Doctoral Thesis

Study on the Holistic Assessment of Beef Cattle's Surroundings and the Methodology of Environmental Enrichment

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CHAPTER 1

Introduction

Intensification of beef production occurred in industrialized countries towards the end of 20th century, with the progress of agricultural technology leading to an increase in the production. Indoor fattening systems that provided cattle with conserved grass or dried cereal grain, or a mixture of the two, gradually replaced systems of fattening cattle on pasture with small amounts of supplementation. The fattening system also made it possible to give animals the opportunity to grow rapidly with feeding of high-quality diets. Housing cattle was largely to increase output through intensive feeding regimes, but also to reduce some costs by housing the cattle (Phillips, 2002a). Especially, European beef cattle husbandry has undergone many changes in the last 30 years in order to cope with economic pressures (Grignard et al., 2001).

However, the intensification of husbandry systems leads the farmers to rear their animals in free-stables or outdoors (Grignard et al., 2000). At this late date, the impact of the system on the animals' welfare is considered, so that it allows the products to have added value. In other words, most of consumers have come to choose the products from animals reared out of consideration of animals' welfare even if those are relatively expensive (Uetake, 2004). After these changes in the consuming public, the systems used for beef cattle have become more diverse than those used for dairy cattle. Some animals are given the opportunity to grow rapidly, with indoor feeding of high-quality diets, and others are kept at low stocking rates on rangeland, where growth will be slow (Phillips, 2002a).

Even in extensive production systems, recent herd size has grown considerably.

Consequently, intensive rearing with mechanical procedure on feeding, and extensive husbandry in which energy and chemical input is reduced and large grazing areas such as mountain pastures are used are conducted at the same time (Boivin et al., 1994). In traditional husbandry systems, the number of animals managed by caretakers had been small and the farmers had spent a lot of time with their animals. Naturally animals had habituated to the presence of people by virtue of routine neutral exposure to humans in the course of daily management (Rushen et al., 1999b). At the present day, however, in both intensive and extensive systems, the number of animals per caretaker is large and consequently the opportunity for contacting each other has reduced. In particular, the opportunities of positive interactions, such as feeding, have been replaced by technology such as mechanical or electronic feeders. On the other hand, many aversive tasks, such as catching and restraint for vaccination, foot care and administration of medication, and transport, still require human intervention. As a result, there is the risk that animals' direct experience with humans will be biased increasingly towards the negative (Rushen et al., 1999b). Thus, changes in production systems used for beef cattle and in the cattle-human relationships should also diversify the factors affecting the cattle's welfare and performance.

In general, individual conditions or environments for cattle could be divided into the following two factors (Hasegawa et al., 1997); 1) Endogenous factors include the genetic or physiological conditions of the species or individual, which could be divided into individual conditions (breed, age, sex, temperament, lactation period, gestation, etc.) and social position (competition, aggression, dominance order, leader-follower relationships, milking order, etc.). 2) Exogenous factors include the physical environment (season, climate, weather, temperature, humidity, wind, photoperiod, etc.) and social environment (stocking rate, area / head, age structure, sex ratio, etc.). In fattening beef cattle, they are generally reared in the same age and sex group, and they are not milked, so that endogenous factors are limited to breed and temperament as individual conditions and dominance order and leader-follower relationships as social position. The rearing environments of beef cattle consist of various combinations of these endogenous factors and exogenous factors based on diversified fattening systems.

In many Japanese beef farms, the intensive systems of feeding and housing are used in demand efficiency in order to produce tender beef. There, beef cattle were provided concentrated feed and hay in a small indoor pen. This kind of intensive keeping has aversive effects on the welfare of cattle, since stocking them at high densities lead to aggression between animals and health problems, such as lameness and tail tip necrosis on slatted floors (Phillips, 2002a). In addition, oral stereotypies such as tongue rolling and bar-biting are observed in the cattle tethered and fed restrictedly (Sato et al., 1994), and reared in the bare environment that social contacts are limited (Seo et al., 1998). In modern production systems, cattle are usually kept in a group on deep sawdust in individual pens at appropriate densities. But, there is a fact that the time spent eating is much shorter for cattle being fed concentrates in a pen than for cattle grazing in a pasture. Consequently, the level of frustration caused by less oral behaviors using tongue and mouth should be high in cattle kept in a pen. Although there are studies on space allowance in penned beef cattle (Fisher et al., 1997a, b), there are few comparison studies between the behaviors of beef cattle reared in intensive pen environment and those in extensive pasture environment.

So, firstly, a comparison study on behaviors between beef cattle reared in an intensive pen environment and those reared in an extensive pasture environment was conducted. Keeping cattle in intensive housing situations relates to the expression of stereotypies such as bar-biting and tongue rolling (Phillips, 2002c), so that the overall oral behaviors such as eating, drinking, grooming, licking objects and tongue rolling were focused on. This subject for study is shown in Chapter 2.

Environmental enrichment is defined as the attempt to improve biological functions (health, lifetime reproductive success and inclusive fitness) (Newberry, 1995) and the quality of life (Fraser et al., 1997) by providing stimuli to perform species-appropriate behavioral and mental activities (Reinhardt and Reinhardt, 2003). Recently, a variety of studies on the effects of environmental enrichment on meat quality (Beattie et al., 2000a), physiological parameters (Beattie et al., 2000b), ease of handling (Day et al., 2002), and the abilities of learning (Sneddon et al., 2000) and memory (de Jong et al., 2000) has been reported mainly in chicken and swine. However, most of these previous studies appear to have just demonstrated the short-term effectiveness of providing stimuli with little biological function (e.g. Schaefer et al., 1990).

As for cattle, although the term of "enrichment" has not been used, there are historically many studies on their social environment and alternative housing systems (e.g. Krohn, 1994). Most recently, some studies on social (Loerch and Fluharty, 2000) and social plus physical enrichment (Bokkers and Koene, 2001) are tried in calves. But there are still few studies on a global scale of environmental enrichment in beef cattle, regardless of outbreaks of the bull-steer syndrome (Blackshaw et al., 1997) and stereotype behaviors like tongue playing (Sato et al., 1994). Only a narrow scope of studies like short-term provision of scratch devices has been shown (Wilson et al., 2002; Pelley et al., 1995).

So, secondly, the effects of introducing the drum can into a pen as a target of eating, investigating and grooming behaviors on the ethogram, physiology and productivity in the early fattening stage were investigated. And furthermore, the subsequent effects of providing the device until the finishing stage were investigated. These studies are shown in Chapter 3.

In addition to the above physiological factors, social and psychological contexts should be considered as environmental factors for cattle. For example, isolation from peers and restraint in a crush are often used as a part of the normal management procedures for beef cattle when weighing or administering medications. These operations also require human intervention or handling. They are, therefore, potentially aversive and possibly have negative impacts on animal welfare. For these reasons, studies of the reactions of cattle while being handled may result in the improvement of human and cattle safety as well as animal welfare and production. In the past, many trials such as the open-field test, docility test, restraint test, sorting test, novel object test and crush test have been performed (1) to assess individual differences in behavioral reactions to human, (2) to assess cattle's temperament (Fordyce et al., 1985; Grandin 1993; Boissy and Bouissou, 1995; Le Neindre et al., 1995; de Passillé et al., 1995, 1996; Boivin et al., 1998), and (3) to determine the effects of human handling on the human-cattle relationship (Boissy and Bouissou, 1988; Boivin et al., 1992a, b, 1994; Le Neindre et al., 1995; Hemsworth et al., 1996; de Passillé et al., 1996; Boivin et al., 1998; Grignard et al., 2000, 2001; Munksgaard et al., 2001). These studies have been produced useful information to improve the relationship between cattle and human.

Another aspect worthy of cattle, handling study is that the behavioral responses once animals are released from the crush could suggest the attractiveness or aversiveness of that restraint conditions. This would shed light on those aspects of animal behavior that are denied during restraint and, as a result, on the cause of flightiness and difficulty in handling. Furthermore, such a study would provide useful information on how to overcome aversive effects of handling as soon as possible afterwards. The idea of the care of animals after unavoidable management procedure has not previously been studied.

So, thirdly, a Y-maze was used to determine the attractiveness to beef cattle of different conditions immediately after release from restraint. The Y-maze approach has been used to evaluate the aversion to different methods of treatment such as being restrained in a crush (Grandin et al., 1994) or being hit or shouted at (Pajor et al., 2003) and the preference of cattle for being offered feed (Pajor et al., 2003). In the first experiment, the relative attractiveness of hypothesized positive conditions such as peers, food and a bare pen was investigated. In the second experiment, the relative attractiveness of hypothesized negative conditions such as a human in different postures and position and a novel object was investigated. And furthermore, in the third and fourth experiment, the existence of sheep that are different species but familiar to cattle was determined their function as conpecific peers. These studies are shown in Chapter 4.

CHAPTER 2

Comparison of oral behaviors of young beef cattle in pen and pasture environments

Objectives

In this chapter, comparative observations in intensive pen and extensive pasture environments were conducted to assess the beef cattle's surroundings in the context of the relationship between beef cattle and barn and pasture conditions.

Housing of cattle is a common practice in production systems in many countries, especially at higher latitudes during winter. In fattening enterprises in Japan, beef cattle are usually reared in pens throughout all stages of production. However, such intensive housing of cattle may have adverse effects on their welfare since stocking at high densities has been shown to result in aggression between animals, in health problems, especially lameness and tail tip necrosis on slatted floors and in a high rate of injury (Phillips, 2002a). Fisher et al. (1997a, b) reported that restricted space allowance in pens reduced growth rate and time spent lying down in finishing beef heifers. Furthermore, in tethered cattle, stereotypic behavior such as tongue rolling has been observed as an abnormal behavior (Redbo, 1990). In Japanese Black cattle in tie stalls, Sato et al. (1994) reported that 76% of a total of 510 cattle performed one or more abnormal behaviors including tongue playing, bar biting, weaving and slowly opening and closing the mouth while looking up.

It is, therefore, likely that cattle fed a restricted quantity of high-concentrate diet and kept in a bare pen at high densities would perform stereotypic behaviors such as tongue rolling and bar-biting even though they were allowed to move freely. It is also possible that other oral behaviors such as self-grooming, allogrooming and licking objects might take the role of displacement activities in such a conflict situation. Sato et al. (1991) reported that social grooming of calves tended to increase when food was restricted. It has been shown that time spent eating is much shorter in fattening beef cattle that were fed a highly concentrated ration in pens than in cattle grazing in a pasture. Consequently, the level of frustration that results from reduced ability to perform oral behaviors may be high in penned cattle.

So in this chapter, behaviors of beef cattle reared in an intensive environment in Japan were compared with those of cattle reared in an extensive environment in Australia. In the comparisons, oral behaviors were particularly focused on.

Materials and methods

Animals and observation procedure

Intensive pen environment

A total of 122 steers at one farm in Sano (36°N, 138.5°E), Tochigi pref., Japan were observed (Fig. 2-1 (a)). Of these, 103 were Japanese Black X Holstein (F1) steers kept in 5 to eight pens (width 6.0 m X length 9.5 m each) with between 12 and 16 steers (3.6 - 4.8 m^2 /head) and 19 Japanese Black (JB) steers kept in one pen (width 12.0 m X length 9.5 m, 6.0 m^2 /head). Each pen housing the F1 steers permitted access to a feeding alley (length 6.0 m) for grain feed, a wood trough (width 0.7 m X length 1.8 m) for dry hay, a self-filling water bowl (diameter 0.5 m) and a resting space. The pen for JB steers allowed access to a feeding alley (length 12.0 m) for grain feed and dry hay, a self-filling water bowl (diameter 0.5 m) and a resting space. The pens used in this study were in a part of two open-sided buildings and each pen was divided by a metal fence 1.4 m in height. The steers were 7-11 months of age at the start of the first observation.

