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“Grass to milk” and beyond

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Abstract

Dr C.P. McMeekan’s book, “Grass to milk”, has been used as the basis of this paper. It is an historical account of a dairying system based on cows harvesting improved pastures *in situ* following a seasonally concentrated calving in the late winter. It was published in 1960, not as a text book, but as McMeekan’s “complete philosophy of New Zealand dairy farming”. The book’s contents present an opportunity to compare “performance” statistics for the described dairying system with those recently published in the peer reviewed literature and elsewhere. Commendable advances have been made in cow yield per lactation and feed conversion efficiency as well as in dry matter harvested per hectare. However, these advances have been partly offset by an increase in cow wastage, largely due to lower reproductive performance, even in research herds, in spite of interventions such as induced calving and treating anoestrous cows. What should be obvious from reviewing the seminal publication of McMeekan is that most of the management concepts described by McMeekan have stood the test of time and are as relevant today as they were 50 years ago.

Keywords: historical perspective; McMeekan; milk production; pasture production; reproduction

Introduction

New Zealand’s livestock industries have been well served by outstanding leaders in teaching, research, extension and industry management. Campbell Percy McMeekan was one such individual, whose leadership in the dairy industry was at its peak during the 1950s and early 1960s. As was mentioned in his biography; “He took a moribund institution and created the most efficient agricultural research centre in the British Commonwealth within the space of 10 years” (McLauchlan 1982).

This was a period that coincided with major changes in farm management. For example, milk harvesting and collection methods were being radically altered. Cows were beginning to be milked in herringbone dairies without “stripping” after cup removal with commencement of tanker collection of milk from the farm removing the time consuming daily task of transporting milk to the creamery. These innovations reduced time spent milking and allowed dairy farmers to devote more time to improving farm management as well as facilitating an increase in herd size. McMeekan’s book “Grass to milk – A New Zealand philosophy” (1960) was the first book to integrate research results and innovations, such as the electric fence, into a farm management system that maximised the utilisation of pasture and optimised herd management. A contributing factor to the successful application of these concepts on farm that should be acknowledged, was the cohesiveness within the dairy industry that allowed the results of research by McMeekan and others to be effectively applied through extension and teaching.

McMeekan’s book is a useful historical document that the author states should not be regarded as a text. It was written in a colloquial style

and does not specifically reference results from quoted research. Neither is it as comprehensive in content as the recent text book “Milk production from pasture – Principles and practices” (Holmes et al. 2007). In spite of these limitations, “Grass to milk” should still be regarded as the initial publication that described the benefits of a management system that integrated pasture and herd management to optimise the grazing system for a family-based labour system.

Efficient grassland dairying

McMeekan outlined three “efficiency” principles for successfully producing milk from grass:

1. “the efficiency of the process depends upon the amount and the seasonal distribution of the feed grown”,
2. “efficiency is governed by the proportion of the feed grown that is actually harvested by the animal”, and
3. “the process is dependent upon the efficiency with which the animal uses the food it does consume”.

From these principles, six key action points that defined the “Ruakura system” for efficient grassland dairying (Page 177) were induced:

- grow as much grass as economically practicable,
- adjust the variable supply of fodder to the needs of the herd,
- carry enough stock to use all the grass grown,
- use animals that will process the grass efficiently,
- harvest all the product by good milking management, and

- minimise herd wastage by control of disease.

“These should be borne constantly in mind by all who are seeking to tackle the job of farm improvement on a technically sound and logical basis” commented McMeekan (Page 177). While each of these recommendations could be modified slightly to “modernise” their relevance, considerable discussion would be necessary before any were deleted or replaced.

There have been changes in the production system since 1960. However, the largest changes have been outside of the six key action points identified by McMeekan. Scale is one such example. Whereas, the average farm size described by McMeekan was 60 cows plus replacements, or 80 cows if replacements were included, on 60 acres (24.2 ha). The 2010/2011 average for New Zealand was 386 cows on 345 effective acres (140 ha) (DairyNZ 2011). McMeekan considered that: “The existing herd unit of 60 cows is already as much as one man can handle conveniently and have some time over for developmental work” (Page 171). The 2010/11 average was 144 peak cows milked per full time equivalent.

