

Dairy - Longevity and Reproduction, Friend or Foe?

Managing for Improved Reproduction

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Introduction

Reproduction and longevity are almost at odds in the commercial dairy. Obviously establishment of pregnancy is essential as it sets the stage for lactation and the generation of income. Reproductive failure may lead to early culling and thus reduced longevity. Inadequate herd reproductive performance, manifested as prolonged calving intervals, increased involuntary culling, or both, may result in less milk and fewer calves per cow per year. Longer-term milk production is often regarded as a biological index of production, health, and reproduction traits; dairy cows have to stay alive, calve, and produce well to be of value. Decisions to replace cows are based mainly on economic considerations; the producer expects higher profit from replacing a cow than by keeping her in the herd. Historically, Holsteins have averaged a herd life of 3.25 lactations.

Interpretation of longevity measures differs depending on whether the measure includes voluntary or involuntary culling. True longevity refers to ability to delay culling, whereas functional longevity refers to ability to delay involuntary disposal. No direct measure of functional longevity is available because of lack of information on why cows were removed from the herd. About half of all culling occurs involuntarily because of health disorders, especially reproductive and udder problems. Culling because of health disorders may either be decided quickly (e.g., downer cow) or delayed (e.g., reproductive problem) because of impact on the milking routine. Reproductive performance has declined in modern dairy systems, while genetic progress for high milk yield continues (Royal et al., 2002; Berry et al., 2003) and this problem is apparently international among diverse combinations of dairy production systems. Examples include high-yielding TMR systems typical of North America and lower yielding pasture-based systems typical of New Zealand (Harris and Kolver, 2001; Lucy, 2003). Nutritional insufficiency clearly has negative effects on re-establishment of pregnancy in early lactation. However, often unrecognized are the effects of the immune system on reproductive function and how stressors tied to lameness, mastitis and heat stress impact immune function and maintenance of normal cyclicity.

This paper will focus on a number of events associated with reproduction failure and reduced longevity in the herd.

Nutrition and Reproduction

It is common knowledge that cows in negative energy balance suffer with poor reproductive performance. However, energy balance is not the sole nutritional factor that affects reproduction (Chagas et al., 2007; Lucy, 2003). Specific nutrients that act independently of energy balance have been reported to directly or indirectly alter reproductive efficiency and fertility. Among these are protein (Armstrong et al., 2001), starch (Armstrong et al., 2001; Burke et al., 2006; Roche et al., 2006), macro and micro minerals (Underwood and Suttle, 2001), and fats (Staples et al., 1998; Boken et

al., 2005) including specific lipids such as n-3 fatty acids (Ambrose et al., 2006), rumen inert fats (Staples et al., 1998), and possibly conjugated linoleic acid (Baumgard et al., 2005). The roles of these nutrients are often complex and experimental results have been inconsistent.

For example, 11 of 14 studies examining the effect of supplementary fat on reproductive success showed a positive effect, while 3 showed a negative effect (Staples et al., 1998). Similarly, inclusion of dietary starch may shorten the duration of negative energy balance, reducing the BCS nadir and increasing the level of circulating IGF-I. Minimizing postpartum loss of BCS and increasing IGF-I shortens postpartum anestrous interval (PPAI), potentially enhancing reproductive success (Burke et al., 2006; Kolver et al., 2006; Roche et al., 2006). However, starch supplements are also reported to reduce oocyte quality (Armstrong et al., 2001), thus they may negate any potential benefits from improved energy balance and reduced PPAI.

Similarly, the effects of protein and its metabolites are unclear. Both Sinclair et al. (2000) and Armstrong et al. (2001) reported a reduction in oocyte quality when dietary protein was increased. Reduced oocyte quality may explain decreased conception rates observed with increased RDP (Canfield et al., 1990). Nevertheless, in pasture-based production systems, where the availability of RDP can be twice the level required by the rumen, conception rates are generally better than those seen in systems in which balanced diets are offered (Royal et al., 2000; Harris, 2005). It is unlikely that any of these specific dietary components will provide simple solutions to the problem of subfertility associated with lactation in high-yielding dairy cows. Further research is required to better understand the effect of these individual nutrients and the interactions among different nutrients on reproductive success.

