production impact of farrowing pen systems, and finally, the behavioural effects of straw-based housing systems.

The preface declares that this book is published "in order to provide a lasting contribution to the development of future, society- and consumer-accepted housing systems for domestic animals". Even though many papers are essentially discussions of work in progress, they do highlight the range of potential mechanisms for assessing and improving farm animal welfare. Animal welfare assessment at the group level is at a relatively early stage, and this collection of papers gives an insight into the work that is likely to be produced in the future.

David C J Main
Department of Clinical Veterinary Sciences
University of Bristol

Robotic Milking

Edited by H Hogeveen and A Meijering (2000). Proceedings of the international symposium, Lelystad, The Netherlands, 17–19 August. Published by Wageningen Pers: PO Box 42, 6700AA Wageningen, The Netherlands. 309 pp. Hardback (ISBN 9074134874).

The recent development of technology to enable teat cups to be automatically attached to a cow has led to the commercial production of fully automated milking units, or milking robots. Such units are now being evaluated world-wide, but especially in Europe. To many lay people, robotic milking of dairy cows will seem an anathema when considering their welfare. However, this is not the message from a new book dedicated solely to robotic milking, especially if one compares the system to the manually operated milking systems in operation on most farms. The book contains 62 papers from a conference held in Lelystad, The Netherlands, in August 2000. The contributions are of varied length and are contained in five sections: milking technique, milk quality, husbandry systems, economics, and health/welfare considerations. There is an author index but regrettably no subject index.

Amongst much technical detail on the performance of robotic milking systems, the book describes the latest research on many aspects of robotic milking that affect the welfare of cows. These include the daily milking frequency and the vacuum and pulsation characteristics, which are standardised for all cows in conventional milking parlours but which can potentially be tailored to the needs of individual cows in robotic milking systems. Given that in some European countries one third of dairy farmers are likely to switch to robotic milking within the next 10–15 years, according to a chapter by Justesen and Dam Rasmussen, the technique clearly has the potential to have a major impact on the welfare of dairy cows. Currently, just over 500 farms are using the system, most of these in Europe, and the next ten years will determine whether the technology has universal application or whether it will be restricted to quite specific circumstances. The technology is most likely to be adopted in areas with small family farms, scarce availability of low-cost hired labour, and an ageing population of farmers wishing to reduce their labour input. Such conditions exist in much of Europe and North America, where there are strong economies in sectors other than agriculture, and Reinemann and Jackson-Smith argue that the technology could help to preserve the family farm in these regions. Large industrial operations are unlikely to adopt the technology widely because a purely economic assessment would not favour their use.

Theoretically, stockpeople should have extra time to look after their cows in a robotic milking system, which, it is estimated, reduces labour requirements for milking by 30 per cent. They are still required to fetch cows that do not want to be milked, to attach the cluster

to cows if the machine malfunctions and to monitor milk storage and cooling. This may involve night attendance! The economic estimates by Arendzen and van Scheppingen show that there is only a potential profit margin from adopting robotic milking if surplus labour can disposed of. This is often difficult, but it may be overoptimistic to assume that cows will be more closely monitored in dairy systems with robotic milking, as older farmers adopting the system may choose to use the time released for leisure activities. Undoubtedly, the adoption of robotic milking systems will increase the need for stockpeople to be better trained technically.

One indication that there may be adverse effects of robotic milking on welfare comes from the reluctance of most cows to volunteer for milking more than once or twice a day. This may be because the stress associated with being milked by a robot is greater than the alleviation of any stress associated with having a full udder. Some of the stress of automatic milking may relate to the automatic udder cleaning and lack of contact with the herdsperson. On the majority of farms, there is a good relationship between the stockperson and the cows, and the direct contact during milking may be valued by both. However, Hopster *et al* present endocrine data which suggest that cows entering a robotic milker suffer *less* emotional stress than in conventional systems, where the forcing of cows by the herdsperson or an electronic crowding gate to enter the parlour leads to stress.