The steers were observed by scan sampling every 10 min during 3 mornings (from dawn till 11:50) and 3 afternoons (from 12:00 till dusk) during March 2004. The duration of all morning observations was 6 h 10 min, while the minimum and maximum length of the afternoon observations were 5 h 50 min and 6 h, respectively. The minimum and maximum temperatures during the six observations ranged from −1.2 - +5.7 (3.4 ± 2.7)℃ to 10.3 - 24.4 (15.1 ± 5.9)℃, respectively. Stormy weather characterized by high winds and (or) precipitation was not encountered during any observations.

The steers kept in the intensive environment were provided a commercial concentrate diet based on the average body weight in each pen, twice daily between 08:30 to 08:40 and between 15:40 to 16:00 at the feeding alley. The steers were also allowed free access to a trough containing Italian ryegrass hay. The dry hay was added to the trough at the same time as the concentrate diet was provided. The diet contained 57% of grain crops (corn, wheat flour and soy flour), 18% of bran (corn gluten feed and wheat bran), 14% of plant-origin oil meal (soybean oil meal and rapeseed oil meal) and 11% of the other additives (alfalfa meal, molasses, calcium carbonate and common salt). The steers were allowed free access to the water bowl.

Extensive pasture environment

A total of 1136 steers kept continually at pasture on 6 commercial beef cattle farms near Dubbo (33°S, 148.5°E), New South Wales, Australia were observed (Fig. 2-1 (b)). The details of the farms are shown in Table 2-1. Observations were conducted on one farm in both 2003 and 2004 (C03 and C04 respectively) but on different animals each year. The steers were approximately 5 - 15 months of age at the start of the first observation.

The steers in a pasture were observed by scan sampling every 15 min over 3 mornings (from dawn till 11:45) and 3 afternoons (from 12:00 till dusk) at intervals of three or four days during August and September in 2003 and 2004. The minimum and maximum length of the morning observations were 5 h 45 min and 5 h 30 min, respectively, while the minimum and maximum length of afternoon observations were 5 h 30 min and 6 h, respectively. The minimum and maximum temperatures during the six observations at each farm in 2003 ranged from 0.3 - 11.5 (4.1 ± 3.2)℃ to 12.8 - 21.1 (16.0 ± 2.2)℃ and from 0.2 - 14.1 (5.0 ± 3.3)℃ to 13.4 - 27.2 (19.5 ± 4.2)℃, respectively in 2004. During periods of inclement weather, observations were not conducted since such conditions caused the steers to curtail their activity and simply stand in the pasture until the weather passed. This has also been reported previously by Gonyou and Stricklin (1984).

Behavioral observation

The details of behavioral categories observed in the each environment are shown in Table 2-2. Because of the distances involved and because the animals tended to form large groups when resting in the shade, it was difficult to determine whether they were ruminating or simply resting. For this reason ruminating was recorded as resting. In this study, oral behaviors consisted of eating (grazing), drinking, self-grooming, allogrooming, licking objects and tongue rolling.

Statistical analysis

Although the observations in the intensive pen environment were conducted on one farm, the data were for the two breeds were analyzed as Farm F1 and Farm JB.

The proportion of steers performing oral behaviors and the other behaviors over the total period of the observations on each farm was analyzed using the chi-square test. A post-hoc test was then performed using Tukey's HSD to analyze the effect of farm on the proportion of steers performing oral behaviors.

The effect of farm on the proportion per day of steers performing all behavioral categories was analyzed using MANOVA (Wilks' Lambda) followed by the post-hoc test was using Tukey's HSD.

The proportion of steers engaged in each behavior was calculated for each 30 min observation. The effect of farm and the time after dawn or before dusk on the proportion of steers engaged in each behavior were analyzed using the two-way repeated measures ANOVA.

(a)

(b)

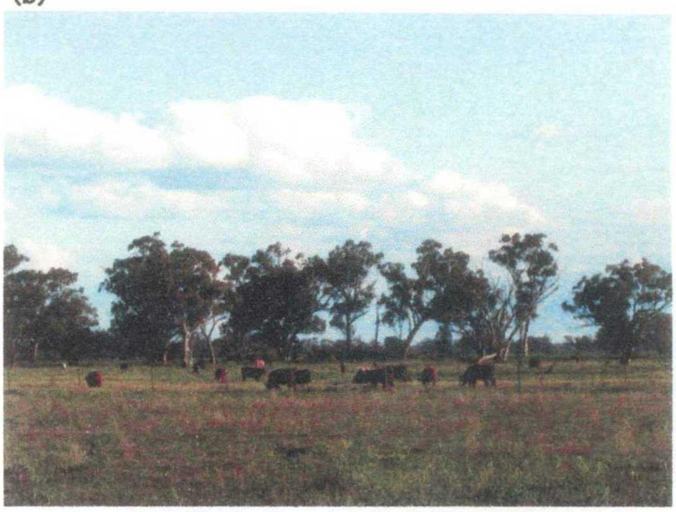


Fig. 2-1. (a) Intensive pen environment in Japan.
(b) Extensive pasture environment in Australia.

Table 2–1. Farm information in extensive pasture environment

	Farm				
	A	B	C03, C04[1]	D	E
Animal					
Number of subject cattle	56	120	500, 170	150	140
Mean number of cattle observed	47.5	103.1	371.4, 166.6	143.4	125.1
Range of age (months)	12 - 15	6 - 12	6 - 12	6 - 12	5 - 14
Breed	Murray Grey	Angus	Angus Murray Grey Herefords Shorthorns Santas Brahmans and various crosses	Shorthorn Shorthorn X Santa Gertrudis	Angus Angus X Hereford Angus X Shorthorn
Pasture					
Grazing system	Continuous grazing	Continuous grazing	Rotational grazing (Rotation in every 2, 3 days)	Rotational grazing	Rotational grazing
Pasture type, area of paddock (ha)	Native pasture, 250	Native pasture, 250 Improve pasture[2], 50	Native pasture Varoius pasture areas ranging from 60 to 150	Native pasture, 200 Native pasture, 100	Native pasture, 420 Improve pasture[3], 40
Contexture (main grass)	Wild and pasture grass	Poaceous wild grass	Wild grass	Wild grass	Papilionaceous pasture grass
Grass height, density[4]	Low, sparse	Low, sparse	Middle, moderate	High, dense	High, dense

[1] Farm G03 was observed in 2003 and Farm G04 was observed in 2004.
[2] After harvesting
[3] Rusan
[4] Assessment by the experimenter

Table 2-2. Behavioral categories observed in this study

Category	Definition
Intensive pen environment	
Eating	Eating concentrate diet at the feeding alley or eating hay at the trough
Drinking	Drinking water at a water bowl
Licking objects	Licking bars surrounding the pen or licking a trough of the pen
Grooming with objects	Scratching or rubbing with bars surrounding the pen or a trough of the pen
Investigating objects	Sniffing or licking bars surrounding the pen or a trough of the pen
Extensive pasture environment	
Eating	Grazing grass in the pasture
Drinking	Drinking water at a water dam or a water tank
Licking objects	Licking a trunk or a branch of a tree or licking the other objects in the pasture
Grooming with objects	Scratching or rubbing with a trunk or a branch of a tree in the pasture or scratching or rubbing with fences surrounding the pasture or the other objects in the pasture
Investigating objects	Sniffing or licking with a trunk or a branch of a tree in the pasture or sniffing or licking with fences surrounding the pasture or the other objects in the pasture
Common category	
Self-grooming	Licking by itself
Allogrooming	Licking other cattle
Tongue rolling	Swinging the tongue out side of the mouth from one side to the other, contorting a tongue or rooling it inside the mouth, stretching the tongue out
Standing resting	Resting in the standing posture, defecating, urinating
Lying resting	Sleeping, resting in sternal or lateral recumbency posture
Moving	Walking, running
Agonistic behavior	Head-throwing, fighting, escape, mock-fighting
Mounting	Getting on the back of other cattle
Excreting	Defecation and urination

Results

Oral behaviors differed significantly from one farm to another (χ^2=3056, P<0.001) (Fig. 2-2). The proportion of steers performing oral behaviors was significantly greater on Farm A (63%), Farm B (63%) and Farm C04 (55%) than on Farm JB (29%) (all P<0.05). Farms A, B and C04 were all extensively managed farms in Australia, whereas Farm JB was an intensive Japanese farm. All other differences were intermediate between these and were also non-significant.

When all behaviors were compared, the proportions of steers performing each behavior also significantly differed among farms (Λ=0.00, P<0.001) (Fig. 2-3). There were significant differences between farms for the proportion of animals self-grooming, allogrooming, licking objects, tongue rolling, standing resting, investigating objects and excreting (all P<0.001), the proportion of animals eating, lying resting and walking (all P<0.01) and the proportion of animals drinking, grooming with objects, engaging in agonistic behavior and mounting (all P<0.05). These data are presented in greater detail in Table 2-3, where it can be seen that the proportion of steers eating was significantly greater on Farms A and B than on Farms F1 and JB (all P<0.05) and the proportion of steers eating on Farm JB was less than that on Farms A, B, C04, C03 and D (all P<0.05).

In the extensive pasture environment, the proportion of steers eating on Farm A, B, C04, C03, D and E accounted for 96.1%, 98.2%, 95.4%, 96.5%, 96.9% and 95.1% of all oral behaviors, respectively. On the other hand, in the intensive pen environment, the proportion of steers eating on Farms F1 and JB accounted for 77.4% and 78.0% of all oral behaviors, respectively. Conversely, the proportion of steers performing the other oral behaviors exclusive of eating on Farms F1 and JB accounted for 22.6% and 22.0% of all oral behaviors,

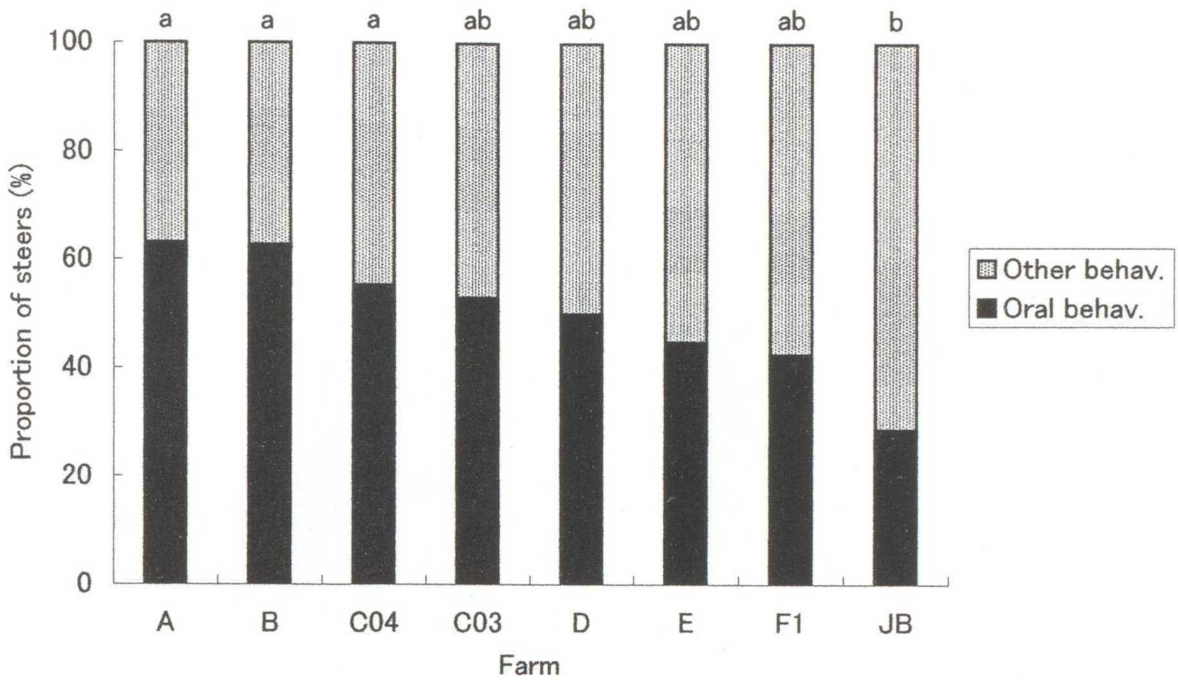


Fig. 2-2. Proportions of steers performing oral behaviors and the other behaviors for total three days (six observations; three morning and three afternoon observations) in each farm. Different letters indicate significant differences (P<0.05).

