Change is Inevitable, Outcomes Aren't

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Change often generates stress. Transition diets, weather, seasonal diet changes, pen moves, day length, stocking densities, virtually any change on a dairy farm can create stress and open the door to potential health and productivity risks. Of the many early indicators that change is creating stress are poor rumination, digestive upsets, manure variability, lost milk and components, and up trending metabolic disease. **Change is inevitable, but outcomes are not.**

Health and productivity of any living animal is modulated and controlled by a collection of body systems. There are 11 commonly-recognized body systems. Examples include the digestive, circulatory, respiratory, reproductive, endocrine and immune systems. When an animal is healthy and productive, body systems work together in harmony to sustain life. The ability of an animal to maintain a constant internal environment in response to environmental changes is a unifying principle of biology called **HOMEOSTASIS**.

There are many things that can throw one or more of a cow's body systems out of balance, threatening homeostasis. An example of a homeostatic state is when cattle diets are well-balanced, fed and consumed. Cattle that are in balance nutritionally optimize rumen fermentation and supply all the needed nutrients that support productivity and health. But what happens when pathogens or mycotoxins are introduced to the diet? What happens post calving with the introduction of increased fermentable starch? Or what if the diet is not available on a consistent basis throughout the day? These are examples of disruptors that can upset the apple cart leading to imbalances and loss of homeostasis.

Another natural principle related to homeostasis is **RESILIENCE**. Resilience is the ability of an animal to resist change, i.e., maintain homeostasis caused by stressors in the environment or diet. Cattle, like any animal, possess varying amounts of innate resilience. This is where the use of specific feed additives can be incorporated into the diet to help bolster a cow's natural resilience.

FACTORS AFFECTING HOMEOSTASIS AND RESILIENCE

OVERALL AFFECT OF STRESS:

The word "stress" can carry broad meaning, but in terms of dairy cattle, anything that alters their physiological or mental status can constitute a stress. From *behavioral and environmental stressors* like crowding, social group, and daily routine changes; to *dietary stressors* like diet changes, access, and quality; have all been found to have common negative effects on animal performance and the **immune system** (Horst E.A. 2019).

DIET CHANGE AND RUMEN EFFECTS:

Regardless of the feeding system, new crop forages and grains inevitably vary to some degree from year-to-year introducing changes in fermentation rates, nutrient content and potential toxins, pathogens and other anti-nutritional factors into the new diet. Along with this, seasonal and environmental changes in temperature, humidity and precipitation can alter feed intakes forcing additional diet adjustments that can exacerbate stresses to total tract health and immunity.

A central and key system to any animal's ability to maintain homeostasis is the total-tract digestive system. Rumen health and function play a critical role in overall cow health and productivity. The rumen is a multi-species community of co-existing, competing and symbiotic organisms that is very complex in nature and highly susceptible to a changing environment. Rumen microbial populations are a byproduct of a cow's genetics and the nutrient content of the diet she eats. Changes in feed intakes (like when push-ups are infrequent), forage to concentrate ratios, water access and quality, and body temperature all make significant alterations to the microbial community. When one species reduces, another is quick to flourish and the effect on cows can be either positive or very negative.

Decreasing the forage to concentrate ratio tends to reduce rumen pH and reduce the number of gram-negative cellulolytic bacteria (those that break down fiber) and increase the carbohydrate-degraders (those that can increase lactate). Providing more roughage has the reverse effects (Zhang J. 2017).

(Plaizier J.C. 2018) highlighted the similar effect where high starch and processed grain TMRs presented with inconsistent or infrequent push-ups and slug feeding events can also negatively affect rumen pH while also reducing the diversity of rumen organisms, decreasing both proteolytic and fibrolytic organisms, while increasing endotoxin concentrations in the gastrointestinal tract which increases the risk of damage to gut integrity and immunity.

All this points to a simple fact: As a cow freshens, it becomes imperative to quickly increase the fermentability (and starch content) of her diet to increase the supply of VFA's (energy), microbial protein, vitamins and other essential nutrients needed to accommodate a rapid increase in milk and component yield. Unfortunately, this forces an inevitable shift in rumen bug populations; decreasing cellulolytic and proteolytic species (gram negative); while increasing lactic acid producing species (gram positive). This results in lower rumen pH, increased acidosis risks, deterioration of rumen papillae, decreases in protozoa populations and an increase in the supply of LPS (endotoxins) from the death of the gram-negative bacteria.