Relationship between Trace Minerals and Reproduction

Probably less well recognized by dairy producers are the effects of trace minerals on reproductive performance. Improving status of trace minerals such as zinc, manganese, copper, cobalt and selenium can enhance reproductive performance, as they play vital roles in reproductive function (Table 1).

Required in the greatest quantity, zinc has been recognized for several decades as indispensable for normal growth and health in animals. It plays a major role in the immune system and certain reproductive hormones (Miller et al. 1988). Zinc is known to be essential for proper sexual maturity, reproductive capacity, and more specifically, onset of estrus. Zinc has been shown to maintain epithelial cell integrity and increase cell replication, the proposed mechanism by which zinc can reduce retained placentas (Hidiroglou, 1979). Maintenance and repair of the uterine epithelium, following parturition, is essential for return to normal reproductive function and estrus.

Zinc deficiency or insufficiency has been shown to reduce conception rate, increase incidence of retained placenta, increase dystocia, and lead to abnormal estrus (Hidiroglou, 1979, Puls, 1994). Lack of adequate zinc supplementation in gestating cattle may result in abortion, fetal mummification, lower birth weight, or altered myometrial contractibility with prolonged labor. Cows with low serum zinc levels showed lower incidence of dystocia when supplemented with zinc prior to calving (Duffy, 1977).

Research has shown that improving zinc status increases conception rate. Dairy cows fed additional zinc (400 mg from complexed zinc and 400 mg from zinc sulfate) prior to calving were detected in estrus and tended to conceive sooner after calving than cows that did not receive additional zinc prior to calving (Campbell and Miller, 1998).

Graham et al. (1992) studied the effect of zinc source (complexed zinc as zinc methionine, Zinpro Corporation) on health status in dairy cows. This study, which covered one year, showed a significant decrease in spontaneous abortion in cows supplemented with zinc methionine complex (Table 2).

Spears (1992) reported that beef cows supplemented with complexed zinc and manganese, rather than zinc and manganese oxide, had a 15.7% improvement in pregnancy rate when artificially inseminated (Table 3). Spears noted that if the goal is to reduce days open and maintain maximum economic potential, then feeding higher bioavailable trace mineral sources needs to be a management consideration.

Table 1. Effects of trace minerals on ruminant reproduction parameters.

	DIRECT	INDIRECT
Zinc	<ul style="list-style-type: none"> - reduced conception rate - atrophy in male reproductive tissue and glands - increase in retained placentas - inhibition of spermatozoa maturation 	<ul style="list-style-type: none"> - mild to severe claw and hoof problems - suboptimal skeletal growth and weight gain - poor feed utilization and efficiency - low quality milk and high somatic cell count - slow wound healing and rough hair coat
Manganese	<ul style="list-style-type: none"> - suppression of estrus or silent heats - reduction of conception rate - delayed ovulation - increased incidence of abortion - delayed opening of the vaginal orifice - light birth weights with infant mortality - inhibited male libido and reduction of spermatozoa 	<ul style="list-style-type: none"> - poor skeletal development - weak and poor condition of legs and joints
Copper	<ul style="list-style-type: none"> - inhibited conception - early embryonic death - increase in retained placentas - subestrus - necrosis of the placenta - central nervous system abnormalities in the offspring 	<ul style="list-style-type: none"> - retarded growth - poor haircoat, reddish in color - skeletal changes - anemia
Cobalt	<ul style="list-style-type: none"> - reduced fertility - increased calf mortality - depressed milk and colostrum yield and quality 	<ul style="list-style-type: none"> - depressed appetite - poor fiber digestion - weight loss - poor growth
Selenium	<ul style="list-style-type: none"> - decreased fetal development and early calf mortality - embryonic degeneration and fetal resorption - retained placentas and poor uterine involution - decreased milk and colostrum quality and volume - decreased spermatogenesis 	<ul style="list-style-type: none"> - decreased mobility with claw and hoof problems - reduced vitamin E metabolism and immune status - poor conception - poor growth and hair coat

Table 2. Effect of zinc supplementation on estimated risk for abortion (Graham et al. 1992).