In comparison, the stocking rate recommendations in the final chapter of his book, entitled “My Farm”, are not greatly different to those debated today. He recommended 1 cow/acre, or 2.5 cows/ha, rising to 1.3 cows/acre or 3.3 cows/ha, as the property was improved, coincidentally the same stocking rate reported as most economic by Macdonald et al. (2011) for Holstein-Friesian cows at the Ruakura No.2 Dairy in the 1990s, albeit with larger cows and 200 kg applied nitrogen as urea. The national average stocking rate in 2010/2011, however, was only 2.76 cows/ha and has never exceeded 2.81 cows/ha (DairyNZ 2011). These comparisons highlight that although there has been a 4.8 times increase in herd size and a 5.8 times increase in farm size over the last 50 years, stocking rate has not changed as significantly. The expansion of the dairy industry to 4.5 million cows has occurred largely through an increase in hectares dedicated to dairy farming. These now total 1.6 million hectares.

Another notable change since 1960 has been the value placed on milk components. The traditional export market 50 or more years ago was the United Kingdom with the main products being butter and cheese. The New Zealand dairy industry also supported a swine industry, with pigs fed mainly on skim milk or whey. The price received by herd owners and quoted frequently in McMeekan’s book was “three shillings per pound of butterfat” (3/- per lb butterfat). This would be equivalent to \$0.66 per kg milk fat. Payment systems did not recognise protein as a valuable component of milk. With a milk protein:fat ratio of 0.7 (Macdonald et al., 2008a), the milksolids price about 1960 would have been approximately \$0.41/kg milksolids! In comparison, the price received for milk fat in 2010/2011 was about \$4.80/kg. The increase in milk fat price from

\$0.66/kg in 1960 to \$4.80 in 2010/2011 represents a compounding increase in milk fat price of 4.0% per year. In comparison, the New Zealand reserve bank reports average compounding inflation to be 6.2% during the same period. The increased profitability of the dairy industry has largely been by recognising the value of milk protein, although there have been significant improvements in dairy cow efficiency, pasture utilisation and stock husbandry (Macdonald et al., 2008a).

Pasture production

McMeekan declared: “I do not claim to be a pasture production expert” (Page 53). He then proceeded to discuss the merits of different pasture species including Montgomery red clover and Yorkshire fog. His fertiliser policy for the Ruakura research farms was simple: “two cwt per acre”, half the amount of superphosphate that was being applied by farmers at the time (Page 59). This is equivalent to 22 kg P/ha. He believed this to be sufficient “under good management of our ryegrass-white clover swards to consistently produce 12,000 to 14,000lb of dry matter per acre” (Page 62), equivalent to 13.5 to 15.7 tonnes DM/ha/year. This was achieved through grazing management systems involving rotational grazing rather than set-stocking and without pasture topping. This range in yields can be compared with the range of 18 to 20 tonnes DM/ha/year reported by Macdonald et al. (2008b) in a stocking rate study from 1998 to 2001 at the Ruakura No.2 Dairy. This was the main experimental dairy used by McMeekan about 50 years earlier. The higher yields measured by Macdonald et al. (2008b) represent an increase in average annual DM production of approximately 31%, although almost half of this increase can be attributed to the 200 kg nitrogen applied.

Ruakura studies comparing set-stocking with rotational grazing demonstrated an increase in production per acre and per cow with the latter system (Page 71). The increases were of the order of 13% per acre and per cow. However, the Jersey cows managed with controlled rotational grazing were “approximately 100 lb. per head more in body weight” (Page 72). When the rotational management system was further intensified by providing two breaks of fresh pasture per day in a series of three trials, no production differences were demonstrated (Page 75).

Although break grazing was not demonstrated to be advantageous during the spring period, it was considered essential during late lactation and winter when “autumn saved pasture” was rationed. This form of pasture storage and utilisation was referred to as the “Wallace system” (Page 100). “It is of special interest to note that the method is being widely adopted by farmers despite the fact that there is no experimental evidence that it actually results in production increases” (Page 100). Although environmental issues were less of an issue in the

1960s than at present, the autumn saved pasture form of management with break grazing was not recommended for the “claylands” of the Manawatu and Northland or the “swamplands” of the Hauraki Plains (Page 101).