GUT HEALTH AND IMMUNITY:

Increasingly, science considers the gut to be a highly sensitive immune-sensory organ (Bravo D.M. 2016) representing about 70% of an animal's entire immune system. The gut wall is made up of epithelial cells (villi) and the mucous layer. When working well, the gut wall keeps the digesta within the gut while absorbing nutrients, 'sampling' gut contents for potential health threats, and protecting neighboring tissues and the blood system from attack. This is referred to as barrier function which is further enhanced by a mixture of microbial species (microbiota) that naturally protect the epithelium and mucous layer.

As mentioned above, the gastrointestinal tract's fate is in part a by-product of what flows from the rumen. This digesta includes nutrients to be absorbed for health and productive uses, but may also contain mycotoxins, pathogens and inflammatory rumen produced LPS (endotoxins). Pathogenic bacteria such as coliforms, salmonella and e. coli are also gram-negative, meaning they have a coat of lipopolysaccharide (LPS) which protects their sensitive inner cell membrane. If these bacteria die in large numbers, the LPS is released adding more endotoxin to the mix. LPS is an acute activator of the Th1 response, attracting immune killer cells such as M1 macrophages and neutrophils to damaged sites; this can be good as they can help to rid the area of harmful material. However, LPS can induce an over-response, which can be extremely harmful, reducing villus height, decreasing crypt depth, and negatively affecting dry matter intake, nutrient digestibility, and absorption. Finally, environmental stressors can directly incite the release of cortisol and other stress hormones that increase inflammatory proteins (cytokines).

Inflammation can be a useful and beneficial response aiding many biological processes ranging from birthing to fighting infection. Excess inflammation, however, is not a friend to gut health and effective barrier function. What imparts effective barrier function is the ability of the gut's "tight junctions" to keep bad elements within the gut while enabling efficient absorption of nutrients into the body and blood stream. Excess endotoxins, LPS, and inflammatory cytokines attack gut epithelia loosening the "tight junctions" and make the gut lining more permeable (leaky). Once compromised, a "leaky gut" allows pathogens, mycotoxins and endotoxins to pass directly into the bloodstream creating a systemic reaction that negatively impacts dry matter intake, milk yield, milk fat, digestion, energy requirements and threaten reproductive performance (Horst E.A. 2019) (Kvidera S.K. 2017).

A big idea:

Beyond the direct health effects, the bottom line is this: compromising gut health and creating an inflammatory immune response costs energy big time! When the gut is compromised and 'leaky', valuable glucose is redirected away from growth and productivity. Remember, glucose makes lactose makes milk. (Kvidera S.K. 2017) induced this response in vivo using gamma secretase inhibition inducing leaky gut in test animals. Results showed increased BHBA and liver triglycerides and decreased milk yield by 42%. (Horst E.A. 2019) similarly reported that approximately one (1) kilogram of glucose is used up by an intensely activated immune system during a 12-hour period in lactating dairy cows (without liver contribution). Since it requires approximately 72 grams of glucose to make 1 kilogram of milk, this shift in glucose use represents a potential loss of up to 13.9 kilogram in milk yield per day!

OXIDATIVE STRESS:
Another disruptor that is often overlooked is oxygen. Oxygen is taken into the rumen whenever a cow eats. This adds oxygen into a rumen which prefers an oxygen-free (anaerobic) state. The adoption of Total Mixed Rations (TMRs) has been a great improvement in the feeding of dairy cattle (Eastridge M.L. 2006), (Maulfair D.D., Fustini M., Hainerichs A.J., 2011), (Schingoethe D.J. 2017). Unfortunately, TMRs also add a significant amount of air (and oxygen) into the diet. Added oxygen can alter the redox balance of the diet potentiating additional alterations in microbial balance while promoting Reactive Oxygen Species (ROS), which can negatively affect nutrient digestibility and promote additional inflammation.