Comparison Group	Odds Ratio ^a
Control ^b + NTX ZnMet ^c	5.37
Control ZnMet	2.30
NTX Control	2.85
NTX ZnMet + Control	3.91

^a Cross product ratio indicating likelihood of having the problem

^b Control = methionine

^c ZnMet = ZINPRO[®] zinc methionine
NTX = No treatment control

Table 3: Pregnancy Rate Percent for AI vs. Bull Bred Beef Cows (Spears 1992).

	Cows/ Treatment	ZnO, MnO	Zn Methionine, Mn Methionine	% Improvement
AI Period—45 Days				
Year 1	22	61.9	52.9	
Year 2	20	52.9	73.9	
Average		57.4	65.9	14.8
Year 3	27	55.5	65.4	
Overall Average		56.8	65.7	15.7
AI + Bulls—80 Days				
Year 1		90.5	88.2	
Year 2		100.0	100.0	
Average		95.3	94.1	-1.3
Year 3		77.8	88.5	
Overall Average		89.4	92.2	3.1

Manganese: Manganese too plays an important role in reproduction (NRC 2001). Research has shown that manganese supplementation provides for optimal ovulation, conception, pregnancy, and parturition. These improvements in fertility can be attributed to the critical role manganese plays in cholesterol synthesis which in turn is required for steroidogenesis. Insufficient steroidogenesis decreases levels of circulating reproductive hormones resulting in abnormal sperm in males and irregular estrus cycles in females (Brown 1986). The corpus luteum has high manganese content and appears to be affected by level of manganese supplementation (Miller et al., 1988).

Research at The Ohio State University (Weiss and Socha, 2004) found that dairy cattle require higher levels of Mn than reported by the NRC (2001). Their findings indicate that lactating dairy cattle require a diet containing 28 ppm Mn, while dry cows require a diet containing 49 ppm Mn to maintain zero Mn balance. Care should be taken when applying these values to dairy ration formulation as they do not account for Mn requirements for tissue accretion due to growth or fetal development nor do these levels account for antagonists reducing Mn availability from feeds, forages or water.

Improvements in reproductive performance are possible by increasing levels of Mn supplementation. Researchers at North Carolina State University (Hansen et al., 2004) found 25% improvements in percent of animals cycling and pregnancy rates when dietary Mn was increased from 20 ppm (control) to 70 ppm.

Copper: Copper supplementation is necessary for proper reproductive performance noted by improved placenta condition. Because copper plays a vital role in bone, lipid and glucose metabolism, it is needed for proper development of offspring and conditioning of the dam. Research substantiates an improved immune system response and proper function of enzyme systems with copper supplementation (NRC 2001). The copper-containing enzyme, lysyl oxidase, plays a key role in hydroxylation of lysine into collagen and elastin fibers (Cromwell 1997). The hydroxylation process gives structural rigidity and elasticity to connective tissues and blood vessels. Depression in this mechanism may cause deterioration in endometrial integrity and weakening of blood vessels leading to destruction of placental membranes and function.

Reproductive problems that relate to copper deficiency manifest themselves in inhibited conception even though estrus may be normal. This reproduction failure is caused by early embryonic death and embryo resorption, as well as an increase in necrosis of the placenta (McDowell, 1992). Offspring of copper deficient dams show central nervous system abnormalities and an inability to suckle properly. Kappel et al. (1984) reported dairy cows with higher serum copper levels had significantly less days to first service, fewer services per conception and fewer days open. In addition to copper supplementation improving female fertility, proper copper supplementation of the sire is needed for production of quality semen.

Cobalt: Cobalt is needed for adequate vitamin B₁₂ synthesis (Puls 1994). Vitamin B₁₂ is required for the conversion of propionate to glucose and for folic acid metabolism in the liver (NRC 2001). Reduced fertility and sub-optimal conditioning of the offspring are noted in a cobalt deficiency and may be due to macrocytic anemia (Puls, 1994). Inadequate cobalt levels in the diet have been correlated with increased early calf mortality.