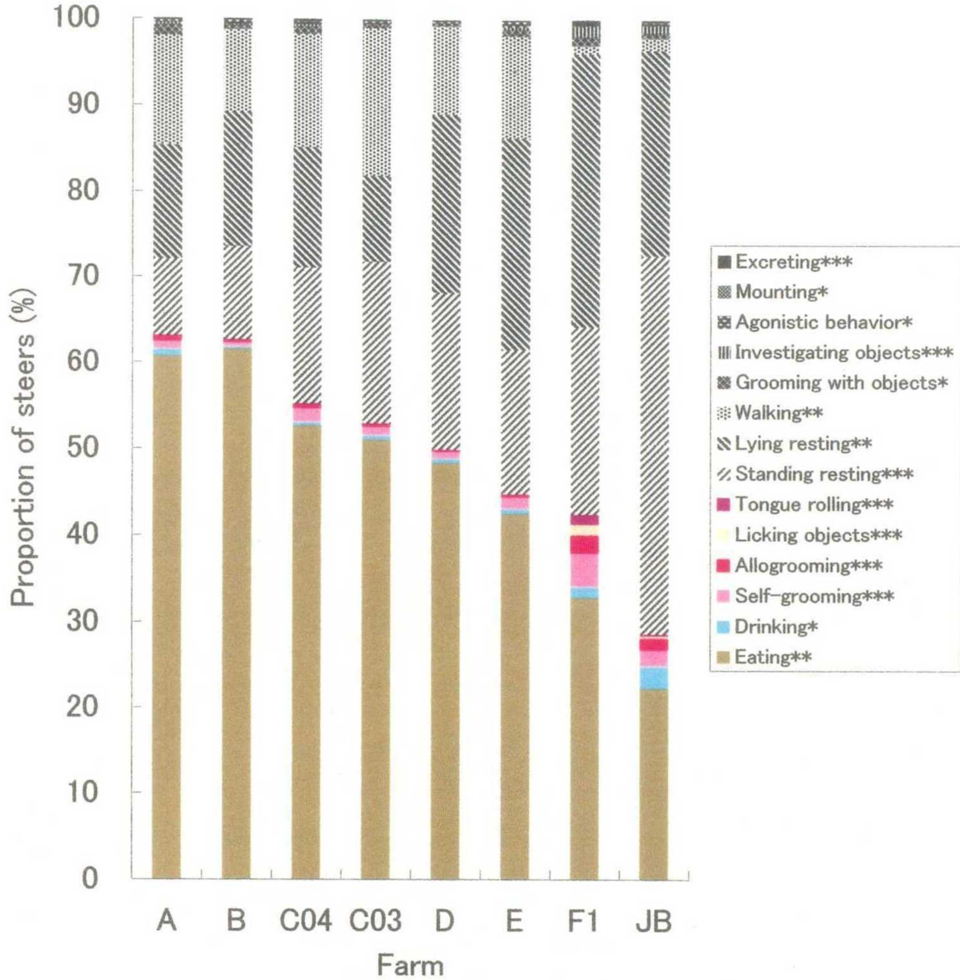


Fig. 2-3. Proportions of steers performing behaviors per one day (one morning and one afternoon observations) in each farm. Probability levels are indicated by ***$P<0.001$, **$P<0.01$ and *$P<0.05$.

respectively, whereas on the Australian farms this ranged from 1.8 to 4.9%.

Of the other oral behaviors, the proportions of steers self-grooming, allogrooming, licking objects and tongue rolling were greater on Farm F1 than in the other farms (all $P<0.05$), while the proportion of steers allogrooming on Farm JB was greater than that in the other farms in pasture environment (all $P<0.05$) (Table 2-3). Finally, the proportion of steers drinking on Farm JB was greater than that on Farms B, C04, C03, D and E (all $P<0.05$).

Taking all behaviors other than oral behaviors, there was significant differences between farms in the proportion of steers investigating objects, and this was greater in intensive environments (Farms F1 and JB) compared to the extensive environments (all $P<0.05$) (Table 2-3). There was also a tendency for the proportion of steers walking to be greater in the extensive environments than in the intensive environments, and this was significant for all extensive environments except for Farm B (all $P<0.05$). The proportion of steers standing resting in Farm JB was greater than that in the other farms (all $P<0.05$). There were also significant differences between farms in the proportion of steers lying resting, grooming objects and excreting, but these differences appeared to be random rather than a result of the two environments (all $P<0.05$). The proportion of steers performing agonistic behavior and mounting was not significantly different among farms.

There was diurnal variation in the proportions of steers performing oral behaviors, and these variations differed from farm to farm for eating ($P<0.001$) (Fig. 2-4 (a), (b)), drinking ($P<0.05$) (Fig. 2-4 (c), (d)) and for self-grooming, allogrooming, licking objects and tongue rolling ($P<0.001$) (Fig. 2-4 (e), (f)). In intensive pen environment, the peak in eating occurred 4 h after dawn and 2 h before dusk. These peaks followed the feeding of concentrate, even though dry hay was available ad libitum. No marked peak in grazing was observed in the pasture environments, although some peaks in grazing were observed on Farms A and C03, as was a decrease in grazing on Farm B during the late morning and early afternoon (Fig. 2-4 (a), (b)).

In both pen environments, the proportion of steers drinking gradually increased after dawn to around midday, but in the afternoon was highly variable (Fig. 2-4 (c), (d)). In the pasture environments, the proportion of steers drinking was generally low in the morning but was higher in the afternoon where some peaks were seen. Inexplicably, on Farm A, the proportion of steers drinking reached 8% on 3.5 h before dusk.

The greatest proportion of steers observed performing oral behaviors other than eating and drinking was observed on Farm F1 (Fig. 2-4 (e), (f)), with two major periods in the morning and one major period in the afternoon being identified. The peaks occurred approximately 1.5 - 2.5 h after dawn and after eating in the morning and afternoon. The proportion of steers performing these behaviors was also elevated on Farm JB where there was a peak after eating in the morning, but this was not as marked as that on Farm F1. In pasture environments, the proportion of steers performing oral behaviors other than grazing and drinking was overall much lower than that in pen environments, with no obvious peaks.

Table 2-3. Proportion of steers performing behaviors per one day (one morning and one afternoon observations) in each farm

	Farm							
	Extensive						Intensive	
Behaviors	A	B	C04	C03	D	E	F1	JB
Oral behaviors								
Eating	60.65 ^{a}	61.50 ^{a}	52.63 ^{ab}	51.03 ^{ab}	48.36 ^{ab}	42.56 ^{abc}	32.89 ^{bc}	22.33 ^{c}
Drinking	0.84 ^{ab}	0.30 ^{b}	0.38 ^{b}	0.50 ^{b}	0.52 ^{b}	0.54 ^{b}	1.24 ^{ab}	2.55 ^{a}
Self-grooming	0.96 ^{b}	0.51 ^{b}	1.64 ^{b}	1.03 ^{b}	0.86 ^{b}	1.39 ^{b}	3.91 ^{a}	1.99 ^{b}
Allogrooming	0.63 ^{c}	0.30 ^{c}	0.39 ^{c}	0.28 ^{c}	0.18 ^{c}	0.27 ^{c}	2.03 ^{a}	1.26 ^{b}
Licking objects	0.00 ^{b}	0.00 ^{b}	0.00 ^{b}	0.00 ^{b}	0.00 ^{b}	0.00 ^{b}	1.29 ^{a}	0.35 ^{b}
Tongue rolling	0.00 ^{b}	0.01 ^{b}	0.15 ^{b}	0.05 ^{b}	0.00 ^{b}	0.01 ^{b}	1.11 ^{a}	0.15 ^{b}
The other behaviors								
Standing resting	9.00 ^{b}	10.96 ^{b}	15.91 ^{b}	18.97 ^{b}	18.38 ^{b}	16.84 ^{b}	21.82 ^{b}	44.00 ^{a}
Lying resting	13.21 ^{bc}	15.60 ^{bc}	14.06 ^{bc}	10.05 ^{c}	20.73 ^{abc}	24.71 ^{ab}	31.77 ^{a}	23.87 ^{abc}
Walking	12.78 ^{a}	9.58 ^{ab}	13.13 ^{a}	17.09 ^{a}	10.25 ^{a}	11.84 ^{a}	0.99 ^{b}	1.45 ^{b}
Grooming with objects	1.30 ^{a}	0.44 ^{b}	0.84 ^{ab}	0.47 ^{b}	0.35 ^{b}	0.81 ^{ab}	1.08 ^{ab}	0.62 ^{ab}
Investigating objects	0.17 ^{b}	0.10 ^{b}	0.24 ^{b}	0.04 ^{b}	0.04 ^{b}	0.23 ^{b}	1.21 ^{a}	0.85 ^{a}
Agonistic behavior	0.30	0.67	0.35	0.27	0.22	0.69	0.24	0.32
Mounting	0.03	0.01	0.02	0.12	0.00	0.00	0.04	0.15
Excreting	0.12 ^{bc}	0.02 ^{c}	0.26 ^{ab}	0.10 ^{bc}	0.09 ^{bc}	0.09 ^{bc}	0.39 ^{a}	0.12 ^{bc}

Different letters indicate significant differences ($P<0.05$).