HEAT STRESS:
Finally, heat stress has a profound effect on energy metabolism and physiology of dairy cattle, and is a central cause of failed barrier function (leaky gut) in many ways (See Beat the Heat, Its Never Too Late to Abate, McNess, 2020). Heat stress creates a catabolic state resulting in milk production losses much higher than the decrease in dry matter intake (mcals) can explain alone. Heat stressed cattle become more insulin resistant, whereby glucose use shifts toward survival and away from productive use. Exacerbating to this shift in glucose, is the effort to remove body heat by sending more oxygenated blood to the extremities and away from the gut. This can lead to a lack of oxygen, or hypoxia, at the gut level hastening cell death and a compromising of gut integrity stealing even more glucose.

So, what is one to do in mitigating inevitable stress and disruptors in the environment and the diet? This paper suggests some useful dietary tools that can help mitigate the outcomes of change and the associated stress that commonly occurs on dairy farms.

MITIGATING CHANGE AND STRESS USING FEED ADDITIVES

If changing conditions around dairy cows involves so many contributing factors, how can we better identify and focus in on the key drivers of stress and loss of homeostasis? KPIs and monitoring processes can help - especially when root causation is identified. Fixing the root cause is faster, cheaper, and more profitable than treating symptoms to restore homeostasis.

Before including the next ‘silver bullet’ nutraceutical and its cost into the diet, it is best to first understand what one is trying to accomplish. A disciplined, consistent quality management process is required. Striking the right balance between monitoring Key Performance Indicators (KPIs) versus documented Standard Operating Practices (SOPs), gaining input from all relevant personnel to the process and gathering well-grounded observations of cow behavior and health are required to identify and prioritize the root cause(s) resulting in an informed implementation of cost-effective solution(s).

This reintroduces the principle of RESILIENCE. Finding feed additive solutions that augment resilience and improve outcomes to specific stress challenges has long been a goal of the animal nutrition industry. Doing so in a more holistic manner is becoming increasingly important to both producer and consumer. The concept of resilience has been described by van Dixhoorn and others in transition cow disorders (van Dixhoorn I.D.E. 2018), (Nakov D. 2019).

(Eastridge M.L. 2006), further suggested that using feed additives, inoculants, pre-biotics, probiotics and enzymes are useful in reducing gut health integrity risks, aids rumen function, and defends animal performance.

YEAST DERIVATIVES AND HEALTH

The beneficial effects of supplementing animal diets with live yeast and yeast derivatives have been well documented (Shurson G.C. 2018) (Upadhaya S. 2019) (Park J-H. 2018). Productivity parameters, gut microbiome support and gut immunity have all been suggested as positive outcomes from the inclusion of yeast derivatives in general nutrition (Sisouvong A. 2018) (Upadhaya S. 2019) (Roto S.M. 2015) (Pourabedin M. 2014) (Valpotic H. 2016). Overall, the addition of yeast derivatives in animals has been shown to:

- Increase the crypt depth and height of villi (Roto S.M. 2015)
- Increase the surface area available for absorption of nutrients
  to alter the balance in numbers of existing gut microbes (the species tend to be fairly constant from shortly after birth) (Pourabedin M. 2014) (Shurson G.C. 2018); and to influence circulating cytokines and immune cells as well as antibody levels (Valpotic H. 2016)
- Support the use of yeast derivatives in calves and increasing health (Quigley J. 2005), (Krol B. 2011), (Singh A.K. 2017).
- The combined result of these factors has been shown to improve average daily weight gain and lower morbidity in herds and flocks.

Unfortunately, loose and interchangeable use of the terms yeast, yeast extract, yeast product, etc. in the animal nutrition industry can get in the way of proper use and recommendation. The ability to impart a biological response to the use of specific yeast derivatives lies in **how** the derivative was derived, **why** it was derived and **how** the derivative works together synergistically within the overall diet scheme to deliver the intended remediating effect. Yeast derivatives of note include the following additive products:

LIVE CELL YEAST

Live yeasts are commonly provided in feed in a live, dried form of whole cells which are fully functional and can multiply after ingestion. These are successfully fed to ruminants as the rumen environment can support yeast growth for a period of time and the cells can interact with the given substrate and microbes there. They have been shown to:

- Stimulate growth of useful rumen microbes (Mosoni P. 2007)
- Stabilize rumen pH (Thrune M. 2009)
- Lower free-radicals (Chaucheyras-Durand F. 2008)
- Reduce methane emissions (Lila Z.A. 2004)
- Degrade and bio-transform mycotoxins (H. Ho, R. Farage, D. Parfitt, 2020)
- Increase energy corrected milk
- Secrete digestive enzymes and amino acids

Selecting a yeast manufactured for imparting these qualities is important to success. Many yeasts used in dairy cattle diets are not up to the challenge. For example, Brewer's yeast is made to convert sugars to alcohol. Baker's yeast is made for the purposes of leavening dough and making bakery products. It's important to select a use-specific yeast designed for the job at hand.

