Breeding and management strategies to improve reproductive efficiency in dairy cattle

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1 Introduction

Approximately 150 million households around the world produce milk (FAO, 2013) with up to one billion people deriving their livelihood from the dairy sector (International Dairy Federation, 2016). Cattle, water buffaloes and other livestock contribute to global milk production, with >80% of milk from dairy cattle, ~15% from water buffaloes and <5% from goats, sheep, camels, yaks and so on. The global value of milk and milk products is estimated to exceed US$300 billion annually (International Dairy Federation, 2016). Clearly, the dairy industry is of huge importance to the global economy.

The global dairy industry is continually changing. China is making substantial investments to develop its dairy industry (Sharma and Rou, 2014); annual growth of domestic milk production was 12.8% from 2001 to 2010, and was projected to be 3.3% between 2011 and 2020, with a projected 38% increase in dairy consumption by 2022. Similarly, India, the

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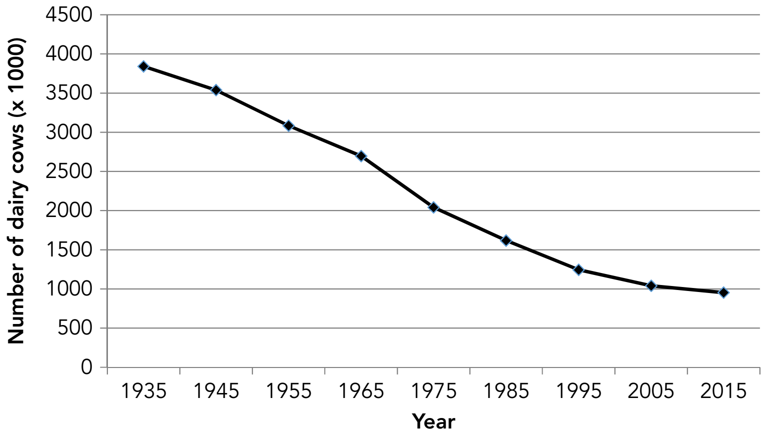

Figure 1 Changes in the number of dairy cows in Canada over the past 80 years. Source: Statistics Canada, accessed through Canadian Dairy Information Centre. http://dairyinfo.gc.ca/index_e.php?s1=dff-fcil&s2=farm-ferme&s3=nb.

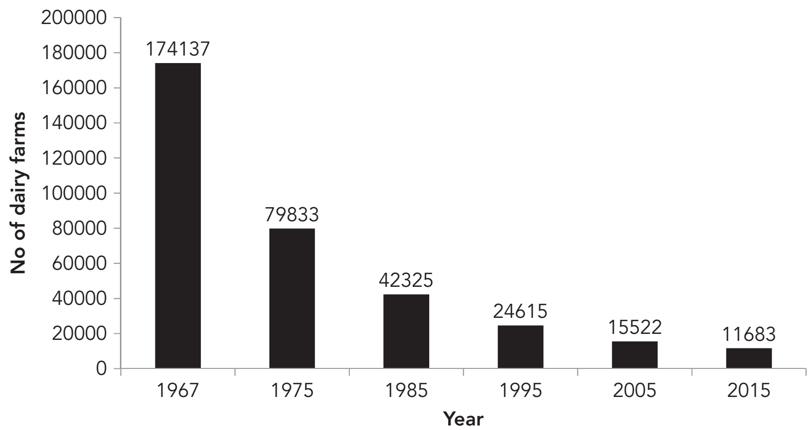

Figure 2 Change in the number of Canadian dairy farms over the past five decades. Source: Canadian Dairy Information Centre. http://dairyinfo.gc.ca/index_e.php?s1=dff-fcil.

largest milk-producing nation (mostly small farms) is modernizing its dairy industry (Swormink, 2014). Concurrently, global milk production has only a 1.9% annual growth rate, with 73% of the additional global milk production of 150 million tonnes this decade expected to come from developing countries, of which 38% is from India and China (Sharma and Rou, 2014).

Countries where most dairy cows are confined (e.g. Canada, the United States and Europe), greatly improved milk yield (per-cow basis), and increased herd size were observed. Changes in the number of dairy cows and dairy farms in Canada over the past several decades are shown in Fig. 1 and 2).