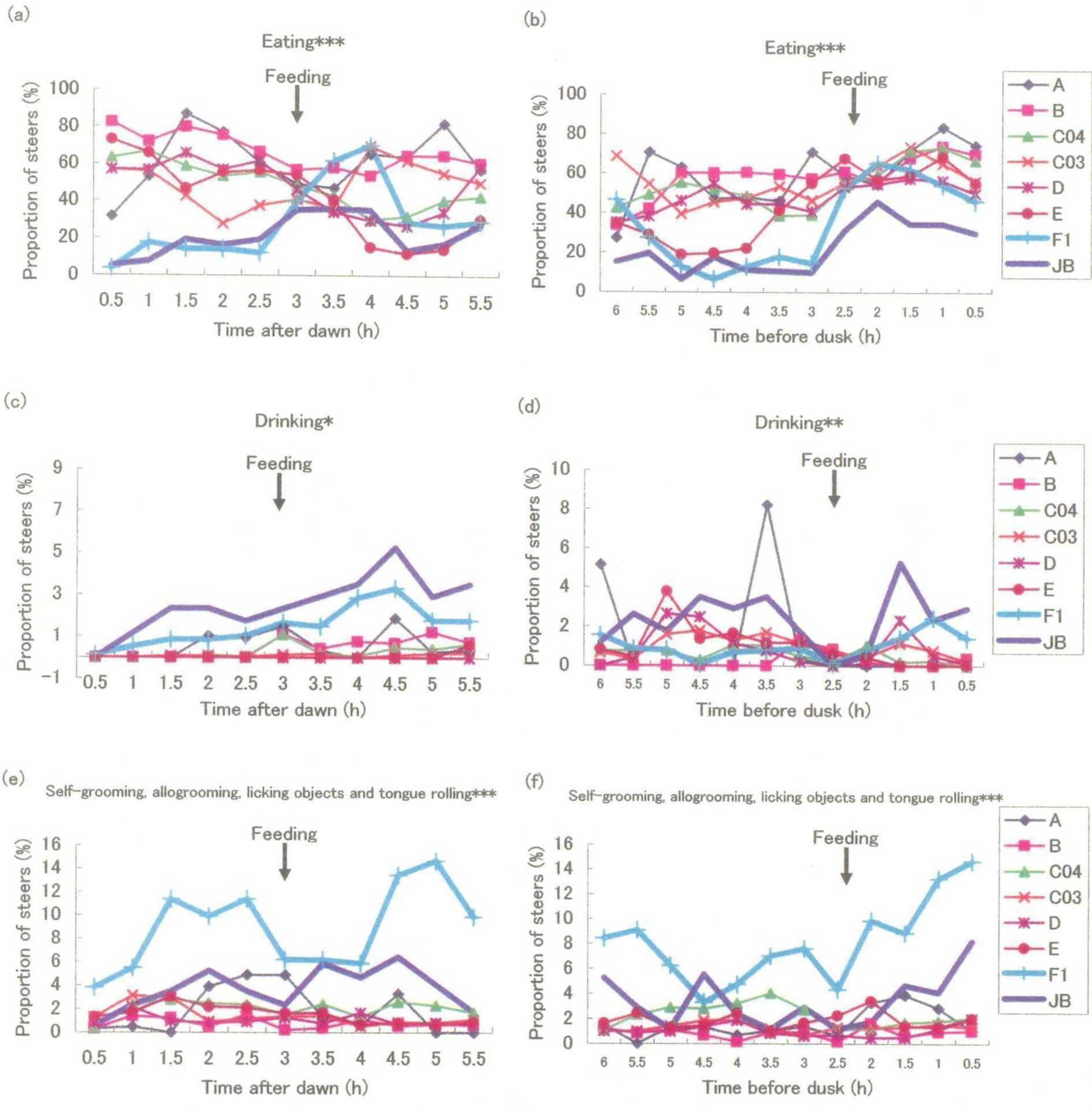


Fig. 2-4. (a) Propotion of steers eating for 5.5 h after dawn, (b) proportion of steers eating for 6 h before dusk, (c) proportion of steers drinking for 5.5 h after dawn, (d) proportion of steers drinking for 6 h before dusk, (e) proportion of steers self-grooming, allogrooming, licking objects and tongue rolling for 5.5 h after dawn. (f) proportion of steers self-grooming, allogrooming, licking objects and tongue rolling for 6 h before dusk. Probability levels are indicated by ***P<0.001, **P<0.01 and *P<0.05.

Discussion

This study showed that variation between the individual farms even within the pasture environment in the proportion of steers performing oral behaviors, although the significant differences were not shown among the farms. The level of oral behaviors was affected by nutritional quality and quantity of grasses in the pasture. It has been known that cattle on sparsely vegetated rangeland have longer grazing time (Phillips, 1993). Farms A and B had a sparsely vegetated native pasture. Grasses on pasture in those farms was poor in nutritional quality compared with the other farms in the pasture environment. Most of grasses in Farm A was poaceous wild grass. The proportion of steers performing oral behaviors reduced with getting better feed condition. Especially in Japanese Black steers, the proportion of steers performing oral behaviors was small. It might be caused by their feeble appetite compared with crossbred steers. On Farm JB, therefore, the significantly lower proportion of steers performing oral behaviors was replaced by a significantly greater proportion observed standing resting.

This study also showed that cattle reared in intensive environments and fed a concentrate ration spent less time eating than cattle reared at the sparsely vegetated pasture. The proportion of steers performing the oral behaviors other than eating and drinking was greater in pen environment than in pasture environment. However, total proportion of steers performing the oral behaviors in Farm F1 was not different from that in all farms in the pasture environment. Also on Farm JB, the total proportion of steers performing the oral behaviors was not different from that on Farms C03, D and E in the pasture environment. The steers reared in intensive environment might perform more self-grooming, allogrooming, licking objects and tongue rolling to compensate for the lower level of feeding behavior appropriate to ruminants, these oral behaviors were neither excessive nor stereotypic.

This was surprising in the light of the published literature on intensively-raised cattle. In tethered dairy cows, restricted allowance of roughage and restricted feeding of a diet with high levels of concentrate increased oral stereotypies (Redbo et al., 1996; Redbo and Nordlad, 1997), and stereotypies were also observed in Japanese Black steers reared in tie stall (Sato et al., 1994). It has also been reported that cattle raised in a tie stall almost completely stopped performing stereotypies after they released onto pasture or into loose barn, but to resume high levels of stereotypies after the re-tethering (Redbo, 1990; Redbo, 1992; Redbo, 1993). In these studies, the animals were raised in tie stalls, and it is possible that the conditions of our study were not sufficiently restricted to provoke such behavior. This is supported by the finding that in calves kept indoors in individual stalls, a high frequency of self grooming has observed (Kerr and Wood-Gush, 1987) and by Seo et al. (1998) who reported that tongue-playing, grooming and other behavior with tongue-movement were greater for calves reared in individual pen than for calves reared in group pen. It is possible that oral stereotypies might occur in steers reared a bare environment with limited social contacts in addition to dietary restriction, conditions that were not present in our study.

Oral behaviors aside, Miller and Wood-Gush (1991) reported that dairy cows kept indoors showed a much higher level of agonistic behavior and avoidance than at pasture. In our study, however, the level of agonistic behavior in the pen environment was not different from that in the pasture environment. Our study did show a higher proportion of cattle performing investigative behaviors in the pen environment compared to pasture and similar results have been reported for calves kept indoors in individual stalls (Kerr and Wood-Gush, 1987) and dairy cows kept in tie-stalls (Krohn, 1994) compared to animals at pasture or in loose housing.

In the intensive pen environment, the proportion of steers eating was affected by feeding time, with a peak of eating occurring 1.5 - 2 h after feeding. Other oral behaviors such as self-grooming, allogrooming, licking objects and tongue rolling were also observed with greater frequency at around the time of eating. In artificially-reared calves, the frequency of calf-directed oral behavior such as cross-sucking was shown to be greatest in the 10 min following milk ingestion (de Passillé et al., 1992; Lidfors, 1993; Bokkers and Koene, 2001; Margerison et al., 2003), and de Passillé et al. (1992) and Lidfors (1993) have suggested that the ingestion of milk stimulated sucking in calves and increased the motivation to perform sucking behavior. Tongue-playing observed in tethered beef cattle followed feeding and was followed by the other tongue-movement behaviors (Sato et al., 1994).

In steers in intensive environment of our study, the ingestion of concentrate diet was expected to stimulate oral behaviors and to increase the motivation to perform oral behaviors. Although the steers were allowed free access to dry hay, eating dry hay was only observed after eating concentrate diet. Furthermore, there was a peak in the frequency of the oral behaviors expect for eating corresponding to about 2 h after dawn. It has been known that grazing lactating dairy cows typically have about five meals per day, each lasting on about 2 h (Phillips, 1993), and Gonyou and Stricklin (1984) showed that cattle in a feedlot began eating associated with the time of sunrise. It is possible that, in our cattle kept in the pen environment under restricted feeding, this bout of oral behavior might correspond to a time when the animals would naturally be eating.

Gonyou and Stricklin (1984) also reported that the periods of eating, drinking and standing were associated with sunrise and sunset and were relatively independent of the feedlot schedule of feeding. As a result, these times shifted with seasonal changes. Our study was too limited to enable us to determine the effects of seasonal changes.

Conclusions

Although cattle reared in an intensive pen environment performed more non-nutritive oral behaviors than cattle in an extensive environment, the level of these oral behaviors was not sufficient to suggest a detrimental effect on animal welfare. It is possible that animals reared in loose pens with restricted feeding times are under much higher conditions of welfare than cattle in tie stalls with limited social interaction. Our data also suggest that cattle in a pen environment under a restricted feeding period might compensate for a missing feeding bout by performing non-nutritive oral behaviors.

CHAPTER 3

Effects of an environmental enrichment using a drum can on behavioral, physiological and productive characteristics in penned beef cattle

Objectives

As results of Chapter 2, time spent eating is much shorter in fattening beef cattle fed high-quality concentrates in an intensive pen environment than in cattle grazing in an extensive pasture environment. However, total proportion of oral behaviors in the pen environment was not different from that in the pasture environment. The cattle in the pen environment seemed to perform more oral behaviors other than eating to compensate for the lack of the occurrence of feeding behaviors. The oral behaviors such as self-grooming, allogrooming, licking objects and tongue rolling were observed mainly after eating concentrates. The cattle performed such oral behaviors in spite of being allowed to access to a trough containing hay freely. Although these oral behaviors were neither excessive ones nor stereotypies, there is a possibility that the cattle would not be satisfied about the amount of roughage provided.

So, in this chapter, a spent oil drum can was installed as an additional trough for hay in the pen to encourage eating more roughage and to compensate for the lack of the time spent eating. Especially for young cattle, eating roughage is important to develop the capacity and function of their rumens. Some positive effects on subsequent productivity are also expected. And furthermore, an artificial turf was attached around the drum can to encourage self-grooming of cattle. It has been reported that hair balls in cattle's rumen were increased by excessive grooming (Bokkers and Koene, 2001). Hair balls in the rumen could lose the appetite of cattle. Introducing the turf for grooming could decrease the frequency of self-directed grooming and its negative effects on the subsequent productivity of cattle.

As studies of environmental enrichment, using the appropriate devices that meet behavioral requirements of animals are needed to make them express normal ethogram of behaviors. In addition to this behavioral aspect, its effects on long-term physiology and productivity are important to be evaluated for farm animals. Therefore, the effects of installing a drum can that encourages steers to do more eating, investigating and grooming as target behaviors on the ethogram, physiological characteristics and productivity, and the subsequent effects of the device until slaughter were investigated.

Material and methods

Animals and management

Seventy-one Japanese Black X Holstein steers were used in two repeated experiments. The steers aged 7-11 months and weighed on average 299.5±22.6 kg were introduced from a market two weeks before the two experiments. Each experiment commenced in the fall of 2001 and 2002 with 35 and 36 steers, respectively.

The steers were allocated to three treatment pens (6.0 X 9.5 m each) (Fig. 3-1 (a)). Pen C (n=11 and 12 in each year) consisted of a feeding alley for grain feed, a wood trough for hay, a water bowl and a resting space (control). In Pen D (n=12 and 12), a spent oil drum can (Φ 58 X H 90 cm; Fig. 3-1 (b)) that can hold additional hay was added to Pen C (Fig. 3-1 (c)). In Pen GD (n=12 and 12), a drum can that was placed around an artificial turf (30 X 120 cm) was added to encourage grooming in addition to provide additional hay (Fig. 3-1 (b)). The turf was fixed with wires at the position of upper one third of the drum can. The both drum cans were cut out the top of them and were put hay in upper one third to make steers eat hay easily. A drum can was chosen because it was easy to obtain as industrial waste at a low price for practical use. The drum cans were installed for 5 months during the early fattening stage to feed enough hay for young cattle and stimulate the rapid development of their rumen. The steers were provided commercial concentrated feed (for the first 2 months TDN 70.5%, DCP 10.0%; for next 3 months TDN 72.0%, DCP10.0%), based on the average body weight in each pen, twice daily around 8:00-9:30 and 14:30-16:30 at a feeding alley. The steers were allowed free access to a trough containing Italian ryegrass hay. After removal of the drum cans, the steers were allowed free access to another concentrated feed (TDN 72.0%, DCP