Another area to consider is how the yeast is grown and harvested. Yeasts multiply by budding. Each time a yeast cell buds, it leaves behind a scar. The longer that yeast cells are allowed to bud and multiply, the more scarring that occurs. Scarring and age reduce the ability of the yeast cell to take in nutrients and undesirable rumen contents while restricting the secretion of enzymes and other beneficial metabolites. Yeast cell sources harvested earlier during the **exponential growth phase** rather than after, will yield yeast cells that are most viable imparting the above benefits at lower inclusion rates than commonly available yeasts.

Keep in mind also that each yeast cell does not live forever in the rumen. By design, the better live yeast cells perform their job of scavenging oxygen, the sooner they will go dormant or die. Once dead, each yeast cell will degrade into its cell wall and corresponding mannan oligosaccharide (MOS), and beta-glucans. They will also contribute valuable nutrients from the cell contents (cytoplasm) including nucleotides and hydrolytic enzymes (Shurson G.C. 2018).

YEAST CULTURES

Yeast culture is the end-product of fermentation of live yeast and the medium on which it was grown. It consists of some live yeast cells, but primarily contains the fermentation metabolites resulting from the fermentation and can include enzymes, amino acids, vitamins and yeast cell wall fractions. It has demonstrated improvements in feed efficiency, normalization of rumen pH and microbial populations, and provides some binding due to its cell wall content. It is good in combination with other yeast derivative ingredients as it provides the benefit of metabolite content into an animal immediately, but does not provide the benefit of subsequent ruminal metabolite contribution and carbohydrate degradation provided by live cell yeast. The consistency of cell wall contribution and agglutination potential can be variable and inclusion rate is generally higher if fed as the sole source of yeast benefit.

MANNAN OLIGOSACCHARIDES (MOS)

Yeast cell walls have concentrated sources of MOS, which have been used in diets for several years. The primary uses of MOS are to:

- Agglutinate pathogens and toxins in the gastrointestinal tract
- Provide a preferential substrate for the growth of beneficial bacteria (lactobacillus and bifidobacterial) in the gastrointestinal tract providing protection to the gut epithelia and the mucous layer.
- Contribute to modulation of the immune system

A comprehensive review of the effects of MOS supplementation can be read in (Spring P. 2015) and (Shurson G.C. 2018), but in summary they have been beneficial in improving average daily weight gain, feed conversion, mortality rates and disease resistance. They are not broken down by low pH environments like stomach contents and they survive pelleting processes well.

A key differentiator in MOS products is the glucomannan content provided and the purpose for which it was produced. Most MOS sources are a **byproduct** of the alcohol industry. As a result, glucomannan content is variable and can range from 18 to 34 percent. Selecting a MOS made from a live yeast that is specifically grown for the quality of the yeast cell wall is important. It is also important how the live yeast is grown, controlling the timing and quantity of oxygen allowed into the process. Working with suppliers of this caliber will deliver a MOS containing a minimum of 45% glucomannan content.

YEAST EXTRACT

Yeast extract consists of the cell contents of yeast without the cell walls. High in nutrients for bacterial culture media, they are excellent in combination with other yeast derivatives to modulate rumen function. Nutrient contribution includes nucleic acid, bioactive low molecular weight peptides, B vitamins and amino acids. These components also provide support of epithelia cell growth and regeneration thus contributing to both rumen and gut integrity and health.

The process to make yeast extract consists of heating yeast cells until they rupture allowing the yeast's own digestive enzymes to break down proteins into simpler compounds (amino acids and peptides), a process called autolysis. The insoluble cell walls are then separated by centrifuge and filtered. The end product is then spray dried to protect quality of protein fractions.

