UNIVERSITY OF GLASGOW

# A COMPARISON OF THE PRODUCTION, HEALTH AND BEHAVIOUR OF DAIRY CATTLE UNDER INDOOR AND OUTDOOR MANAGEMENT SYSTEMS

by

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A thesis submitted towards the fulfilment of the requirement for MASTER OF SCIENCE and comprising a report of studies undertaken at SAC Crichton Royal Farm, Dumfries in the Faculty of Science, of the University of Glasgow

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*To*

*My parents, Marina and Jose Luis;*
*My grandparents, Graciela, Antonio, Francisco, Leonor;*
*and my sisters, Graciela, Fabiola, Marina.*

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**SUMMARY**

This study was carried out at the Scottish Agriculture College (SAC) Crichton Royal Farm, Dumfries, over the summer period from May to October 1999, and incorporated two experiments.

The general objective of Experiment 1 was to compare two groups of dairy cows, under two different management systems (indoors or outdoors). The specific objectives within the experiment were to evaluate animal performance, animal health and animal behaviour. Experiment 2 aimed to observe further on the cow's behaviour and adaptation of the outdoors group (O/I) when it was introduced into the cubicle house after the grazing period during the summer. The same twenty eight Holstein-Friesian spring calving dairy cows were used in both experiments. Cows were allocated and paired between treatments on the basis of milk yield, lactation number and calving date. In experiment 1, milk production and composition were recorded monthly; cows were also locomotion scored every two weeks; mastitis (clinical and subclinical) and fertility records were taken monthly and compared. Behavioural observations were made on ten cows from each group. Cows were observed once each month for ten hours during daylight and scanned every five minutes on their feeding, ruminating and lying behaviour and the time they spent doing nothing. Financial performance of each treatment was also evaluated.

The objective of Experiment 2 was to compare the same groups, and particularly to note the adaptation, from outdoors to indoors, of the cows which had been grazed over the previous five months. In Experiment 2 the same length of time and number of animals were used for behaviour observations. And the animal's production and health were again compared.

In experiment 1, milk production was not different between treatments. The indoor treatment however produced milk with a higher fat content (4.37 %) than the outdoors (3.64 %), but it also produced significantly less ($p<0.001$) protein compared to the outdoors group, 3.06 % and 3.38 % respectively. The indoor treatment showed higher liveweights ($p<0.01$) but cows were poorer in condition score ($p<0.001$) compared to the outdoor treatment. In experiment 1, the outdoors was the most economical treatment with a margin over all feed of 4.4 ppl per cow greater than indoors treatment and was demonstrated to be more efficient in forage energy conversion, forage providing maintenance energy plus 19 litres, compared with maintenance plus 10 litres for the indoor group.

The number of cows scoring a locomotion score 3 (clinically lame) or more, was higher for the indoor treatment ($p<0.01$). Somatic cell count (SCC) was significantly higher ($p<0.05$) for the outdoors treatment over the five months. The fertility records showed that 19 cows (70 %) became pregnant in the indoors treatment compared to 20 cows (77 %) pregnant in the outdoors treatment, this difference was not significant.

The behavioural observations showed that the cows kept outdoors spent significantly ($p<0.001$) longer feeding but also significantly ($p<0.001$) less time ruminating while standing compared to the indoor treatment. However the indoor treatment spent significantly longer ruminating over the five months experiment. In experiment 2, behaviour observations made in the cubicle house showed that the group which had been outdoors and then housed indoors (O/I), decreased their feeding time, increased the time spent ruminating while standing and the total ruminating time became similar to the I/I treatment, which had been indoors the whole experimental period.

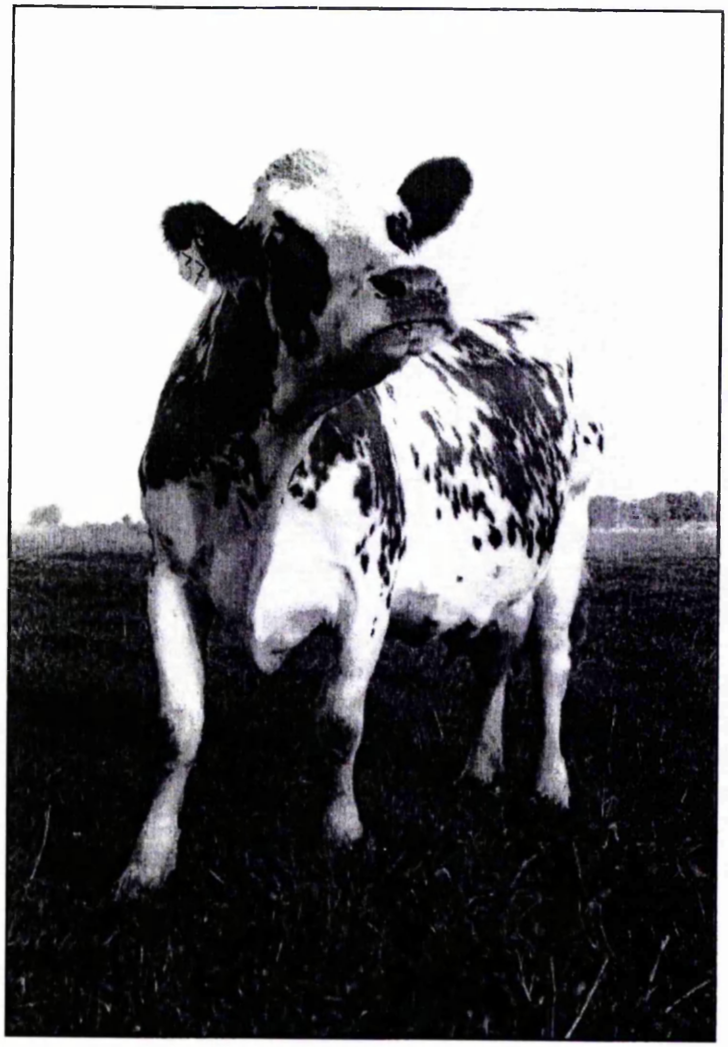
In experiment 1, the outdoor treatment spent longer ruminating whilst lying down, which is considered as a normal behaviour. In Experiment 2, the behaviour of the O/I treatment group, which had previously spent less time ruminating whilst standing, changed after housing to a similar behaviour pattern to the group which had been indoors through the summer.

## INTRODUCTION

Welfare , health and performance of the dairy cow will depend on management and knowledge is required to improve the environment where modern housing systems are used.. Although many diseases are controlled , mastitis and lameness are still disorders influenced by the environment. Thirty to forty years ago when modern intensive animal production started , the herd size kept on farms increased and the productivity achieved was improved by the progress in animal breeding and nutrition. In the UK the number of dairy farms dropped between 1969 and 1986, while the herd size increased from 16 to 60 animals. Another major change was the introduction of cubicle housing systems in the 1960's (Harper, 1983). Then different diseases started to be influenced by the high density of animals. The intensification of dairy cows depends now on mechanical equipment, feeding and manure removal. This became the major adaptation challenge to the dairy cow from their normal condition into a totally different environment . Although they are protected from cold , rain and predators , and food and water are supplied, the outbreak of a new disease under these conditions may occur (Hartung, 1994) . Therefore, optimal housing management will ensure a long productive life for the dairy cows (Blom 1982 ). This may be a reverse adaptation process from cows when they are at pasture (Metz and Wierenga, 1986 ).

O'Connell *et al* (1989) when comparing cows at pasture and housing found cows to be more restless indoors . Lying and ruminating behaviour were affected and feeding time was greater when cows were at pasture. Also Blowey and Edmondson (1995) highlighted the risk of mastitis infection when the bedding and faeces are mixed with the milk dropped from the cows teats at the rear of the cubicle.

The objective of this experiment is the comparison and evaluation of two groups of spring calving dairy cows under different farm management systems (housed and grazing). Cows production, health and behaviour were the specific objectives to assess .



# CHAPTER 1 REVIEW OF LITERATURE

## 1.1 *HOUSING SYSTEMS AND ENVIRONMENT*

Summer grazing and winter housing is the most common management system for dairy producers in the UK. When the grazing season has ended, cows are housed within a confined space with shared areas for walking, feeding and lying behaviour. In a housing system good welfare standards and management are required. Therefore accommodation must provide the dairy herd with an individual access to feed and water troughs, a comfortable bedded, well drained lying area, shelter from adverse weather and the required space for sexual and social interaction behaviour (Farm Animal Welfare Council, 1997). Movement is restricted and the normal instinctive behaviour can be affected when cows change environments from pasture to housing. Metz and Wierenga (1986) considered that housing systems with high density of animals must have artificial floors. However, a concrete floor (solid or slatted) is an extremely hard surface which causes animals difficulties in moving, which is unknown in natural conditions outdoors. Lameness is considered as the behavioural expression of claw and leg disorders . Feet and leg disorders presents a disadvantage when cows are under unsatisfactory housing conditions such as slippery floors, small cubicles and overcrowded feeding and lying areas (Metz and Wierenga, 1986). Blom (1982) also reported that the incidence of foot rot and sole ulcers disorders can be higher on different housing systems (slatted floor, concrete floor, stanchion barns). However foot rot problems are likely to be found more frequently in loose housing (cubicles) owing to the constant exposure of the claws to dung on the floors. Behaviour patterns have also been shown to be different when cows are at pasture or housed . Research work completed by Miller and Gush (1991) showed the observed social behaviour of forty dairy cows and found that patterns of feeding and lying behaviour are different under different environments. They conclude that outdoors social patterns have a much greater degree of synchrony . Metz and Wierenga (1986) suggested that the synchrony behaviour at pasture may be due to the necessity of the herd to perform their activities as a social unit Then, housing might have some negative effect on these normal features. It is suggested that under housing conditions social leadership and movement of the herd are no longer synchronizing factors. Physical changes on the environment such as light regime and climate factors, might also cause some effect on the synchronising behaviour. (O`Connell, Meaney and Giller 1993). Successful improvements in housing management are achieved when some of these differences between pasture and housing are reduced. Metz and Wierenga, (1986) considered that drastically changed environments introduce behavioural problems of adaptation, therefore cows behaviour must be taken as the most important criteria of first level of expression of the influence of housing on production, health and the cow`s well being. O'Connell *et al,* (1993) also considered the importance of the clear understanding of the dairy cow behaviour under various environmental conditions for a more complete analysis of the results on physiology, nutrition, breeding and management. Thus, these valuable results will help to achieve the improvement of winter housing.

### 1.1.1 Loose housing systems

The two acceptable loose housing systems used for dairy cows are cubicles and straw yards (ADAS, 1988 a, Farm Animal Welfare Council, 1997).

***Cubicles***

| *Advantages* | *Disadvantages* |
|---|---|
| • Low quantity of bedding required | • Walking areas contaminated with slurry |
| • Opportunity to use alternative bedding materials and mats | • High risk of lameness disorders |
| • Low risk of mastitis infection | • The building cannot be used for other activity during the grazing season |
| • One slurry system which can be automated | |
| • | |

***Straw yards***

| *Advantages* | *Disadvantages* |
|---|---|
| • Low incidence of lameness | • Large quantity of bedding required |
| • Less risk of damage to knees, hips and hocks | • Two handling systems, solid manure and slurry |
| • Flexibility of use of the building | • Higher risk of environmental mastitis |
| | • Feeding and passageways contaminated with slurry |

Some of these lameness disadvantages in the cubicles compared to straw yards agree with the work reported by Singh, Ward, Lautenbach, Hughes and Murray, (1993). They suggest that some foot and leg problems in first lactation cows were caused when they were not able to lie comfortably in the cubicles. They also found that first lactation cows preferred to stand half in the cubicles, some of them shifting their weight frequently. This leads to the suggestion that prolonged standing on hard surface may bring about alterations in weight distribution which may be an important factor in the development of sole lesions. The unfamiliarity of the cubicle to the first lactation cow could have been one reason she refused to use of the cubicles. Several researchers have demonstrated that cows will lie down longer when softer bedding is provided. Singh, Ward, Lautenbach and Murray (1993) also proved the preference of the straw yards by cows without lameness disorders, compared to cubicles. They observed that a group of cows lay down for significantly longer in the straw yard than another group of cows in cubicles. The group in the straw yard had previously refused to use the cubicles. This may show that straw yards are considered more comfortable than cubicles owing to the deeper straw, more space and thus less disturbance than the cubicles. Straw yards may be more comfortable for cows to lie down in, and thus the bedding will also provide a soft surface for cows to stand and reduce foot and leg problems. However if the straw is not replenished frequently enough and cows have to stand on wet straw, there is the possibility of an increase of lameness (Farm Animal Welfare Council,1997).

### 1.1.2 Cubicle housing system

The characteristics of cubicles can directly affect social and other behaviour in dairy cows, therefore the house design should include the right number and type of feeding stations; the width of the feeding passage; the width of the other passageways; the number, size and design of cubicles; the ease of access to water; the uses of the building by other stock and by man ; the dung disposal system ; and flooring characteristics (Potter and Broom, 1987 ) . The space requirements of the feeding area, the walking area and the lying area must be considered separately, because the individual functions of these elements of the cubicle system are different. The feeding area is used only for the intake of offered food. The walking area is an important space, that connects the feeding barrier with the water troughs and the cubicles with each other. Within this area cows will perform social, sexual and comfort behaviour. Most of the resting, lying and ruminating will take place in the cubicles, which is also a place of social contact between cows where they can perform social licking while standing or lying (Wierenga, 1983). It is concluded that the importance of the cubicle for lying and standing, appears to differ for individual cows according to factors like age, stage of lactation, social position, housing system (bedding, size and partitions; layout of the house) and management (feeding system, overcrowding) (Wierenga and Hopster, 1990). Although cubicles can be important for resting sometimes low ranking cows may consider them as a protection place from dominant cows (Potter and Broom, 1987).

### 1.1.3 Cubicles design (dimensions ) and management

#### *1.1.3.1 Length*

Cows successfully use cubicles that allow the cows to perform their principal activities (standing, lying and rising). When designing cubicle length for dairy cows the right measurement should be the size (weight) of the cow in relation to the base of the cubicle. This means that an average of the body weights of the largest cows representing 20% of the herd should be taken as measurement. Table 1 shows some dimensions in relation between cow and cubicle length.

**Table 1 Relation between body weight and cubicle length (ADAS, 1988b)**

| Cow body weight (kg) | Cubicle length (m) |
|---|---|
| 375 | 2.00 |
| 425 | 2.04 |
| 475 | 2.08 |
| 525 | 2.12 |
| 575 | 2.16 |
| 625 | 2.20 |
| 675 | 2.24 |
| 725 | 2.28 |
| 775 | 2.30 |
| 825 | 2.33 |

The length given allows for the forward space demand to enable a cow to rise .

In the natural way at pasture a cow will rise by lunging forward and will prefer shifting her weight forward rather than to the side, allowing her hindquarters to be raised more easily . In some cases by lunging to the side cows may successfully exit a freestall or cubicle without injury, but seem more careful about their movements (McFarland and Gamroth, 1994). There is a tendency for cows to refuse stalls and struggle to exit from them when inadequate lunging space is provided and sized according to their resting position instead of weight. For cows to accept stalls shorter than 2.3 m, solid front barriers need to be removed to allow lunging forward. Therefore, length recommended for open front stalls for Holstein cows should be 2.3 m and 2.44 m for stalls with solid or slatted front barrier. It has been suggested by producers and designers, when freestalls are placed in rows head to head, that length might be reduced and thus lunging space affected (with an open front stall). In this case cows will lie down across from each other or only one cow will be lying when the other in the opposite stall stands, affecting their lying time and making them stand for longer. The combined stall length of 4.6 m will provide the animals plenty of head space while resting, which is important for air circulation and also reduces cow contact. O`Connell, Meaney and Giller (1993) used behavioural studies to assess the effectiveness in five different cubicle designs: Newton Rigg, Dutch Comfort, Super Dutch Comfort, Dutch Cantilever, and Dorsdunn. All cubicles measured 2130 mm x 1160 mm with a floor slope of 100 mm and Kerb height of 225 mm over the dunging passage. They found the comfort and acceptability of the Dutch Cantilever and of both Dutch Comfort type cubicles associated with the availability of sufficient head space to enable cows to rise readily. It may be concluded that cows in an small cubicle (length) are restless while lying and find it difficult to rise. Thus their behaviour will be affected every time they refuse to make complete use of the cubicle.

#### *1.1.3.2 Width*

Stalls (cubicles) which are too short or too narrow are not accepted by cows and they will prefer the scraped alley to lie down in. Inadequate dimensions will also lead cows to lie in dirty conditions since their position is not controlled . For Holstein cows a stall width of 1.22 m allows the cow to express comfort behaviour with minimum risk of injury while she is entering, resting and exiting the stall. For cows weighing more than 725 kg, stalls must be 5 to 10 cm wider than this for cows lighter than 590 kg, stalls must be 5 to 10 cm narrower (McFarland and Gamroth, 1994).

#### *1.1.3.3 Partition design*

Partition height and design has also an important influence on comfort and the animals health. It must guide the cow as she enters, provide protection from other cows while she is resting and help her exit the stall without injury (McFarland and Gamroth, 1994).

#### *1.1.3.4 Partition height*

To encourage cows to use stalls properly, the partition height prevents them turning around. This should be placed on the top rail at 105 to 122 cm above the rear curb; a lower rail height of 30 to 46 cm from the cubicle base helps to avoid injuries and keep cows from getting trapped (ADAS, 1988b; McFarland and Gamroth, 1994).

#### *1.1.3.5 Partition length*

To position cows in the stall, the partition length in the loop type stall should be 23 to 30cm shorter than the stall length. McFarland and Gamroth, (1994) suggested that this prevents the chance of partition/cow impact as cows enter and exit the stall and will reduce partition/tractor impact during alley scraping. In stalls with partitions that are too short, cows will walk along the rear of the stall base rather than the scrape alley.

### *1.1.3.6 Partition shape*

The stalls' partition shape must be selected according the stall size. The most common used for dairy cows is the "suspended" loop partition. If the stall dimension allows animals easy forward lunging and the slope encourages good animal position, a U-shape loop partition can be used .

The Dutch type (MSU) might work when freestalls are shorter than 2.3 m, since it allows cows to lunge to the side rather than forward lunging as they will in stalls of normal size. The brisket board can be recommended for Dutch type stalls of the proper size. The brisket board helps to define the head and body space in the stall. The positioning is improved and the cow is prevented from injury, entrapment and will keep the stall clean. The brisket board should be placed 20 to 30 cm above the top of the stall bed and angled forward slightly (30 degrees from vertical) to follow the contour of the cows brisket and neck. A brisket board placed too forward is ineffective, and if placed too far back cows might refuse the stall owing to the lack of adequate body space. It is suggested also that brisket boards might interfere with lunging forward when the animal rises and they also can become trapped when they work themselves forward to lying down in stalls (Dutch type) shorter than 2.3 m (McFarland and Gamroth, 1994)

#### *1.1.3.7 Training Rail*

This support encourages cows to back out of the stall while rising and discourages them from walking too far forward in the stall and lets them lie in a suitable position. Training rail should be adjustable and placed (with the normal length stall) at 1.7 m from the alley side of the rear of the curb or directly above the brisket board (McFarland and Gamroth, 1994; ADAS, 1988 b)

#### *1.1.3.8 Cubicle Base*

The ideal base will provide cow comfort and minimise injury. A durable base with a minimum maintenance requirement is also important. No matter what type of base is used, bedding will always be necessary. There are several types of base to select for cubicles. The concrete base is the most economic and easiest base for maintenance, although it seems not be preferred by cows. Therefore, to improve cow comfort, a bedding layer 50 mm deep must be added. Bedding also should absorb moisture and help cow cleanliness. For convenience dairy farmers should look for bedding that is available most of the time and at a low cost. Bedding materials may be categorised as organic and inorganic and each of these further divides into traditional and non-traditional materials (McFarland and Gamroth, 1994).

#### *1.1.3.9 Bedding*

*Traditional organic bedding:*

The most popular bedding choices for dairy producers are straw, sawdust, hay and shavings, which will be determined by availability and cost.

*Non-traditional organic bedding:*

Some dairy producers have found chopped newspaper an excellent bedding material . The low cost of this material, its absorption qualities, the benefit property of reducing the house odours and the lower growth of bacteria in this paper bedding have proved to be a good choice for dairy farmers. However, it might not be as easy to handle as other bedding materials.

*Traditional inorganic bedding materials*:

Sand is the common inorganic bedding material used. This bedding material provides a poor environment for the growth of bacteria, which can be responsible for mastitis infection. Several types of bedding have been used to make concrete cubicles more comfortable. Additional kinds of bedding apart from straw and sawdust, such as different types of mats, have also been introduced. Mats can be made of rubber, polyester or polyethylene mixtures and are placed along the cubicle base. They will protect the cow's knee and hock from damage. Although some bedding is required (sawdust, straw, shavings) it will be in less quantity. The quantity when using chopped straw or shavings on mats can be reduced to 0.75 kg/ cubicle/day in early lactation and 0.5 kg/cubicle/day in mid and late lactation. The wet faecal matter and solid bedding on the mats should be removed twice a day; this can be carried out while cows are being milked, ensuring the area is kept clean (ADAS, 1988b). It is concluded that bedding material and the frequency with which bedding is added may vary with the producer. However, when inadequate bedding material type or amount (layer) is used this will be reflected in cows which are reluctant to use the cubicle and lie in the scraped alley, turning into dirty cows with an increase in mastitis and leg disorders (McFarland and Gamroth, 1994).