Other benefits of supplying dairy cattle with adequate amounts of cobalt is reduced ketosis (Puls, 1994) and improved fiber digestion (NRC, 2001). Improved fiber digestion may explain improvements in fat-corrected milk yield and feed conversion. Washington State researchers observed when diets of late gestation and early lactation dairy cows were supplemented with 10 and 20 mg of cobalt (Kincaid et al., 2003; Kincaid and Socha, 2007), conversion of feed energy to milk energy improved 2.56 and 7.37% even though these diets contained in excess of NRC (2001) cobalt requirements and were fortified with approximately 10 and 20 mg/d Co, respectively,

from organic cobalt (CoPro, Zinpro Corporation). These studies indicate that NRC (2001) cobalt recommendations may not be adequate for dairy cattle.

Iodine: Iodine is required for the synthesis of the thyroid hormone, thyroxin, which regulates the rate of metabolism (NRC 2001). Signs of a subclinical iodine deficiency in breeding females include suppressed estrus, reproductive failure, abortions, stillbirths, increased incidences of retained placentas and extended gestation periods (Hetzel 1990, Puls 1994). Calves born to cows that are marginally deficient in iodine are weak and may be hairless (Puls 1994). Lactating cows suffering from a mild iodine deficiency will produce less milk, have a poor hair coat and have increased incidences of mastitis, thus increasing the potential for reproductive failure (Puls 1994).

Chromium: Chromium potentiates insulin action, resulting in increased uptake of glucose and amino acids by cells in the body (Stoecker 1990). Signs of a chromium deficiency include reduced growth rate, reduced feed efficiency and reduced immune function (Puls 1994). A chromium deficiency in lactating cows may result in increased incidences of ketosis and decreased milk production (Puls 1994). Hayirli et al. (2001) showed reduced plasma NEFA concentration due to possibly enhanced insulin responsiveness, increased dry matter intake, decreased body condition loss and improved milk yield in dairy cows supplemented with complexed chromium (MiCroPlex, Zinpro Corporation) during the periparturient period. One might predict an improvement in reproductive performance in cows showing a more positive energy balance in the early post-partum period when supplemented with complexed chromium. Bryan et al., (2004) reported grazing cattle supplemented with complexed chromium at 0.06 mg/kg body weight^{0.75} had higher 28d pregnancy rates than cows not receiving chromium. Similarly, Etchebarne et al., 2005 reported cows supplemented with MiCroPlex chromium had higher first service conception rates (36.8 vs. 21.7, $P < 0.05$), fewer services/conception ($P < 0.05$) and fewer days open (94 vs. 106, $P < 0.15$) than cows not receiving chromium.

Selenium: Reduced fetal development is attributed to selenium deficiency while marginally selenium deficient animals will abort, or calves will be weak and unable to stand or suckle (Puls 1994). Lowered selenium status is documented in embryonic degeneration, leading to increased fetal resorption (McDowell, 1992).

Selenium also plays a vital role in immune response and has an associated role in vitamin E activity. Under-fortified animals will have a weakened immune system resulting in increased incidence of mastitis, pneumonia and early calf mortality (Puls 1994).

Selenium supplementation has been shown to increase sperm mobility. In females, it has improved uterine involution and decreased incidence of retained placenta, cystic ovaries, metritis and mastitis. Reduced abortion, stillbirth and periparturient recumbency have all been reduced when cattle has sufficient selenium status (Puls 1994). In pregnant animals, selenium toxicity will produce abortions, stillborns and weak and lethargic calves as selenium accumulates in the fetus at the expense of the cow (Puls 1994).