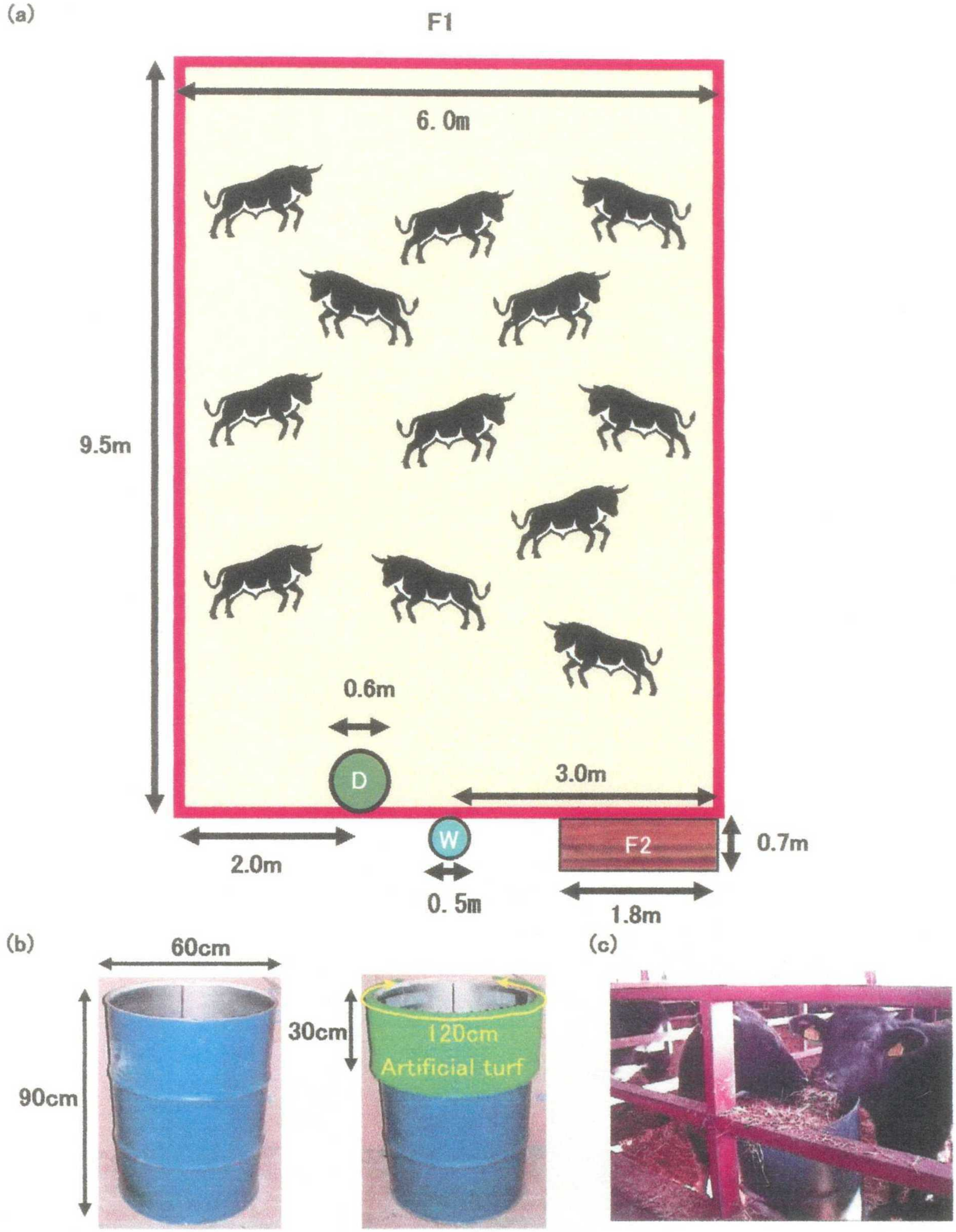


Fig. 3-1. **(a)** Schematic layout of an experimental pen. (F1) a feeding alley, (F2) a trough, (D) a drum can (Φ58 X H 90 cm), (W) a water bowl.
(b) Spent oil drum cans installed in Pen D and GD.
(c) Cattle eating hay at a drum can in Pen D.

10.0%) and oat straw. The steers were allowed free access to a water bowl over the experiment.

Measurements

Behavioral observations were made for 2 h at 10 min intervals after morning and evening feedings for 3 d in 5 successive months after installation of the drum cans and at 0, 1, 3 and 5 months after their removal. Eating, grooming, investigating, resting and tongue rolling were recorded as behavioral categories (Table 3-1). In addition to these categories, agonistic interactions to assess dominance order (DO) were observed continuously for 1 h after both the feedings.

Sampling blood from the jugular vein, measuring body weight, recording ultrasonic images between the 6th and 7th rib, and measuring body sizes were performed bimonthly just before, after 2 and 4 months of the drum can installation and after 1, 3 and 5 months of its removal. These treatments other than measuring body sizes were performed individually in a crush. Blood samples were centrifuged at 4000 rev min^{-1} for 15 min to dispense them to serum and plasma. The centrifuged samples were stored at −80℃, and were analyzed by an outside laboratory (SRL, Inc., Tokyo, Japan). Serum was analyzed for the concentrations of GH, insulin, leptin, vitamin A, triglyceride, NEFA and total cholesterol. Plasma was made analyses of adrenalin, noradrenalin, dopamine, cortisol and glucose.

Entrance order into a crush and temperament scores to human handling at the above mentioned were recorded as well. Temperament was assessed in a scale of 0 to 3 (the lower the score, the calmer the steer). Temperament score was rated by particular persons.

The steers were slaughtered at 27-32 months of age. Area of the rib eye muscle, beef belly

Table 3-1. Behavioral categories observed in this study

Category	Definition
Access to the drum can	Eating hay at the drum can, grooming with the drum can, invetigating the drum can
Eating	Eating hay at the drum can or the trough, eating concentrated feed
Eating hay at the drum can	Eating dry hay at the drum can containing dry hay
Eating hay at the trough	Eating dry hay at the trough for dry hay
Eating concentrates	Eating concentrated feed at the feeding alley
Drinking	Drinking water at a water bowl
Grooming	Grooming with the drum can or the equipments of the pen, grooming each other, self-grooming
Grooming with the drum can	Scratching or rubbing with the side of the drum can or the artificial turf attached to drum can
Mutual grooming	Licking other cattle
Self-grooming	Licking by itself
Grooming with the equipments	Scratching or rubbing with bars of the pen or a trough of the pen
Agonistic behavior	Head-throwing, fighting, escape, mock-fighting
Investigating	Sniffing or licking the drum can or the equipments of the pen
Investigating the drum can	Sniffing or licking the drum can
Investigating the equipments	Sniffing or licking the equipments of the pen
Licking bars of the pen	
Moving	Walking, running
Salt-licking	Licking or sniffing a salt block
Active behaviors	Eating, drinking, agonistic behavior, grooming, investigating, moving and salt-licking
Resting	Sleeping, resting, defecating, urinating
Stand-resting	Resting in the standing posture, defecating, urinating
Lateral resting	Sleeping, resting in the lying posture
Chewing	Chewing in the standing or lying posture
Stand-chewing	Chewing in the standing posture
Lateral chewing	Chewing in the lying posture
Tongue rolling	Swinging the tongue out side of the mouth from one side to the other, contorting a tongue or rooling it inside the mouth, stretching the tongue out
Inactive behaviors	Resting, chewing

thickness, subcutaneous fat thickness, carcass proportion (yielding ratio), beef marbling score (1-12) and dressed carcass weight were measured after slaughter. Carcass value was estimated by the previous year's average in Tokyo Meat Market.

Research protocols were approved by the Animal Experiment and Care Committee of Azabu University, Sagamihara-shi, Japan.

Statistical analysis

The effect of month after installation of the drum can on the number accessing to it was analyzed by using the repeated-measure ANOVA using the GLM procedure of SAS (SAS Institude Inc. 1990). If the effect was significant, post-hoc test was performed with Tukey's HSD.

Eating patterns, namely transition of eating places, in the drum-can-installed pens (Pen D and Pen GD) were analyzed using MANOVA (Wilks' Lambda). Then, post-hoc test was performed with Scheffé's F.

The effect of pen on the mean number of sampling points for behaviors during 2-h morning and evening observations, the concentration of blood constituents and the average daily gain (ADG) for 4 months after installation of the drum can was analyzed using the repeated-measure ANOVA by using the GLM procedure of SAS (SAS Institude Inc. 1990). The effect of pen on the post-slaughter measurements and the estimated carcass value was analyzed using one-factor factorial ANOVA. If the effect was significant, post-hoc test was performed with Tukey's HSD or Scheffé's F test. As for behaviors, these analyses were performed separately for morning and evening observations because of unequal intervals of feeding.

The proportion of all behaviors for 2 h after feeding for 5 months after installation in each pen was analyzed using the chi-square test. Then, to analyze the effect of pen on the proportion of each behavior, the post-hoc test was performed with Tukey's HSD.

Association between ADG, DO, the post-slaughter and behavioral measurements was determined using Spearman's correlation coefficient. Association between ADG and temperament scores was also determined using Spearman's correlation coefficient.

Results

Behavioral measurements

The frequency of the steers' access to a drum can was higher for a few months (from 2 to 3 months in the morning observations, from 2 to 3 months in the evening observations) compared to just after (0 month) and after 4 months of installation (all $P<0.05$). In detail, the mean frequency ($\pm$SD) of access during the morning observations was 2.03 ± 1.68, 1.95 ± 1.71, 2.60 ± 1.84, 2.85 ± 1.90 and 2.02 ± 1.58 times/ 2h of observation period in 0 (just after installation)- 4 months, respectively. In the evening observations, it was 1.77 ± 1.56, 2.31 ± 1.79, 2.47 ± 1.77, 2.46 ± 1.64 and 1.76 ± 1.51 times in 0-4 months, respectively (Fig. 3-2).

The mean frequencies ($\pm$SD) of all behaviors observed in this study for 5 months after installation and removal of the drum can are shown in Table 3-2 and Table 3-3. The installation of the drum can increased the total frequency of active behaviors ($P<0.01$), which include eating, drinking, agonistic behavior, grooming, investigating, moving and salt-licking. In particular, the frequency of eating was significantly higher in Pen D than in the other pens, and it was higher in Pen GD than in Pen C both in the morning and evening observations (all $P<0.01$). In the morning observations, the frequency ($\pm$SD) of eating was 5.43 ± 1.80, 6.76 ± 2.19 and 6.32 ± 1.89 times in Pen C, D and GD, respectively. In the evening observations, the frequency ($\pm$SD) of eating was 5.39 ± 1.69, 6.56 ± 1.91 and 6.17 ± 1.82 times in Pen C, D and GD, respectively. On the other hand, the frequency of active behaviors was not different between pens after removal. The frequency of eating became the lowest in Pen GD in the morning observations ($P<0.05$). In detail, the frequency ($\pm$SD) of eating was 3.76 ± 2.10, 3.72 ± 2.04 and 3.38 ± 1.77 times in Pen C, D and GD, respectively.

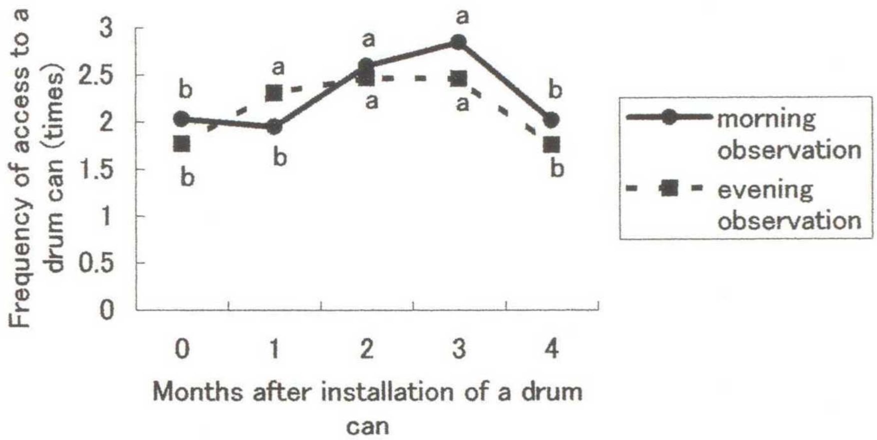


Fig. 3-2. Frequency of access to the drum can for 5 months after installation. Different letters indicate significant differences (P<0.05).