#### *1.1.3.10 Concrete kerb*

Inadequate cubicle design leads cows to stand for longer periods in the slurry passages or half-in the cubicle with the hind feet in the slurry channel. When the kerb is very high it might impose strain on the hind legs of animals when they are standing in this way. Kerbs with heights greater than 30 cm may cause some cows to drag their teats ends on the kerb while entering and exiting the stall causing major health problems. Also, it is recommended that the rear slope of the kerb be rounded to avoid injuries. However, the kerb should not be too low to prevent the bed being contaminated with slurry. The necessary height to prevent this problem, 20 to 30 cm to the rear slope of the kerb (Farm Animal Welfare Council, 1997, ADAS, 1988b; McFarland and Gamroth, 1994).

#### *1.1.3.11 Slope*

A gentle downward slope from the front (head end) to rear of the cubicle is necessary to provide drainage and help position the cow. When cows are lying facing uphill there is reduced rumen pressure on their diaphragm (Farm Animal Welfare Council, 1997). A slight longitudinal degree of elevation at the front of the stall (6% of slope) is preferred by cows when they are lying down and makes it easier for them to rise. However, a lateral slope seems to be also important when cows are lying down. A cow usually lies with her back up the slope, therefore 3% of lateral slope is recommended to help cows to lie in the same direction. This will also prevent cows exposing their udder and teat to the hoof and legs of a cow next to them (Irish and Merrill 1986).

#### *1.1.3.12 Feeding facilities and conditions*

Competition for food is rare in normal conditions at pasture, because food may be available at any time and the need to defend food by an individual is not important (Metz and Wierenga,1986). In housing systems, in some aspects the cows' life is governed by the management system and this will influence the behaviour change between cows, for example whether food is offered once or twice daily. In loose housing conditions with cows under free feeding competition, the feeding conditions are governed by the type and amount of feed, type of feed rack and feed trough design. If feeds (concentrate or fodder) are given in restricted conditions this along with the management must allow all cows to eat at the same time (Konggaard, 1983).

It is suggested that overcrowding and the use of automatic devices would have less behaviour effects if synchronising factors could be excluded. Also, if cows were fed according to individual different time schedules , cows should not then be restricted from their movements because of the missing feeds or water facilities places (Metz and Wierenga, 1986). Potter and Broom, (1987) reported that low ranking cows spend slightly but not significantly less time feeding in the morning feed period. However, this did not show lower intake or that they were feeding later than higher ranking. It was also demonstrated that cows may have some preference for some particular feeding places. Higher ranking cows were more likely to maintain their positions for a particular section at the feeding barrier, especially at the far ends of the house. It is possible that a mutual repulsion effect exists between dominant cows, the accommodation of long feeding barriers can help with this behavioural trait. If the appropriate quantities of suitable feed are available and distributed in a manner which allows access to all animals, cattle should no longer suffer from inadequate nutrition (Farm Animal Welfare Council,1997).

### *1.1.3.13 Space*

Dairy cows are likely to live in high densities when they are housed, which means that they are forced to live close together. This affects animal behaviour and as a result aggression increases, suggesting that the reduced space between animals plays an important role in the increase in aggression. Some of this increase in aggression may be competition for a desirable position at feeding or a lying place. Also, the increase in aggression will be caused when animals try to defend their own personal space which seems to be more important than another space or position in some specific areas. It is known that cow space can be manipulated by dehorning which decreases the distance between individuals; and placing partitions between animals. Wierenga (1983) observed that when the amount of space (and cubicles) was reduced the time spent in the walking area increased significantly, and there was also a higher amount of aggression. Probably this was caused not only by the reduction of the area itself, but also by the reduction of the lying places. Wierenga (1983) also found that cows used cubicles for 15 h 20 min per 24 hours when there is a lying place for each cow, but when there were only 16 places for 20 cows (25% overcrowding) the time spent in the cubicles decreased by 44 minutes and by 103 minutes when there were only 11 places for 17 cows (55% overcrowding). This reduction in the cubicle using time was higher for cows of low ranking social position. It is concluded that the reduction of number of cubicles increases competition affecting the aggressive behaviour and decreasing the time spent in the cubicles. Although when extra space is given, cows will not use it very much, if the amount of space is reduced movement is restricted and aggressive interaction increases.

#### *1.1.3.14 Scraping System*

The passageways are usually wet and slippery owing to the accumulation of slurry, which can predispose cows to foot problems when they spend long periods standing in this area. Therefore it is important to minimise the accumulated slurry by scraping it out of the passageways at least twice each day or by the use of slatted passageways and by daily removal of the manure from the areas base (Farm Animal Welfare Council, 1997). In Potter and Broom (1987) it is pointed out that in areas with excessive amount of slurry, animals will decrease the amount of locomotion. Also these areas will be more slippery and less used by the animals. It is considered that when a scraped system is needed on the passageway areas, it might disturb the cows by moving them closer together. In particular cases when these areas are being scraped by tractor, it should be done while cows are away (milking time) to avoid disturbance or injuries (ADAS, 1988b).

#### *1.1.3.15 Layout*

Passageways and cubicles should be designed in straight runs for the easy movement of cows. Clearways of two to three cubicles width should be provided for every 20 cubicles. The clearways should be raised to the height of the kerb to facilitate cleaning. The cubicle passages must be 2.4 m wide and feed passages at least 3.2 m wide. Water troughs are usually located in the clearways to provide an extra space for cows to by-pass others that are drinking. To prevent water splashes into the adjacent cubicle bed, splash guards should be placed in each trough. A standard water trough of 1.8 m should provide the water for 30 cows . The feeding system will determine the mangers, location and length. Well-designed mangers to avoid injury and reduced feed wastage and labour in handling feed (ADAS, 1988b). In the housing system each component (cubicle, passageways, feed mangers and water troughs) on its own must reach the proper standard which the animal requires to ensure their approval and to make the best use of them. Singh, Ward, Lautenbach, Hughes and Murray, (1993) also suggest that the temperature of the cubicle and the weather had some effect on the use of cubicles . They found that adult cows preferred cubicles away from the door where there was less wind.

Wierenga and Hopster, (1990) considered the importance of the cubicle as a hiding place depending on the layout of the cubicle house. This use of the cubicle as safety place will be less important when cows have other alternatives to avoid confrontation in the cubicle house. In this report, when they compared the old cubicle house and the new cubicle, they found in the old cubicle house (50% overcrowded) that the low ranking cows spent longer time standing at the feeding barrier. It was suggested that the long partitions between animals at the feeding place, could be used as a hiding place to avoid confrontation . This indicated the importance of the house design for cows when they try to avoid confrontations, but it is not possible to judge how important it is for cows to have these as a place to hide.

### 1.1.4 Housing over day and night

An experiment was carried out by Wierenga and Hopster (1990), with a cubicle housing system under normal conditions (same number of feeding and lying places as number of cows), and +25, +33.3 and +55% overcrowded conditions (11 feeding and lying places for 17 cows). Experimental work compared the daily rhythms of behaviour. In the "normal" group more cows were seen at the feeding rack when new feed was offered, at 07:00 and 11:00h. No cows were seen eating between 02:00 and 06:00h. Between 11:00h and the afternoon milking 50% of the cows were in the cubicles at any one time; following the afternoon milking the number of cows in the cubicles increased to 80%.

In the most overcrowded group (+55%) all the cubicles were occupied, except at the feeding times and immediately following the afternoon milking. Over the whole day the number of cows observed in the walking area was higher in the +55% group than in the "normal" group, especially between 02:00 and 06:00h.

In three levels of overcrowded conditions the time spent standing in the cubicles was reduced, but only in extreme conditions of overcrowding (55%) was the lying time affected, mostly at night. The reduction of the time spent standing in the cubicles occurred at three times: before the cow lay down, if the lying period was interrupted or at the end of the lying period. The reduction of time standing in the cubicles in overcrowded conditions can probably be explained as a reaction to the competition for cubicles. If there was more competition cows lay down more quickly once they succeeded in obtaining a cubicle. In this situation it was observed that cows that were standing in the cubicle were more often displaced than cows that were lying in a cubicle, suggesting that in overcrowded conditions, when a cow stands up after a lying period she is likely to be displaced quickly. Thus these reactions resulted in a reduction in the time standing in the cubicles compared with normal conditions. Weirenga and Hopster (1990) reported that with low levels of overcrowding, a compensation for the reduction in lying time in the night occurred at another time. With 25% overcrowding, there was a reduction in the time spent standing in the cubicles. With 33.3% overcrowding the cows increased their lying time during the evening.

In the "normal" group cows stood for a period of time before and at the end of the lying bout. Also, a standing period took place during the lying bout as the cows interrupted their lying period when they wished to change their lying side. With severe conditions of overcrowding cows will try to remain lying down and not undertake exercise or short periods of standing time. Therefore, it appears that for cows, lying is important, but will be more important than standing in the cubicle when conditions are severely overcrowded (Wierenga and Hospter, 1990).

### 1.1.5 Summer versus winter

Research work by O'Connell, Giller and Meaney (1989) showed that the temporal feeding pattern (late season) at pasture is affected by the periods of milking. It was observed that a group of spring-calving Friesian cows in mid-gestation had two major peaks of synchrony grazing behaviour following after milking (0900 h and 1600 h) and a smaller grazing period around midnight.

The most intensive grazing bout during the early season (April to July) and the late season (August to October) has also been reported to take place after the afternoon milking. The grazing bout before morning milking in early season is replaced with one around midnight in late season (Phillips and Leaver, 1985).

Singh, Ward, Lautenbach, Hughes and Murray (1993) evaluated the behaviour of first lactation and adult dairy cows while housed and at pasture. They found that both groups spent a longer time ruminating lying at pasture compared to when they were housed. For O'Connell *et al,* (1989) results at pasture, demonstrated a high correlation between

ruminating and lying, which may possibly be considered as more normal behaviour. However, rumination also occurs when cows are standing or walking slowly, especially when they are housed. Also, during housing the ruminating pattern of behaviour is not as clearly defined as that at pasture. This reflects the discomfort and the disturbed lying down and feeding pattern. Rumination has been observed not to be different between cows at pasture and housed, although during the daylight hours rumination is higher indoors and while at pasture most rumination takes place at night. Phillips and Leaver (1985) also showed that during the grazing season, cows concentrate their rumination time into the hours of darkness but rumination was also observed between the grazing bouts during daylight. However, as the season advanced, and grazing time increased, the rumination time was less during the daylight hours and more at nights. The social interactions (agonistic and grooming) are considered to be similarly distributed in winter housing and at pasture; both coincided with the start of feeding periods. The level of agnostic interactions is significantly greater during confinement where the two major incidents coincide with the offering of fresh silage and at pasture with the return from milking (O'Connell *et al,* 1989). The social hierarchy has been observed to have some change with some cows establishing their rank when they are moved from pasture into the confined house. The increase of agnostic behaviour when cows are confined may be associated with the general reduction of living space. By these differences O'Connell *et al* (1989) considered that when confined a cow's position in the hierarchy is probably more important than at pasture.

## 1.2 *COW HEALTH*

As dairy cows become higher-yielding milk production costs increase, the management systems for dairy cows becomes more difficult and this often develops an adverse environment and increases in diseases and involuntary culling. The major, and economically most important, diseases in dairy herds such as mastitis, feet disorders, reproductive disorders and traumatic injuries (to body and legs) are all environmentally dependent diseases (Blom, 1982)

### 1.2.1 Lameness

Lameness is described as the disability of movements of the limbs owing to pain, muscle weakness, joint damage or when cows suffer a combination of these disorders. 90% of cases of lameness are due to inflammation or injury to the hoof or skin between the hooves. Other traumatic injuries of the limbs include swollen knees and hocks caused by lying conditions. Of greatest welfare concern, foot lameness in the modern dairy cow has annual incidence of 5-6% (cases treated by veterinary surgeons) and 25% incidence when cases treated by farmers are included. It has been estimated that in the dairy industry the morbidity rate due to lameness is close to 100%. In the UK the most common clinical signs of lameness are aseptic laminitis, white line disease and solar ulcers. Laminitis can be described as any form of inflammation of the highly vascular laminated corium that links the hoof to the rest of the foot. As a separation of the junction between the sole and the wall of the hoof, white line disease will expose living tissues to infection up to the laminae of the wall or across the sole, causing inflammation and pus. Sole ulcers will appear at the junction between the sole and heel. This area will be thin, soft and painful but once open can be a constant source of infection (Webster, 1987) When clinical signs of lameness appear suddenly cases are easy to diagnose. More commonly, symptoms are less obvious (signs are more silent) and difficult to diagnose and many of these cases will remain untreated (Bergsten, 1995). Lameness is described as a clinical sign of many conditions and constitutes a group of diseases affecting the animal's well-being , which is usually associated with pain and discomfort of long duration (Alban, Agger and Lawson, 1996). Lameness is one of the major diseases after infertility and mastitis, which affects a large proportion of the British dairy industry, with financial losses of millions of pounds sterling each year (Scott, 1988). The extra financial burden is due to increased labour requirement, increased treatment costs, reduced milk production, reduced fertility, involuntary culling and decreased slaughter value (Alban, Agger and Lawson, 1996). Lameness also means an aberration in gait which is often due to the pain caused by an inflammation of the sensitive corium of the claw (Bergsten, 1995). The slow onset of some kinds of lameness such as sole ulcer, means that farmers may not consider lameness to be as important as other diseases like mastitis or reproductive problems (Alban, Agger and Lawson, 1996). In fact, lameness requires rapid treatment to prevent it from becoming worse (Bergsten, 1995) and the knowledge of the risk factors which might be used to reduce its incidence (Alban, Agger and Lawson, 1996).

#### *1.2.1.1. Predisposing factors*

As a result of an adverse interaction between the cow and her environment, the predisposing factors of lameness may occur long before the cow becomes lame (Farm Animal Welfare Council, 1997). Some predisposing factors are nutrition, environment (buildings, beddings, walkways, season), management (knowledge of cows, care of feet,

inadequate exercise), genetics (breed and sire), age and stage of lactation (Colam-Ainsworth, Lunn, Thomas and Eddy, 1989 ; Collick, Ward and Dobson, 1989).

#### *1.2.1.2 Lameness and Animal Behaviour*

It has been well documented that lameness affects behaviour (Bergsten, 1995, Singh, Ward, Lautenbach and Murray, 1993). Even grass, the most most natural surface for cows to walk and lie down on, is not always uniform and soft and may cause traumatic claw problems (Herlin, 1994). Research by Hassall, Ward and Murray (1993) demonstrated that lame cows lie down for significantly longer and grazed for significantly shorter periods than normal cows during the summer and that cows with severe lameness can be seen to graze from a lying position for most of the day. This suggest that by lying for longer periods, lame cows would alleviate pain. The slower bite rates and the shorter grazing periods from lame cows indicates that they are less likely to be efficient producers in terms of fertility, milk or meat. Research work by Singh, Ward, Lautenbach, Hughes and Murray (1993) showed that lame cows during winter housing (cubicles) lie down for significantly longer during the day than the normal cows, and longer at night than during the day, which suggested to be a more normal behaviour. This work showed that longer standing periods in cubicles predisposes heifers to develop lameness within a short period of time. They also found that in one herd with lameness signs, heifers and cows refused to lie down in the cubicles and showed aberrant behaviour (lying outside or half-in the cubicle). This proved that the use of cubicles is related to their comfort, and that there is a correlation between the use of cubicles and the incidences of lameness in dairy heifers. With the increase of 1 bale per 10 cows per day to make cubicles more attractive no new cases of laminitis and sole ulceration occurred. In another study, training heifers to use the cubicles

and providing large, well bedded cubicles improved conditions and thus the incidence of lameness was reduced (Singh, Ward, Lautenbach, Hughes and Murray 1993). The changes in hoof load distribution during pregnancy may have some detrimental effect on the cow's digits by increasing their load pressure (Scott, 1988). It has been shown that the pressures on the four digits increases as pregnancy progresses and is reduced after calving. Therefore the predisposing factor to lameness problems, especially on the hind feet (most commonly affected) can be related to the metabolic stress of pregnancy and long standing time in faecal material. Lameness occurrence also has been reported during the first 100 days in early lactation (Collick,Ward and Dobson,1989) when cows are at peak yield and defecate more often; as a result, highly productive cows may produce 50 to 100 kg of soft manure a day owing to the high rate of gastrointestinal passage of feed (Bergsten and Pettersson, 1992; Bergsten, 1995). There is therefore more likelihood of cows standing in faeces. Sometimes a gradual recovery may be observed as lactation progresses, when hoof trimming is done prior to calving (Manson and Leaver, 1988b). It is also associated with the reduction of fertility by an increase in the interval from calving to conception up to forty days due to sole ulcerations in dairy cows (Collick, Ward and Dobson, 1989). This is considered to be one reason for the reduction of movement, which limits the cow in showing oestrous behaviour (Chaplin,1994) .

#### *1.2.1.3 Foot Care*

Hoof trimming is an important preventive method against lameness (FarmAnimal Welfare Council, 1997). The best time for trimming has been reported to be prior to calving so that hoof shape is at its optimum in early lactation. This has a positive effect on the prevalence of lameness (Manson and Leaver, 1988b). Also cows walking weekly through a footbath

containing 5% formalin have been reported to have reduced the incidence of interdigitial dermatitis (Greenough, 1996) as it helps to clean feet, kill bacteria and to harden the hoof horns (Farm Animal Welfare council, 1997). These preventative measures have successfully helped to reduce lameness. However, it is concluded that lameness problems are likely to increase in the future if the trend towards more intensive management continues (Greenough, 1996).

### 1.2.2. Mastitis in dairy cattle

#### *1.2.2.1 Mastitis*

Mastitis was one of the first observed diseases of farm animals since cattle were domesticated 5000 years ago and has been one of the majors diseases problems on dairy farms ever since (Dodd & Booth, 2000). The word mastitis can be defined as "inflammation of the udder". This can be associated with the inflammatory quarter together with a change in the milk appearance. Mastitis also occurs in a subclinical form, which means there are no visual external changes, but the infection is still present (Blowey & Edmondson, 1995). Every clinical case is likely to represent many more subclinical cases. However, many dairy herds are not in this position (Faull, Hughes & Ward 1997) thanks to the five point plan on mastitis control formed by National Institute for Research into Dairying in the 1960s (Table 1). This plan has greatly improved mastitis control in the UK. Mastitis has decreased over the last twenty five years during which time clinical incidence has reduced from 121 cases per 100 cows per year in 1968, to about 50 per 100 cows in 1995. The two basic types of mastitis are contagious and environmental. The greatest progress has been made in reduced incidence of the contagious mastitis (Blowey & Edmondson 1995). Contagious mastitis, describes a group of infections caused by bacteria which can survive and multiply on the skin of the teat and in the udder. These infections are transmitted from cow to cow during milking. The most common bacteria from contagious mastitis are *Staphylococcus aureus* and *Sreptococcus agalactiae.* Environmental mastitis, normally caused by *Escherchia coli* which is not likely to be found on the skin or in the udder but enters the teat canal from a contaminated environment such as the cubicle bed on which the cow is lying (Webster 1987). Somatic cell counts (SCC) are related to the level of contagious mastitis infection. The incidence of environmental mastitis has not changed since 1960, largely due to an increased herd size and higher milk yields (Blowey & Edmondson 1995).

**Table 2 Five point plan on mastitis control.**

| | |
|---|---|
| **1** | Treating and recording all clinical cases |
| **2** | Dipping teats in disinfectant after every milking |
| **3** | Dry cow therapy at the end of lactation |
| **4** | Culling chronic mastitis cases |
| **5** | Regular milking machine maintenance |

#### *1.2.2.2. Somatic Cell Count*

SCC is the number of cells present in milk (body cells distinguished from invading bacterial cells) which are made up of a combination of white blood cells and ephitelial cell. SCC can be used as an indicator of udder infection. White blood cells represent about 98-99 % of the somatic cells present in milk , which are a response to inflammation due to disease or injury. Ephitelial cells are shed from the lining of the udder tissue. The contagious mastitis organisms are responsible for the high number of somatic cells as they make up the majority of subclinical infections. When the mastitis organism enters the udder large number of white cells are sent by the body's defence mechanisms into the milk to try to kill the bacteria. If the infection is eliminated, cell counts will fall back to their normal level, but if the infection is not eliminated by the white cells, then a subclinical infection is established and white cells will be continually secreted into milk leading to a rise in cell count. SCC are measured in thousands of cells per ml of milk; a reported count of 250 refers to 250,000 cells per ml of milk (Blowey & Edmondson 1995). Losses in milk yield are stated to increase for every increase in somatic cell of 100,000 above the basis of 200,000 (Östensson *et al*, 1988). Cell counts in milk from an individual cow of < 200 000 /ml is considered physiologically normal, while cell counts > 300 000/ml is indicative of inflammation. A SCC of 250 000/ ml is suggested as normal for an individual cow. SCC of herd bulk milk is used as an indicator of milk quality, mastitis control and hygienic production of the milk. In the European Union countries somatic cell counts of 400 000/ ml is the legal standard for an acceptable milk and 750 000/ml for the United States. There is no evidence of a risk to human health associated with somatic cell counts present in milk (Smith 1996).

Several factors may influence SCC; one is age, older cows tend to have higher cell counts, probably because previous lactations have damaged the teat canal, allowing easier access for bacteria to the mammary gland. The immune response from older cows is poorer than to the young cows resulting in less bacteria elimination. Stage of lactation is another factor, where cell counts are often high in the first 7-10 days of lactation. However, this may vary with the individual cow. Diurnal effects mean that cell counts tend to be higher in the afternoon milking than in the morning milking. This is a concentration effect due to the lower milk yield in the afternoon. Stress, caused by oestrus (bulling), sickness or events like tuberculin testing may affect the cell count. Milking frequency, when reducing the frequency of milking to once daily or every other day before drying off towards to the end of lactation, is likely to increase cell counts, even in the absence of subclinical infection. A herd under a 200 000 SCC /ml will have little contagious mastitis present compared to a herd of 500 000 SCC/ml. Herd cell counts however do not necessarily correspond to the number of clinical cases, which are mainly linked to a high level of environmental mastitis (Blowey & Edmondson 1995). Pathogens responsible for mastitis are classified as a *major* and *minor* pathogens. The major pathogens are *Staphylococcus aureus*, *Streptococcus agalactiae*, *Streptococcus dysgalactiae*, *Streptococcus uberis*, *Echerichia coli* and *Actinomyces pyogenes*. The minor pathogens are *Corynebacterium bovis* and coagulase negative staphylococci.

