should NRC in the future discuss how nutrient requirements evolve with genetic progress for different traits?

José: NRC has always been based on what can be supported by scientific research. NRC is unlikely to make recommendation unless experiments have demonstrated such effects or mechanistic studies have shown possible mechanisms that can be extrapolated whenever data are lacking.

The biggest issue the NRC committee faces is to find the data from mechanistic experiments or from empirical experiments that demonstrate such relationships (e.g. changes in amino acids maintenance requirement with improved genetic breeding value of cows). If those data are not available, NRC might write and make comments, but it is unlikely to make a clear recommendation with distinction among genetic groups, unless data are available.

Q: By using genomics and heavy selection of specific traits, are we heading toward merging genetic "lines," like what happens with poultry or swine?

Kent: In theory we could do this, but realistically we seem to be concentrating each of the major dairy breeds into a single line (through inbreeding). I think such lines are most useful in species where a terminal cross can be made, like a maternal line crossed with a growth line, then crossed with a carcass line.

Q: Do you think the cow's rumen microbiome could be a genetic selection criteria?

Kent: Yes, we are working on this. We know from transfaunation studies (exchanging rumen contents) that the cow controls her rumen microbiome profile. There are lots of studies about the impact of diet and other factors on the microbiome, as well as studies in which the calf's rumen is inoculated with the rumen bugs from a high or low producing cow. Most of these studies are small, though, and they often rely on cannulated cows, which are in short supply. We and a couple other universities have studies on ways to get rumen microbiome studies less invasively (buccal swab, tube, etc.), and this would be necessary if we want to do large-scale studies and characterize genetic variation in the rumen microbiome at the population level.

Q: So… better feeds or quality forage in the farm should be fed to fresh cows?

José: Yes, cows in early lactation or early and peak lactation are the queens of the farm. The producer should always prioritize the best forages to those cows. Unquestionable.

Q: If selection aims to have more resilient cows and not only produce more, but also being healthier, will it be more profitable to capture the milk potential on a full third or even a fourth lactation of the cows (considering that it takes two lactations to "break even")?

Kent: See the 1st question on page 3.

Q: Jose, how much better could we do, if we had a fresh cow pen, plus a high production pen later, vs having directly only a high production pen (first half of lactation for example)? What would be the impact on milk production? In % of improvement?

José: Fresh cows deserve increased attention, and the diets we formulate for fresh cows (e.g. first 3 to 4 weeks) should not be the same as those we formulate for cows in the high group (e.g. 30 to 150 DIM).

There are some key reasons for that. Cows in the fresh pen have less than ideal DMI and, therefore, the supply of microbial protein is limited. They almost always respond to improved supply of MP, in particular if the MP contains adequate amounts of limiting amino acids for most dairy diets such as methionine, lysine, and, perhaps, histidine. Also, fresh cows respond to some feed additives that are probably less important past 4 weeks in lactation (e.g. rumen-protected choline). Finally, because fresh cows have limited intake (e.g. in the first 4 weeks intake might average 20 kg/d), the limitation in intake caused by physical fill of the rumen is less if one decides to feed a diet with increased forage content. Imagine that the diet contains 55% forage and 22% forage NDF in the total DM. When you feed such a diet to a group of fresh cows averaging 20 kg of DMI, the individual cow is only eating 11 kg of forage or 4.4 kg of forage NDF. If the same diet is fed to the high group, with cows eating 28 to 30 kg of DMI, such concentration of forage or forage NDF might limit intake because of rumen fill (at 28 kg of DMI, those cows would be consuming 15.4 kg of forage or 6.2 kg of forage NDF). Remember, the rumen of a cow does not increase in size dramatically from 2 to 10 weeks in lactation to accommodate another 2 or 2.5 kg of forage NDF easily! Whenever possible, fresh cows deserve their own pen and their own diet. How much more milk you will make, I can't answer that question!

The answers to these questions are provided in good faith and are the scientific opinions uniquely of Dr. Kent Weigel, Department Chairman, Animal and Dairy Sciences, University of Wisconsin; Professor, Breeding and Genetics and Dr. José Santos, Professor, Dairy Cattle Nutrition and Reproduction, Department of Animal Science, University of Florida

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