Direct Effects of Trace Minerals on Reproduction

Improving the availability of trace minerals prior to parturition positively impacts postpartum reproductive performance. Research has demonstrated that complexed

sources of trace minerals are more bioavailable (Wedekind et al., 1992) and have better animal retention than inorganic sources (Nockels et al., 1993). Replacing inorganic zinc, copper and cobalt with complexed sources of these minerals in diets of pre and postpartum cows reduced uterine infections (Rakes et al. 1993). Responses to supplying additional zinc, manganese, copper and cobalt in complexed form are enhanced under certain conditions. Campbell et al., (1999) observed small numeric improvements in reproductive performance when cows fed complexed zinc, manganese, copper and cobalt did not retain the fetal membrane. However, when the placenta was retained, cows fed complexes showed estrus 37 days sooner, first luteal activity 11.8 days earlier and first corpus luteum 5.4 days earlier than cows that did not receive mineral complexes (Campbell et al., 1999). Results from this study indicate that cows fed complexed trace minerals were better able to respond to stress such as a retained placenta, as evidenced by the quicker return to normal ovarian activity. In another study, feeding complexed zinc, manganese, copper and cobalt prior to calving reduced incidence of retained placentas, cystic ovaries and mastitis/metritis (Nocek, 1994).

In a summary of twenty studies, dairy cows supplemented with complexed zinc, manganese, copper and cobalt both before and after parturition showed improved milk production (0.9 kg/d, $P \leq 0.0001$), energy-corrected milk (0.9 kg/d, $P \leq 0.0001$), reduced SCC (17,000 cell/mL, $P \leq 0.12$), and days open (7d, $P \leq 0.001$; Ballantine et al., 2002; DeFrain et al., 2009 ; Ferguson et al., 2004; Griffiths et al., 2007; Hackbart et al., 2008; Kellogg et al., 2003; Kincaid and Socha, 2004; Monardes et al., 2002.; Nocek et al., 2006; Siciliano-Jones et al., 2008; Toni et al., 2007; Uchida et al., 2001). It should be noted that the control diets fed in most of these studies exceeded NRC requirements for these trace minerals, in some cases by several fold. Claw integrity was also evaluated in some of these studies and supplementing pre and postpartum cows with a combination of complexed zinc, manganese, copper and cobalt reduced incidence of claw lesions (Ballantine et al. 2002; Ferguson et al., 2004; Nocek et al., 2006; Siciliano-Jones et al., 2008).

Trace mineral availability plays a key role in determining enzyme and immune function and productive performance. Supplementation with highly bioavailable complexed trace minerals may further enhance animal performance even when status is considered adequate.

Impact of Lameness on Reproduction

Although only about 16% of cows (NAHMS, 2007) are culled for lameness, lameness may increase the number of cows culled due to reproductive failure. According to a 2007 National Animal Health Monitoring System survey of dairy management practices, 26.3% of cows are culled due to reproductive failure. A summary of data collected from DHI records processed in Provo, Utah, USA indicates that fertility may not be improving in our dairy cattle. Between 1990 and 2000, days open increased by 23 days (Olson, 2001; Table 4). Some management specialists would argue that this increase in days open should be attributed to dairy producers intentionally delaying rebreeding while using rBST to maintain profitability, thus increasing lactation length. However, the Provo DHI records indicate that this is not the case as days to first service during this same period have increased by only 3 days.

Table 4. Comparison of reproductive performance between the years 1990 and 2000 (Olson, 2001).

Item	1990	2000
Days to first service	82	85
Days open	130	153

Although a survey of 13 Dutch dairy herds (Bakerma et al., 1994) indicated that there is no relationship between reproduction and lameness, a growing database contradicts these findings. Researchers have found that lame cows are open between 11 and 28 days longer than cows that are not lame (Argaez-Rodriguez et al., 1997; Collick et al., 1989; Lee et al., 1989; Lucey et al., 1986). Furthermore, the type of claw disorder may affect the impact of lameness on fertility (Hernandez et al., 2000). Cows with abscesses/sole ulcers or cows with two or more claw disorders had more days open ($P < 0.05$) than cows without claw disorders (Table 5). Cows with abscesses/sole ulcers were open 63 days longer than healthy cows, while cows with two or more claw disorders were open 76 days longer. Furthermore, there were a lower percentage of cows with abscesses/sole ulcers pregnant at the end of lactation than healthy cows (Table 5).