#### *1.2.2.3 The environment and mastitis*

Cows are kept grazing on pastures during the dry summer and wet spring or autumn. They may be housed in open yards in hot climates like Arizona, California and, Israel, or in cubicles or strawyards in Europe. Housing is likely to increase cow-to-cow contact and there is therefore a great opportunity for faecal contamination of the teats. Humid and damp conditions (at pasture) helps the movement of faeces onto udders and this allows greater multiplication of environmental organisms (Blowey & Edmondson 1995).

#### *1.2.2.4 Housing*

During the housing period the major mastitis pathogens can be found in clean baled straw, sawdust and shavings. When these materials are used for bedding cattle contaminate them with dung, urine and milk. This occurs when the bedding temperatures is raised either through composting or by the cows`s body heat. With straw the pathogen is usually *Str. uberis* and coliforms with wood products. These even occur in bedding that appears to be clean (free from dung) providing it is moist, warm and a source of nitrogen. Such a condition will suddenly result in a coliform and *Str. uberis* mastitis. All organic bedding will have the same problems. The use of washed sand greatly reduces clinical mastitis, because composting does not occur. However, sand is heavy and abrasive and increases the problems of slurry storage and spreading (Dodd & Booth 2000)

#### *1.2.2.5 Culling*

It is likely to be more economic to cull on the basis of milk yield than to increase the culling for mastitis. Research work completed by Lucey and Rowlands (1984) also showed, that a reduction in milk yield is likely to be greater when mastitis occurs before peak yield, with the proportional reduction higher in higher-yielding than lower-yielding cows. Clinical mastitis between peak yield and ten weeks after peak yield also significantly affected yield and lactation length, however occurrences of clinical mastitis later in lactation were shown not to have an effect on a 305 day yield. They also concluded that once a cow has had mastitis it may not achieve its full milk-yield potential in the next lactation, probably because the damage of the udder of cows may continue to be subclinically infected through the dry period into the next lactation.

## 1.3 BEHAVIOUR OF DAIRY CATTLE

### 1.3.1. Cattle behaviour

What cattle do and why, may be comprehended by their patterns in terms of production, health and welfare which are altered when the environment is modified. These reactions are believed to be *innate* and *acquired* behaviour; as when the calf at birth struggles to its feet and seeks for its mothers teat to feed (innate behaviour) (Webster, 1987) or the *innate* wisdom of diet selection by cows and acquiring the knowledge, by learning, to avoid toxic plants and some of the grazing process (Phillips, 1993). These actions (unlearnt and learnt) are external (caused by heat, cold, predators), internal (hunger, thirst) or internal heightened by external such as sexual behaviour. They can be directed towards:

- Maintenance, involving eating, drinking, urinating, defecation, grooming, resting, rumination and sleeping.
- Social security – the herding instinct of cattle is most likely to be an evolved innate action for protection against predators, as in their own wild habitat. Nevertheless, cattle will try to preserve their own social space within the herd. This can be explained when two cows unknown one to another, are in very close to each other. This event is likely to provoke aggression. Within a herd where the social hierarchy is not well established, it is usually the heavier cow that wins, and then every cow will remember its place. In stable herds of 50 cows, aggression can be sometimes minimised (except when new heifers arrive) as cows can recognise between 50 and 70 other cows as individuals and their own place in the social hierarchy (Webster, 1987).

#### *1.3.1.1 Strategy of grazing*

Cattle evolved as prey animals with a foraging strategy. Their foraging strategy helped them to minimise the predation risk, by consuming grasses as rapidly as possible. Later (at night) in relative safety they could lie down and continue with the mastication process (rumination) (Phillips 1993). This was shown by experimental work completed by Rind and Phillips (1999) when they evaluated social behaviour of grazing cows in groups of four, eight and 16. They found that cows in the small group grazed more closely to each other and increased their rate of lateral head movements, suggesting that this action may have an anti-predator function as cows could monitor the horizon more frequently and benefit from grouping against an attack by a predator. They also had an increased ruminating time, although this did not have any benefit for digestion, and there was no difference in production between treatments. This increase in ruminating time may serve to increase their vigilance compared to when they are asleep. However, grazing time may change owing to the cows' nutrient requirements which can vary depending on their physiological state. This may involve pregnancy, body fatness, stage of lactation in its genetic potential for high yielding cows and the need to provide milk for the offspring (Phillips 1993). It has been shown that both lactating and dry cows may increase total grazing time and total bites per day as sward heights decrease, lactating cows will have a greater intake than dry cows (Gibb, Huckle, Muthall & Rook 1999). The need to replace nutrients used by the cows' metabolism may properly be called *hunger* (Webster 1987), which exists to maintain the intake of the major nutrients like energy and protein. This may be limited by the perceptive powers of cattle (sight, smell, taste, distance and chemical); for example cows increase consumption with palatable foods, which also stimulates their appetite (Phillips 1993). However, food intake (energy) can be limited not just by feeding behaviour but by the physical constraints of the quantity of undigested material remaining in the rumen (Phillips 1993, Webster 1987). Grazing strategy is also controlled by *grazing cost minimisation,* apart from nutrients like energy. Cows that spend 12 hours out of 24 grazing, will probably take between 24,000 to 30,000 bites within this time. The only advantage to the cow in minimising grazing time is to reduce the energy costs of grazing.

#### *1.3.1.2 Grazing process and selection*

The mechanisms involved during grazing by a cow, including the use of its lips, teeth and tongue, to secure the feed in the mouth before ripping it from the sward, are reinforced by the steady forward movement with the head swinging from side to side in front of the fore legs. The herbage gathered by the tongue is gripped between lower incisors and dental pad before being severed by a jerk of the head. The herbage is manipulated into the back of the mouth by tongue and jaw movements where it is masticated or chewed between the upper and lower morals on alternating sides of the mouth. The lower jaw is moved upwards and inwards to contact the upper jaw on one side and by the same process achieves contact on the other side. During this process, together with the salivation (which helps to lubricate food and start part of the digestion), a bolus of fibrous material is made and the cell contents released. Manipulated by the tongue, this bolus is carried into the pharynx and starts peristalsis contraction of the oesophagus behind the bolus to deliver it to the rumen. Then another portion of food is obtain and the cycle recommences (Hodgson 1986, Phillips 1993). The basic pattern of the total jaw movements before the bolus is being swallowed, may be explained and separated as follows: the rate and direction of movement in the initial assessment of the herbage, the frequency of biting, the number of bites made between swallows, the size of individual bolus and the time for which herbage is chewed before swallowing. This basic process can be affected by the characteristics of the herbage on which the cattle is grazing (Hodgson 1986). The cows must also make behavioural choices, such as whether or not to take a bite or bites of the available herbage, and what components of the sward to bite, which will also affect their nutritional status. An understanding of the basic process of foraging and grazing behaviour is therefore an important prerequisite for the design of efficient grazing management systems (Rooke, 2000). The feed intake of the grazing process can be determined from the grazing time x rate of intake (Figure 1). The rate of intake can be subdivided into bite mass and biting rate. Bite mass (intake per bite) is determined by the product of the herbage density (weight per unit of volume) and bite size or bite volume. Bite volume is considered as the product of bite depth (the vertical distance between the sward surface and the severed ends of leaves) and bite area or the number of leaves gripped at a bite. Bite depth appears to be more sensitive to sward variations than bite area, and it is determined by sward height (Phillips, 1993; Hodgson, 1986). Thus in 10 cm pasture (spring) intake rate is about 25-30 g DM/min, whereas a 5 cm pasture (autumn) can only be eaten at 15-20 g DM/min. This explains that grazing time and biting rate can be modified by cattle to compensate for the reduction of bite depth, but this ability to compensate herbage intake not only depends on short swards but on the bite depth reduction and the cows intake requirements. Cows normally will graze about 10-12 hours per day with a biting rate of 65-70 bites/min respectively, but if intake requirements are high, the compensatory ability by the extended grazing time, or the increase in biting rate will be limited.

| | |
|---|---|
| Feed intake (g DM / day) | Grazing time (min / day) x Rate of intake (g DM / min) |
| Rate of intake (g DM / min) | Bite mass (g DM) x Biting rate (bites / min) |
| Bite mass (g DM) | Herbage density (g DM / $cm^3$) x Bite volume ($cm^3$) |
| Bite volume ($cm^3$) | Bite area ($cm^2$) x Bite depth (cm) |
| Bite area ($cm^2$) | Palate breath (cm) x Distance between tongue and palate when mouth touches sward (cm). |

**Figure 1.** ***Mechanistic model of the grazing intake of cattle (Phillips 1993).***

Dairy cows normally have about five meals per day and each meal lasts an average of 110 minutes. Dry cows and mature bullocks are likely to have shorter and fewer meals. Typically cattle have their meals after dawn and have two or three meals between morning and afternoon milking and a short meal at about 1a.m. The most intensive and longest meal takes place around dusk, which is probably to provide enough food to digest during the night (Phillips 1993). Sheep and cattle selectively eat leaves in preference to stem, and young or green material rather than dry or old material. The material eaten usually is higher in nitrogen and lower in fibre (Arnold 1978 ). Some selection occurs even in the most uniform pastures, having the greatest ease of prehension on tall swards, and thus reducing grazing time. Despite this cattle do not leave short areas untouched (Phillips 1993). Rather than simply grazing over the sward surface, cows initially select short grasses when they first enter a new field but increase the proportion of bites and as short grass is grazed down cows are forced to extend their use of tall swards. This change towards the tall swards reflects selection for green leaf content (Bao, Giller & Stakelum 1998). Dark green pastures indicate a higher nitrogen content and dense pastures a greater bite weight. Cattle, unlike sheep, can select a greater proportion of leaf material owing to their vertical grazing action which allows them to select and graze the upper strata of the sward (2 cm above the soil surface) which contain more leaf material. Swards lighter and browner than the grazed green herbage indicates to the cattle low nutritive value. This is typical of the herbage around dung deposits, which is usually rejected because of the smell of the faeces and its maturity (Phillips 1993). It has been demonstrated that the average sward area affected by a single dung patch can be $1.04m^2$ and intake is reduced consistently as grazing progresses to an average of $0.51m^2$ (Bao, *et al* 1998). It appears that the opportunity for horizontal selectivity around dung deposit and herbage with hairy or waxy leaves, is limited by the mouth parts of cows, because their uncleft upper lip and broad dental arcade, limits their ability to choose individual plants as sheep and goats (Phillips 1993). Grazing the edge of a dung patch is likely to occur in the early grazing stage of the field, and marked reduction not only of the sward height but the dung patch area through the mid-final grazing, is likely to be as a result of grazing pressure (cows/ha). Thus, selective grazing is also conditioned by the presence and distribution of dung patches and its sward type (Bao *et al,* 1998).

#### *1.3.1.3 Grazing behaviour and sward heights*

On dairy farms grass is the cheapest feed. Its high rate of growth during the early stage can lead to a wastage of grass and reduce grass condition for the rest of the season. Therefore effective management during the first eight weeks of grazing is very important for its efficient utilisation. Grass also must achieve good growth during spring, which is essential for grazing heights at this time of the season and may affect both milk yield and feeding value of grass (Table 1 and Table 2).

| Table 3 Effect of grass height in spring on cow performance | | | |
|---|---|---|---|
| | Grass height | | |
| | Close | Medium | Tall |
| Spring grass height (cm) | 6.6 | 7.8 | 9.6 |
| Spring stocking rates (cow/ha) | 6.4 | 5.5 | 4.7 |
| Milk yield in spring (kg/cow/day) | 25.0 | 25.5 | 26.5 |
| Milk fat (%) | 3.89 | 3.74 | 3.87 |
| Milk protein (%) | 3.38 | 3.43 | 3.35 |
| | | | (Fisher, 1991) |

| Table 4 Effect of grass height in spring on sward condition | | | | | | |
|---|---|---|---|---|---|---|
| | Grass heights in spring | | | | | |
| | Close | | | Tall | | |
| | Early | Mid | Late | Early | Mid | Late |
| No of live tillers (thousand/$m^2$) | 27 | 29 | 25 | 26 | 25 | 20 |
| No of dead tillers (thousand/$m^2$) | 0.5 | 5 | 1 | 1 | 9 | 4 |
| Grass (MJ ME/kg DM) | 11.5 | 10.8 | 11.2 | 12.2 | 10.5 | 10.8 |
| Grass (g CP/kg DM) | 241 | 222 | 280 | 237 | 171 | 248 |
| | | | | | | (Fisher, 1991) |

Experimental work completed by Gibb *et al* (1999) evaluated the effect of the sward surface height (SSH) of 5, 7 and 9 cm, on the grazing behaviour and intake on Holstein cows. They found that the total grazing time was not significantly affected between treatments (SSH) although there was a tendency for it to decline as sward heights increased. They also found significant increase in total grazing jaw movements on sward heights of 5 cm but no difference on 7 and 9 cm SSH. Biting rate usually decreases as sward heights increase and as intake per bite increases. This is because manipulative movements of the jaw during biting increases as intake per bite increases, according the size of individual plants (Chambers, Hodgson and Milne 1981). However, for intake per bite and bite rate in response to the variation of the sward, (in this case tall swards); cows may maintain a steady rate of intake, but they are unlikely to balance intake per bite on short swards, thus intake rate will decline (Hodgson 1986). The organic matter (OM) intake per day (kg) as a result of OM g/min, was also greater on the treatment of 7 cm sward height than the 5 and 9 cm. Thus, the number of bites required per kg OM intake was significantly more on the 5 and 9 cm SSH treatment than on the 7 cm SSH.

Ruminating time was also significantly extended (by over 1 h) as the number of mastications required on the tallest sward (9 cm) increased which may be the consequence of the quantity and quality of the food (length of the laminae) ingested to reduce particle size. Alternatively, less rumination may be required to handle small particle sizes at SSH of 4 cm, making it possible to extend grazing at the expense of ruminating time. The foraging cost for these cows will be high because they not only spent more time grazing, but because of their high biting rate with smaller intake per bite as shown by Rook, Huckle & Penning (1994). Cows in all three treatments spent an average of 7.5 h each day on other activities (idling, lack of grazing or ruminating). It was possible to suggest that cows could not reduce the time on such activities, which are also an integral part of the digestive process (Gibb, Huckle, Nuthall & Rook, 1999). As a result cows on the 9 cm SSH treatment tended to reduce grazing time (NS) and OM/d intake was also affected ($p < 0.05$). However, intake of good quality grass was reduced and therefore productivity declined (Greenhalgh and Reid, 1969), with significant differences in milk yields of 16.54, 20.00 and 19.17 kg/day from cows on treatments 5, 7 and 9 cm respectively (Gibb, Huckle, Nuthall & Rook, 1999).

#### *1.3.1.4 Other Eating Behaviour*

Conserved forages are usually more fibrous than fresh grass and concentrate. The rate of intake is usually highest for concentrates, followed by conserved forages and grazed grass (Phillips, 1993). The cow's physiological state may also influence the rate of her intake. Lactating cows, with high intake requirements, eat faster than dry cows, dominant cows eat faster than subordinates and heifers take longer to eat concentrate in the parlour. Animal size is also thought to be a factor on rate of intake. Acidic feeds like silage are eaten

faster, but meals are shorter. Cows can be as selective while eating silage as when they are grazing at pasture. Cows "nose" silage to find the bits that taste and smell the best. It is possible that cows might reject silage marked or contaminated with another cow`s saliva (Phillips 1993). Wierenga and Hospter (1990), have reported that the two periods with many cows at the feeding rack, were when they were fed (07.00, 11.00 h) which is when feed is probably least selected and cows will it eat faster. Cows eating silage may turn nosing into tossing or waste of feed. This often occurs when they take a mouthful of silage and, with a twist of the neck upwards, the silage is thrown to the air, landing on the back of the animal. It is possible that feed tossing behaviour is a sward ripping behaviour action. Housed dairy cows will eat silage for 4-7 hours (6-12 meals/d) (Phillips, 1993), which is less than cows grazing at pasture.

#### *1.3.1.5 Feeding behaviour and the environment*

Cows' main grazing pattern is during the daylight, with the major grazing bouts at dawn and dusk (Arnold, 1978). The number of cows engaged in a particular activity as a proportion of the total possible number of pairs can be described as a *synchronising behaviour*. On the other hand, lactating dairy cows are subject to possible artificial synchronising, as they are removed from pasture to the milking parlour at least twice a day (Rook & Huckle, 1995), although the same occurs when they are indoors. However, activities of cows at pasture appear more or less synchronised. While indoors at least the social leadership, the moving of the herd and the synchronising effects of the physical environmental such as the light are no longer evident (Metz & Wierenga 1986). When cows are at pasture, their grazing activity has been reported to be more synchronised than

ruminating or idling (lack of grazing). Rook, Huckle and Penning (1994), found that cows would graze for 567 (0.88%) minutes out of 646 minutes during the daylight with the major peaks of grazing during mid-morning and late evening. This was suggested to be a possible fasting effect following milking, but a small meal around midnight has also been reported (O'Connell, Giller & Meaney, 1989). The increase in herbage intake as the day progresses may be related to the increased sugar content of the plant during the day, or the need to have enough to digest at night (Phillips, 1993). During housing this distribution of feeding activity (synchronising) is upset and the overall feeding can be extended over most of the day (O'Connell, *et al*, 1989). The only degree of synchrony found in feeding behaviour when cows are housed is when food is given, falling from 100% to 30% after two hours and remaining in 25% of cows which can be seen feeding at any one time during the rest of the day (Miller & Wood-Gush, 1991). Only a small number of cows will be feeding at the same time about midnight (Wierenga & Hopster, 1990) especially subordinate cows (Phillips, 1993). The number of aggressive interactions can also increase dramatically from pasture to normal cubicle system. O'Connell *et al*, (1989), showed that low ranking cows could increase their rank position by more than five places when they were moved from pasture to winter housing. Research work completed by Miller and Gush (1991), also found that the number of agonistic behaviour interactions (pushes, threats, butts and avoidance) by cows at pasture was 1.1 per h compared 9.5 per h while housed, in which, from all agonistic interactions; 67% occurred in the feeding corridor, 7% in the cubicles and 26% in the remaining corridor space. The two peaks of agonistic activity coincided with the presentation of fresh silage during housing, while at pasture, the incidence of agonistic behaviour was with the return of cows to the pasture after milking (O'Connell *et al*, 1989). First lactation cows hold the lowest rank within the herd while older cows would consume significantly more at the expense of the low-ranking cows. A relationship has been found between rank and body weight and clear tendency towards increased feed intake with increasing rank position in the herd (Konggaard, 1983). Thus, when housed, a cow's position in the hierarchy would be more important as she can gain more advantage in terms of feeding by establishing a higher position (O'Connell *et al*, 1989).

### 1.3.2 Ruminating behaviour

#### 1.3.2.1 *Rumination*

Rumination enables the cow to chew the plant cell walls so that solutes are released and the walls are exposed to microbial digestion in the rumen (Phillips 1993). This highly adapted digestive system breaks down the cellulose and other components of grass and others forages, thanks to the microbial ecosystem which the cow has evolved (Kelly 2000). To aid this process the feed is mixed with saliva, which lubricates the chewing process, and adds chemical buffers and predigestive enzymes to aid digestion (Phillips 1993). In order to achieve this, the cow needs to produce 100-150 litres of saliva each day to maintain the optimal rumen pH 6-7, in which this amount of saliva will contain 3.5 kg bicarbonate, the amount necessary to buffer the acidity produced in the rumen. When the daily diet of the cow is acidic such as silages , the buffering required will be greater. In order to produced the necessary amount of saliva, the cow needs to make 30000-50000 chewing movements each day. To ensure sufficient chewing, the cow must ingest 2 kg of long fibre, which is suggested to be at least 2-4 cm. Each kilogram of fibre will stimulate 20-30 minutes of chewing. In adult cows this behaviour (chewing) will be done when lying down. It has been suggested that more saliva is produced when cows are free from stress

and provided with clean and comfortable lying conditions. Cow comfort and lying time are clearly important. Cows under comfortable conditions can lie down for 14 hours each day, but this can be decreased to 6-7 hours in poor conditions such as inadequate bedding and small, uncomfortable cubicles (Kelly 2000). Rumination in normal conditions (pasture) usually occurs altogether for about six to seven hours each day, in between the grazing bouts and with the most intensive period being a few hours after dusk (Phillips 1993). Ruminating during the day may indicate that cattle need to ruminate in order to aid passage from the rumen and hence facilitate further intake (Rook *et al* 1994) . O'Connell, Giller and Meaney 1989, found that cows indoors spent more time ruminating during the daylight while cows outdoors ruminate for longer during the night. It also has been reported that first lactation cows and adult cows spent longer lying and ruminating than standing and ruminating at pasture. Also, the time spent ruminating and lying while at pasture was longer than indoors and the time standing and ruminating was less at pasture than indoors for both first and adult cows (Singh, Ward, Lautenbach, Hughes and Murray 1993). Ruminating time can be also variable during the grazing season. At the beginning the low ruminating time is probably reflecting low fibre intakes likely caused by the low fibre in herbage, but at the end of grazing season the low ruminating time may be caused by the low herbage intake (Phillips & Leaver 1985). Rumination is not a continuous process but is done in about eight bouts of 45 minutes each per day. This regular pattern of mastication normally at about 60-70 bites per minute is associated with reduced of alertness and its rhythmic action may induce to a hypnotic effect in the cow. Ruminating is a voluntary control which cattle can ceased when they are disturbed as they are taken for milking. The extent of ruminating required for a specific diet depends largely on its fibre content but also on the dry matter and surface water content. Conserved forages are normally harvested at a more mature stage than grazed grasses and typically require more rumination. Wet grasses are not easily ruminated and cows compensate by increasing ruminating time. Larger ruminants have a more efficient fibre digestion process than small ruminants. Older cattle are therefore more efficient forage digesters than young cattle, and may be this is why they masticate slower (Phillips 1993).