Stocking rate

No description of dairying in New Zealand would be complete without considering the studies related to stocking rate. McMeekan described a series of six experiments, partly because he considered that replicating a trial in consecutive years was preferable to replicating within year. Whereas this approach has been maintained in subsequent farm systems trials in New Zealand, Victorian studies are usually replicated within year. In the Ruakura trials completed around 1960, the stocking rates varied from 2.1 to 4.1 cows/ha. Yields per cow for complete lactation studies for the lower stocking rate in each experiment varied from 115 kg milk fat, or about 195 kg milksolids, to 207 kg milk fat or 352 kg milksolids, whereas the higher stocking rates ranged from 93 kg milk fat or 158 kg milksolids to 189 kg milk fat or 322 kg milksolids. An efficiency ratio was calculated as the percentage reduction in per cow production associated with the higher stocking rate. It ranged from -7% to -20% (Page 84). Yields per acre always favoured the higher stocking rates by from +17% to +43%, with the maximum yield being 522 kg milk fat/ha equivalent to 887 kg milksolids/ha with Jersey cows stocked at 4.1 cows/ha.

A change in the breed structure of the New Zealand dairy industry from predominantly Jersey, through Friesian-Jersey crossbreds to mainly Holstein-Friesians, has seen most recent stocking rate studies conducted using Holstein-Friesian cows (Macdonald et al. 2008b). Although per cow yields in the more recent studies may differ from the earlier studies because of breed differences (Jersey vs Holstein-Friesian), per hectare comparisons retain relevance. Macdonald et al. (2008b) compared stocking rates ranging from 2.2 to 4.3 cows/ha, although small amounts of supplements were purchased at the two highest stocking rates of 3.7 and 4.3 cows/ha. No supplements were purchased with the stocking rates of 2.2, 2.7 and 3.1 cows/ha. By comparison with McMeekan's studies, per cow yields for milk fat and milksolids declined from 231 kg and 393 kg to 150 kg and 255 kg, respectively, in a linear fashion with increasing stocking rate. The higher yields per cow achieved by the cows in the more recent studies contributed to milk fat and milksolids yields increasing from 507 and 895 kg/ha to 647 and 1,141 kg/ha with increasing stocking rate. The economic implications of these interactions have been modelled by Macdonald et al. (2011).

Macdonald et al. (2008b) concluded that: “The amount of pasture grown tended to increase with increasing stocking rate, and the quality of the pasture on offer increased linearly, reducing the

potential impact of cows per hectare. Milk production per cow declined linearly with increasing stocking rate, primarily because of lower peak and less persistent milk profile and a shorter lactation. However, milk production per hectare increased, and there was only a small decline in the efficiency of converting feed energy into milk energy as stocking rate increased.” These conclusions would have impressed McMeekan as he engaged in a well-publicised debate over the relevance of the interaction among stocking rate and pasture production and quality, wherein changes to pasture management such as rotation length at key times of year, to accommodate higher stocking rates, could alter feed quality as well as amount of pasture harvested. This confounded some of the interpretations surrounding higher stocking rates from a simple energy-balance perspective (Page 96). It is also likely that he would have supported the recommendation of Macdonald et al. (2008b) with the concept of calculating comparative stocking rate. This involves taking into account the live weight of the cows, the potential of the land to produce pasture and the amount of supplement purchased. McMeekan also considered that the genetic merit of a herd as well as breed should be taken into account (Page 80).

Animal size and efficiency

Cow live weight was identified by McMeekan as an important factor influencing animal efficiency (Page 42). The recommended target calving live weight for a Jersey heifer was 372 kg (Page 23). He reported that heifers that calved 45 kg (12%) smaller than this produced almost 14 kg less milk fat or approximately 36 kg milksolids. Macdonald et al. (2007) also reported an 18 kg drop in milksolids production in a heifer's first lactation when she calved 14% smaller than a well-grown contemporary.