Table 5. Effect of claw lesion on reproductive performance of dairy cattle (Hernandez et al., 2000)

Variable	Healthy, No Claw Disorders	Digital Dermatitis	Abscess / Sole Ulcer	Foot Rot	Two or More Claw Disorders
# of cows	464	23	39	4	18
Days to first service	70	70	71	71	77
Days open	92 ^y	120 ^{yz}	155 ^z	106 ^{yz}	168 ^z
% pregnant at end of lactation	97 ^y	96 ^{yz}	90 ^z	100 ^{yz}	94 ^{yz}

^{yz} Within row, means differ ($P < 0.05$)

Australian researchers also observed that lameness reduced % of cows that became pregnant. In a survey of 29,411 cows in 168 herds (Morton, 1999), pregnancy rates were reduced in cows clinically and subclinically lame, whether cows were lame before the voluntary waiting period or lame the first 6 weeks after the voluntary waiting period (Table 6).

Table 6. Effect of lameness on pregnancy rate^a (Morton, 1999).

Item	Pregnancy rate, % Lame Before Voluntary Waiting Period	Pregnancy rate, % Lame First Six Weeks After Voluntary Waiting Period
Not lame	33	34
Subclinically lame	29	23
Clinically lame	25	28

^a Pregnancy rate = submission rate x conception rate.

Lameness may also impact fertility by lowering the first service conception rates and increase incidence of ovarian cysts as indicated by results of a University of Florida study (Melendez et al., 2002). Cows that were clinically lame due to a claw disorder in the first 30 days postpartum had a 58.9% decrease in first service conception rates ($P < 0.05$), a 125% increase in ovarian cysts and a 8.2% decrease in pregnancy rate at 480 d postpartum (Table 7). Probably the most noteworthy observation was that 30.8% of cows that were lame during the first 30 days of lactation were culled prior to recording any reproductive event compared to 5.4% of non-lame (control) cows.

Table 7. Effect of lameness during the first 30 days of lactation on reproduction^a (Melendez et al., 2002).

Item	Lame cows	Control
Days to first service	99	94
First service conception rate, %	17.5 ^y	42.6 ^{yz}
Ovarian cysts, %	25.0 ^y	11.1 ^z
% Pregnant @ 480 d postpartum	85.0 ^y	92.6 ^z
% Culled before any reproductive event	30.8 ^y	5.4 ^z

^a Fertility of 190 cows was evaluated (cows bred under timed insemination were not included in evaluation). Sixty-five cows showed claw lameness within 30 days postpartum. These cows were compared with 130 cows that did not exhibit lameness during the first 150 d of lactation.

^{yz} Within row, means differ ($P < 0.05$)

Motivating dairy producers to change management, environmental and nutritional practices to reduce lameness in their herds is difficult as the prevalence and severity of lameness is often underestimated. In a Michigan State University study, dairy producers estimated that only 4.5% of their cows were clinically lame, while independent observers identified 52% of the cows were clinically lame (Kopcha et al., 2003).

Sprecher et al. (1997) found that using a locomotion scoring system based on back posture of cows both standing and walking was an effective means of assessing potential for reproductive failure. This system identifies cows on a 1 to 5 scale with 1 representing normal healthy animals and 5 as clinically lame. The Sprecher work (1997) found cows scoring a 3 or greater were 2.8 times more likely to have increased days to first service, 15.6 times more likely to have increased days open and 9.0 times more likely to have increased services per conception (Table 8). In addition, cows scoring 3 or greater were 8.4 times more likely to be culled.

Table 8. Impact of locomotion scoring on reproduction and culling: Risk of reduced fertility for cows scoring greater than 2 (Sprecher et al. 1997)

Reproductive Parameter	Predictive Risk of Happening
Increased days to first service	2.8 X more likely
Increased days open	15.6 X more likely
Increased services/conception	9.0 X more likely
Culled (Exit herd)	8.4 X more likely

Results of these studies indicate that greater lameness severity results in greater economic losses. Early diagnosis of lameness and intervention is essential to minimizing the severity of lameness. Robinson at University of California, Davis (2001) reported that cows newly identified as a score 3 (moderately lame) were 4

times more likely to become a 4 or 5 (lame, clinically lame cow) than a 2 (mildly lame) in 30 days, if no intervention occurred.