### 1.3.3 Lying behaviour

#### 1.3.3.1 *Lying*

The lying and getting up behaviour means a great strain for cows when they try to move their body weight of more than 600 kg. When cows are lying down at pasture, they first seek for a suitable place, then explore it more closely to check that it is suitable. Finally, the cows lie down (Herlin 1994). Usually cows lie down on their briskets with both forelegs tucked under their body, and the weight of their abdomen resting on one hind limb and the other hind limb stretched out to one side (Webster 1987) . The natural environment for the cow is the field. When she is lying down she needs a thick carpet of grass to support 80% of her body weight on her two knees and her hock joint. The average Holstein/Friesian measures 1.8 (6 ft) from tail to brisket and 60 cm (2ft) from brisket to nose . This means that when a cow is lying down and ruminating with her head outstretched, she will take a length of 2.4 m (8ft) and in this position her jaw will be 38 cm (15 inches) above the pasture and the width taken by the stomach and hip is 1.2 m (4 ft) (Hughes 1996). Cows normally lie down front legs first and get up front legs last, however in each case this involves a forward lunge. Cows in poorly designed cubicles learn alternative strategies for lying down and changing position and may adopt abnormal but apparently successful postures such as "dog-sitting" (Webster 1987). At pasture, cows like

to lie down uphill which helps them to take away the pressure of the rumen on the diaphragm and consequently the heart and lungs (Hughes 1996). There appears to be a preference for cows to lying down on their left side but they regularly change sides to avoid putting excess pressure in the laid-on limb (Webster 1987). Pregnant cows prefer to lie down on their left side probably because the growing foetus area is on the right side of the abdominal cavity, at least in the later stages of pregnancy. However, as cows get older they show more preference for the right side, because there is more room in the abdominal cavity where there is less chance of damage to the foetus when lying on the right side (Arave & Walters 1980). As at pasture, cubicles during the winter period must allow cows freedom to perform all their natural movements without any difficulty. It has been reported that conventional cubicles usually have design faults that are likely to cause lameness, discomfort and injury. It also showed that the 30 natural movements that cows make when rising are reduced to half during confinement, and this results in constriction, discomfort and difficulty in ruminating, which forces cows to stand (Hughes 1996).

### *1.3.3.2 Lying down behaviour Indoors and Outdoors*

Cows at pasture lie down approximately 12 hours/day and 7 hours of this time they spend ruminating. Of the ruminating time, 5.5 hours is spent lying down and 1.5 hours standing. Cows housed in straw yards during the winter, usually lie down for 13 hours/day and ruminate for 8 hours. Of this, they spend 6 hours ruminating lying and 2 hours ruminating standing. The ruminating time is reduced to 8 hours/day of which only 1.5 hours are spent ruminating lying down in cubicles (Hughes 1997). Experimental work has showed that cows during housing lie down for longer during the night than during the day time (Singh, Ward, Lautenbach, Hughes and Murray, 1993).

They also found that the maximum number of cows lying down is after the morning and afternoon milking. The cows lying down at this recorded hours are usually more adult cows than first lactation. However, the time spent lying and ruminating is less than standing and ruminating for the first lactation cows, and ruminating lying is also less for the first lactation cows compared with the adult cows. In the same experiment, when they compared the cows behaviour indoors with outdoors, they also reported that the lying behaviour at pasture was more synchronised and longer than it was indoors, for both first lactation and adult cows. But the lying time was longer at night than during the day. This suggests that cows may compensate by lying down during the day when they are indoors. This is in agreement with work reported by Wierenga and Hopster 1990, who found that during the housing period cows under overcrowded conditions (33%) reduced their lying time significantly during the night, especially low ranking cows, but it was compensated during evenings. This shows that with increasing competition during housing the low-ranking cows will be the first to experience the consequences. At pasture there is a greater choice of lying places, as there is likely to be more space available where cows can lie down a considerable distance from each other.

The way a cow normally lies down when at grass takes place in several stages, to lower her body to the ground. If the design of housing causes injury to the cow whilst lying down, the cow may then associate lying behaviour with pain and reduce her time spent lying (Herlin, 1994).

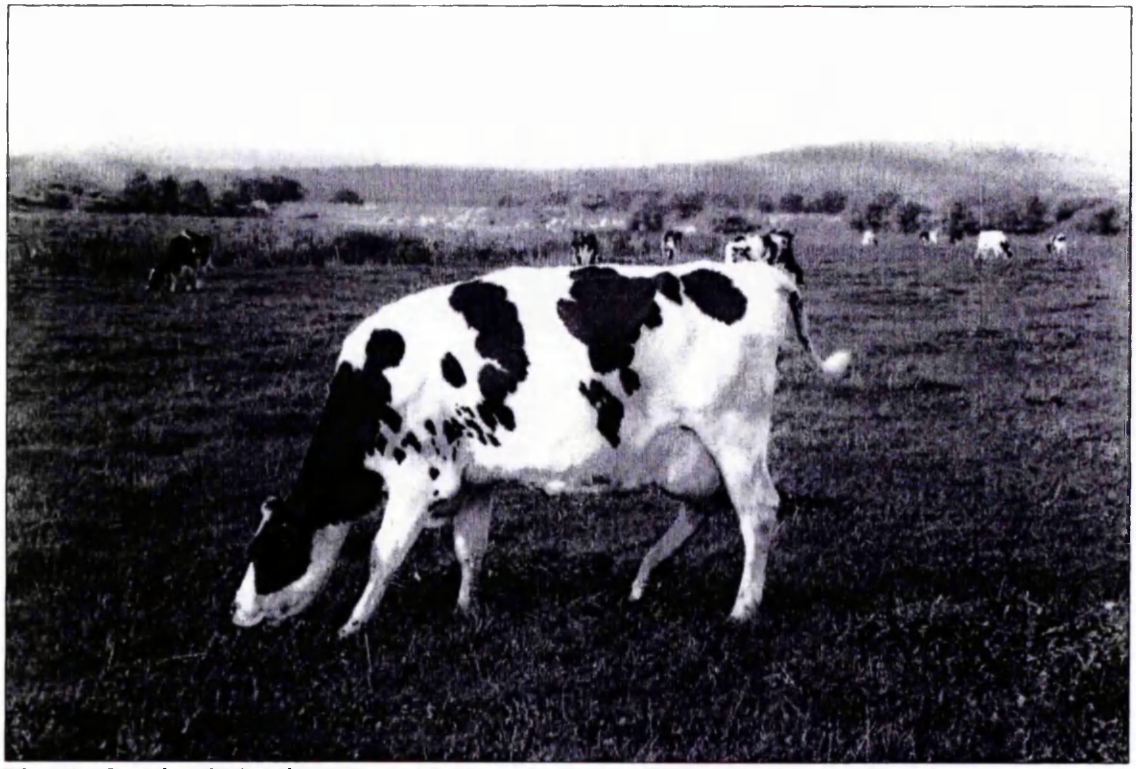


Plate1. Grazing behaviour

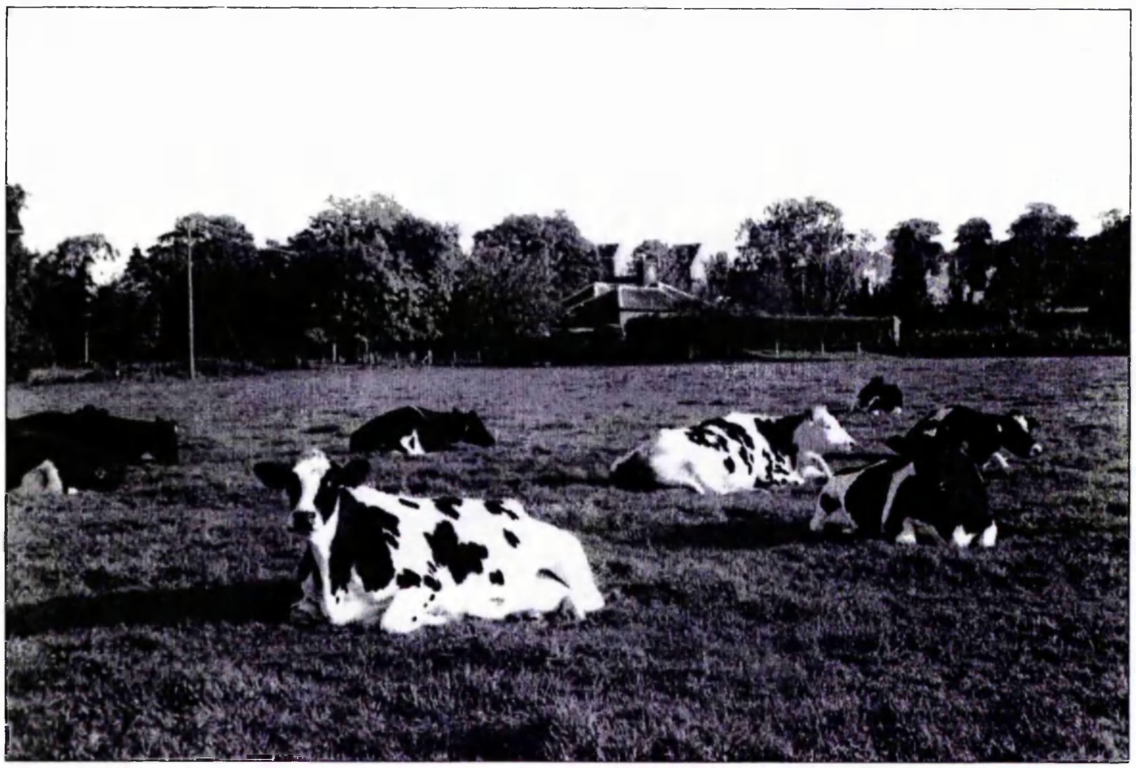


Plate 2. Lying behaviour


Plate 3. Ruminating lying behaviour

Plate 4. Ruminating standing behaviour

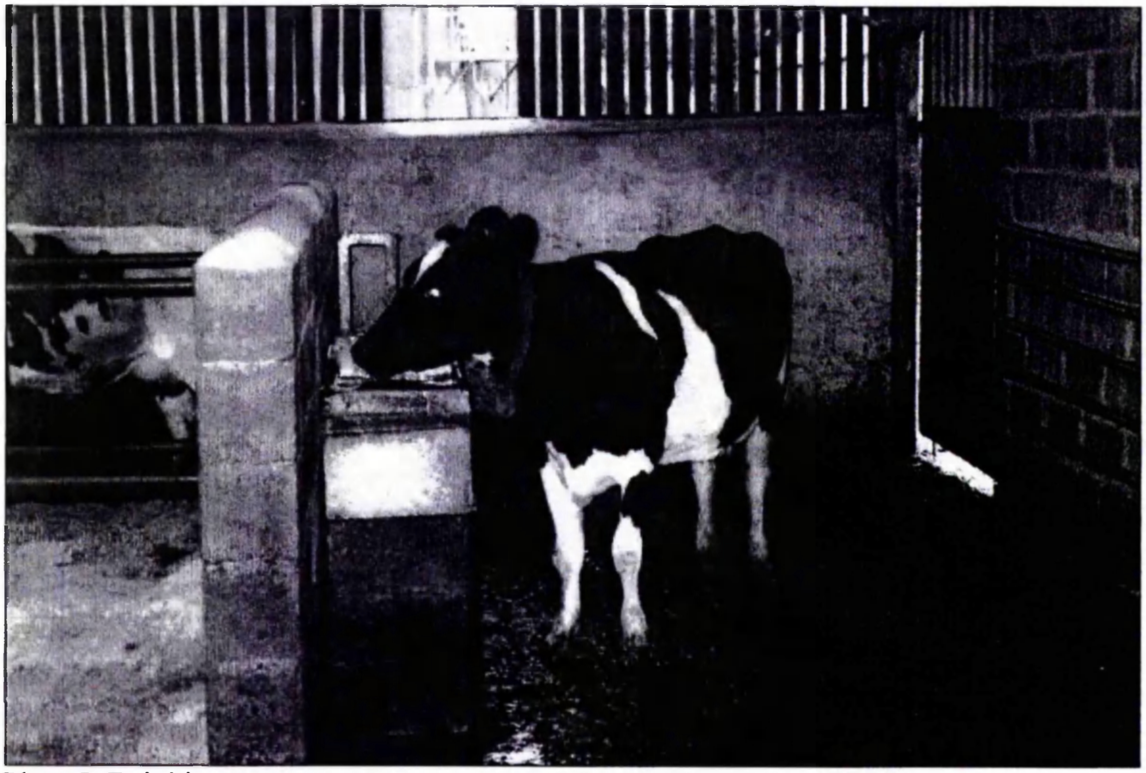


Plate 5. Drinking

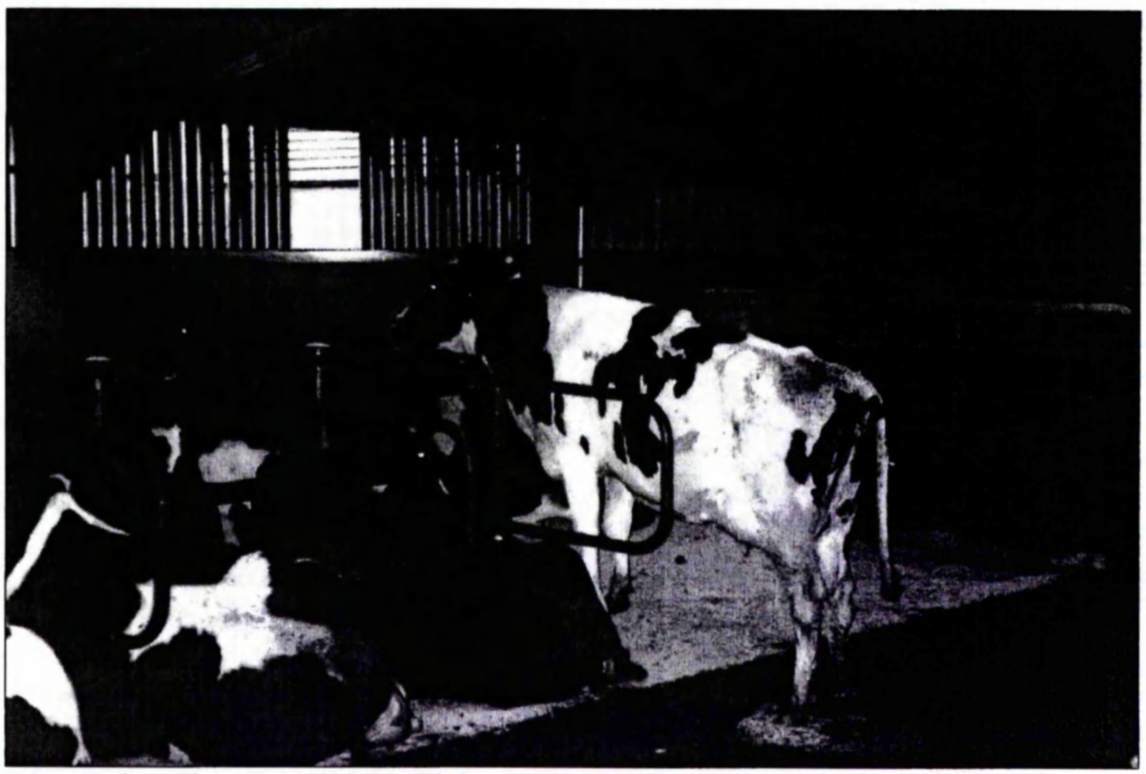


Plate 6. Standing, half in the cubicle

# CHAPTER 2 EXPERIMENTAL STUDY

## 2.1 *EXPERIMENTAL STUDY*

The experiment study was conducted at the *Scottish Agricultural College (SAC), Crichton Royal Farm, Dumfries*, at the Main Steading and Acrehead Units, during the summer period from May to October 1999.

### 2.1.1 The Crichton Royal Farm

This farm extends to 262 ha and is located 2 miles south of Dumfries on the east bank of the River Nith. The farm is 75 m above sea level with predominantly sandy loam and silty clay type soils. Crichton Farm is divided into five units:

- Main Steading 211 dairy cows
- Acrehead 140 dairy cows
- Rosehall rearing unit for youngstock from Main Steading and Acrehead
- Netherwood dry cow and youngstock unit
- Arable 23 ha used for cereal trials, maize and fodder beet

All calves are reared at the farm and heifers served at 15 months of age (350 kg liveweight), to calve at 2 years of age weighing not less than 525 kg. All cows are Friesian/Holstein and are bred by artificial insemination. This means AI sires are specially selected for cows as they are selected for heifers.

### 2.1.2 The Weather

At Crichton Farm the weather data is collected every day from the Meteorological Station on the farm and reported to the Meteorological Office. The pattern of rainfall is evenly

distributed throughout the year and the climate is relatively mild with usually very little snow during the winter (Table 5)

| Table 5 Annual meteorological report summary | | | |
|---|---|---|---|
| | **1997** | **1998** | **1999** |
| Rainfall (mm) | 1085 | 1223 | 1124 |
| Days > 0.2 mm rain | 178 | 195 | 192 |
| Max Temp ($^0$C) | 13.29 | 13.13 | 13.00 |
| Min Temp ($^0$C) | 5.87 | 5.85 | 6.60 |

### 2.1.4 The Experimental Farm Units

#### *2.1.4.1 Main Steading Dairy System Unit*

This unit with 211 dairy cows has its individual and group feeding facilities and is located at the main centre of the farm. The group of cows at this unit are divided into sub-groups of which some are kept indoors all year round (fed a silage/concentrate diet) while other sub-groups graze (a grass/concentrate diet) during the summer period and are housed during the winter time (being fed silage/concentrate). The main purpose and management of these cows at the Main Steading Unit is of detailed research, on individuals or groups on cow performance. All sub-groups of cows are milked twice daily in their respective order through the same parlour, with the same man in charge. The milking machine used at this unit is an Alfa Laval 16 x 16 Herringbone Milking Parlour with Auto ID, Auto Feed, Auto Milk yield recording and auto cluster removal (ACR). The rate of milking is 60-70 cows/man/h. The milk produced is stored in refrigerated tanks and sold to Scottish Milk who collect it every day.

#### *2.1.4.2 Acrehead Dairy System Unit*

The Acrehead Unit, located 1 km from the Main Steading, is specifically designed to carry out system studies (group research) at the farm level. The 140 Holstein/Friesian cows in this unit are separated into two 70 - cow groups: the Low Input Unit (Unit 1) and the High

Output Unit (Unit 2). Both groups are milked twice daily through the same parlour and with one man in charge. The milking machine used at this unit is an Alfa Laval 20 x 20 Herringbone Milking Parlour with ACR, low jar and Manual Reading Program Feeding (60-70 cows/man/h). Both units have an area of 45 ha. The nitrogen input for Unit 1 is 0 while 220 kg/ha are applied to the grazing area in Unit 2. The milk is produced from grass, grass/clover and silage for Unit 1 and from 0.5 tonnes/cow/year of concentrate. For Unit 2, milk is produced from grass, silage and concentrates 1.7 tonnes/cow/year. The milk produced is stored and refrigerated in separate tanks and sold to the Nestlé Milk Company who collect every other day.

### *2.1.4.3 Main Steading and Acrehead Unit*

All units at the Crichton Farm are administered by the same Farm Manager. Cows at the Main Steading and Acrehead units are milked by their own herdsman, who is also responsible for their health care. Each unit is located at a different area within the farm and includes its own grazing fields, fields selected for silage making, silage pits, slurry stores and cubicle house, with their own milking parlours and farm staff. Weather conditions are not different between units; although they are both approximately 1 km apart from each other they are still in the same farm area. Approximately 120 ha are used for silage first cut. Weather conditions determine the periods of wilting, which ranges from 12-24 hours, and the aim is to achieve silage of 20-25% DM (Table 6).

**Table 6 Silage analysis**

| | 1995 | | 1997 | |
|---|---|---|---|---|
| | 1st cut | 2nd cut | 1st cut | 2nd cut |
| DM (g/kg) | 240 | 346 | 247 | 244 |
| CP (g/kg DM) | 125 | 150 | 167 | 156 |
| ME (MJ/kg DM) | 12.0 | 11.6 | 11.4 | 11.4 |

Research studies carried out at the Main Steading Unit are usually involved with concentrate compositions and response in cows' performance to feeding different amounts and types of concentrate. At the Acrehead units, the concentrate is bought and distributed between both units respectively. In 1996, Acrehead Unit 1 had milk sales of 5503 l/cow, using 0.07 kg concentrate/litre and Acrehead Unit 2 had 8451 1 /cow using 0.23 kg concentrate/litre. In 1998 milk sales were 5739 l/cow, using 0.1 kg concentrate/litre for Unit 1 and Unit 2 were 7952 l/cow using 0.27 kg concentrate/l. Cow performance from the main units during 1996 and 1997 are shown below in Table 7.

**Table 7 Crichton and Acrehead milk yield and composition 1996 to 1998**

| | Main Steading | | Acrehead Unit 1 | | Acrehead Unit 2† | |
|---|---|---|---|---|---|---|
| | 1996/97 | 1997/98 | 1996/97 | 1997/98 | 1996/97 | 1997/98 |
| Milk yield (305 d) | 6280 | 6841 | 5503 | 5752 | 8451 | 8145 |
| Butterfat (%) | 4.26 | 4.44 | 4.08 | 4.22 | 4.11 | 4.08 |
| Protein (%) | 3.31 | 3.25 | 3.16 | 3.31 | 3.33 | 3.36 |

† 3 times a day milking

The experimental study shown and discussed in this thesis was carried out at the Main Steading and Acrehead units by using animals from both dairy herds units and by the selection of specific number of animals from each herd according the required basis. The work was divided into Experiment 1 and Experiment 2.