McMeekan emphasised the importance of body condition at calving through reporting the results of two experiments in which Jersey cows were fed to either gain or lose live weight, effectively body condition, pre-calving. Cows on the higher plane of nutrition pre-calving had an average lactation live weight of 358 kg compared with 324 kg for those on the lower plane (Page 42). The heavier cows produced 19% more milk/cow/day (10.6 kg vs 8.92 kg) but needed only 8.5% more dry matter (Page 42). The cattle were not body condition scored, but in other trials where cows either gained 63 kg live weight during the dry period or lost 14kg, the heavier cows produced 23 kg more milk fat (Page 44).

The Jersey breed was definitely favoured over the Holstein-Friesian in McMeekan's studies. “In practice, it is generally found that three Jerseys can be carried for two Friesians. (*Since*) yield of fat per cow of the two breeds is similar, per acre yields are substantially improved by using the smaller animal” (Page 42). Results of a three-year study by the Dairy Board's Herd Improvement Department involving 66

herds of Jerseys and 66 herds of Friesians was quoted in support of this breed-related conclusion, where Jersey cows only produced 9% more milk/ha but produced 23% more milk fat. The study indicated that average milk fat yields were 138 kg/cow and 135 kg/cow for Jerseys and Friesians, respectively, but yields per hectare were 76 kg and 62 kg. A point of note in these data is that yields per cow and stocking rates among herds included in this study were substantially less than those at Ruakura.

Cross breeding was uncommon in New Zealand dairy herds before 1970. Holmes et al. (2007) quote statistics that 81% of production recorded cows in 1962 were Jerseys and 12% were Friesians, with no figure recorded for crossbreds. The equivalent figures for the three breed types in 1999 were: 16%, 57% and 19%, respectively. The most recent statistics for production recorded herds in 2010/2011 are: 15%, 40% and 45% for Jersey, Holstein-Friesian and Holstein-Friesian/Jersey crossbreds, respectively (DairyNZ 2011). The importance of crossbreeding to the New Zealand dairy industry is reflected in this shift in the national statistics and in the use of semen from “Kiwi” crossbred bulls, which has increased from less than 5% in 2004/2005 to 25% in 2010/2011. There has been a steady decline in semen usage patterns for the two “pure” breeds (DairyNZ 2011).

Comparisons with the per cow production figures quoted by McMeekan are complicated by the fact that the breed statistics in Table 1 are based on lactation lengths of 221 or 222 days and not on whole of lactation figures averaging 274 days (DairyNZ 2011), whereas McMeekan’s figures are mainly whole of lactation. However, live weight of Jersey cows has increased, as the well-fed cows in the earlier Ruakura studies weighed 358 kg compared with the *average* Jersey in production recorded herds in 2010/2011 weighing 383 kg (DairyNZ 2011). Yields of milk fat/cow for both Holstein-Friesian and Jersey cows in production recorded herds have also increased dramatically from those quoted by McMeekan (187 kg in 2010 vs 135 kg pre-1960 for Holstein-Friesians and 173kg vs 138kg for Jerseys even with the shorter lactation lengths in 2010/2011).

The proportional increases in milk fat yield

since 1960 may have been greater for Holstein-Friesians than for Jerseys, consequently reducing the stocking rate advantage relative to live weight for the smaller breed of cow. In addition, the Holstein-Friesians do have an advantage in protein yield, which improves the economic efficiency of the Holstein-Friesian. An approximate assessment of cow efficiency in terms of \$ earned/kg of live weight, however, still favours the smaller Jersey breed by 8.5%, or \$6.11/kg live weight vs \$5.63/kg live weight (Table 1). This is possibly because they produce a similar weight of protein/kg live weight at 0.32 kg protein/kg live weight for Holstein-Friesians and 0.33 kg/kg live weight for Jerseys. Both breeds have become more efficient in producing protein because of the selection emphasis on protein yield in calculating breeding worth (BW) and production worth (PW). The Holstein-Friesian/Jersey crossbred is similar, producing 0.34 kg protein/kg live weight, but with a financial return similar to Jerseys of \$6.09/kg live weight.

