REDUCED REPRODUCTIVE PERFORMANCE IN HIGH PRODUCING DAIRY COWS: IS THERE ACTUALLY A PROBLEM?

Is de gedaalde vruchtbaarheid bij hoogproductieve melkkoeien wel degelijk een probleem?

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ABSTRACT

The fertility of high yielding dairy cows has been declining over the past 25 years. Several studies have clearly demonstrated that the resumption of ovarian activity has been retarded and that conception rates have dropped significantly from 55 to 40%. Accordingly, the calving interval has increased from about 385 days to 412 days. The percentage of cows culled because of infertility has risen from 5 to 8% per year. This decrease in fertility results has led to a decline in the profitability of dairy herds. In a 100 cow herd this yearly loss amounts to at least 5000 euros.

The 'subfertility syndrome' is a multifactorial problem in which, first and foremost, the period of negative energy balance and nutrition affect endocrine signaling, follicular growth and probably also oocyte and embryo quality. Although a lot of research has already been done, many problems still need to be unraveled. Solutions for this complex problem are difficult to achieve because they involve optimizing a whole series of critical factors such as housing and management, estrus detection, nutrition during the dry, transition and lactation periods, timing of insemination, hygiene and care around parturition, claw health and the use of good quality semen.

SAMENVATTING

De vruchtbaarheid van hoogproductieve melkkoeien is de laatste 25 jaar sterk verminderd. Zo is het drachtigheidspercentage van de eerste inseminatie gedaald van 55 naar 40%, is de tussenkalftijd gestegen van 385 dagen naar 412 dagen en is het percentage koeien dat elk jaar moet worden opgeruimd wegens subfertiliteit gestegen van 5 naar 8%. Dit alles resulteert in een aanzienlijk economisch verlies dat voor een bedrijf met 100 melkkoeien geraamd wordt op ongeveer 5000 euro per jaar.

Het "syndroom van subfertiliteit" is een multifactorieel probleem waarbij vooral de periode van de negatieve energiebalans en de voeding een invloed blijken te hebben op het endocrien metabolisme, de folliculaire groei en de eicel-en embryokwaliteit. Ondanks heel wat voortreffelijk onderzoek is de exacte pathogenese van subfertiliteit nog onvoldoende bekend. Het complexe probleem van de verminderde vruchtbaarheid kan enkel adequaat worden opgelost door voldoende aandacht te schenken aan talrijke risicofactoren, zoals de voeding en het management.

INTRODUCTION: SOME EYE-OPENING FIGURES

Modern dairy cows are able to produce vast amounts of milk mainly due to significant genetic improvements, combined with enhanced nutritional management. A prerequisite for good lactation performance during the cow's life span is producing a calf at regular intervals. Therefore reproductive efficiency is a world-wide concern in the modern dairy industry as it influences average daily milk production, average days in milk, number of calves born per year and the generation interval (Johnson and Gentry, 2000). Many studies have reported a worrisome decrease in the reproductive performance of dairy cows and this problem seems to affect all countries housing high yielding dairy herds.

For example, in Belgium the average calving interval increased from 390 to 412 days during the last 10 years (personal communication, Flemish Cattle Breeding Association). The number of AI per conception rose from 1.43 to 1.75 in the same period. In the Netherlands, the success rate at first AI dropped from 55.5% to 45.5% in 10 years time and the number of cows showing their first heat before day 50 postpartum decreased (Jorritsma and Jorritsma, 2000). In the same period, milk production increased from 7558 kg fat corrected milk in 305 days to 8744 kg. Research from Opsomer *et al.* (1998), which was later confirmed by others, revealed that about half of the modern dairy cows have abnormalities of the cycle during the postpartum period, resulting in prolonged anestrus and ovarian cysts. Others have reported an increase in uterine disorders early postpartum, and a rise in embryonic mortality (Sheldon *et al.*, 2006). Especially during hot seasons, dairy cows seem to be very vulnerable to reproductive disorders (López-Gatius, 2003). In the USA, a tremendous increase in the number of AI per conception (from 1.75 to over 3) over a period of 20 years has been described (Lucy, 2001). In Ireland, the number of AI required for conception went from 1.54 to 1.75 between 1990 and 2000 and the conception rate dropped by 0.96 per annum (Mee *et al.*, 2004). Similar reports can be found in France and Canada (Bousquet *et al.*, 2004). Pregnancy rates to first service in the UK have reached an absolute nadir of 40% and the pregnancy rate of the modern UK dairy cow is declining at approximately 1% per annum (Royal *et al.*, 2000).

Almost all publications concerning fertility in high producing dairy cows are unequivocal and conclude that the declining reproductive performance is one of the major factors threatening the profitability of the modern dairy industry.