BETA-GLUCANS (BGC)

The cell walls of yeasts also contain beta-glucans. This is an area of much misinformation in the industry. While MOS does include beta-glucans, they are not bioactively available being bound within the glucomannan matrix. Therefore, to be effective, beta-glucans must be "purified", or separated, from the glucomannan by enzymatic hydrolysis to a concentration of 80% or more.

Beyond purity, efficacy of beta-glucan depends on the structure of the molecule. Beta 1,3;1,6-D glucan has demonstrated to directly activate the innate immune system with subsequent activation of the adaptive immune system. The effectiveness is further impacted by:

- The length of the backbone
- The branching frequency between the 1,3 and 1,6 branches, and
- The length of the branches.

Overall, beta-glucans have been found to stimulate the immune system, influencing cytokines and improving phagocytosis in innate cells and reducing disease rates and mortality rates (Vetvicka V.L. 2014) (Volman J.J. 2008). Care should be taken to avoid over feeding beta-glucans which can cause an overstimulation of the immune system. Activation of the immune system diverts energy from productive uses, thus can be costly in excess.

SPECIFIC STRAIN BACILLUS SUPPLEMENTATION

Bacillus fermentation products and extracts are varied and can be grown to do many specific tasks. Therefore, it is important to choose specific strains intended for the purpose at hand. They are very hardy and survive the heat of pelleting and inclusion in supplements containing inhospitable mineral and phytogenic ingredients.

They are used generally for their benefit in the post ruminal gastrointestinal tract, but not exclusively. Functions of benefit for dairy cattle health and performance include:

- Added oxygen scavenging
- Increased rate of starch and fiber breakdown

- Competitive exclusion of pathogens in favor of beneficial gut bacteria
- Protective organic acid production
- Production of antimicrobial properties and pathogen protection.
- Increase milk yield response in dairy cows without affecting intakes and may be beneficial to the rumen or gastrointestinal microbial flora community (Souza V.L. 2017).

IMPORTANCE OF SOURCE AND SYNERGISM OF COMPONENTS

A final word about the use of feed ingredients intended to enhance dairy cattle resilience: the importance of source. The supply of nutraceutical ingredients is plentiful and varied. It is extremely important to know the source of your ingredient specific to its composition, expression, and mode of action. A metaphor is in the selection of cattle: success requires going beyond the selection of breed alone, but further to understanding the specific genetic lines within the breed and how the genetic lines perform within the environment of the farm.

Important too, is to understand how each ingredient brought to the table interact with each other within the animal. Specific to the purpose each ingredient fulfills, but also the ability of ingredients to work symbiotically and synergistically in delivering a comprehensive solution optimizing animal resilience.

A SUGGESTION ABOUT MANAGING CHANGE

As an addendum to the earlier comments regarding avoidance of seeking 'silver bullet' solutions, an extremely popular tool used to manage manufacturing processes has been adopted across many businesses. It is based on Toyota's management protocols (Sobek D.K. 2008). "Plan, Do, Check, Act" or PDCA. Applying this method, or something like it, to individual dairy farms can help identify where to best concentrate efforts and resources to mitigate the inevitable risk that seasonal changes bring to every farm.

Using the model above, problems can be broken down into five key areas:

1. **People:** Get everyone involved with the problem, such as dairy nutritionist, veterinarian, herdsman, mixing personnel, etc.
2. **Environment:** Temperature, humidity, cow comfort, pen changes, time budget, feed/water access, etc.
3. **Management:** Standard Operating Procedures and Policies, etc.
4. **Equipment:** Wagons, push-back aids, ration breakdown, etc.
5. **Monitoring KPIs:** Intakes, manure, BCS, locomotion, shaker data, computer data, etc.

Whenever diets and environments change, applying these problem-solving techniques can help to target timely interventions efficiently and help measure the ongoing results of their effectiveness.

In summary, there are clearly benefits to mitigating stress by keeping rumen and gastrointestinal tract health consistent and in peak condition. Protecting genetic potential by optimizing milk yield and dry matter intakes is an efficiency goal of today's dairy industry. Even in times of high ration costs, feed efficiency is improved by reducing the negative effects of change and stress increasing marginal milk profits that pay dividends.

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