Table 3-2. Mean frequency (±SD) of each behaviors during 2h of the morning and evening observations for 5 months after installation of a drum can

Behavior	Observation time[z]	Pen[y] C	D	GD	P value
Active behaviors[1)]	M	8.11±1.98 ^{c}	9.40±1.99 ^{a}	8.94±2.04 ^{b}	<0.01
	E	8.99±1.68 ^{c}	9.96±1.57 ^{a}	9.53±1.73 ^{b}	<0.01
Access to the drum can	M	–	2.47±1.93 ^{a}	2.10±1.59 ^{b}	<0.10
	E	–	2.15±1.75	2.15±1.62	ns
Eating (total)	M	5.43±1.80 ^{c}	6.76±2.19 ^{a}	6.32±1.89 ^{b}	<0.01
	E	5.39±1.69 ^{c}	6.56±1.91 ^{a}	6.17±1.82 ^{b}	<0.01
Eating hay at the drum can	M	–	2.36±1.92 ^{a}	1.90±1.54 ^{b}	<0.01
	E	–	2.08±1.74	1.97±1.55	ns
Eating hay at the trough	M	2.14±1.50 ^{a}	1.38±1.55 ^{b}	1.10±1.22 ^{c}	<0.01
	E	2.08±1.37 ^{a}	1.60±1.42 ^{b}	1.30±1.26 ^{c}	<0.01
Eating concentrates	M	3.28±1.31 ^{a}	3.02±1.29 ^{b}	3.31±1.35 ^{a}	<0.01
	E	3.30±1.30 ^{a}	2.88±1.22 ^{b}	2.89±1.09 ^{b}	<0.01
Grooming (total)	M	1.36±1.24	1.36±1.36	1.32±1.28	ns
	E	1.83±1.35	1.62±1.37	1.71±1.40	ns
Grooming with the drum can	M	–	0.04±0.22 ^{b}	0.08±0.29 ^{a}	<0.05
	E	–	0.02±0.15 ^{b}	0.06±0.30 ^{a}	<0.05
Mutual grooming	M	0.74±0.96	0.73±1.03	0.64±0.92	ns
	E	1.03±1.08	0.94±1.14	1.00±1.02	ns
Self-grooming	M	0.44±0.69	0.42±0.65	0.48±0.80	ns
	E	0.60±0.83	0.48±0.75	0.51±0.76	ns
Grooming with the equipments	M	0.18±0.45	0.17±0.46	0.12±0.35	ns
	E	0.21±0.50	0.17±0.46	0.13±0.38	ns
Drinking	M	0.21±0.41	0.24±0.46	0.28±0.50	ns
	E	0.20±0.41	0.24±0.47	0.25±0.48	ns
Agonistic behavior	M	0.21±0.46 ^{ab}	0.23±0.47 ^{a}	0.15±0.41 ^{b}	<0.10
	E	0.40±0.65	0.46±0.73	0.41±0.67	ns
Investigating (total)	M	0.12±0.34 ^{b}	0.15±0.41 ^{b}	0.25±0.54 ^{a}	<0.01
	E	0.17±0.41 ^{b}	0.16±0.42 ^{b}	0.26±0.58 ^{a}	<0.05
Investigating the drum can	M	–	0.07±0.27 ^{b}	0.12±0.39 ^{a}	<0.05
	E	–	0.05±0.21 ^{b}	0.12±0.39 ^{a}	<0.01
Investigating the equipments	M	0.12±0.34 ^{ab}	0.08±0.31 ^{b}	0.14±0.38 ^{a}	<0.10
	E	0.17±0.41 ^{a}	0.11±0.34 ^{b}	0.14±0.38 ^{ab}	<0.10
Licking bars of the pen	M	0.10±0.32 ^{a}	0.05±0.23 ^{b}	0.10±0.32 ^{ab}	<0.05
	E	0.12±0.33 ^{a}	0.05±0.22 ^{b}	0.09±0.30 ^{ab}	<0.01
Moving	M	0.73±0.86 ^{a}	0.64±0.82 ^{ab}	0.58±0.78 ^{b}	<0.10
	E	0.97±0.97 ^{a}	0.90±0.97 ^{a}	0.68±0.77 ^{b}	<0.01
Salt-licking	M	0.05±0.31	0.02±0.17	0.04±0.27	ns
	E	0.03±0.16	0.02±0.15	0.04±0.25	ns
Inactive behaviors[2)]	M	3.89±1.98 ^{a}	2.60±1.99 ^{c}	3.05±2.04 ^{b}	<0.01
	E	3.00±1.69 ^{a}	2.04±1.57 ^{c}	2.46±1.73 ^{b}	<0.01
Resting (total)	M	3.63±1.87 ^{a}	2.37±1.81 ^{c}	2.81±1.89 ^{b}	<0.01
	E	2.77±1.55 ^{a}	1.96±1.51 ^{c}	2.34±1.67 ^{b}	<0.01
Stand-resting	M	3.01±1.63 ^{a}	1.75±1.38 ^{c}	2.23±1.69 ^{b}	<0.01
	E	2.62±1.54 ^{a}	1.81±1.46 ^{c}	2.12±1.55 ^{b}	<0.01
Lateral resting	M	0.62±1.23	0.61±1.30	0.59±1.18	ns
	E	0.16±0.55	0.15±0.61	0.23±0.76	ns
Chewing (total)	M	0.26±0.67	0.23±0.70	0.24±0.68	ns
	E	0.22±0.61 ^{a}	0.09±0.38 ^{b}	0.12±0.43 ^{ab}	<0.01
Stand-chewing	M	0.15±0.47 ^{a}	0.08±0.32 ^{b}	0.11±0.40 ^{ab}	<0.10
	E	0.13±0.36 ^{a}	0.05±0.26 ^{b}	0.08±0.30 ^{ab}	<0.01
Lateral chewing	M	0.10±0.50	0.15±0.64	0.13±0.48	ns
	E	0.10±0.44 ^{a}	0.04±0.29 ^{b}	0.04±0.27 ^{b}	<0.10
Tongue rolling	M	0.11±0.33	0.14±0.44	0.12±0.42	ns
	E	0.11±0.37	0.13±0.42	0.06±0.25	ns

1) Active behaviors include eating, drinking, agonistic behavior, grooming, investigating, moving and salt-licking
2) Inactive behaviors include resting and chewing
[z] M: morning observation ; E: evening observation
[y] C: control pen; D: enriched pen using a drum can; GD: enriched pen using a drum can with an artificial turf
Different letters indicate significant differences at a certain P value described in the far right colum

Table 3-3. Mean frequency (±SD) of each behaviors during 2 h of the morning and evening observations for 5 months after removal of a drum can

Behavior	Observation time[z]	Pen[y] C	Pen[y] D	Pen[y] GD	P value
Active behaviors[1)]	M	5.91±2.37	5.82±2.52	5.66±2.34	ns
	E	6.87±2.35	7.00±2.32	6.70±2.43	ns
Eating (total)	M	3.76±2.10 [a]	3.72±2.04 [a]	3.38±1.77 [b]	<0.05
	E	4.17±2.09	4.06±2.03	3.97±2.03	ns
Eating hay at the trough	M	1.17±1.60	1.02±1.35	0.86±1.24	ns
	E	1.43±1.47	1.48±1.48	1.19±1.34	ns
Eating concentrates	M	2.59±1.39	2.69±1.52	2.51±1.33	ns
	E	2.74±1.44	2.57±1.28	2.75±1.31	ns
Grooming (total)	M	1.28±1.20	1.13±1.14	1.25±1.27	ns
	E	1.50±1.29	1.57±1.29	1.43±1.22	ns
Mutual grooming	M	0.74±0.94	0.69±0.91	0.69±0.92	ns
	E	0.98±1.07	1.06±1.11	0.89±1.01	ns
Self-grooming	M	0.33±0.65	0.28±0.53	0.38±0.72	ns
	E	0.34±0.60	0.36±0.59	0.34±0.58	ns
Grooming with the equipments	M	0.21±0.48	0.17±0.40	0.18±0.45	ns
	E	0.18±0.45	0.15±0.40	0.21±0.42	ns
Drinking	M	0.18±0.41	0.20±0.42	0.22±0.43	ns
	E	0.22±0.47	0.26±0.51	0.21±0.43	ns
Agonistic behavior	M	0.20±0.48	0.17±0.43	0.24±0.52	ns
	E	0.28±0.54	0.40±0.69	0.38±0.67	ns
Investigating (total)	M	0.08±0.29 [b]	0.15±0.38 [ab]	0.18±0.46 [a]	<0.05
	E	0.18±0.43	0.13±0.37	0.21±0.44	ns
Licking bars of the pen	M	0.05±0.24	0.08±0.27	0.09±0.35	ns
	E	0.16±0.35	0.09±0.32	0.13±0.36	ns
Investigating bars of the pen	M	0.03±0.18 [b]	0.07±0.25 [ab]	0.08±0.29 [a]	<0.05
	E	0.07±0.25	0.04±0.19	0.06±0.24	ns
Moving	M	0.36±0.63	0.41±0.72	0.37±0.68	ns
	E	0.49±0.77	0.52±0.72	0.48±0.79	ns
Salt-licking	M	0.03±0.17	0.03±0.20	0.03±0.18	ns
	E	0.03±0.20	0.05±0.72	0.02±0.14	ns
Inactive behaviors[2)]	M	5.81±2.25	5.89±2.42	6.05±2.27	ns
	E	5.13±2.35	5.00±2.32	5.30±2.43	ns
Resting (total)	M	5.39±2.12	5.43±2.33	5.61±2.27	ns
	E	4.69±2.25	4.53±2.26	4.87±2.42	ns
Stand-resting	M	3.75±2.06 [b]	3.86±2.42 [b]	4.28±2.28 [a]	<0.05
	E	3.78±2.21	3.53±2.15	3.62±2.17	ns
Lateral resting	M	1.63±1.96	1.57±1.95	1.33±1.88	ns
	E	0.91±1.44	1.00±1.57	1.25±1.79	ns
Chewing (total)	M	0.42±0.87	0.47±0.87	0.43±1.01	ns
	E	0.44±0.95	0.47±0.98	0.43±0.88	ns
Stand-chewing	M	0.22±0.56	0.23±0.59	0.23±0.66	ns
	E	0.24±0.60	0.21±0.51	0.23±0.59	ns
Lateral chewing	M	0.21±0.65	0.24±0.67	0.20±0.69	ns
	E	0.20±0.62	0.26±0.77	0.20±0.66	ns
Tongue rolling	M	0.05±0.21	0.17±0.53	0.09±0.37	ns
	E	0.07±0.25	0.13±0.49	0.06±0.27	ns

1) Active behaviors include eating, drinking, agonistic behavior, grooming, investigating, moving and salt-licking

2) Inactive behaviors include resting and chewing

[z] M: morning observation ; E: evening observation

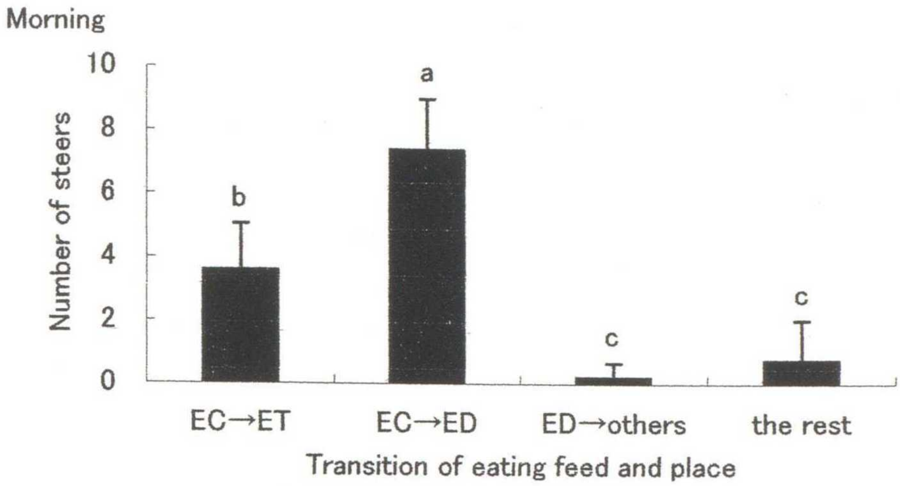
[y] C: control pen; D: enriched pen using a drum can; GD: enriched pen using a drum can with an artificial turf

Different letters indicate significant differences at a certain P value described in the far right colum

Usage of the drum can was different between Pen D and Pen GD. The frequency ($\pm$SD) of eating hay at the drum can was higher in Pen D (2.36 ± 1.92 times) than in Pen GD (1.90 ± 1.54 times) in the morning observations ($P<0.01$). The frequency of grooming with the drum can was higher in Pen GD (0.08 ± 0.29 and 0.06 ± 0.30 times in the morning and evening observations, respectively) than in Pen D (0.04 ± 0.22 and 0.02 ± 0.15 times in the morning and evening observations, respectively) both in the morning and evening observations (both $P<0.05$). The frequency ($\pm$SD) of investigating the drum can was higher in Pen GD (0.12 ± 0.39 and 0.12 ± 0.39 times in the morning and evening observations, respectively) than in Pen D (0.07 ± 0.27 and 0.05 ± 0.21 times in the morning and evening observations, respectively) in the morning ($P<0.05$) and evening ($P<0.01$) observations.