These “financial” outcomes substantially reflect the benefits of using a common standard for comparing every breed and genetic combination within a single calculation for assessing each animal’s breeding worth and production worth. The live weight and milk volume disadvantages with the Holstein-Friesian breed can be offset against its ability to synthesise protein, whereas the Jersey breed invests excessive amounts of energy in the less valuable milk component, milk fat. The Holstein-Friesian/Jersey crossbred lies between the two extremes.

Issues of size and live weight have been a focus of research following the widespread use of semen from Holstein-Friesian sires of North American origin from about 1990. Whereas McMeekan believed that the “grade” Jersey was the ideal animal for a payment system based on “butterfat”, the increasing value of protein created interest in importing semen from North American sires carefully selected for high protein:fat and protein test. Since the Scandinavian countries were the only ones who were progeny testing bulls for traits other than production traits, such as fertility, the compromised reproductive performance of daughters of North

Table 1 Differences in lactation length, milk fat, milk protein and milksolids yields, as well as income per cow, per kg live weight and income per kg live weight for Friesian, Jersey and Crossbred cows in production recorded herds in 2010/2011 (DairyNZ 2011).

Breed	Holstein-Friesian	Jersey	Holstein-Friesian/ Jersey X-breed
Days in milk	221	222	222
Milkfat (kg/cow)	187	173	189
Protein (kg/cow)	155	126	148
Milksolids (kg/cow)	342	299	337
\$/cow (\$4.8 x Mfat + \$12 x Protein)	2,762	2,339	2,681
Live weight (kg)	491	383	440
\$/kg live weight	5.63	6.11	6.09

American sires when used in seasonally calving systems was not fully understood. As the proportion of North American genetics within the Holstein-Friesian breed in New Zealand increased from approximately 2% in 1980 to 38% in 1999, the extent of the strain-related decline in fertility became increasingly apparent. The outcomes include increased awareness of the importance of reproductive performance of cows in pasture-based annually calving systems, preferably to a level achieved by the grade Jersey cows in McMeekan's herds at Ruakura.

An intensive series of trials has been summarised by Macdonald et al. (2008a). The comparison involved cows that were representative of New Zealand Holstein-Friesians of high genetic merit about 1970 (NZ70) and during the 1990s (NZ90) as well as cows of equivalent genetic merit to the NZ90 cows, but descending from North American sires that had been progeny tested in New Zealand (NA90). High and low feed allowances were compared within each genotype that allowed performance to be modelled at an annual intake of 6 tonnes of dry matter per cow. The NZ70 cows weighed 473 kg, 14 kg and 30 kg less than the live weight of the NZ90 and NA90 cows, respectively. The NZ70 cows also had a higher average body condition score of 5.1 on a 10 point scale (Roche et al. 2004) than the NZ90 at 4.5 and the NA90 cows at 4.1. The impact of selecting for protein within the New Zealand population was also apparent, as the NZ90 cows had average milk protein concentrations of 3.71% compared with 3.41% and 3.43% for the NZ70 and NA90 cows, respectively. Feed conversion efficiencies increased with stocking rate within each strain. The highest efficiencies in terms of kg milksolids/kg live weight^{0.75} were 4.24, 5.02 and 4.72 for the NZ70, NZ90 and NA90, respectively. The authors concluded that: "Combined with poor reproductive performance, this means that NA90 cows are less productive than NZ90 cows in pasture-based seasonal calving systems with low levels of supplements" (Macdonald et al. 2008a). Similar conclusions have been reached in similar studies conducted at Moorepark in Ireland (Horan et al. 2004; Horan et al. 2005). They justify McMeekan's confidence in strongly recommending the use of artificial insemination even though the advantages were less apparent in 1960 when sire selection was less reliable. The importance of progeny testing sires for traits other than production traits like fertility, is clearly necessary.

Animal health, fertility and survival

McMeekan considered that the New Zealand dairy farmer was particularly fortunate in being able to minimise herd wastage rates and to maximise cow productive life (Page 155). In support of his contention, he provided figures extracted from the New Zealand Dairy Board's Annual Report of 1956.