## 2.2 *INTRODUCTION*

Experiment 1 evaluated two groups of dairy cows under different environments of indoor and outdoors management systems during the summer period. Each group was compared on the basis of response to the different environments and the effect of it upon their performance, health and behaviour.

## 2.3 *MATERIALS AND METHODS*

### 2.3.1 Animals

This experiment was carried out during the summer period from May to September 1999. During this period, two groups of twenty-eight Friesian Holstein, spring calving cows were used for the comparison of their production, health and behaviour. One group of 28 cows were indoors in the cubicle system while the other group of 28 cows were outdoors (grazing). Each group was part of a milking group of 48 (Main Steading Unit) and a herd of 69 (Acrehead Unit 1) spring calving cows respectively, in which they remained during the experimental study. Cows between the indoors and outdoors treatments were allocated to 14 blocks of 2 cows on the basis of similarity in milk yield, calving date and lactation number. Twenty cows chosen at random, allocated within blocks were used for the behavioural observation. The mean parity between treatments was 3 and their calving dates ranged from January 26$^{th}$ to April 8$^{th}$. The mean initial milk yield and liveweight for the indoor and outdoor groups were 31 l/d, 589 kg and 30 l/d, 579 kg respectively.

### 2.3.2 Indoors

The twenty-eight cows were housed in a cubicle system (Standard) on a concrete floor which was scraped every hour. The dimensions of the cubicles were 2.03 m x 1.13 m. Cubicles were bedded twice weekly with sawdust. Cows were milked twice daily at about 06.00 and 14.00 hours. Forage silage was offered *ad libitum* once daily between 08.00-09.00 h. The silage was weighed every day and the refusal and the amount offered was used to estimate animal intake, which ranged from 10 to16 kg DM/d. The daily ration of concentrate ranged from 6.5 to 3.4 kg DM/d offered in the parlour. Cows in this group had been previously selected to carry out a trial, which involved a special type of concentrate fed with different amounts. The trial carried out on this group of cows had already started before this experiment commenced and the rest of the trial took place during the present experiment. Water was available to all cows in the cubicle area. Forage silage and concentrate feeds were recorded every month.

### 2.3.3 Outdoors

Twenty-eight cows were grazed on eight fields (set-stocking system) and spent 3 to 4 four days on each field. The fields ranged from 3.75 to 9.9 ha with a stocking rate, which varied within grazing field with a mean of 9 cows/ha. Cows grazed fields on sward heights maintained at average of 9 cm. The cows were milked at 05.00 and 15.00 h daily. Maize silage was offered *ad libitum* as buffer for a period of one hour after pm milking during the months of May and June. Silage intake ranged from 2 to 3 kg DM/ d, plus a daily ration of concentrate. This had a range from 1 to 3 kg DM/d and was offered in the parlour. One water trough was available in each field and cows were free to drink water at any time. Maize silage and concentrate amounts fed were recorded every month.

### 2.3.4 Animal performance

Milk yields of individual cows for each treatment were recorded monthly and samples were taken for fat, protein and somatic cell count analysis. Liveweight and condition score were recorded every two weeks for each cow after the second milking of the day (Mulvany, 1977). Cleanliness was also scored monthly for individual cows for each treatment and it was assessed by the amount of dung present in areas such as the hooves, lower legs and hind underbelly. Cleanliness scores were from 0 for a very clean animal up to 3 for a very dirty animal (Scott and Kelly, 1989).

### 2.3.5 Animal Health

Percentage prevalence of mastitis was recorded monthly for each treatment. Fertility management as dates of oestrus, first and following services, services per conception and pregnancy diagnosis were also recorded for individual animals in each treatment.

### 2.3.6 Locomotion scoring

Individual animals in each treatment were scored every two weeks for their locomotion. The scores were taken as assessment from 1 to normal condition, 3 clinical lame and 5 severely lame animal (Manson and Leaver 1988a). The percentage prevalence and incidence cases of lame cows were also recorded for each treatment.

### 2.3.7 Sward Measurements

Sward heights were measured weekly using the HFRO sward stick by taking no less than fifty measurements including grazed and rejected areas and avoiding gateways and around water troughs, walking in a "W" pattern in each treatment field.

### 2.3.8 Behavioural observations

Observations were made monthly on individual cows for each treatment group, within 24 hours, respectively. Observation were recorded from 08.00 to 14.00 h and from 17.00 to 21.00 h, except for the hours during the milking period, thus a total of ten hours during each observation. Cows in each treatment were observed once every 5 minutes and a record made if they were; grazing, ruminating/standing, ruminating/lying, drinking, nothing/standing and nothing/lying. All the cows had large white numbers painted on their sides to aid identification. All the behaviour results were calculated as a percentage of the recording hours

### 2.3.10 Statistical analysis

The milk yield, composition and the results for animal performance and health; locomotion score, incidence of lameness, live weight, condition score, cleanliness and behavioural observation data were analysed using Analysis of Variance (Genstat 4). This program statistically analysed the difference between animals group, time and interaction between treatments (month/group). Prevalence of mastitis, prevalence of lameness and fertility results, percentage of cows pregnant, percentage pregnant to 1st service, service/conception were analysed by Chi-squared test. Days to 1st service and days to conception were analysed using the student T-test. Incidence is defined as the number of new cases, over a period of time, for the herd, and prevalence as the number of cows in the herd with mastitis, or lame, at one time (expressed as a percentage).

## 2.4 *RESULTS*

### 2.4.1 Animal performance

Milk yields are presented in Table 8 and Figure 2.1. Milk yield did not differ significantly between treatments. Milk composition is also presented in Table 8. On average fat content was significantly higher and protein content significantly lower for the indoors treatment. The difference in protein content diminished with time. The outdoor treatment showed constantly higher ($p<0.05$) somatic cell count throughout the experiment compared to indoor treatment (Table 9). The mean monthly milk yields were 24 l (indoors) and 24.9 l (outdoors). Liveweights and condition score results are shown in Table 10. The indoor treatment tended to have an increased liveweight particularly towards the end of the experiment. Throughout the experiment the condition score was slightly poorer for the indoor treatment compared to outdoor treatment. The cleanliness results recorded on the

three last months of the experiment are presented on Table 11. Indoors treatment appeared to be dirtier than outdoors treatment and had a significantly higher cleanliness score ($p<0.001$).

**Table 8 Milk yield and composition**

| Group | May | June | July | Aug | Sep | Mean | s.e.d Group | | group/month | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Milk Yield (kg/d)* | | | | | | | | | | |
| In | 31.7 | 27.1 | 22.3 | 21.3 | 17.7 | 24.0 | 0.66 | NS | 1.47 | NS |
| Out | 30.5 | 29.1 | 25.5 | 22.8 | 16.9 | 25.0 | | | | |
| *%Bfat* | | | | | | | | | | |
| In | 4.18 | 4.30 | 4.03 | 4.42 | 4.93 | 4.37 | 0.07 | *** | 0.16 | NS |
| Out | 3.44 | 3.38 | 3.56 | 3.50 | 4.31 | 3.64 | | | | |
| *% Prot.* | | | | | | | | | | |
| In | 2.88 | 2.87 | 2.91 | 3.22 | 3.42 | 3.06 | 0.02 | *** | 0.06 | *** |
| Out | 3.31 | 3.31 | 3.31 | 3.41 | 3.56 | 3.38 | | | | |

***p<0.001

**Table 9 Somatic cell count ('000/ml)**

| Group | May | June | July | Aug | Sep | Mean | s.e.d. Group | | group/month | |
|---|---|---|---|---|---|---|---|---|---|---|
| In | 71 | 253 | 268 | 168 | 124 | 177 | 59.10 | * | 132.10 | NS |
| Out | 429 | 224 | 330 | 205 | 299 | 297 | | | | |

*p<0.05

**Table 10 Liveweight (kg) and condition score**

| Group | May | June | July | Aug | Sep | Mean | s.e.d. Group | | group/month | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Live weight* | | | | | | | | | | |
| In | 575 | 591 | 599 | 618 | 622 | 601 | 7.33 | ** | 16.39 | NS |
| Out | 565 | 586 | 589 | 586 | 590 | 583 | | | | |
| *Condition Score* | | | | | | | | | | |
| In | 2.15 | 1.84 | 1.90 | 1.97 | 2.01 | 1.97 | 0.05 | *** | 0.12 | NS |
| Out | 2.22 | 2.25 | 2.15 | 2.09 | 2.25 | 2.19 | | | | |

**p<0.01 *** p<0.001

**Table 11 Cleanliness score**

| Group | July | Aug | Sep | Mean | s.e.d. Group | | Group/month | |
|---|---|---|---|---|---|---|---|---|
| In | 2.19 | 2.17 | 2.25 | 2.20 | 0.09 | *** | 0.16 | NS |
| Out | 1.82 | 1.28 | 1.63 | 1.57 | | | | |

*** p<0.001

### 2.4.2 Feed Intakes

The mean feed intakes over the five months of the experiment are shown in Table 12. The indoor forage silage intakes range from 10 to 16 kg DM/day and 2 to3 kg DM/day of maize

silage for outdoors treatment on May and June. Indoor treatment concentrate intakes range from 3.4 to 6.5 kg DM/day and 1 to 3 kg DM/day for outdoors treatment. Grass height results are shown in Figure 2.2. The grass height measurements obtained weekly from the grazing fields showed that the outdoors treatment grazed over a range of 6.5 to 12.5 cm grass heights.

| **Table 12** | **Feed intakes (kg/d DM)** | | | | |
|---|---|---|---|---|---|
| Group | May | Jun | July | Aug | Sep |
| *Grass silage* | | | | | |
| In | 11 | 10 | 16 | 11 | 11 |
| *Maize silage* | | | | | |
| Out | 2 | 3 | 0 | 0 | 0 |
| *Concentrate* | | | | | |
| In | 6.5 | 5.8 | 5.3 | 4.8 | 3.4 |
| Out | 3.0 | 3.0 | 2.0 | 1.0 | 1.0 |

### 2.4.3 Animal health

The mean locomotion scores are presented in Table 13. The indoor treatment showed a constantly high score compared with the outdoors treatment and this was significant over the whole experiment ($p<0.01$). In both treatments there were slightly increased scores towards the end of the experiment. The observations recorded of cows scoring 3 (clinical lame) or more, over the 5 months in every two weeks represented an incidence of 71% (indoors) and 54% (outdoors). The results are presented in Table 14 and differences were not significant. Also, the number of lame cows in each month, presented as the prevalence of lameness is shown in Table 15.

| **Table 13** | **Locomotion score** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | s.e.d. | | | |
| Group | May | June | July | Aug | Sep | Mean | Group | | Group/month | |
| In | 1.87 | 1.78 | 1.96 | 1.93 | 2.08 | 1.92 | 0.05 | ** | 0.12 | NS |
| Out | 1.75 | 1.62 | 1.85 | 1.78 | 1.92 | 1.78 | | | | |
| **p<0.01 | | | | | | | | | | |

| **Table 14** | **Percentage incidence cases of lameness** | | |
|---|---|---|---|
| **Group** | | **s.e.d.** | **Significance** |
| In | 71 | 0.25 | NS |
| Out | 54 | | |

| Table 15 | Percentage prevalence of lameness | | | | | |
|---|---|---|---|---|---|---|
| Group | May | June | July | Aug | Sep | Significance |
| In | 10.7 | 3.6 | 21.4 | 25.0 | 28.6 | NS |
| Out | 10.7 | 0.0 | 10.7 | 7.1 | 25.0 | NS |

### 2.4.4 Clinical mastitis

Of the 28 cows from each group, individual cases of clinical mastitis were recorded monthly. The results were not significant between treatments. Thus this represented the prevalence of clinical mastitis in each month for each group (Table 16). As there were 28 cows in each group, a prevalence of 7.1% represents 2 cows and a prevalence of 3.6% would represent 1 cow. In both treatments the number of cases of cows with clinical mastitis decreased towards the end of the experiment.

| Table 16 | Percentage prevalence of mastitis | | | | | |
|---|---|---|---|---|---|---|
| Group | May | June | July | Aug | Sep | Significance |
| In | 0 | 14.3 | 7.1 | 3.6 | 0 | NS |
| Out | 10.7 | 14.3 | 7.1 | 3.6 | 0 | NS |

### 2.4.5 Fertility

The fertility records presented in Table 17 showed no significant differences between indoors and outdoors treatment. From the indoor treatment 19 cows (70 per cent) became pregnant and from the outdoors treatment 20 cows (77 per cent) became pregnant. Services per conception did not differ significantly between treatments. Also the mean intervals from days to first service and service to conception were not significantly different.

| Table 17 | Fertility | | | | | |
|---|---|---|---|---|---|---|
| Group | % Pregnant | % Preg. to $1^{st}$ service | Service/ conception | Days to $1^{st}$ service | Days to conception | Significance |
| In | 70 | 57 | 2.2 | 91 | 98 | NS |
| Out | 77 | 70 | 1.9 | 91 | 101 | NS |

### 2.4.6 Animal behaviour

Eating and grazing behaviour are present in Table 18. The proportion of time that the indoors treatment spent eating was variable during the experiment with the longest proportion of time eating in June. For the outdoor treatment the proportion of time spent grazing increased towards the later part of the grazing season, with the longest and most intense grazing periods observed in September. However, this behaviour differed significantly between both treatments over the five months period (p<0.001) .

**Table 18 Eating and grazing behaviour (% of ten hours)**

| Group | May | June | July | Aug | Sept | Mean | s.e.d Group | P Group/month |
|---|---|---|---|---|---|---|---|---|
| In | 37 | 49 | 43 | 37 | 43 | 42 | 0.01 *** | 0.04 *** |
| Out | 49 | 57 | 47 | 59 | 69 | 56 | | |

***p<0.001

### 2.4.7 Ruminating lying

In both treatments the proportion of time spent ruminating while lying did not differ significantly (Table 19). However for indoors treatment was least marked compared with the outdoors treatment which on proportion of time ruminating lying behaviour decreased on the last two months of the experiment.

**Table 19 Ruminating lying behaviour (% of ten hours)**

| Group | May | June | July | Aug | Sept | Mean | s.e.d Group | P Group/month |
|---|---|---|---|---|---|---|---|---|
| In | 23 | 15 | 21 | 23 | 17 | 19 | 0.01 NS | 0.03 NS |
| Out | 25 | 15 | 26 | 17 | 17 | 20 | | |

### 2.4.8 Ruminating standing

From the animal behaviour experiment, the observations made of cows ruminating and standing resulted in one of the most different behaviour patterns. The results were significantly different between both treatments over the whole experiment (p<0.001).

However, results presented in Table 20 and Figure 2.5 show that the indoor group preferred to spend a longer part of their ruminating activity while standing. Although it was not too variable it was constantly higher compared to the outdoor treatment in each month, as if it was a normal cow behaviour. But the results also showed that the outdoor treatment did not undertake this behaviour as a priority. However, the total proportion of ruminating time differed significantly between treatments (Table 21). The results showed that the indoor treatment group spent more time ruminating than outdoors, and sometimes even two times more, as it was recorded in the observations of June and August.

**Table 20 Ruminating standing behaviour (% of ten hours)**

| Group | May | June | July | Aug | Sept | Mean | s.e.d Group | P Group/month |
|---|---|---|---|---|---|---|---|---|
| In | 9 | 14 | 10 | 11 | 16 | 12 | 0.01 *** | 0.02 NS |
| Out | 1 | 0 | 2 | 0.1 | 3 | 1 | | |

***p<0.001

**Table 21 Total ruminating behaviour (% of ten hours)**

| Group | May | June | July | Aug | Sept | Mean | s.e.d Group | P Group/month |
|---|---|---|---|---|---|---|---|---|
| In | 33 | 30 | 32 | 35 | 33 | 32 | 0.01 *** | 0.03 ** |
| Out | 26 | 16 | 29 | 18 | 21 | 22 | | |

**p<0.01 ***p<0.001

### 2.4.9 Idling lying

During the experiment the time spent idling lying was very similar for both treatments, although in the last month of observation (September) the outdoor treatment group proportion of time spent on idling while lying was very low compared to the indoor treatment cows. However, this behaviour did not differ significantly between treatments (Table 22), as the total percentage of time spent lying also did not differ significantly between groups (Table 23).

| Table 22 | Idling lying behaviour (% of ten hours) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Group | May | June | July | Aug | Sept | Mean | s.e.d Group | P Group/month |
| In | 16 | 8 | 12 | 15 | 10 | 12 | 0.01 NS | 0.03 NS |
| Out | 15 | 9 | 18 | 14 | 03 | 12 | | |

| Table 23 | Total lying behaviour (% of ten hours) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Group | May | June | July | Aug | Sept | Mean | s.e.d Group | P Group/month |
| In | 40 | 23 | 34 | 38 | 26 | 32 | 0.02 NS | 0.05 NS |
| Out | 41 | 25 | 45 | 31 | 21 | 32 | | |

### 2.4.10 Idling standing

The mean results are shown in Table 24. This behaviour was significantly different between treatments ($p<0.001$). Indoors treatment showed to spent more time standing and not doing anything at all (idling) over the five months of the experiment compared to outdoors treatment. However the total proportion of time spent standing did not differ between treatments (Table 25).

| Table 24 | Idling standing behaviour (% of ten hours) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Group | May | June | July | Aug | Sept | Mean | s.e.d Group | P Group/month |
| In | 12 | 10 | 11 | 9 | 13 | 11 | 0.01 *** | 0.02 NS |
| Out | 5 | 8 | 5 | 7 | 6 | 6 | | |
| ***p<0.001 | | | | | | | | |

| Table 25 | Total standing behaviour (% of ten hours) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Group | May | June | July | Aug | Sept | Mean | s.e.d Group | P Group/month |
| In | 60 | 75 | 66 | 61 | 73 | 67 | 0.02 NS | 0.05 NS |
| Out | 56 | 66 | 55 | 68 | 79 | 65 | | |