Cows with poor feet and legs tend to seek soft, comfortable locations to lie which may be unclean alleys, wet areas or stalls without dividers or neck rails. Increased stress due to lameness may depress the immune system and therefore the combination of unclean resting surfaces and depressed immune function may lead to higher incidence of mastitis.

Impact of Mastitis on Reproduction

Mastitis has been implicated in decreasing reproductive performance of dairy cows. Moore et al. (1991) reported a negative correlation between clinical mastitis and reproduction due to altered inter-estrus intervals and decreased length of the luteal phase in cows with clinical mastitis caused by gram-negative mastitis pathogens. In a retrospective study looking at the records of 1001 cows, Santos et al., (2004) observed that cows that develop mastitis prior to breeding are almost twice as likely to abort the pregnancy as cows that do not develop mastitis prior to breeding. University of Tennessee (Table 9) research indicates that mastitis both before 1st service or between 1st service and being confirmed pregnant increased days to 1st service, services/conception and days open. Reduced fertility as a result of mastitis maybe be attributed to endotoxin release which may induce luteolysis (regression of the corpus luteum, CL) and influence conception and early embryonic survival by release of inflammatory mediators (Moore and O'Connor 1983).

Table 9. Effects of time of mastitis occurrence on reproductive performance.

Mastitic Insult	Days to 1st Service	Days Open	Services/Conception
Before 1 st service	75.7	106.2	2
1 st Service to pregnancy	75.2	143.5	3.1
After preg. or uninfected	67.8	85.4	1.6

Oliver, S. P. et al. 2000. Proc. of Conf. on Managing Repro. in Southeastern Dairy Herds.

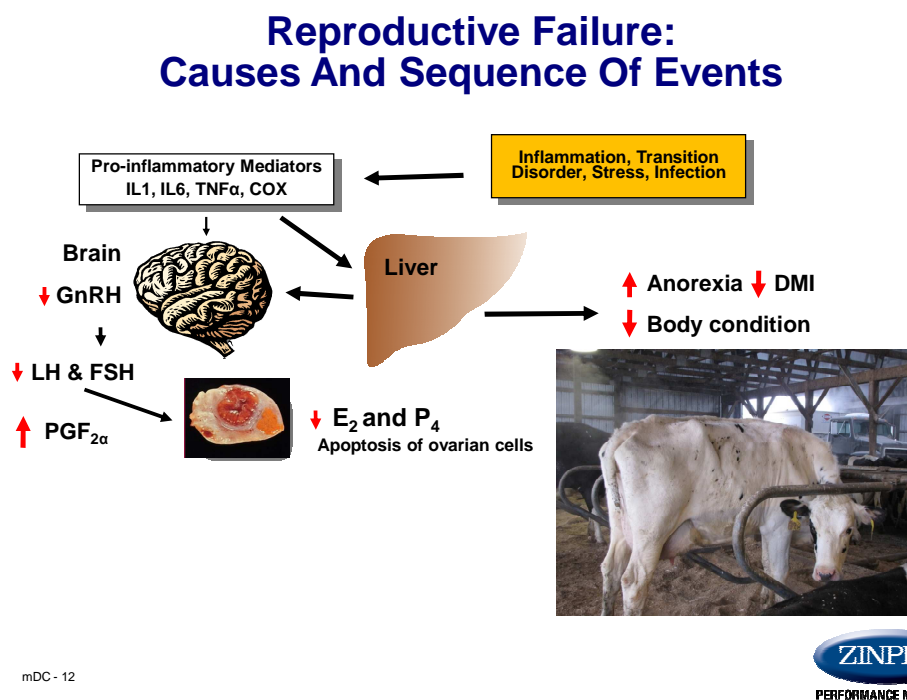
University of Florida researchers (Risco et al. 1999) reported a 2.7 times higher risk of abortion in cows experiencing an incident of clinical mastitis in the first 45 days of lactation. Hockett et al. (2001) reported an increase in days to first service of 22.6 days (71 to 93.6 days) for cows with clinical mastitis before first service. Services per conception were also increased from 1.6 for cows without mastitis to 2.9 for those with clinical mastitis after first service. Barker et al. (1998) indicated an increase in days to conception from 92.1 for cows without mastitis to 136.6 for those with clinical mastitis after first service. Furthermore, Schrick et al. (2001) reported that cows with either clinical mastitis or subclinical mastitis have impaired reproductive capabilities.