ECONOMIC CONSEQUENCES OF SUBFERTILITY FOR A DAIRY HERD'S PROFITABILITY

Underlying reasons for reduced fertility in dairy herds may be associated with many different factors, of which the inadequate management practices associated with increased herd sizes are the most important (de Kruif and Opsomer, 2002). There is no doubt that fertility failure has a major negative economic impact. The extra costs arising from subfertility include lost income from milk and calf sales, feed and quota costs, extra veterinary and semen expenditures, and the costs associated with culling and extra replacement of subfertile cows (Royal *et al.*, 2000). These extra costs vary markedly from one country to another. For the Benelux countries, Huirne *et al.* (2002) took all the relevant factors into account and calculated that the optimal calving interval for first lactation cows is still exactly one year, while for older cows the interval is even shorter than one year! Lengthening the calving interval from 12 to 13 months causes a loss of US$ 1.83 per day, while the loss due to further lengthening amounts to US$ 2.37 – 2.70 per extra day. Furthermore, the calculations of economic benefit are especially sensitive to changes in the shape of lactation curves. A significant increase in persistency allows a longer calving interval without associated extra economic losses. Finally, the average loss per cow culled for disappointing fertility reasons was determined to be US$ 220 to 280 (Huirne *et al.*, 2002).

For the UK it has been estimated that a 10% improvement in conception rate would benefit the British dairy industry by approximately 300 million pounds per year (Royal *et al.*, 2000). These figures clearly indicate that dairy fertility is extremely important for guaranteeing a dairy herd's profitability.

MULTIPLE PATHWAYS TO SUBFERTILITY: FACTS AND SECRETS

On the basis of the surveys mentioned above, the 'syndrome of subfertility' can be divided into two major pathways. The first possible way to subfertility is the resumption of normal ovarian activity early postpartum, which is retarded in high producing dairy cows. These cows have a high proportion of abnormal estrous cycles (Opsomer *et al.*, 1998). The presence of normal follicular growth on the ovary determines the interval from parturition to first AI. Several studies have determined the major risk factors for ovarian dysfunctions (reviewed by Butler, 2003). Much of the research effort has been focused on alterations in endocrine signaling (hypothalamus-pituitary-ovary axis). The effects on follicular development and the subsequent indicators of impaired fertility such as reduced estrus symptoms or anestrus, cyst formation, delayed first ovulation, and prolonged calving to first insemination intervals have been extensively documented elsewhere (Harrison *et al.*, 1990; Beam and Butler, 1997; Opsomer *et al.*, 1998; de Vries and Veerkamp, 2000; Vanholder *et al.*, 2002; Diskin *et al.*, 2003; Lopez *et al.*, 2004). In these studies correlations were found between energy balance, body condition and blood parameters (such as NEFA, glucose, insulin

and insulin-like growth factor I) and the resumption of ovarian activity.

Despite this vast amount of excellent research, a lot of work still has to be done. What do we know, for example, about the influence of receptor and post-receptor effects for insulin and gonadotrophines at the level of the follicular cells in the ovary? Is it possible that the metabolic changes characterizing the period of negative energy balance (NEB) have toxic effects on granulosa or theca cells? Very recent results from our lab seem to confirm this new way of thinking (Vanholder *et al.*, 2005). What subtle signals determine the fate of a preovulatory follicle: atresia, ovulation or a prolonged growth phase resulting in cyst formation?

However, even when a positive energy balance and correct endocrine signaling are re-established, which ultimately results in ovulation, reproduction is still not guaranteed. As already has been mentioned, dairy cow fertility has shown a dramatic drop without any obvious reduction in sperm quality. Early embryonic mortality is proposed to be a significant cause of reproductive failure in ruminants (Dunne *et al.*, 1999; Mann and Lamming, 2001; Bilodeau-Goeseels and Kastelic, 2003). Thus in addition to the resumption of ovarian activity, oocyte and embryo quality are two further crucial points determining reproductive efficiency. It is only recently that some studies – driven by these observations – have begun to focus on the oocyte and subsequent embryo quality. And indeed, some of these studies have confirmed that the oocyte quality could be in danger in high producing dairy cows (Snijders *et al.*, 2000; Wiltbank *et al.*, 2001; Walters *et al.*, 2002). A field trial performed at our lab in collaboration with the Flemish Cattle Breeding Association revealed that embryos from high yielding dairy cows are inferior compared to the embryos of non-lactating dairy heifers or beef cows (Leroy *et al.*, 2005). Furthermore, we were able to demonstrate in our IVF lab that high NEFA and low glucose environments during oocyte maturation are detrimental for the oocyte's developmental competence (Leroy *et al.*, 2005; Leroy *et al.*, in press). But what do we know about the specific environment of the oocyte or embryo? It is crucial for further research to investigate the follicular, oviductal and uterine environment thoroughly and to learn more about how this microenvironment can be influenced. Finally, good corpus luteum quality and optimal maternal pregnancy recognition are unmistakably important in establishing a successful gestation (Mann and Lamming, 2001).