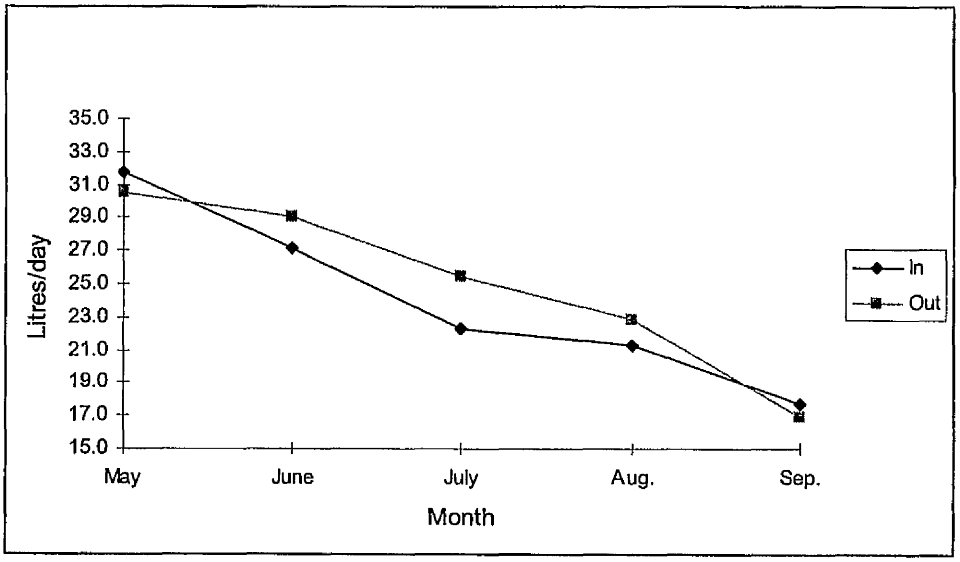



*Figure 2.1 Milk yield (litres/day)*

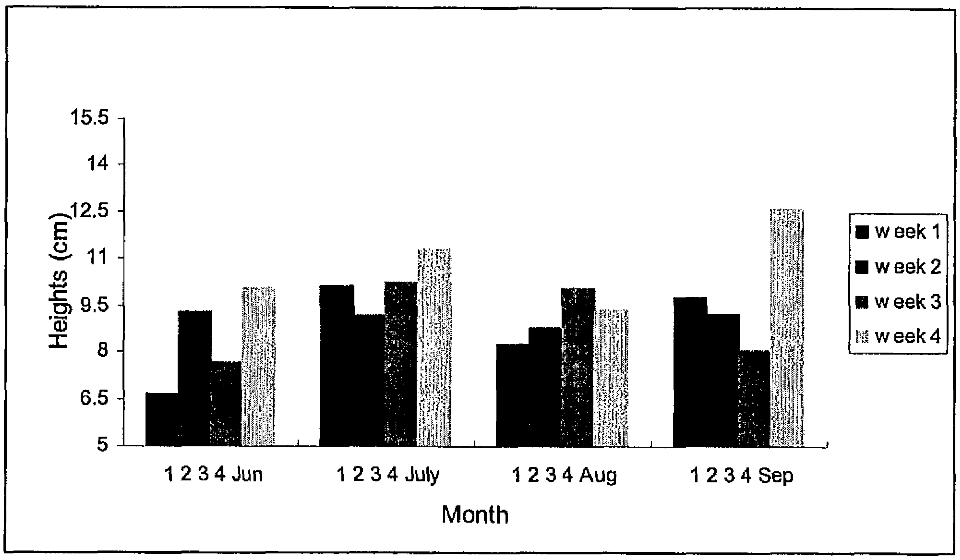



*Figure 2.2 Sward heights*

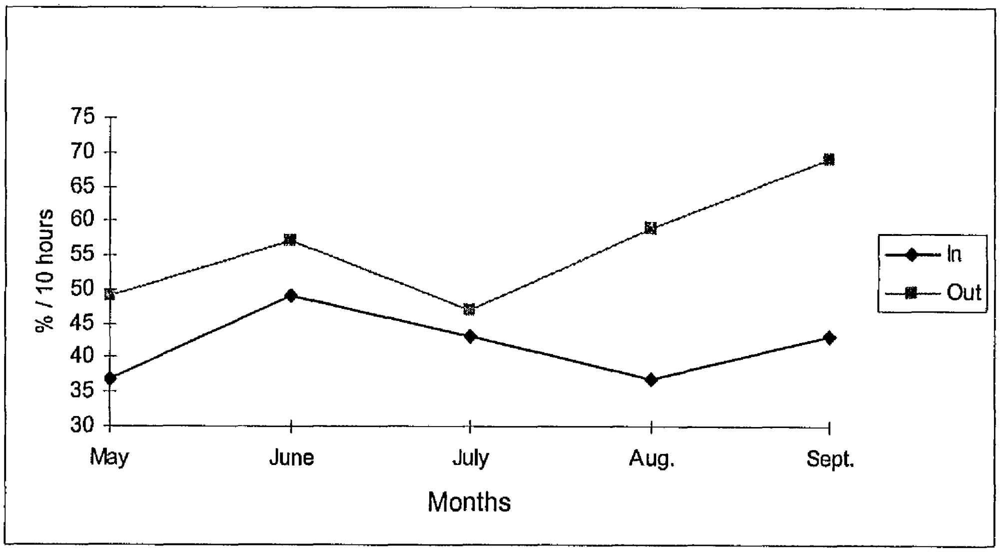



*Figure 2.3 Eating and grazing behaviour (% of ten hours)*

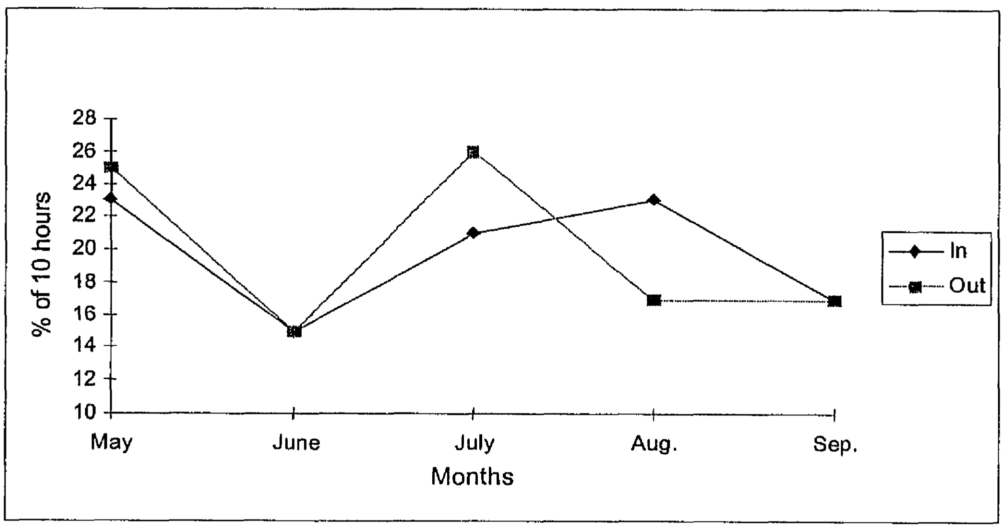



*Figure 2.4 Ruminating lying behaviour (% of ten hours)*

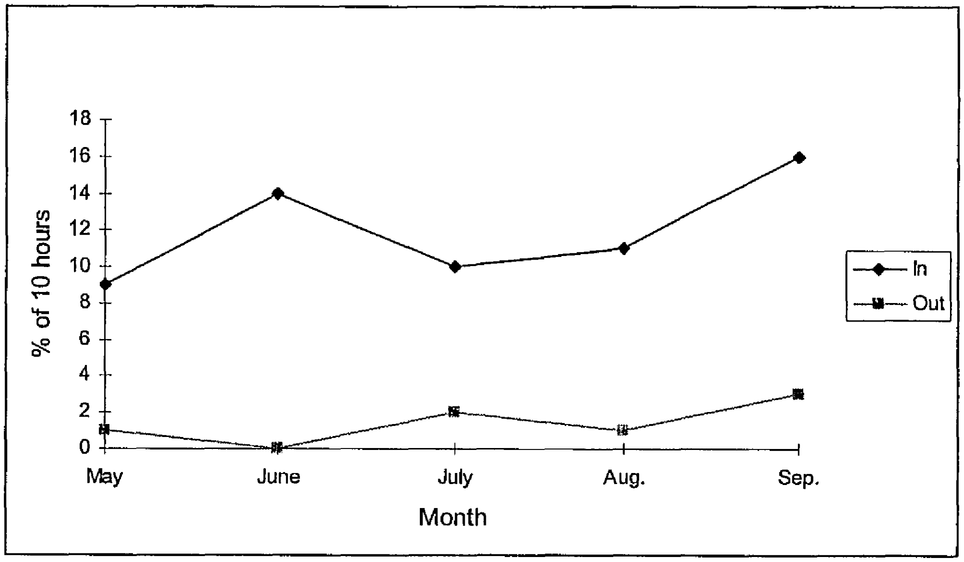



*Figure 2.5 Ruminating standing behaviour (% of ten hours)*

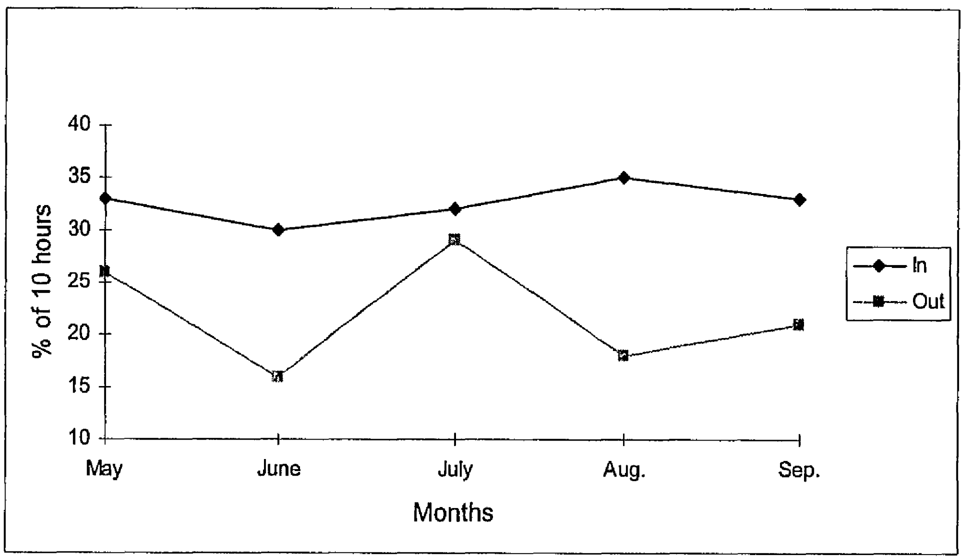



*Figure 2.6 Total ruminating behaviour (% of ten hours)*

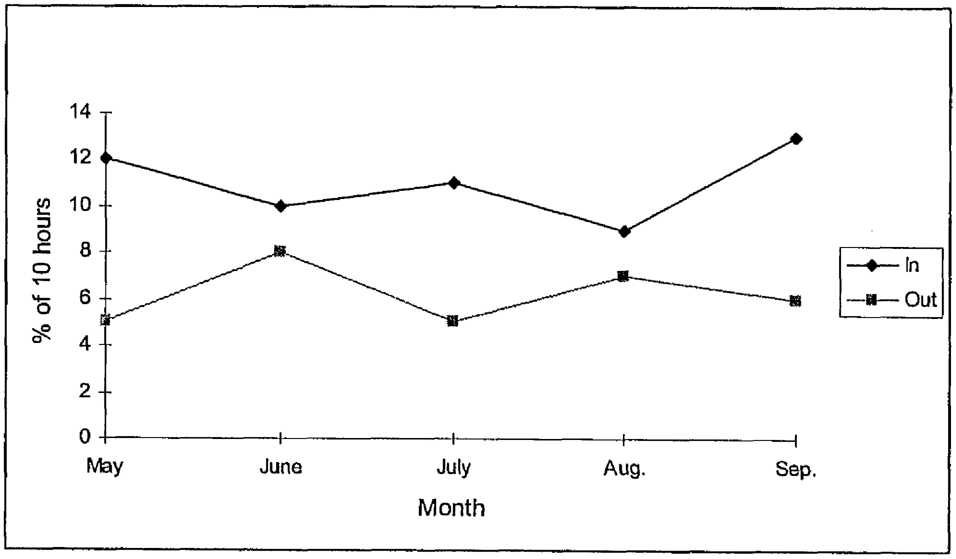



*Figure 2.7 Idling standing behaviour (% of ten hours)*

## 2.5 *DISCUSSION*

### 2.5.1 Animal performance

In this first experiment milk production did not differ between treatments indoors (24 l/d) and outdoor (25 l/d) (Figure 2.1). Milk composition differed between animals on different management systems. Cows on the indoor treatment (housed) produced significantly ($p<0.001$) more milk fat (4.37%) than the outdoor treatment (3.64%) at pasture. However, milk from the indoor treatment contained significantly less protein ($p<0.001$) than the outdoor treatment, 3.06% and 3.38% respectively (Table 8). Butterfat content of milk traditionally falls in the UK when cows are eating lush spring grass because of its low fibre content; however, butterfat increases with the addition of long fibre to the diet in the form of hay, silage or straw. Milk protein also may fall after a period of inadequate energy intake, in parallel with a drop in condition score, but a fall in milk quality by high yielding cows may simply be a dilution factor (Kelly, 2000). Somatic cells present (000/ml) in milk were significantly lower ($p<0.05$) for the indoor treatment (177/ml) compared to the outdoor treatment (297/ml) (Table 9). Metcalf (1998) demonstrated by comparing cows from different housing systems (cubicles & straw yards), that there is no relation between somatic cell counts and the cows' cleanliness. However, only heifers were used in that former report. The results in this experiment are therefore similar when the indoors treatment which appeared to be significantly dirtier ($p<0.001$) (Table 9) were expected to present higher somatic cell counts in milk. According to the milk statement monthly reports from the Nestlé Dalston Factory Average (1999) somatic cell counts (SCC 000/ml) were low (172/ml) compared to the outdoor treatment (297/ml) but slightly closer to the results from the indoor treatment (177/ml). Total bacteria counts (TBC 000/ml) also was higher (91/ml) than the Factory average than treatments indoors (25/ml) and outdoor (19/ml) (Table 26). The Dalston Factory results are, however, from milk collections during the summer period, where the majority of farm animals were under outdoor management systems. Live weight and condition scores increased for both treatments towards the end of the experiment (Table 10) as most of the cows were at final stage of lactation. However, DM intake, silage and concentrate decreased for both treatments (Table 12) and swards heights increased up to 12 cm in the last month for the group at pasture (Figure 2.2) and milk yields dropped at the same time (Table 8). Despite this trend, cows from the indoor treatment showed higher liveweights (601 kg), significantly higher ($p<0.001$) than those in the outdoor treatment (583 kg). Condition scores also differed ($p<0.001$) and were lower for indoor treatment. A condition score point equates to a loss of 30-50 kg body weight depending on breed type (Kelly, 2000), which disagrees with both liveweight and condition score results between treatments in this experiment. However, the established method of condition scoring by Mulvany (1977) may sometimes be a very subjective technique, and may have been in this particular case, where each group was condition scored by a different person. Although height of cows was not measured, it is possible that cows from the indoor group were also taller and thinner, which might explain not only the difference of liveweights between groups but also in condition score.

**Table 26 Comparison of experimental group with Nestle Dalston factory average**

| | May | June | July | Aug | Sept | Average |
|---|---|---|---|---|---|---|
| **Bactoscan** | | | | | | |
| Factory average | 107,461 | 64,175 | 45,083 | 114,547 | 127,099 | 91,673 |
| Indoors treatment | 18,000 | 32,000 | 24,000 | 28,000 | 26,000 | 25,600 |
| Outdoors treatment | 14,750 | 11,000 | 14,000 | 39,000 | 19,666 | 19,683 |
| **Cell Count** | | | | | | |
| Factory average | 164,093 | 176,583 | 182,486 | 175,844 | 163,185 | 172,438 |
| Indoors treatment | 71,000 | 253,000 | 268,000 | 168,000 | 124,000 | 177,000 |
| Outdoors treatment | 429,000 | 224,000 | 330,000 | 205,000 | 299,000 | 297,000 |

### 2.5.2 Animal health

The sudden change from grazing on relatively soft pasture to cubicle house accommodation with hard concrete floors has been associated with the development of laminitis in dairy cows (Bergsten, 1995). In this experiment the measurement of lameness based on the scoring of cows for their locomotion (Manson and Leaver, 1988a) showed no difference in the incidence and prevalence of lameness between groups (Table 14 and Table 15). Nevertheless, the mean locomotion score was significantly different ($p<0.01$) in cows scored 3 or more (clinically lame), higher for the indoor cows (1.92) than for the outdoor animals (1.78) (Table 13). Lameness can have a serious effect on the productivity of dairy cows because of associated behavioural changes (Hassall *et al*, 1993). In this experiment, milk performance between lame cows from individual treatments compared with those not affected by lameness was not evaluated, but milk yields from the indoor treatment (which presented more cases of lame cows) did not differ from the outdoor treatment. Fertility records (Table 17) showed that 70% of the cows became pregnant during the experiment for the indoor group compared to 77% for the outdoor group. From the indoor group 57% of the cows became pregnant at first service compared to 70% from the outdoor treatment. Services per conception were higher for the indoor treatment (2.2) than for the outdoor treatment (1.9). Interval days from calving to first service were the same for both treatments (91 days) but interval days from calving to conception were slightly more for the outdoor group (101 days) compared to the indoor group (98 days). None of these differences were significant, which differs from those reported by Collick *et al* (1989), who found that lameness in all periods up to 120 days after calving were significantly associated with the increase of intervals from calving to conception compared to the control group. They also observed that sole ulceration cases between the period of 71 to 120 days after calving were significantly associated ($p<0.05$) with the increase of 11 days interval from

calving to first service for lame cows and that more services per conception were required. The number of days to first service for these cows was influenced by the management system of not serving cows until six weeks after calving. However fertility records were not significant between treatments (Table 17), therefore results from this experiment can not consider reproduction in terms of fertility affected by lameness. Health results also demonstrated that cases of clinical mastitis affected only a small number of animals in each herd. Thus the percentage prevalence of mastitis did not have a significant impact between treatments, although subclinical infection high (SCC) was more common in the outdoor treatment. Milk samples were taken and analysed at the laboratory where *Staphylococcus aureus* bacteria was found. In many countries *S aureus* has been reported to be the most common cause of subclinical infection but not necessarily of clinical mastitis. However, it is a very persistent infection, frequently lasting for several months and even years (Frank *et al*, 2000). These analyses were made some months after the experiment was concluded from cows reported as clinically infected.

### 2.5.3 Animal behaviour

The indoor management system during the winter drastically changes the environmental conditions for the animals and introduces problems of behavioural adaptation, which may be different from the adaptation process that occurs at pastures (Metz and Wierenga, 1986). The feeding patterns were different from the indoor group compared with those observed from the outdoor group at pasture. During observation cows from the outdoor group were seen to graze at the same time, but this was different from the indoor group, when only during the mornings, after silage was offered, all animals were seen at the trough eating at the same time. This agrees with the work by Miller and Gush 1991, who observed that with an indoor group the only time when any degree of synchrony in feeding was seen was when fresh food was given in the mornings. The relative form in which food could be obtained and ingested may explain the decrease in feeding time for the indoors treatment compared to the outdoor treatment, 42% and 56% respectively (Table 18 and Figure 2.3). Thus, the total time spent feeding was greater at pasture than indoors ($p<0.001$). Conserved forages are more fibrous than most grazed herbage or concentrate and these are usually chewed for a long period, during eating and ruminating (Phillips, 1993). In this experiment the total ruminating time between treatments was higher for the indoors (32%) than the outdoors treatment (22%) (Table 21 and Figure 2.6). This was significant ($p<0.001$). This results agreed with those found by Singh, Ward, Lautenbach, Hughes and Murray (1993). However, O'Connell *et al* (1989), found the overall ruminating time was not different between cows at pasture and winter housed animals fed silage. But in their experiment the housed cows were dry when observed, requiring a much lower feed intake than lactating animals which have higher feed intakes and therefore need more ruminating time. They also found during the daylight hours more rumination activity ($p<0.005$) for housed animals, and more rumination activity ($p<0.005$) during the night in cows at pasture. However in our experiment behaviour observations took place during daylight and only for ten hours, because most of the observations were made by only one person. It is possible that if observations were made also during the night, the overall rumination time would have been different between treatments, as for cows at pastures the majority of rumination activity takes place during the night when they are relatively safe (Phillips 1993). The ruminating activity was also observed to be more synchronised at pasture, as all cows usually ruminated while lying down. However, the time spent ruminating and lying over the observations period did not differ between treatments, 19% and 20% of time respectively (Table 19 and Figure 2.4). The surprising results appeared to be that ruminating behaviour could be modified or influenced by the difference of environments at pasture and housing

systems. Thus, the results showed that the indoors treatment spent significantly ($p<0.001$) more time ruminating standing (12%) compared to the outdoors treatment (1%) (Table 20 and Figure 2.5). As in the study by Singh, Ward, Lautenbach, Hughes and Murray (1993) first lactation and adult cows spent significantly longer time ruminating and lying and less time ruminating and standing at pasture than when observation were made indoors. This correlation between ruminating and lying down, can be construed as a normal behaviour pattern. However, rumination can and does occur while animals are standing or walking slowly, especially when housed (O'Connell *et al*, 1989). It is also recognised that only healthy and unstressed cattle will ruminate as a sign of contentment and that lying is also important for rest, predator avoidance and association (Phillips 1993). Thus, cubicle housing may then alter the overall behavioural pattern or the ingested food might have required further rumination and cows would have continue ruminating after a lying period. Metz and Wierenga (1986) demonstrated that when lying time was prevented, cows were still able to maintain their mean daily lying time by compensating with specific lying time in the afternoon and early evening. In this experiment the total lying time did not differ between treatments, 32% indoors and 32% outdoors (Table 23). However, Singh, Ward, Lautenbach, Hughes and Murray (1993) found by observations made over 24 hours that first lactation and adult cows lie down for longer at pasture than when housed. They suggested that while indoors some animals were dominant and, because the availability of space at pasture, outdoor cows were free to lie anywhere and at considerable distances from each other. It is also important to mention that cubicle dimensions used by the indoor group were 2.03 m long and 1.13 m wide and cows liveweight was 601 kg on average. The recommended cubicle dimensions for 590-725 kg (LW) Holstein cows, to avoid cubicle refusal and prevent injuries, is 2.3-2.44 m in length and 1.22 m in width (McFarland and Gamroth 1994), so it is possible that the indoor cows in this study were not very comfortable lying down in cubicles. The time idling while lying did not differ between treatments (Table 22), but during housing the indoor cows spent significantly ($p<0.001$) more time idling standing (11% of the time observed) than the outdoors treatment (6% of the time observed) at pasture (Table 24 and Figure 2.7). It may be suggested that during housing cows had extra 'spare' time when some behaviour, such as grazing or the need to seek food, was not necessary and therefore eating time may also be reduced.

### 2.5.4 Financial performance

Milk value and feed costs are presented in Table 27. Milk sales average overall was 18.4 ppl for the indoors treatment and 18.0 ppl for the outdoor treatment. There was a difference of 1.71 ppl in margin over concentrate (MOC) between the indoor and outdoor treatments. The outdoor cows also produced milk with a higher margin over all feed compared to that of the indoor cows. The pricing used to calculate milk and feed costs are shown in Table 28. Milk and financial performance were also compared to 15 dairy farms over Scotland which were recorded in SAC Milk Manager 1999-2000 (Goldie, 2000). These farms sold their milk to different milk purchasers, and therefore the average price for their milk is recorded, which has not been based on one particular pricing structure. The SAC Milk Manager data were taken from reports over the period from May to September 1999. The majority of the reported farms were under outdoor management systems at that period of time, with calving period all year round. These results are shown in Table 29. The milk yield and composition average from the Milk Manager reports were 20 l/cow/d with butterfat content of 3.91% and protein content of 3.38%. Production of the indoor and outdoor cows on this study were 24 l/cow/d with 4.37% fat and 3.06 % protein, and 25 l/cow/d with 3.64% fat and 3.38% protein, respectively. The difference in butterfat concentration between the SAC Milk Manager average and the outdoors experimental

treatment resulted in a greater MOC in the Milk Manager figures. With a concentration of 3.91% and 3.64% respectively for Milk Manager and outdoors treatment, the difference in payment for butterfat was 0.56ppl (based on the Nestle payment rate). Although slightly more concentrate was used per kilogram of milk produced, the value of this was less than 0.56p. The Forage Value (milk production possible after maintenance, expressed as kg milk, assuming 5.2MJ/kg milk) and concentrate usage (kg/l) were also compared.