Total wastage was only 17.8%, with the major category being "culled for low production" (6.57%). The "total disease wastage" of 6.76% included only 3.6% related to low fertility. These figures suggest that cows averaged 5.6 lactations. Comparable figures for 2011 are not readily available. However, 52.5% of cows averaged at least five lactations in 2010/2011 compared with 50% in 1996/1997 (DairyNZ 2011).

Without providing figures, McMeekan emphasised the need to maintain a compact calving pattern to avoid reduced lactation lengths associated with later calving, and to allow each cow to have a dry period of two months. This had to be achieved without recourse to interventions such as induced calving and anoestrous treatments. Macdonald et al. (2008b) aimed to have 50% of cows calved by Week 2 from the date identified as the planned start of calving, with another 40% calving in the next four weeks and the remainder in the next two weeks. This was achieved by having 9% of the Holstein-Friesian cows induced to calve early and 35% treated for anoestrus in the previous season.

The widespread use of induced calvings since about 1975, as well as applying anoestrous treatments since about 1992, has allowed many herd owners to maintain compact calvings without addressing underlying issues of infertility. The adoption of crossbreeding from about 1980 also delayed the need to address any fertility changes within the two main breeds. The decline in reproductive performance became more apparent as the numbers of NA90 daughters increased. The NZ90 cows were found to have a longer period of anoestrus than NA90 cows (Macdonald et al. 2008a; Piccand et al. 2011) but had higher conception rates to first insemination of 46%, 45%, and 39% for NZ90, NZ70 and NA90 cows, respectively. They also had a shorter gestation of 8 days less than NA90 (Horan et al., 2004). As a result of the lower conception rates in NA90 cows, pregnancy rates after six weeks of artificial insemination were lower in NA90 cows at 54%, 70%, and 69% for NA90, NZ70 and NZ90, respectively. Pregnancy rates after 12 weeks were 87%, 93% and 93%, respectively. These results are similar to those obtained in several other New Zealand studies and have been confirmed at Moorepark in Ireland (Horan et al., 2004). Wastage rates due to failure to conceive in the NZ70 and NZ90 cows of 7% were double those reported by McMeekan (3.6%; Page 156) but were 3.6 times higher in the NA90 cows at 13%.

The lower reproductive performance of the NA90 cows is, at least in part, associated with their lower body condition score and loss of condition post-calving compared with NZ70 and NZ90 cows (Roche et al. 2006; Macdonald et al. 2008a). The importance of retaining body condition and post-calving loss were recognised but not quantified by McMeekan. Their relevance to cows in seasonally calving, pasture based systems has been highlighted by Roche et al. (2007) and Roche et al. (2009). They

reported that body condition at calving was critical to reducing the anoestrous interval, so that a higher proportion of cows had recommenced cycling before the start of the artificial insemination program. There are also benefits in production, especially in milk fat test, and likely benefits in welfare.

Results from transcriptome and endocrine comparisons indicate physiological differences between the strains that contribute to both the difference in body condition score and, probably independently, to the lower fertility. In the modern dairy cow, the growth hormone/Insulin-like growth factor-1 (IGF-1) axis, the somatotrophic axis, becomes uncoupled. This means that the cow has increased concentrations of growth hormone that are not associated with increased concentrations of IGF-1. This is important because growth hormone is a potent lipolytic agent (Roche et al., 2009). Differences in transcription and circulating hormone concentrations (Grala et al. 2011; Lucy et al. 2009) indicate a greater uncoupling of the axis and a delayed re-coupling of the axis in NA90 cows compared with NZ90 cows. This means that NA90 cows have higher concentrations of growth hormone and lower concentrations of IGF-1 and insulin. In addition, NA90 cows are less responsive to circulating insulin (Chagas et al. 2009). All of these factors combine to ensure NA90 cows lose more BCS than NZ90 cows. However, the effect very likely extends beyond the effect on body condition score, *per se*. Insulin and IGF-1 are hormones that increase the sensitivity of developing follicles to gonadotrophins. Low concentrations, therefore, result in compromised ovarian follicle growth and a greater chance of an aged or less fertile follicle being ovulated. In addition, higher plasma concentrations of non esterified fatty acids (Kay et al., 2009) from the greater body condition score mobilisation have been reported to compromise oocyte competence and early embryo development in *in vitro* studies. Recent studies have also indicated that the lower conception rates of the NA90 cows appear to involve differences in the recognition of embryo signalling, nutrient supply to the developing embryo, endometrial receptivity and suppression of the maternal immune system to facilitate embryo development (Walker et al. 2012). These strain related differences demonstrate the risks associated with yield-related selection programs that do not take into account the influence of traits other than production traits on animal survival and farm profitability. Strategic use of forms of intervention that may assist in maintaining compact calving patterns can be justified in the short term to account for adverse climatic events, but longer term reliance on their use will create an unhealthy dependence unless any negative genetic correlations between yield and survival factors are taken into account in sire selection programs.