FACTORS AFFECTING FERTILITY

Reproductive failure is certainly a multifactorial problem. The amount of milk produced, as such, only plays a minor role compared with the importance, for example, of NEB early postpartum (Loeffler *et al.*, 1999; de Vries and Veerkamp, 2000; Snijders *et al.*, 2000; Lucy, 2001). Daily milk yield is not an appropriate indicator of NEB because feed intake and management practices both confound the association between yield and energy balance (Villa-Godoy *et al.*, 1988; McMillan *et al.*, 1998; de Vries and Veerkamp, 2000; Kruip *et al.*, 2000). It is probably not the net energy shortage as such, but rather the degree of adaptation of a cow to the shortage of energy that is responsible for the fertility changes. This can affect the resumption of ovarian activity by altering the endocrine signaling. But the direct side-products and side-effects of this maladaptation to this NEB (high NEFA, urea and BHB concentrations and low glucose and IGF-1 concentrations) also seem to have a deleterious effect on follicle and oocyte quality (Leroy *et al.*, 2005; Vanholder *et al.*, 2005).

Other factors, such as the high energy and protein-rich rations typically fed to modern dairy cows to sustain the high level of milk production, together with the increased herd size, have been associated with disappointing fertility outcomes (Butler, 1998; Lucy, 2001; Fahey *et al.*, 2002; Lucy, 2003), though the relationship between protein-rich rations and fertility is inconsistent between different studies (Laven and Drew, 1999).

For decades now, dairy cows have been strictly selected for high milk yield. Some studies suggest that this genetic selection as such could also have an adverse effect on fertility by affecting ovarian activity and oocyte quality (Snijders *et al.*, 2000). In contrast with the findings of Snijders *et al.* (2000), Veerkamp *et al.* (2003) and Horan *et al.* (2005) suggest that high genetic merit for milk production is also associated with a more severe NEB. This higher metabolic stress may explain the disappointing reproductive performance. Silke *et al.* (2002) did not find any significant relationship between the extent or pattern of late embryonic loss and genetic merit. Future research should reveal whether genetic selection towards fertility could partly solve the problem without losing milk yield.

Along with selection towards higher milk production, modern dairy cows became more sensitive to heat stress as their internal heat production significantly increased (reviewed by Kadzere *et al.*, 2002). In other words, the temperature at which dairy cows

currently start experiencing heat stress has shifted to a lower point. It has been proven that heat stress is pernicious for reproduction (reviewed by De Rensis and Scaramuzzi, 2003). In addition to the detrimental effects on energy balance, follicular dynamics and the hypothalamus–hypophysis–ovarian axis, it has also been suggested that high body temperatures can directly be toxic for the oocyte and embryo proper (Rocha *et al.*, 1998).

Finally, it is generally accepted that high yielding dairy cows are more vulnerable to metabolic and infectious diseases. It has even been suggested that postpartum diseases are a more important risk factor for reproductive failure than NEB (Loeffler *et al.*, 1999). Especially the incidence of mastitis has increased, and this is probably due to a depressed immune system early postpartum (Ingvartsen *et al.*, 2003). Mastitis early postpartum, as well as intramammary infections around the moment of AI, are strongly associated with reduced conception rates (Loeffler *et al.*, 1999), and more specifically with higher risks of abortion within the following 90 days (Risco *et al.*, 1999). Claw disorders and other painful conditions also result in subfertility. The possible mechanisms involved in the link between infectious diseases and embryonic mortality have been extensively reviewed by Hansen *et al.* (2004).

THE ROLE OF GOOD HERD MANAGEMENT

Good herd management is extremely important for cow fertility (de Kruif and Opsomer, 2002). Methods of farming have changed considerably during the last 25 years. Some farmers have been able to cope with those changes, while others have experienced huge difficulties. The relationship between the farmer and his cows is complicated and difficult to assess. Fahey *et al.* (2002) demonstrated that herd management can overcome many of the adverse effects of high milk production on reproductive performance. Some farmers consistently manage high genetic merit herds so as to achieve acceptable conception rates (personal communication). Thus optimal herd management is indispensable for maintaining a high yielding dairy herd (de Kruif and Opsomer, 2002). A well balanced ration (protein and energy) and good housing conditions during the dry period, transition period and the first weeks of lactation are of paramount importance. They can prevent an excessively deep NEB. The subsequent augmented IGF-I and insulin levels have clearly been shown to benefit resumption of ovarian activity and to improve conception rates (Beam and Butler, 1997).

Genetic selection towards better reproductive performance is difficult because of the low heritability of all major fertility parameters. However, selection for indirect fertility parameters such as body condition score or endocrine characteristics (e.g. progesterone profiles, LH response to a GnRH challenge) could be much more fruitful because of their higher heritability (Royal *et al.*, 2000).

CONCLUSION

On the basis of the studies cited above, it is clear that the performance of dairy cows has deteriorated significantly. This certainly impairs the profitability of a dairy herd. The 'subfertility syndrome' is a multifactorial problem in which both the NEB and nutrition play an important role. Many other secrets concerning the pathogenesis of subfertility remain to be solved. One crucial factor in this matter is the management of the herd. It remains a challenge for researchers and veterinary practitioners to turn the negative trend of dairy fertility in a positive direction.

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