**Table 27 Milk value and feed costs[1]**

| | |
|---|---|
| **Milk** | |
| Fat | 1.95 p |
| Protein | 3.23 p |
| | |
| **Feed** | |
| Concentrate | 14 p/kg DM |
| Silage | 10 p/kg DM |
| Grass | 3.5 p/kg DM |

[1] Feed costs based on actual concentrate price of £140/t, silage production cost of £100/t DM and grass production cost of £35/t DM

**Table 28 Margin over feed (MOF)**

| | In | Out |
|---|---|---|
| Milk price (p/l) | 18.41 | 18.02 |
| Concentrate costs (p/l) | 3.5 | 1.4 |
| MOC (p/l) | 14.91 | 16.62 |
| Silage (p/l) | 5.42 | 0.8 |
| Grass (p/l) | | 1.90 |
| **MOF (p/l)** | **9.49** | **13.92** |

| Table 29 Comparison of experimental groups with SAC Milk Manager costed farms | | | | | | |
|---|---|---|---|---|---|---|
| | May | June | July | Aug | Sept | Mean |
| **Average milk yield (kg/d)** | | | | | | |
| Milk Manager | 22 | 20 | 19 | 20 | 20 | 20 |
| Indoors treatment | 32 | 27 | 22 | 21 | 18 | 24 |
| Outdoors treatment | 31 | 29 | 26 | 23 | 17 | 25 |
| **Forage Value (M+ kg milk/day)** | | | | | | |
| Milk Manager | 17 | 15 | 14 | 13 | 10 | 14 |
| Indoors treatment | 13 | 11 | 7 | 8 | 9 | 10 |
| Outdoors treatment | 21 | 20 | 20 | 19 | 13 | 19 |
| **Butterfat (%)** | | | | | | |
| Milk Manager | 3.88 | 3.89 | 3.88 | 3.89 | 3.99 | 3.91 |
| Indoors treatment | 4.18 | 4.30 | 4.03 | 4.42 | 4.93 | 4.37 |
| Outdoors treatment | 3.44 | 3.38 | 3.56 | 3.5 | 4.31 | 3.64 |
| **Protein (%)** | | | | | | |
| Milk Manager | 3.33 | 3.37 | 3.37 | 3.39 | 3.43 | 3.38 |
| Indoors treatment | 2.88 | 2.87 | 2.91 | 3.22 | 3.42 | 3.06 |
| Outdoors treatment | 3.31 | 3.31 | 3.31 | 3.41 | 3.56 | 3.38 |
| **Conc. Use (kg/l)** | | | | | | |
| Milk Manager | 0.11 | 0.09 | 0.08 | 0.09 | 0.26 | 0.13 |
| Indoors treatment | 0.24 | 0.25 | 0.27 | 0.26 | 0.23 | 0.25 |
| Outdoors treatment | 0.11 | 0.12 | 0.08 | 0.07 | 0.09 | 0.09 |
| **MOC (p/l)** | | | | | | |
| Milk Manager | 15.47 | 13.86 | 17.97 | 18.42 | 18.20 | 16.78 |
| Indoors treatment | 14.10 | 14.20 | 13.48 | 15.33 | 17.49 | 14.9 |
| Outdoors treatment | 15.76 | 15.56 | 16.50 | 16.88 | 18.63 | 16.7 |

Overall conclusions are contained in the Conclusions section on Page 97.

# CHAPTER 3 EXPERIMENT 2 (September to October 1999)

## 3.1 *INTRODUCTION*

Experiment 1 compared the difference in the performance, health and behaviour of two groups of cows while they were kept under Indoor or Outdoor management systems during the summer period (May - September).

Experiment 2 evaluated and compared the same two groups of dairy cows and the effect of the Indoors and Outdoors environments upon their performance, health and behaviour during the transition, of the outside group, from outdoor to indoor. It also evaluated and compared the changes in the performance, health and behaviour of the Outdoors group over their transition from pasture (outdoors) into their winter housing (indoors) system. This made possible to confirm whether or not the environment had an effect on the two groups of cows, as the outdoors group was still grazing for a short period in the mornings.

Experiment 2 also compares similarities and differences with the other group of cows (indoors) while they both (Outdoors and Indoors) were under the same environment while Indoors Management System.

## 3.2 *MATERIALS AND METHODS*

### 3.2.1 Animals

This experiment was carried out during late summer period from September to October 1999. During this period two groups of twenty-eight Friesian Holstein spring calving cows were used for the comparison of their production, health and behaviour. One group of 28 cows were indoors in the cubicle system while the other group of 28 cows were outdoors grazing during the first month of the experiment study. During the second month the outdoors treatment cows were allowed to graze only for two hours (08.00 to 10.00 h am) during the mornings then housed in the cubicle system where they remained the rest of the day. The cubicle houses in which each treatment group were kept were in different and separate areas within the same farm (Main Steading and Acrehead Unit 1). Each of the both groups belonged to a main milking herd of 48 and 69 spring calving cows respectively, in which they remained during the experimental study. Cows between the indoors and outdoors treatments were allocated to 14 blocks of 2 cows on the basis of similarity in milk yield, calving date and lactation number. Twenty cows chosen at random allocated within blocks were used for the behavioural observations only.

The mean parity between treatments was 3 and their calving dates ranged from January $26^{th}$ to April $8^{th}$. The initial mean milk yield and liveweight were 21.26 l/d, 618 kg and 22.81 l/d, 586 kg respectively.

### 3.2.2 Indoors

For a detailed description of the management of the indoor cows, see Chapter 2, section 2.3.2. The management was the same in Experiment 1 and Experiment 2.

### 3.2.3 Outdoors

During the first month of Experiment 2 the outdoor treatment was at pasture grazing on eight differents fields (set-stocking system), each of which which they spent 3 to 4 four days grazing. The fields ranged in area from 3.75 to 9.9 ha. The stocking rate varied between each of the grazing fields, with a mean of 9 cows/ha. The sward heights were maintained at average height of 10.7 cm. From October $10^{th}$ cows were increasingly brought indoors, grazing time was reduced and they were allowed only two hours of strip-grazing (08.00 to 10.00 am) after the morning milking. The cubicle system was on a concrete floor with automatic scraping every hour. The cubicles were of the "Newton Rigg" type . The cubicle dimensions were 2.01 m x 1.18 m. Each cow had access to one cubicle. Cubicles were bedded twice weekly with sawdust. Cows were milked at 05.00 and 15.00 h daily. Forage silage was offered *ad libitum* while they were indoors. Silage was fed on the feeding track before the cows were brought from the field to the cubicle house. A daily ration of concentrate was offered in the parlour. One water trough was available in each field and cows, while at pasture, were free to drink water at any time. Water was also available in the cubicle area. Forage silage and concentrate intakes were recorded every month.

### 3.2.4 Animal performance

Milk yields for individual cows for each treatment were recorded monthly and samples were taken for fat, protein and somatic cell count analysis. Liveweight and condition score were recorded every two weeks for each cow after the second milking of the day. Cleanliness was also scored monthly for individual cow for each treatment and it was assessed by the amount of dung present in allocated areas, as the hooves, lower legs and hind underbelly. Cleanliness scores were from 0 for a very clean animal up to 3 for a very dirty animal (Scott and Kelly 1989).

### 3.2.5 Animal Health

Percentage prevalence of mastitis was recorded monthly for each treatment. Cows for both indoors and outdoors treatments were in mid-late lactation and groups were 70 and 77 % pregnant respectively.

### 3.2.6 Locomotion scoring

Individual animals in each treatment were scored every two weeks for locomotion. The scores were taken as assessment from 1 to normal condition, 3 clinical lame and 5 severely lame animal (Manson and Leaver 1988 a) . The % prevalence and incidence cases of lame cows were also recorded for each treatment.

### 3.2.7 Sward Measurements

During the first and second month sward heights were measured weekly using the sward stick by taking no less than fifty measurements including grazed and rejected areas and avoiding gateways and around water troughs, walking in a "W" pattern over each treatment field.

### 3.2.8 Behavioural observations

Observations were made in each of the two months for individual cow for each treatment group one day at the time respectively. Each observation was recorded from 08.00 am to 14.00 pm and from 17.00 to 21.00 hours pm, except for the hours during the milking period, thus a total of ten hours during each observation. During the first month treatment outdoors was observed at pasture while it was still 24 hours grazing and indoors treatment was observed at the cubicle house. The second observation (October) for treatment outdoors was made when they started grazing the first two hours of the day outdoors (pasture) and then the observation continued after they were brought into the cubicle house. At this time behaviour differences for both treatments were first observed while they both were at the same management system (indoors) and the gradual environmental changes from summer grazing into the winter housing system upon the behaviour for the outdoors treatment was also evaluated. Cows in each treatment were observed once every house. At this time behaviour differences for both treatments were first observed while they both were at the same management system (indoors) and the gradual environmental changes from summer grazing into the winter housing system upon the behaviour for the outdoors treatment was also evaluated. Cows in each treatment were observed once every 5 minutes and a record made if they were grazing, ruminating/standing, ruminating/lying, drinking, nothing/standing and nothing/lying. All the cows had large white numbers painted on their sides to aid identification . All the behaviour results were calculated as a percentage of the recording hours.

### 3.2.9 Statistical analysis

The milk yield, composition and the results for animal performance and health, locomotion score, incidence of lameness, live weight, condition score, cleanliness and behavioural observation data were analysed using Analysis of Variance (Genstat 4), this program statistically analysed the difference between animals group, time and interaction between treatments (month/group). % prevalence of mastitis and prevalence of lameness were analysed by Chi-square test.

## 3.3 *RESULTS*

### 3.3.1 Animal performance

The mean milk yields are presented in Table 30 and Figure 3.1 and showed no difference between treatments (as in Experiment 1). However, in this second experiment at the end of the summer period, I/I treatment showed slightly higher milk yields than the O/I treatment, with means of 15.9 l/d and 15.0 l/d respectively. Content of butterfat and milk protein results are also presented in Table 30. Percentage of butterfat did not differ significantly between treatments, although the interaction group/month was significant in that the O/I treatment fat content increased markedly from September to October (Table 8).

Both groups showed an increase in protein content during Experiment 2 compared to Experiment 1. The O/I group had a significantly higher milk protein content than the I/I group, as it also had in Experiment 1.

The O/I group had a higher SCC ($p<0.001$) than the I/I group, and there was a marked increase in SCC for the O/I animals after housing, as shown in Table 31.

**Table 30** **Milk yield and composition**

| Group | Sep | Oct | Mean | s.e.d. Group | | group/month | |
|---|---|---|---|---|---|---|---|
| **Milk Yield** | | | | | | | |
| I/I | 17.7 | 14.1 | 15.9 | 0.79 | NS | 1.11 | NS |
| O/I | 16.9 | 13.0 | 15.0 | | | | |
| *Butterfat content (%)* | | | | | | | |
| I/I | 4.93 | 4.94 | 4.94 | 0.13 | NS | 0.19 | *** |
| O/I | 4.31 | 5.26 | 4.78 | | | | |
| *Protein content (%)* | | | | | | | |
| I/I | 3.42 | 3.53 | 3.47 | 0.05 | ** | 0.07 | NS |
| O/I | 3.56 | 3.67 | 3.61 | | | | |

**p<0.01 ***p<0.001

| Table 31 Somatic cell counts | | | | | | | |
|---|---|---|---|---|---|---|---|
| Group | Sep. | Oct. | Mean | s.e.d. Group | | group/month | |
| I/I | 124 | 197 | 160 | 67.90 | *** | 96.00 | NS |
| O/I | 299 | 448 | 373 | | | | |
| ***p<0.001 | | | | | | | |

### 3.3.2 Liveweight and condition score

Mean liveweight and condition score results are presented in Table 32. This results were significantly different between treatments (p<0.05). O/I treatment slightly increased in liveweight mean (618 kg) on the last month of the experiment. However I/I treatment showed higher liveweight (kg) means over the two months of the experiment. These results appeared to be similar to those in Experiment 1 (Table 10). Although liveweight means have been higher for I/I treatment over the two experiments, in comparison to O/I treatment they both tended to increase towards the end of both experiments with the highest liveweight means in the last month of Experiment 2, of 627 kg (I/I) and 618 kg (O/I). Condition score means were higher for O/I treatment compared to I/I treatment. This result was significant (p<0.01); however, over the two months of Experiment 2 and also over the five months on Experiment 1 (Table 10), I/I treatment showed slightly poorer condition score compared to O/I treatment, with a tendency to improve as Experiment 1 and 2 progressed. Mean cleanliness scores are shown in Table 33. The I/I treatment showed higher cleanliness scores than O/I treatment (p<0.01). Although the results shown in Experiment 1 (Table 11) are very similar in relation to the difference in cleanliness between I/I and O/I treatment, when they were both evaluated at housing and pasture respectively in the first month of this second experiment, as in the last three months of Experiment 1, the score became very close (2.17 and 2.16 respectively) when both

treatments were evaluated indoors in the second month of Experiment 2 (Interaction p<0.01). Cleanliness results from Experiments 1 and 2 are shown in Figure 3.2.

**Table 32 Liveweight (kg) and condition score (units)**

| Group | Sep | Oct | Mean | s.e.d. Group | | group/month | |
|---|---|---|---|---|---|---|---|
| **Liveweight** | | | | | | | |
| I/I | 622 | 627 | 625 | 9.73 | * | 13.76 | NS |
| O/I | 590 | 618 | 604 | | | | |
| **Condition score** | | | | | | | |
| I/I | 2.01 | 2.06 | 2.03 | 0.08 | ** | 0.11 | NS |
| O/I | 2.25 | 2.21 | 2.23 | | | | |

* p<0.05 **p<0.01

**Table 33 Cleanliness score**

| Group | Sep. | Oct | Mean | s.e.d. Group | | Group/month | |
|---|---|---|---|---|---|---|---|
| I/I | 2.25 | 2.17 | 2.21 | 0.12 | ** | 0.17 | ** |
| O/I | 1.63 | 2.16 | 1.89 | | | | |

**p<0.01

### 3.3.3 Feed intake

The mean feed intakes are shown in Table 34. The forage silage intakes for I/I treatment range were from 11 to 13 kg DM/d and 8 kg DM/d for O/I treatment on the second month of the experiment. Concentrates intakes for I/I treatment were from 3.4 to 3 kg DM/d and 1 to 0.9 kg DM/d for O/I treatment. Grass height measurements are shown in Figure 3.3. The height of treatment O/I grazed grass ranged from 8 cm to 20 cm.

**Table 34 Estimated daily dry matter intakes (kg/cow)†**

| Group | Sep | Oct |
|---|---|---|
| **Silage** | | |
| I/I | 11 | 13 |
| O/I | 0 | 8 |
| **Concentrate** | | |
| I/I | 3.4 | 3.0 |
| O/I | 1.0 | 0.9 |

†Cows on treatment O/I were also on extended grazing for 2 hours/day, with an estimated herbage intake of 2kg DM/cow (Roberts, personal communication).

### 3.3.4 Animal health

The mean locomotion scores are presented in Table 35. The results differed significantly higher for I/I treatment ($p<0.05$) compared to O/I treatment over the two months experiment. The results showed I/I treatment poorer in locomotion specially in the last month. However O/I treatment did not show a big change in locomotion when it was evaluated during the indoor period compared with the locomotion evaluation made outdoors in the first month. The lower locomotion scores results and therefore the healthier condition for the O/I treatment over the two months, were also seen in Experiment 1 (Table 13) although with lower scores at pasture. The observations recorded of cows scoring 3 (clinically lame) or more, over the 2 months in every two weeks represented an incidence of 46% (I/I) and 42% (O/I). These results are presented in Table 36 and were not significantly different. The number of lame cows in each month presented as the prevalence of lameness are shown in Table 37.

**Table 35 Locomotion score**

| Group | Sep. | Oct | Mean | s.e.d. Group | | Group/month | |
|---|---|---|---|---|---|---|---|
| I/I | 2.08 | 2.24 | 2.16 | 0.10 | * | 0.14 | NS |
| O/I | 1.92 | 1.95 | 1.93 | | | | |

*p<0.05

**Table 36 Percentage incidence cases of lameness**

| Group | | s.e.d. | Sig. |
|---|---|---|---|
| I/I | 46 | 0.16 | NS |
| O/I | 42 | | |

**Table 37 Percentage prevalence of lameness**

| Group | Sep. | Oct. | Sig. |
|---|---|---|---|
| I/I | 28.6 | 32.1 | NS |
| O/I | 25.0 | 25.0 | NS |

### 3.3.5 Clinical mastitis

Individual cases of clinical mastitis were recorded monthly. The results reported no clinical cases of mastitis.

### 3.3.6 Animal behaviour

Eating and grazing behaviour are present in Table 38. The proportion of time that the I/I treatment spent eating in the first month was less 43(%) compared to O/I treatment 69(%) grazing time. These results did not change from what occurred in Experiment 1 (Table 18). However, O/I treatment decreased on proportion of time spent eating a value similar to the I/I group when the cows had been housed. The results were significant (p<0.001). Figure 3.4 presents the eating and grazing behaviour from Experiment 2.

| Table 38 | Eating and grazing behaviour (% of ten hours) | | | | |
|---|---|---|---|---|---|
| Group | Sep | Oct | Mean | s.e.d Group | group/month |
| I/I | 43 | 39 | 41 | 0.02 *** | 0.03 *** |
| O/I | 69 | 34 | 51 | | |
| ***p<0.001 | | | | | |

### 3.3.7 Ruminating lying

The mean ruminating lying results are presented in Table 39. There were no significant differences. However both treatments tended to increase the proportion of time ruminating and lying in the last month during this second experiment. These results were also very close to each other in Experiment 1.

| Table 39 | Ruminating lying behaviour (% of ten hours) | | | | | | |
|---|---|---|---|---|---|---|---|
| Group | Sep | Oct | Mean | s.e.d Group | | group/month | |
| I/I | 17 | 23 | 20 | 0.03 | NS | 0.04 | NS |
| O/I | 17 | 27 | 22 | | | | |

### 3.3.8 Ruminating standing

The mean results are presented in Table 40. I/I treatment demonstrated a longer time of ruminating activity whilst standing than the O/I treatment in the month of September. The same behaviour and difference between treatments were seen in Experiment 1(Table 20 and Figure 2.5). However, during the second month, when both groups were observed in the indoor housing system, the proportion of time that the O/I treatment spent ruminating whilst standing became very close to that time spent by the I/I treatment, 8% (O/I) and 10% (I/I). I/I cows spent a significantly higher ($p<0.001$) proportion of time ruminating standing in the first month, which occurred also in the five months of Experiment 1. When both treatment were housed the mean times were slightly less for O/I treatment but very similar and the interaction between group and month was significantly different.

Cows in the O/I treatment group were also able, in the second month (October), to graze during the mornings (2 h) and therefore spend some time outdoors in which ruminating behaviour could be different. Ruminating standing data from Experiment 1 and Experiment 2 is also shown in Figure 3.6. The total ruminating time (Table 42) was also significant between treatment ($p<0.05$) and higher for I/I treatment on the first month, while indoors (housed) and O/I treatment at outdoors (pasture) as shown in Experiment 1 (Table 21). However mean times became similar, perhaps slightly higher for O/I treatment in October while at housing and being offered the same diet.

**Table 40 Ruminating standing behaviour (% of ten hours)**

| Group | Sep | Oct | Mean | s.e.d. Group | group/month |
|---|---|---|---|---|---|
| I/I | 16 | 10 | 13 | 0.01 *** | 0.02 ** |
| O/I | 3 | 8 | 5 | | |

**p<0.01, *** p<0.001

| Table 41 | Total ruminating behaviour (% of ten hours ) | | | | |
|---|---|---|---|---|---|
| Group | Sep | Oct | Mean | s.e.d. Group | group/month |
| I/I | 33 | 32 | 32 | 0.02 * | 0.03 *** |
| O/I | 21 | 34 | 27 | | |
| *p<0.05, ***p<0.001 | | | | | |

### 3.3.9 Idling lying

The time spent doing nothing (idling) when cows from both treatment were lying did not differ significantly between treatments (Table 43). Cow from both treatments tended to increase their proportion of time of idling while lying down in the last month (October) – 18% (I/I) and 17% (O/I). The results of idling lying were not constantly higher for any of the two treatments, however they varied between months. The same variation was shown in Experiment 1 (Table 22). The total lying time were not significantly different between treatments (Table 44) the same results as Experiment 1 (Table 23). However, both treatments spent a smaller proportion of time lying during September: 26% (I/I) and 21% (O/I) and increased their lying time in the last month to 40% (I/I) and 44% (O/I) while both sets of cows were indoors (housed).

| Table 42 | Idling lying behaviour (% of ten hours) | | | | |
|---|---|---|---|---|---|
| Group | Sep | Oct | Mean | s.e.d. Group | group/month |
| I/I | 10 | 18 | 13 | 0.01 NS | 0.02 NS |
| O/I | 3 | 17 | 10 | | |

| Table 43 | Total lying time behaviour (% of ten hours) | | | | |
|---|---|---|---|---|---|
| Group | Sep | Oct | Mean | s.e.d Group | group/month |
| I/I | 26 | 40 | 33 | 0.04 NS | 0.05 NS |
| O/I | 21 | 44 | 32 | | |

### 3.3.10 Idling standing

Cows from both treatments spent part of their time doing nothing standing (Idling). These results, shown in Table 44, were higher for I/I treatment in September (p<0.05), although when it was compared to O/I on the following month the proportion of time spent doing

nothing standing were similar between treatments, 10% and 10% respectively. In Experiment 1 the mean results were significantly higher for I/I treatment (Table 24) over the five months experiment but did not become as close when cows form both treatments were indoors (Experiment 2). The total standing time was not significant between treatments (Table 46) However, observations made in the second month reported a decrease in the total standing time for both treatments, 59% and 53% respectively, although the I/I group spent more time on total standing in the first month than in the following month, compared to O/I treatment. In Experiment 1 (Table 25) I/I treatment (indoors) spent more time standing than O/I treatment (outdoors), although results did not differ significantly between treatments.