The cows' reluctance to be milked by a robot makes it usual to offer concentrate feed during milking. In the book, some researchers express concerns that this will lead to metabolic disorders if the robot is visited frequently and large amounts of concentrates are fed at each visit. Other researchers are concerned that cows in negative energy balance will be driven to attend regularly for more food, which will increase milking frequency and yield and thereby exacerbate the negative energy balance. The separation of concentrate and forage feeding in this way could reverse the recent trend of mixing concentrates and forage before feeding. An interesting Swedish paper reports that feeding during milking increases oxytocin production and milk let-down and reduces cortisol production, suggesting less stress to the cows.

An alternative to concentrate feeding to entice cows into the robot is to position the milking unit between the cubicles and the cows' food source, and force the cows to be milked when moving between these two. Cows reduce their frequency of passage between the two systems when this is done, indicating some reluctance to visit the milking robot. The loss of freedom associated with this enforced milking almost certainly reduces their welfare, but possibly no more than in conventional milking systems, where they are usually forcibly milked twice a day.

Because of the high cost of robotic units compared with conventional ones, there is usually only one unit provided for every 40–60 cows. This may lead to queues of cows waiting to be milked at preferred times of the day, especially in the morning, leading to frustration and aggression between animals. One research team reported a mean queuing time per milking of seven minutes on commercial farms, or 34 minutes per day, which they point out is less than in most conventional milking systems. Some farms use electrified 'cattle drivers' in the robotic units to accelerate cow movement through the unit or associated passages. This will reduce motivation to attend and was reported by Millar to increase disease incidence in the cows.

Mastitis, or inflammation of the mammary gland, is a particularly common cause of poor welfare in modern dairy systems. For several reasons, the incidence of mastitis and the milk

parameters associated with this disease, such as the somatic cell count, are usually increased by robotic milking, particularly during the first few months of operation. Perhaps the largest contributing factor is the sharing of a single cluster by many more cows than in conventional semi-automatic milking. Another problem is that udder cleaning is often inadequate in robotic milking systems. In some systems there is no cleaning, but usually the udder is washed with wet brushes moving backwards and forwards over the udder. A herdsperson would recognise a particularly dirty udder and clean it more thoroughly, which cannot yet be done by the machine. Neither can the machine always determine which of the four glands in the udder have mastitis and divert the milk to a separate container. There is no possibility to take a sample before milking and examine it for clots, as is legally required in many countries. If a robot fails to detect that a cow being milked has mastitis, and the milk enters the bulk tank, the somatic cell count will increase. A Slovakian paper showed that failing to detect just 1 per cent of cows with mastitis could increase the bulk milk somatic cell count by more than 50, 000 cells ml^{-1}.

It is difficult for the herdsperson to assist in recognition of infected glands when he or she is not necessarily present at milking. Some incidences of mastitis can be detected automatically from measurements of milk conductivity during milking, but not all. De Mol and Ouweltjes demonstrate that adding data on milk yield (reduced during mastitis) and temperature (increased during mastitis) can increase the detection sensitivity to 100 per cent and the specificity to 98 per cent. They also show that a fuzzy logic model could increase the specificity to the necessary 100 per cent, allowing abnormal milk to be automatically separated with a high degree of confidence. Mottram *et al* recommend automated detection of the enzyme *N*-acetyl-D-glucosaminidase (NAGase), which is released into milk following mammary tissue damage. However, they acknowledge that it will require a major research effort to develop an automated detector. A Japanese team has obtained encouraging results with near-infra-red spectroscopy.

Another potential cause of mastitis that is described is the failure of some cows to be milked at the first attempt. They may wait an hour until they try again, with a period of lying on a dirty bed in between. During the first attempt, the teat canal opens as a conditioned reflex, and milk may exude from the teat. This allows bacteria to invade when the cows are lying on dirty bedding.