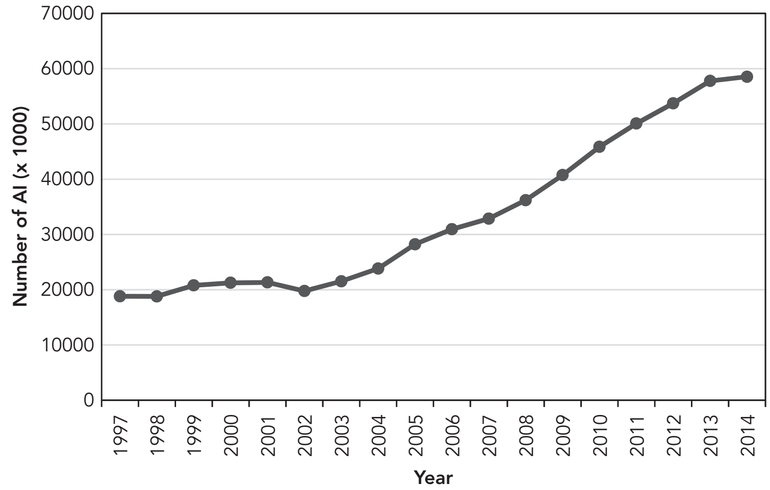

Figure 3 Growth in use of AI in India. Number (millions) of AI in cattle and water buffalo performed by government agencies in India between 1997 and 2014. Source: National Dairy Development Board.

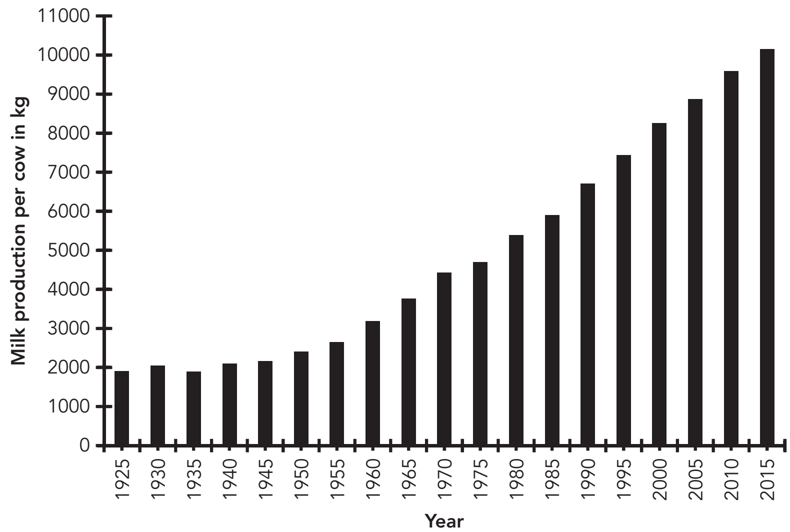

Figure 4 Milk production per cow (kg/y) in the United States from 1925 to 2015. Source: USDA, National Agricultural Statistics Service.

The use of artificial insemination (AI) to improve genetic merit of dairy cows started in the late 1930s (Foote, 2002). Approximately 90% of dairy cows in Europe, >80% in the United States (Gillespie et al., 2014) and >75% in Canada (Van Doormaal and Kistemaker, 2003) are bred by AI. In India, the use of AI tripled (~20 million to > 60 million) in the past decade (Fig. 3). Due to the resulting genetic progress (and improved management), annual milk production per cow has increased from <2000 kg in 1925 to >10 000 kg as of 2016 in the United States (Fig. 4; USDA-NASS, 2016) and this currently exceeds 11 400 kg in Israel (Flamenbaum and Galon, 2010).

2 Reproductive efficiency in dairy cattle

Although high reproductive efficiency is critical to sustainable dairy farming, reproductive failure is the primary reason for culling dairy cows in many countries (Seegers et al., 1998; Rozzi et al., 2007; Swedish Dairy Association, 2009–12; Ahlman et al., 2011; Ansari-Lari et al., 2012), and accounts for ~30 and 36.5% of all culling in North America (USDA, 2002; CanWest DHI, 2014; Fig. 5) and England (Esslemont and Kossaibati, 1997), respectively. Infertility is also the primary reason for culling dairy cattle managed on pasture (Crosse et al., 1999, cited by Maher et al., 2006).

Concurrent with increasing milk production, dairy cow fertility is generally declining in North America (Lucy, 2001; Westwood et al., 2002) and elsewhere (Macmillan et al., 1996; Royal et al., 2000; Lopez-Gatius, 2003; Kumaresan et al., 2009; Barbat et al., 2010; Dochi et al., 2010; Walsh et al., 2011). Annual decreases in conception rate (CR) in the United States (Beam and Butler, 1999) and Canada (Bosquet et al., 2004) were ~0.4% (mid-1970s to 1990s) and 0.5% (1990–2000) and even faster in Europe (Hoekstra et al., 1994; Jorritsma and Jorritsma, 2000). Royal et al. (2000) reported that the CR to first service (insemination) after calving in the United Kingdom declined from 56% to ~40% between 1975 and 1998. Although an antagonistic association between milk production and reproductive performance may be inferred, there is no clear evidence of