**Table 44 Idling standing behaviour (% of ten hours)**

| Group | Sep | Oct | Mean | s.e.d. Group | Group/month |
|---|---|---|---|---|---|
| I/I | 13 | 10 | 11 | 0.01 * | 0.01 *** |
| O/I | 6 | 10 | 8 | | |

*p<0.05

**Table 45 Total standing behaviour (% of ten hours)**

| Group | Sep | Oct | Mean | s.e.d. *Group* | *Group/month* |
|---|---|---|---|---|---|
| I/I | 73 | 59 | 66 | 0.03 NS | 0.05 NS |
| O/I | 79 | 53 | 66 | | |

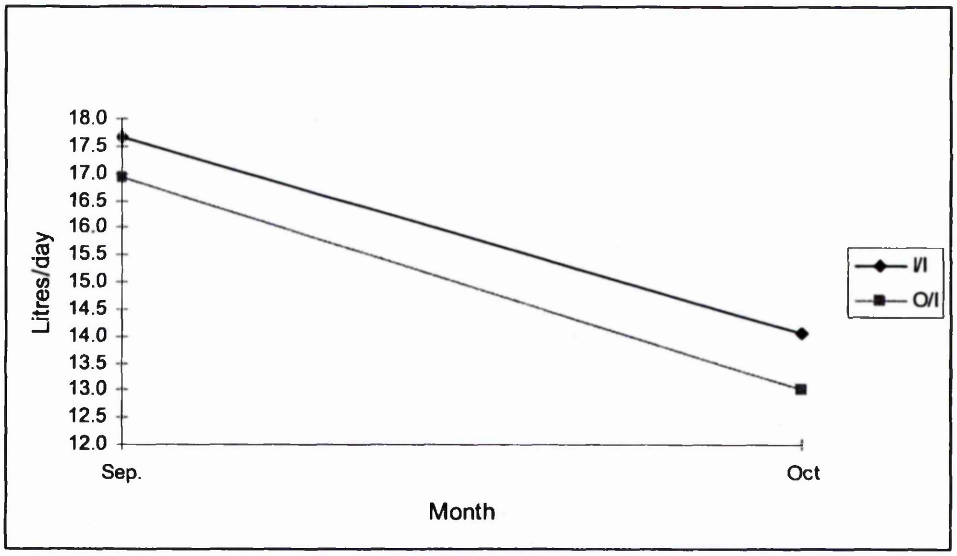



*Figure 3.1 Milk yield (litres/day)*

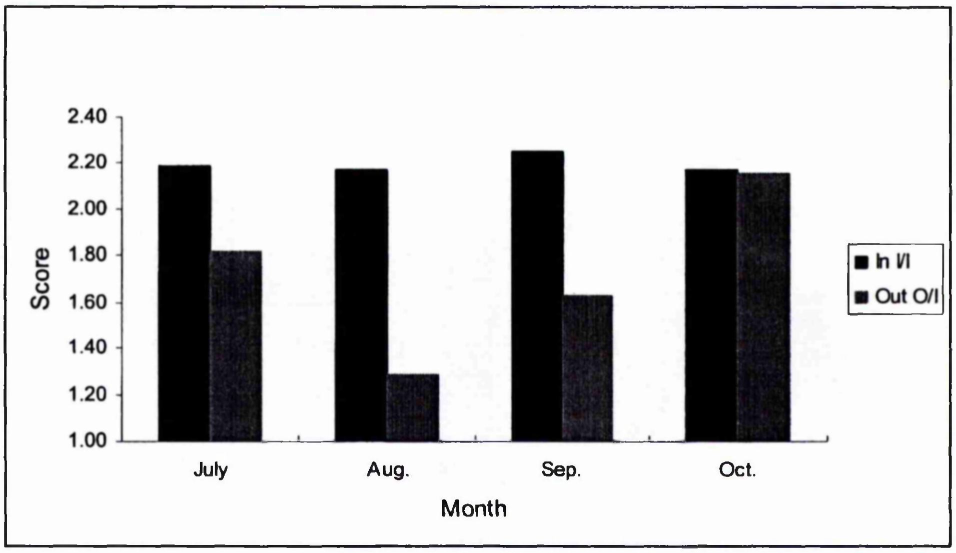



*Figure 3.2 Cleanliness scores, experiments 1 and 2*

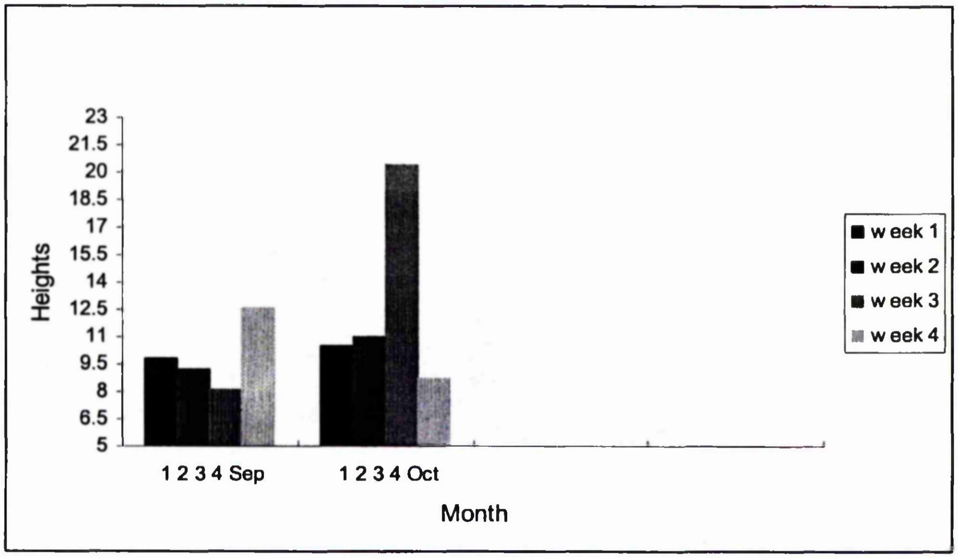



*Figure 3.3 Sward heights (cm)*

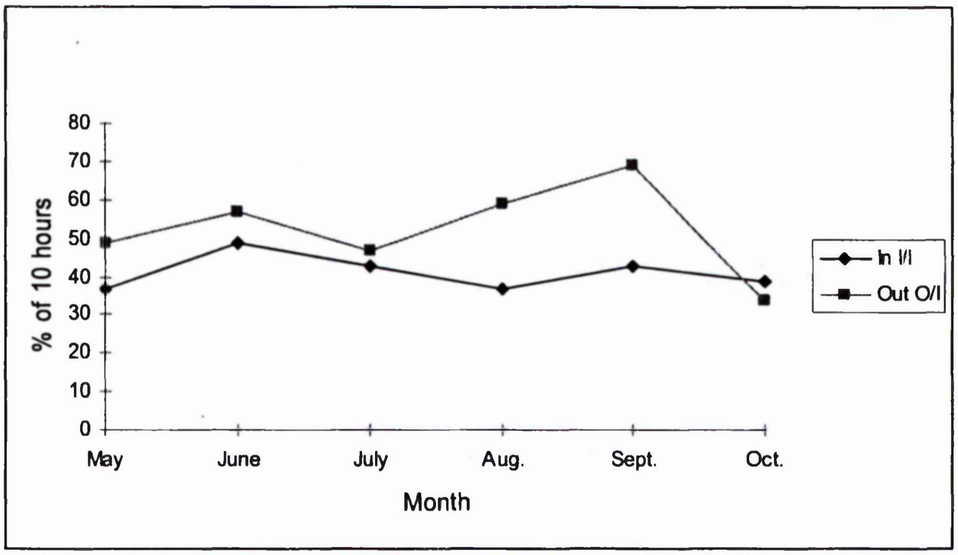



*Figure 3.4 Eating and grazing behaviour (% of 10 hours), experiments 1 and 2*

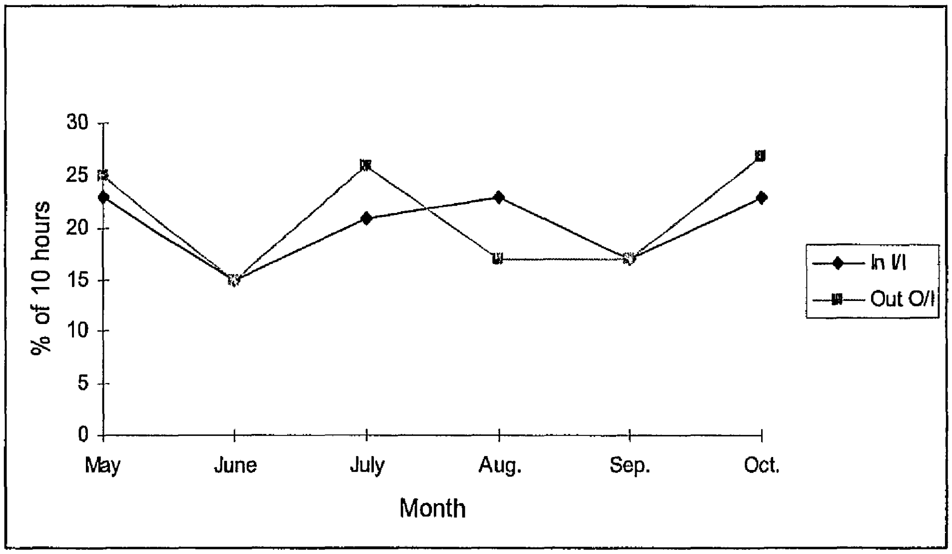



*Figure 3.5 Ruminating lying behaviour (% of ten hours), experiments 1 and 2*

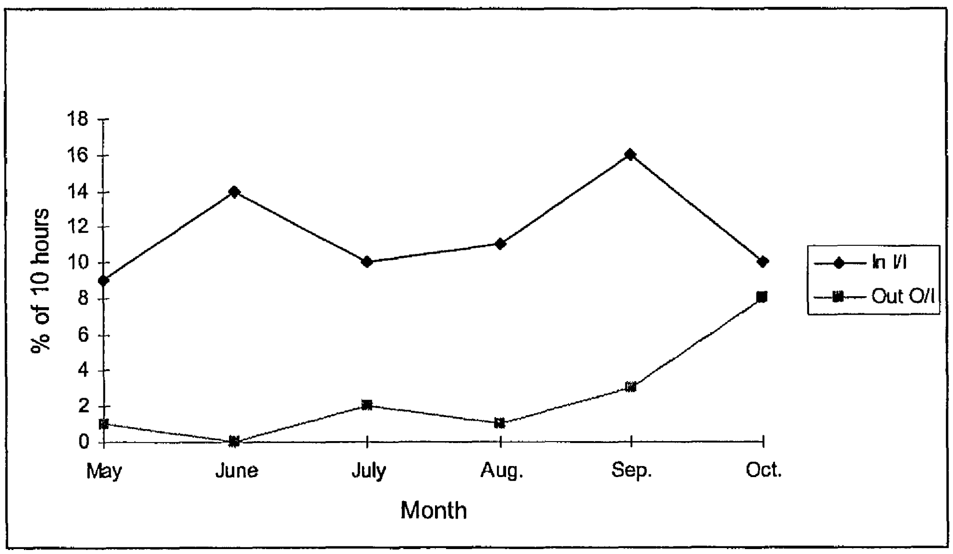



*Figure 3.6 Ruminating standing behaviour (% of ten hours), experiments 1 and 2*

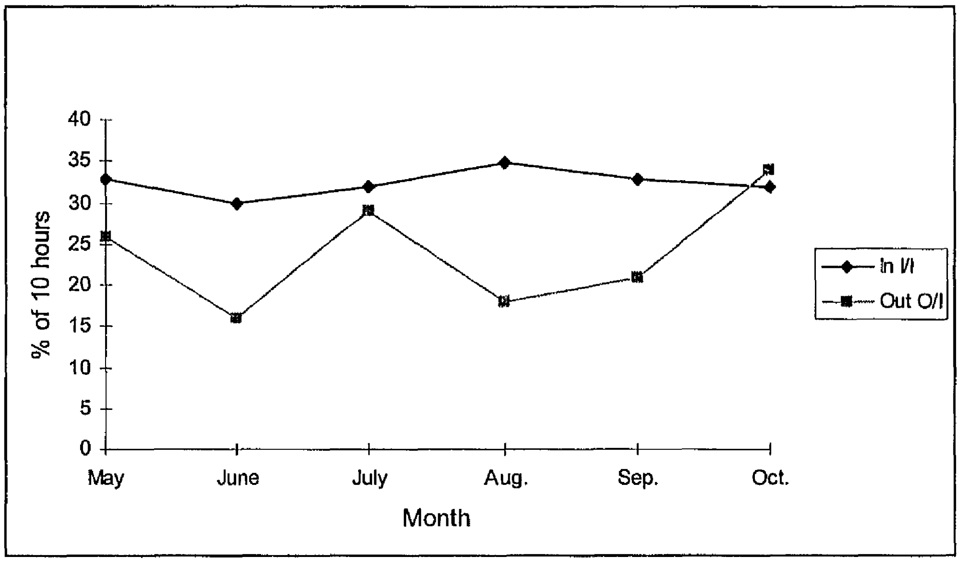



*Figure 3.7 Total ruminating behaviour (% of ten hours), experiments 1 and 2*

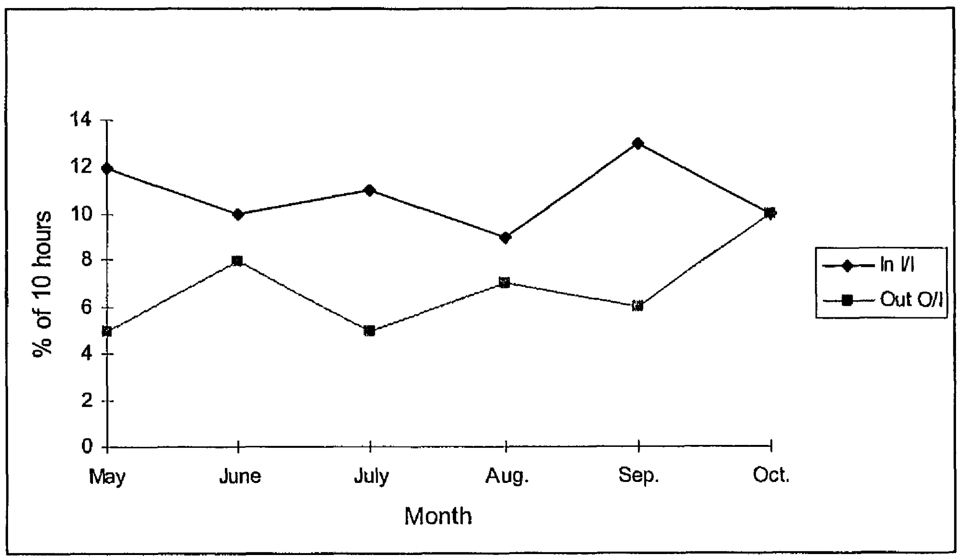



*Figure 3.8 Idling standing behaviour (% of ten hours), experiments 1 and 2*

## 3.4 *DISCUSSION*

In Experiment 2 when the outdoor group was introduced into the housing system (O/I) behavioural changes were also evaluated and compared to the indoor group (I/I) who had remained indoors since Experiment 1. The results demonstrated that some behaviour patterns do not change at all while others are easily changed as the cows try to adapt to their new environment (cubicle house). The main areas of discussion are based on the changes seen in the outdoor group between their last month outside (September) and after housing (October), and comparing this to the performance and behaviour of the I/I group which were housed all the time.

Feeding behaviour. The eating and grazing behaviour over the two months of the experiment was significantly different ($p<0.001$). This was mainly because during the month of September the O/I group spent more time grazing (69%) than the I/I group eating (43%). However, when observations were made (on 13th Oct), three days after the O/I group were brought into the cubicle house (10th Oct), the feeding time was reduced for the O/I group (34%) and was similar to the time that the I/I group spent eating (39%) (Table 38 and Figure 3.4). This is likely to be due to the different rate of intake for conserved feed compared to late summer grazing (Phillips, 1993).

The total ruminating time increased when the O/I group were housed. This is consistent with an increase in the fibre content of the diet. Cows under straw yard management have also been reported to ruminate longer when lying down compared to cows in cubicles (Singh, Ward, Lautenbach and Murray, 1993). It is possible that straw yards are seen by cows as small paddocks.

Ruminating behaviour of the O/I group also changed in that they began to spend more time ruminating while standing after being housed. While the ruminating and standing time had been much greater for the I/I group in September, there was a very small difference between groups in October, largely due to the O/I increase. Change of diet from a grass-based ration to a silage-based one may have been a contributing factor to this increase. Also, as their ruminating time increased, the O/I group might have had to spend some of their standing time in rumination.

Locomotion score did not change for either group between September and October, with the I/I group having the higher score in both months. The O/I treatment group may not have been exposed to indoor conditions which predispose to lameness (slurry, walking on hard surfaces) for long enough to increase their locomotion score in October, and this may be why no difference was seen for this group either in average locomotion score, or prevalence of lame cows, between September and October.

A marked increase in cleanliness score was noted for the O/I treatment animals after housing, suggesting that cows kept indoors are dirtier than cows outdoors. This is supported by the fact that the I/I group were dirtier than the O/I group throughout September, when only the I/I treatment cows were housed. Cleaner surroundings in a field, coupled with rainfall, predispose to cleaner animals than indoor conditions, where there is more slurry, even when this is scraped away regularly.

The increased agonistic interactions during the housing period are also associated with the reduced access to feeding track (O`Connell et al, 1989) and this may lead to lower feed intake by the subordinate animals. However, Experiment 2 has shown that by housing, the environment of cattle is drastically changed and that behaviour reactions are the most important expression of the animals and their interaction with environment (Metz and Wierenga, 1986). Therefore one of the major aims of successful management of cattle must be to reduce these differences in the indoor and outdoor management systems (O'Connell *et al*, 1989) in terms of animal welfare.

# CHAPTER 4 GENERAL DISCUSSION

## 4.1 *IMPLICATIONS FOR DAIRY MANAGEMENT SYSTEMS*

The differences in behaviour have been discussed in each experiment chapter. Therefore in this section the implications for dairy farmers will be discussed.

There were very few differences in the production levels between groups over the experimental periods, and feeding was not adjusted to manipulate milk yields. One of the reasons given for housing cows is that more control over their feeding will lead to more predictable milk yields; however, the results from this work would suggest that this is not the case. It may be that the weather conditions during 1999, and the grazing system operated, did not compromise the grass intake of the outdoor cows. The results may, however, have been different with higher yielding cows.

Milk constituents. Butterfat content was higher ($p<0.05$) throughout both experiments for the indoor cows (apart from October when the O/I treatment cows produced less milk of a higher fat content than the I/I group) and protein content higher ($p<0.05$)for the outdoor animals. Manipulating milk quality to enhance the milk price would be possible by using appropriate supplementary feeds when cows are at grass. Depending on the payment level for milk constituents this could also lead to an increase in margin over all feeds.

There would be merit in considering the reduction of outdoor cows' milk somatic cell counts, which were very high compared to the indoor group and the factory average,

throughout both experiments. This carries a cost implication to the farmer. The cause of the problem is the key – if a high bulk tank somatic cell count is caused by only a few cows with subclinical mastitis then culling them would help increase the value of the milk from the whole herd.

The margin over all feed for the cows was higher for the outdoor group (Experiment 1). This suggests that farmers would need to have reasons to house cows during the grazing season, other than purely financial. These may be related to the yield of the cows, or farm layout making grazing difficult.

With increased interest in cow health and welfare, farmers need to consider these from a financial point of view and in terms of image. The indoor group would give rise to greater concern, in terms of lameness and cleanliness, as they had a higher locomotion score and were dirtier, even although the housing system was of a high standard. The results from these experiments would suggest that farmers need to be concerned about these issues. A possible way to overcome these types of problems in indoor systems would be to allow cows access to an exercise paddock.

## 4.2 *FUTURE EXPERIMENTS*

In future, experiments should include 24 hour behavioural observations. This would give a better indication of cows' behaviour over the total day, but would demonstrate how their activity is distributed, leading to a better understanding of behaviour patterns under indoor and outdoor management systems.

Future research should also include a straw yard housing system as an extra treatment. Thus, behaviour responses would be compared between cows under three different management systems and the environmental influence on the animals' production and health would also be assessed. The 24 hour observations would provide a better understanding of the animals behaviour under normal conditions (pasture) but also the extra treatment under a different housed system would demonstrate which housing management (cubicles or straw yard) was more flexible for example in terms of animal welfare. It would be possible to decide to which system the cows most easily adapted and behaved as normal, as they do when at pasture. During the 24 hour behaviour watches, cows in the cubicle house may be expected to ruminate for longer, to lie down for less time and to ruminate less while lying down compared to the group at pasture (Singh, Ward, Lautenbach, Hughes and Murray 1993 ). However, cows in the straw yards may be expected to lie down for longer, to spent longer lying-ruminating but not to differ in eating and ruminating total time compared to cows in the cubicle house (Singh, Ward, Lautenbach and Murray1993).

It would also be an important study of behaviour adaptation to evaluate how quickly changes of behaviour take place after cows are introduced to the cubicle house from being managed at grass. This would involve continuous monitoring over a long period (possibly 14 days) before and after housing.

Other experiments that should be considered would involve different cubicle designs and housing layout. It may be possible to offer the same forage to indoor and outdoor animals (for example, by zero grazing), although this would not remove differences due to grazing compared to eating cut forage.

## 4.3 *CONCLUSIONS*

- Cows housed in cubicles spent the same amount of time lying down and more time ruminating compared to the cows outdoors. The indoor cows spent 12% of the 10 hour behaviour observation time standing and ruminating, whilst this behaviour only occurred for 1% of the time in the outdoor group.

- The cows which were outdoors and then housed reverted to similar behaviour patterns as the indoor group within one month of housing.

- During the two experiments milk production dropped as lactation progressed. However, milk yields were not different between treatments. Milk composition was related to the different regimes. The indoor cows produced higher levels of butterfat, while those outdoors produced milk of higher protein content.

- The outdoor group had a margin over all feed of 4.4 ppl greater than the indoor treatment. The forage provided M + 19 litres for the outdoor group and M + 10 litres for the indoor cows.

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