Schrack et al. (2001) summarized that endotoxins released by the death of gram-negative or gram positive bacteria significantly lower gonadotropin releasing hormone (GnRH) pulse amplitude, lower GnRH and luteinizing hormone (LH) concentrations, increase cortisol and progesterone (P₄) while increasing body temperature. Inflammation stimulates the immune system, resulting in the release of cytokines which may inhibit the action of FSH on LH receptors. Therefore, mastitis may influence reproductive function via alterations in LH and FSH activity or function, affecting follicular development and (or) oocyte maturation (Schrack, 2001).

Impact of Inflammation on Reproduction

A growing body of evidence indicates that immune activation may be one of the primary causes of pregnancy failure (Bertoni et al., 2008; Erlebacher, et al., 2004; Gimble 1990). Common pro-inflammatory cytokines (TNF α , IL-1, IL-6 and COX, immune cell chemical messengers) produced during stressful insults such as heat stress, lameness, water deprivation, infection (mastitis or metritis), metabolic diseases, parasites, trauma and endotoxins from the gut have been reported to induce ovarian resistance toward gonadotropins (Belknap et al., 2002; Grimble, 1990; Schrick, 2001). These cytokines are known to be primary mediators of endotoxic shock and tissue damage (Belknap et al., 2002; Lambert et al., 2002). This response ultimately results in pregnancy failure by inhibiting ovarian progesterone production (Erlebacher et al., 2004) (Figure 1.).

Figure 1. Impact of inflammation and infection on reproductive failure.



For example: heat stress often results in increased core body temperature, decreased dry matter intake, depressed milk yield and reproductive failure. However, an unforeseen response to this stress may be increased gut permeability. It is this increase in gut permeability to endotoxin, a component of the walls of Gram-negative bacteria, that causes local and/or systemic inflammatory reactions (Lambert et al., 2002). The inflammatory response is marked by the production of TNF- α and IL1- α which are both pro-inflammatory and responsible for systemic changes in blood flow while stimulating the production of prostaglandins (Lambert et al., 2002).

Similarly, Belknap and coworkers (2002) investigated the effects of grain feeding acidosis on production of pro-inflammatory mediators in feedlot cattle. They found acute rumen acidosis resulted in a marked increase in production of TNF- α , IL1, IL6

and COX possibly as the result of lipopolysaccharide (LPS) leakage from the gut. The occurrence of acute acidosis in commercial dairy cows is low, whereas the prevalence of subacute rumen acidosis (SARA) is widespread. For example, surveys indicate that in Wisconsin, 19 to 26% of lactating cows fed TMR diets experienced SARA (Garrett et al., 1997; Oetzel et al., 1999), and in Ireland, almost 50% of grazing cows from 12 herds experienced moderate to severe SARA (O'Grady et al., 2008). Subacute ruminal acidosis causes the dairy industry significant financial losses associated with lameness, treatment of sick animals, and decreased milk production (Krause and Oetzel, 2006) and may be another cause of reproductive failure.

Summary

A vast body of evidence supports the premise that nutrition, inflammation (immune activation), heat stress, lameness and infection individually or combined may significantly impact fertility of dairy cattle and lead to early culling from the herd. Research has shown that cows that are stressed, lame, contract mastitis, or are heat stressed have increased days open and reduced reproductive efficiency. Therefore, management strategies must be established to address cow comfort, including heat abatement, detection and correction of lameness and prevention of mastitis in an effort to minimize their negative effects on fertility. Trace minerals play key roles in preventing lameness and mastitis and in maintaining reproductive function. Supplementing cows with highly bioavailable trace mineral sources helps ensure cows will have adequate trace minerals status even when dietary, management and environmental conditions may be less conducive to mineral absorption.

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