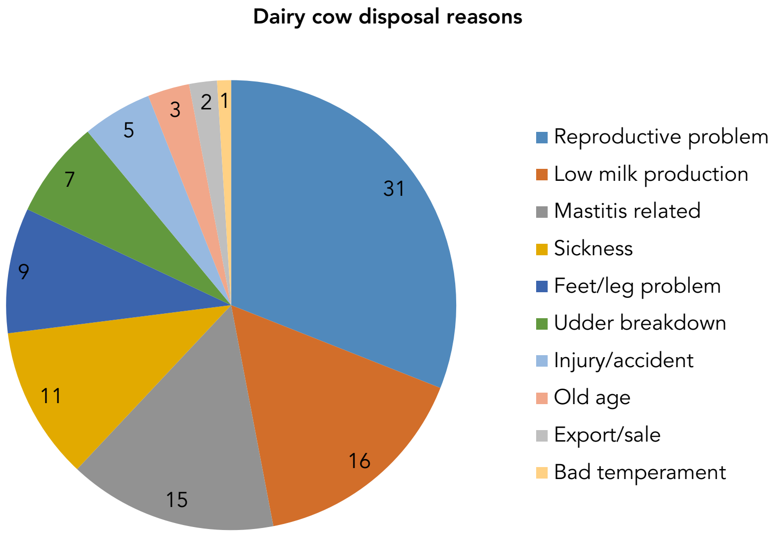

Figure 5 Reasons for culling dairy cows in Canada (expressed as per cent). At 31%, reproductive problems remain the primary reason for culling. Source: CanWest DHI Ontario Progress Report, 2014.

a cause-and-effect relationship (Raheja et al., 1989; Bello et al., 2012). In this regard, high milk production and high first-service CRs often co-exist in well-managed dairy herds (Peters and Pursley, 2002; Lopez-Gatius et al., 2006; Galon et al., 2010; Leblanc, 2010, 2013).

The cow-to-person ratio usually increases with herd size, which may reduce reproductive efficiency. Therefore, it is essential to assess reproductive performance, identify key problems and deficiencies, and plan and deliver corrective actions.

Due to the widespread use of AI in the dairy industry, accurate oestrus detection and timely and skilful performance of AI are of paramount importance to optimize reproductive efficiency if cattle are bred following detection of oestrus. Therefore, all persons involved in AI should have a very good understanding of the oestrous cycle and of both the primary and secondary signs of oestrus.

It is essential to sustain the motivation of those who are engaged in oestrus detection. An excellent attitude, interest and knowledge are extremely important for achieving reproductive success in dairy herds. Casual and new employees may not realize the importance of reproductive management and could have limited or no interest in oestrus detection. So, it becomes all the more important to send such staff to extension meetings and workshops dealing with dairy reproductive management so that they could gain first-hand knowledge.

3 The oestrous cycle and oestrus behaviour

The oestrous cycle of dairy cattle averages 21 days (range, 18–24) and has four phases (Fig. 6). Pro-oestrus, the interval from regression of the corpus luteum (CL) until manifestation of behavioural oestrus, lasts 3 to 4 days. Oestrus is the sexually receptive (and shortest) phase, and its primary sign is that cows 'stand' to be mounted by a bull or female herd mate (Fig. 7). For AI, breeding must be done during or shortly after the end of 'standing oestrus' to maximize CRs (Fig. 8). Duration of standing oestrus varies considerably and is longer in heifers than in cows (18–24 vs 8–12 h, respectively; O'Connor, 2007) with very short oestrus intervals and few mounts in high-producing cows (O'Connor, 2007). Metoestrus begins at the end of oestrus and lasts 3 to 5 days. Ovulation occurs during metoestrus, usually 24–32 h after the onset of standing oestrus (O'Connor, 2007). Vaginal bleeding during metoestrus is more common in heifers than in cows (Hansen and Asdell, 1952) and is attributed to extravasation of blood after oestrogen concentrations decrease (Hansen and Asdell, 1952; Peter et al., 2009a). Dioestrus, the longest phase of the cycle, is characterized by the CL actively secreting progesterone to prepare the uterus for implantation. If a viable embryo is present in the uterus, at ~15 d after oestrus, the elongating embryo produces interferon-tau, which suppresses the expression of oestrogen receptor alpha and oxytocin receptor, thereby suppressing the oxytocin-dependent pulsatile release of prostaglandin $F_{2\alpha}$ (PGF) and preventing luteolysis (Thatcher et al., 1989; Bazer, 2013). Concurrently, activation of numerous genes in the conceptus and maternal endometrium facilitate cross talk between the embryo and the uterus (Mamo et al., 2012), leading to maternal recognition of pregnancy (i.e. maintenance of CL). However, in the absence of a viable embryo, oestradiol from the dominant ovarian follicle binds to endometrial oestrogen receptors, resulting in the release of PGF, luteolysis and then oestrus.

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