Some features of robotic milking could potentially *reduce* the risk of mastitis, but any reduction in somatic cell count compared with conventional milking must be treated with suspicion as it could be the result of a dilution effect of increased milk yield. However, more regular evacuation of the gland can genuinely reduce bacterial proliferation. The application of the vacuum to the teat cups can be individually programmed for each cow and, indeed, for each teat, minimising the risk of over-milking, teat congestion and teat sinus occlusion. This, according to a short paper by Davis *et al*, is most likely to occur in cows with conical teats. Other aspects of individual management offer considerable promise. Ketosis could be detected in cows by acetone sensors at the head of the stall, as described by King and Mottram. The monitoring of milk composition could allow major stresses to the cow to be detected, perhaps as changes in protein content. Restriction of the milking frequency of cows in severely negative energy balance could potentially be used in order to reduce milk yield and hence the metabolic strain on the cows, as proposed by Maltz. Furthermore, cows in negative energy balance could be detected automatically by regular weighing in a crush adjacent to the unit, or by monitoring of milk protein concentration. However, if the

maximum frequency is changed too frequently, it could cause cows to become confused and frustrated. If there is no restriction in milking frequency, the increased frequency compared with conventional twice-a-day systems may encourage excessive loss of body condition as a result of increased milk production. A Czech research team reports serious difficulties getting their cows in calf after a robotic milking system had been installed on their research farm.

Many people are concerned that cow attendance will be reduced when they are out at pasture, although two papers suggest that they can satisfactorily graze at least 350–400 m from the robot without the number of visits per day declining. However, concentrates had to be offered to entice the cows to be milked, and this would adversely affect the efficiency of pasture utilisation. Also, the milking robot is not evenly used over the day, as the cows return to be milked in groups, so waiting times can be long and the robot unused for quite long periods of the day. The book cover provocatively shows contented, grazing cows, but there is no information on whether they were milked by a robot! Any reduction in the availability of grazing to cows as a result of farmers adopting robotic milking is likely to reduce the cows' freedom of movement and probably their welfare. Cows using cubicles change their lying position less and lie in an unnatural sternally recumbent position, compared with cows at pasture. Parsons and Mottram suggest keeping cows indoors overnight and at pasture during the day, but previous research has shown that this can cause lameness. Grazing cows show reduced incidence of many diseases compared with housed cows. Hence, Mathijs correctly identifies the potential movement from grazing to housing systems, and the associated adverse effects on animal welfare, as the major reason for an adverse attitude of the public towards robotic milking.

Whilst the editors and publishers are to be congratulated on the speed with which they have got this collection of papers into print, it is clear that individual contributions have not been properly edited. Most of the contributions are from scientists whose native language is not English, and some are difficult to understand. The lack of care in preparation is not just a result of the authors' unfamiliarity with the English language. References in some papers are poorly prepared, out of order and missing. Regrettably, the technical quality of the papers varies considerably: some are very good, but there are several of limited scientific value. It is important to get material into print quickly, but the extra care required to produce an easily read and understood volume could have transformed this useful book into an excellent one.

On balance, it seems that the robotic milking systems in use today are likely to reduce the welfare of cows, compared with conventional parlour milking systems. This is not apparent when reading the book, perhaps because most of the articles are written by researchers who believe that robotic milking is the only way forward for the dairy industry. Particular concerns exist over the ability of the robot to recognise quarters that are dirty or infected with mastitis. Enforced attendance is also a cause for concern in some systems. However, there is potential to improve several aspects of cow welfare by providing for the requirements of individual teats during milking, by reducing any exposure to stressors, particularly when collecting cows for milking, and by relieving the herdsperson of the most time-consuming job on the dairy farm, which will allow him or her to spend extra time managing the herd and looking for problems with individual cows.

Clive Phillips
Department of Clinical Veterinary Medicine
University of Cambridge, UK