There have been some recent studies with crossbred cows that have reported quite remarkable

levels of fertility. For example, McNaughton et al. (2007) studied the reproductive performance of two experimental herds of second cross (F2) Holstein-Friesian x Jersey cows that provided 1,780 lactation records. The caveat was that the cows averaged only 15.1% of their ancestry from NA sires. Calving induction was not used and only 59 cows were treated for anoestrus. First service pregnancy rates over the three years of the study ranged from 61% to 69% with three-week submission rates of 94% to 98%. The range in six-week in-calf rates of 81% to 83% exceeded industry targets of 78% and demonstrated that compact conception and calving patterns can still be obtained with cows in herds with good breeding management and suitable genetics.

Although NA90 heifers were heavier at 15 months of age than NZ70 and NZ90 heifers at 361 kg versus 331 kg and 337 kg, their average age at puberty was later at 373 days versus 329 days and 356 days. In addition, 26% were not cycling at 15 months of age when their breeding program commenced compared with 12% and 4% in NZ70 and NZ90 heifers (Macdonald et al. 2007). This later onset of puberty could be a cause for concern where heifers in commercial herds may not be as well reared as those enrolled in the research trial. In this instance, similar percentages of heifers of each genotype conceived in the first six weeks.

Diseases such as brucellosis, trichomoniasis and vibriosis, where the bull is a principal vector, are referred to by McMeekan (Page 156) but are now uncommon, in part due to the widespread use of artificial insemination. Bloat, milk fever and grass staggers are mentioned as “irritating” diseases, but no mention is made of facial eczema. Mastitis is also mentioned, although it only contributed to 0.83% of cows being culled (Page 155). Tuberculosis was deemed as “not a serious source of direct economic loss to the individual producer”.

Conclusions

Impressive gains have been made in productivity since McMeekan published “Grass to milk” in 1960. Increases in cow performance have been matched by increases in pasture productivity in a research setting. The interactions involving stocking rate with yield/cow and yield/hectare that were defined by McMeekan when advocating rotational grazing, remain with the modern cow of high genetic merit. Breed changes linked to the introduction of payment for protein have led to a decline in the proportion of cows that would be equivalent to McMeekan’s “grade” Jerseys and an increase in Holstein-Friesians and crossbreds.

Holstein-Friesians, such as the NZ90 animals used in the experiments by Macdonald et al. (2008a), Horan et al. (2004) and Horan et al. (2005) have longer post-partum anoestrous periods, but this has not been recognised as a disadvantage because of the efficacy of treatments based on progesterone, their

high conception rate when cycling, and their shorter gestation period. The insidious decline in fertility has been accommodated through the strategic use of induced calving and anoestrous treatments. Their use may have to be modified to placate market and welfare concerns. In that case, greater emphasis will have to be placed on improving reproductive performance through a combination of breeding and management, with the latter becoming increasingly challenging in herds of 600 cows or more. Certainly, research to identify genes that influence the probability of oestrus/anoestrus and embryo survival are critical to maintaining compact calvings, while still achieving acceptable levels of production per cow at current, or higher, stocking rates. These advances will be necessary if the management principles defined and described by McMeekan are to be maintained within the low cost pasture-based systems internationally regarded as the unique feature of dairying in New Zealand.

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