Transition of eating feed and place was not different between the morning ($\Lambda=0.99$, $P=0.93$) and evening ($\Lambda=0.96$, $P=0.49$) observations. In both observations, steers ate hay at the drum can (7.4 ± 1.6 and 7.0 ± 2.0 times in the morning and evening observations, respectively) more frequently than at the trough (3.6 ± 1.5 and 4.2 ± 1.9 times in the morning and evening observations, respectively) (both $P<0.01$) after they finished eating concentrates at the feeding alley (Fig.3-3).

Pen differences in other behaviors were also found (Table 3-2 and Table 3-3). The frequency of investigating in Pen GD was higher than those in other pens both in the morning (both $P<0.01$) and evening (both $P<0.05$) observations during the installation period. As for 5 months after removal, the frequency of investigating in Pen GD became higher than those in Pen C in the morning observations ($P<0.05$). The frequency of licking bars was higher in Pen C than in Pen D in the morning ($P<0.05$) and evening ($P<0.01$) during installation, whereas it became higher in Pen GD than in Pen C in the morning observations ($P<0.05$ after removal). The frequency of moving was higher in Pen C and Pen D than in Pen GD in the evening



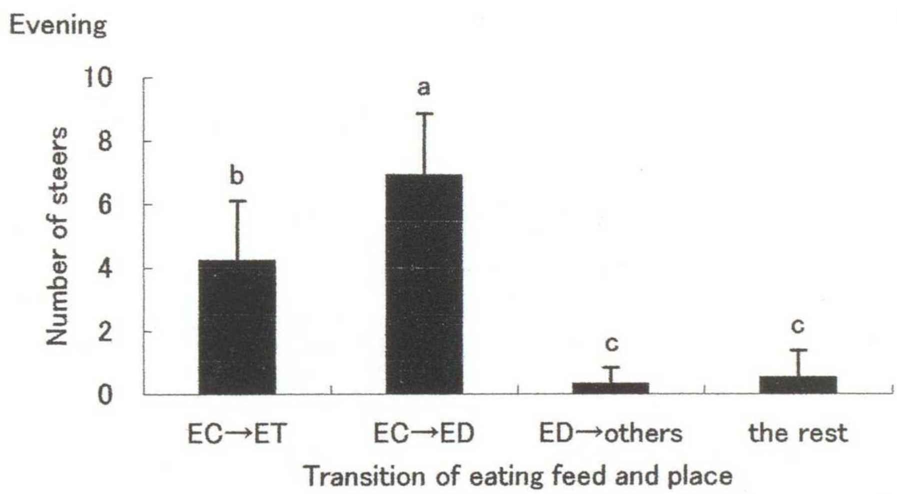


Fig. 3-3. Eating patterns of steers in enriched pens (Pen D plus Pen GD) in which a drum can was installed in the morning (above) and evening (below) observations. EC→ET: Transition from eating concentrates at the feeding alley to eating hay at the trough. EC→ED: Transition from eating concentrates at the feeding alley to eating hay at the drum can. ED→others: Transition from eating hay at the drum can to other places. Different letters indicate significant differences (P<0.01).

(P<0.01) for 5 months of installation. The frequency of inactive behaviors which consisted of resting and chewing was higher in Pen C than in the other pens, and it was higher in Pen GD than in Pen D in the morning and evening (all P<0.01) during installation. The frequency of resting and stand-resting were higher in Pen C than in the other pens, and it was higher in GD than in Pen D in the morning and evening (all P<0.01) during installation. The frequency of chewing and stand-chewing were higher in Pen C than in Pen D in the evening (both P<0.01) during installation. The frequency of tongue rolling was not significantly different between pens both during installation and after removal. The frequency of stand-resting became higher in Pen GD than in Pen C and D in the morning observations (P<0.05) after removal.

The proportion of all behaviors for 2 h after feeding for 5 months after installation is shown in Fig. 3-4. There was a relevance between the proportion of behaviors and pen conditions (χ^2=397.7, P<0.001). The proportion of eating hay was greater in Pen D and GD than in Pen C, and that was greater in Pen D than in Pen GD (both P<0.05). On the other hand, the proportion of licking objects was less in Pen D than in Pen C (P<0.05). The proportion of performing stand resting was less in Pen D and GD than in Pen C (P<0.05). In addition to these results, the proportion of walking was greater in Pen C than in Pen GD (P<0.05). The proportion of investigating objects was greater in Pen GD than in Pen C and D, and that was greater in Pen D than in Pen C (both P<0.05). However, the proportions of self-grooming and allogrooming were not significantly different between pens.

Correlation coefficients of DO with behaviors for 5 months after installation of the drum can are shown in Table 3-4. In Pen GD, the frequencies of access to (r_s= -0.59, P<0.01), eating hay at (r_s= -0.49, P<0.05), and grooming with a drum can (r_s= -0.54, P<0.01) correlated negatively with DO. In Pen D, the frequency of eating concentrates at the feeding alley (r_s= -0.41, P<0.05) and self-grooming (r_s= 0.49, P<0.05) correlated with DO. ADG tended to

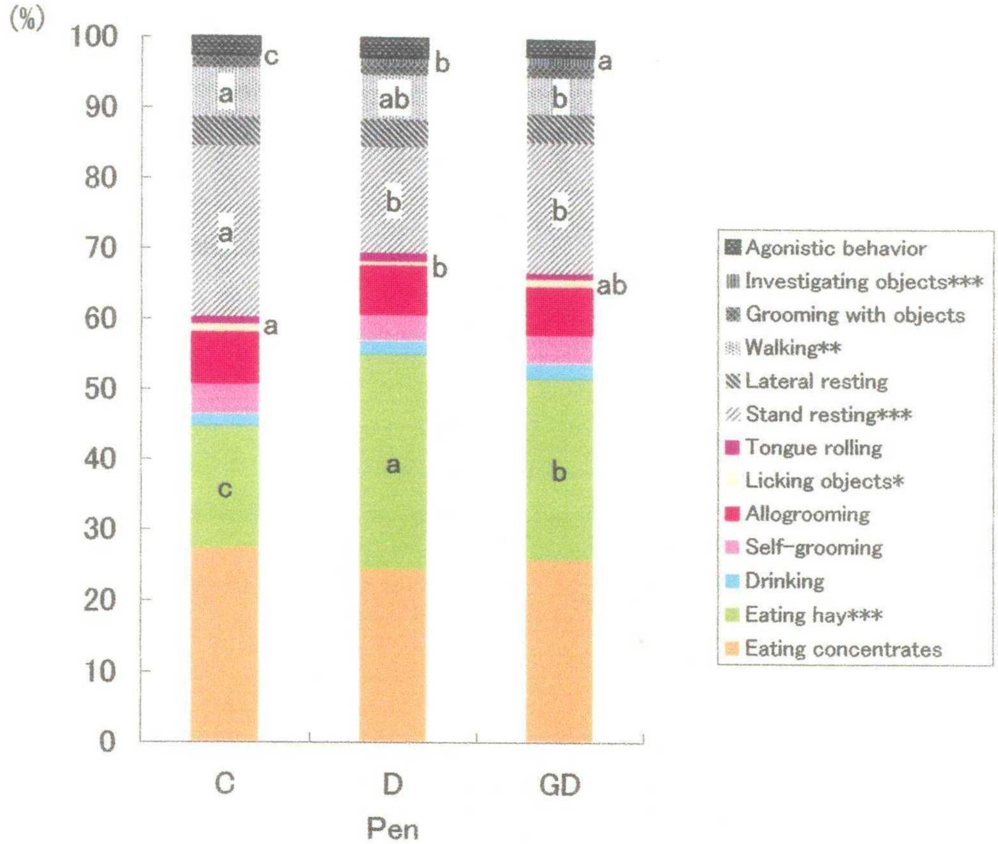


Fig. 3-4. The proportion of all behaviors for 2 h after feeding for 5 months after installation in each pen. Different letters indicate in each behavior significant differences (P<0.05).

Table 3-4. Correlation coefficents (r_s) of DO with the frequencies of behaviors for 5 months after installation of a drum can

Behavior	Pen[z] C	D	GD
Access to a drum can	–	−0.28	−0.59 **
Eating	−0.13	−0.38 †	−0.26
Eating hay at the drum can	–	−0.26	−0.49 *
Eating hay at the trough	−0.12	0.06	0.42 *
Eating concentrates	−0.04	−0.41 *	−0.30
Grooming	−0.08	0.24	−0.16
Grooming with the drum can	–	−0.12	−0.54 **
Mutual grooming	−0.20	0.20	−0.24
Self-grooming	0.24	0.49 *	0.12
Grooming with the equipments	0.07	−0.33	0.02
Investigating	−0.15	0.05	−0.17
Investigating the drum can	–	−0.20	−0.11
Investigating the equipments	−0.15	0.16	0.04
Licking bars of the pen	−0.13	0.06	0.05
Resting	0.10	0.23	0.24

Significant correlations at †P<0.10, *P<0.05 and **P<0.01

[z] C: control pen; D: enriched pen using a drum can;
GD: enriched pen using a drum can with an artificial turf

correlate negatively with DO (r_s= -0.22, P=0.07).

Physiological parameters

Mean plasma dopamine concentrations (±SD) for 5 months after installation were higher in Pen D (11.71±7.79 pg/ml) than in Pen C (6.73±3.57 pg/ml) (P<0.05) (Fig. 3-5 (a)), and mean serum triglyceride concentrations (±SD) tended to be higher in Pen C (26.50±3.71 mg/dl) than in Pen GD (23.27±5.53 mg/dl) (P=0.06) (Fig. 3-5 (b)). Other blood constituents in plasma and serum samples were not significantly different between pens.

Mean serum total cholesterol concentrations (±SD) in Pen D (111.38±20.15 mg/dl) became higher than in Pen C (93.67±15.73 mg/dl) and GD (105.12±20.71 mg/dl) (both P<0.05) after removal, and those in Pen GD became higher than in Pen C (P<0.05) (Fig. 3-6 (a)). In addition, mean serum triglyceride concentrations (±SD) were higher in Pen C (26.09 ±3.62 mg/dl) and D (25.53±5.49 mg/dl) than in Pen GD (22.68±4.88 mg/dl) (P<0.05) (Fig. 3-6 (b)).

Productive traits

Although change in body weight after installation of the drum can was not significantly different between pens, the average body weight (±SD) in Pen D (423.6±30.2 kg) and Pen GD (420.6±26.6 kg) at 4 months after the installation was heavier than that in Pen C (414.5 ±28.2 kg).

Correlation coefficients of ADG with the frequencies of behaviors for 5 months after installation are shown in Table 3-5. ADG was not significantly different between pens, but it

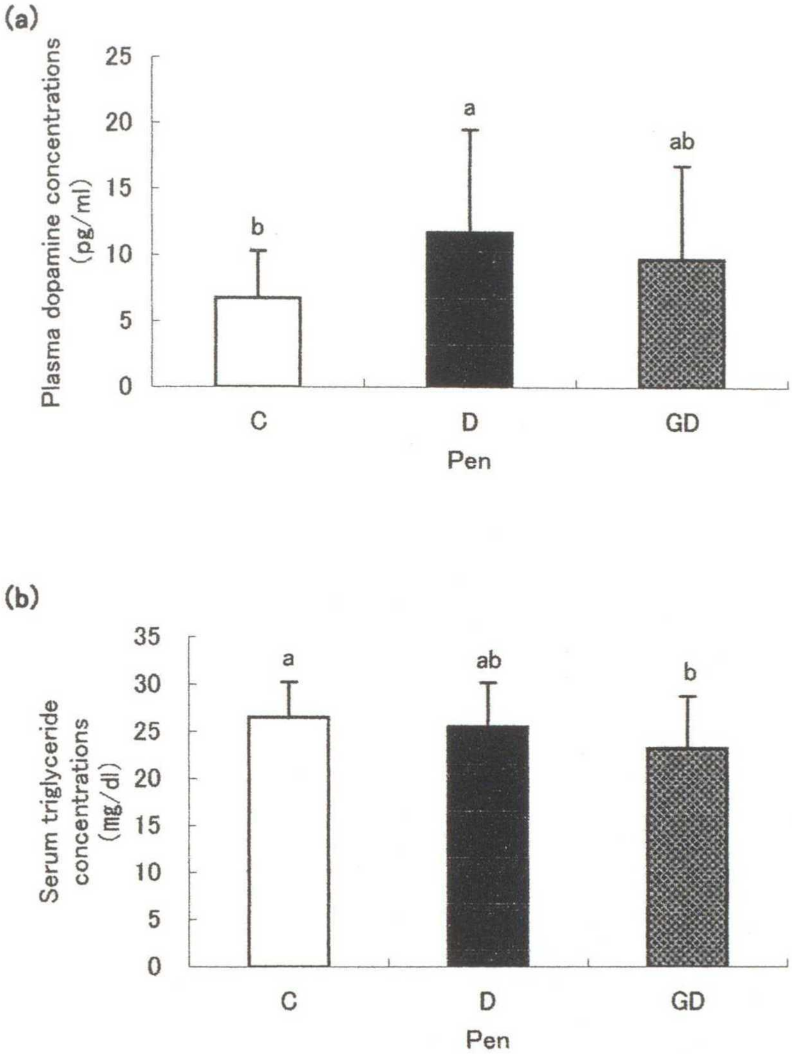


Fig. 3-5. Mean concentrations (±SD) of **(a)** plasma dopamine concentrations and **(b)** serum triglyceride for 5 months after installation of a drum can. Different letters indicate significant differences ($P<0.05$).

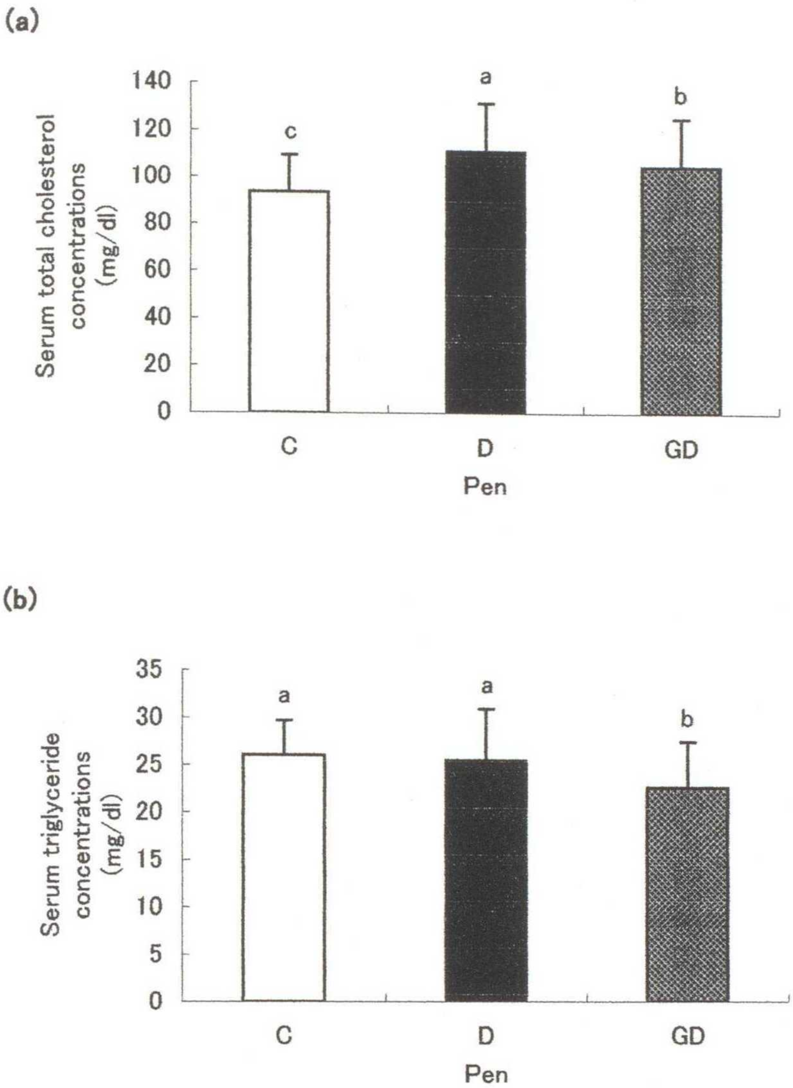


Fig. 3-6. Mean concentrations (±SD) of **(a)** serum total cholesterol and **(b)** serum triglyceride for 5 months after removal of the drum can.
Different letters indicate significant differences (P<0.05).

correlated positively with the frequency of eating hay at the drum can in Pen D (r_s= 0.52, P<0.01). In Pen C, ADG tended to correlate with the frequency of eating hay at the trough (r_s= 0.35; P<0.10). In Pen GD, ADG correlated positively with the frequency of eating concentrates at the feeding alley (r_s= 0.51, P<0.05). In Pen D and GD, the frequency of resting correlated negatively with ADG (Pen D: r_s= -0.41, P<0.05; Pen GD: r_s= -0.42, P<0.05).

Correlation coefficients of ADG with the frequency of each behavior for 5 months after drum can removal are shown in Table 3-6. In Pen GD, ADG correlated positively with the frequency of investigating the equipments (r_s= 0.49, P<0.05). In addition, ADG correlated negatively with the frequency of grooming (r_s= -0.41, P<0.05) and mutual grooming (r_s= -0.39, P<0.05). In Pen C, ADG correlated with the frequency of eating concentrates (r_s= 0.62, P<0.01) and the frequency of self-grooming (r_s= -0.45, P<0.05).

Although temperament scores at 4 different handling treatments were not different between pens, ADG for 5 months after installation correlated negatively with the temperament score on the scales in Pen D (r_s= -0.60, P<0.01) (Table 3-7). In Pen GD, ADG for 5 months after installation tended to correlate negatively with the temperament score on the scales (r_s= - 0.37, P<0.10) and at the blood sampling (r_s= -0.35, P<0.10). As for 5 months after removal, there were no significant correlations between ADG and temperament scores.

As for carcass characteristics, beef belly (±SD) was thicker in Pen D (7.73±0.84 cm) than in Pen C (6.97±1.12 cm) (P<0.05). Beef belly (±SD) in GD was 7.41±0.95 cm thick. Although the beef marbling number was not significantly different between pens, it correlated with the frequencies of eating hay at the drum can (r_s=0.45, P<0.05), investigating the drum can (r_s=0.44, P<0.05) and grooming with the drum can (r_s=0.40, P=0.07) in Pen GD (Table 3-8). In Pen D, the beef marbling number tended to correlate with the frequencies of eating hay at the drum can (r_s=0.41, P=0.06), eating hay at the trough (r_s= - 0.39, P=0.07) and eating

Table 3-5. Correlation coefficents (r_s) of ADG with the frequencies of behaviors for 5 months after installation of a drum can

Behavior	Pen[z] C	D	GD
Access to the drum can	—	0.50 *	0.18
Eating	0.16	0.37 †	0.50 *
Eating hay at the drum can	—	0.52 **	0.18
Eating hay at the trough	0.35 †	-0.15	0.21
Eating concentrates	-0.11	0.18	0.51 *
Grooming	0.26	0.03	-0.04
Grooming with the drum can	—	0.07	-0.03
Mutual grooming	0.24	0.09	0.02
Self-grooming	-0.14	-0.25	-0.12
Grooming with the equipments	0.08	0.24	0.16
Investigating	-0.30	-0.33	0.02
Investigating the drum can	—	-0.19	-0.14
Investigating the equipments	-0.30	-0.28	0.13
Licking bars of the pen	-0.31	-0.24	0.19
Resting	-0.21	-0.41 *	-0.42 *

Significant correlations at †P<0.10, *P<0.05 and **P<0.01

[z] C: control pen; D: enriched pen using a drum can;
GD: enriched pen using a drum can with an artificial turf

Table 3-6. Correlation coefficents (r_s) of ADG with the frequencies of behaviors for 5 months after removal of a drum can

Behavior	Pen[z] C		D		GD	
Eating	0.41	†	0.12		0.47	*
Eating hay at the trough	−0.16		0.17		0.29	
Eating concentrates	0.62	**	−0.12		0.21	
Grooming	−0.23		−0.23		−0.41	*
Mutual grooming	0.07		−0.17		−0.39	*
Self-grooming	−0.45	*	−0.30		−0.28	
Grooming with the equipments	−0.23		0.09		0.09	
Investigating the equipments	−0.09		0.06		0.49	*
Licking bars	0.01		0.01		0.23	
Resting	−0.25		0.10		−0.13	

Significant correlations at †P<0.10, *P<0.05 and **P<0.01

[z] C: control pen; D: enriched pen using a drum can;
GD: enriched pen using a drum can withan artificial turf

Table 3-7. Correlation coefficents (r_s) of ADG with temparament scores at 4 handling treatments for 5 months after installation and for 5 months after removal of a drum can

	For 5 months after the drum can installation Pen[z]			For 5 months after the drum can removal Pen[z]		
Temperament score	C	D	GD	C	D	GD
On the scales	0.14	−0.60 **	−0.37 †	−0.17	−0.12	0.12
At sampling blood	0.06	0.16	−0.35 †	0.02	−0.11	−0.04
At recording ultrasonic image	−0.20	−0.06	−0.09	−0.11	0.10	0.02
At measuring body size	−0.23	−0.30	−0.21	−0.16	0.08	0.01

Significant correlations at †$P<0.10$ and **$P<0.01$

[z] C: control pen; D: enriched pen using a drum can; GD: enriched pen using a drum can with an artificial turf

concentrates (r_s= 0.37, P=0.08). In Pen D, furthermore, dressed carcass weight correlated with the frequency of eating hay at the drum can (r_s= 0.43, P<0.05). Subcutaneous fat thickness correlated with the frequency of grooming with the drum can (r_s= 0.51, P<0.05) in Pen D. In Pen GD, subcutaneous fat thickness correlated with the frequency of eating hay at the drum can (r_s=0.46, P<0.05), and it tended to correlate with the frequencies of grooming with the drum can (r_s=0.38, P=0.08) and investigating the drum can (r_s=0.41, P=0.06). Although it was not statistically significant, the estimated average carcass value (±SD) in Pen D (¥601,123± 129,616) and Pen GD (¥580,988±93,421) was higher than in Pen C (¥532,408±145,160).

Table 3-8. Correlation coefficents (r_s) of carcass characteristics with the frequencies of behaviors for 5 months after installation of a drum can in Pen D and GD

Behavior	Pen[z]	Post slaughter measurements[y] REA	BBT	SFT	ER	BMS No.	DCW
Access to a drum can	D	−0.12	0.18	0.21	−0.28	0.38 †	0.41 †
	GD	0.27	0.16	0.57 **	−0.03	0.48 *	0.26
Eating	D	−0.32	−0.18	0.19	−0.34	0.02	0.24
	GD	−0.05	0.25	0.11	−0.04	0.10	0.13
Eating hay at the drum can	D	−0.08	0.22	0.21	−0.25	0.41 †	0.43 *
	GD	0.26	0.20	0.46 *	0.04	0.45 *	0.21
Eating hay at the trough	D	−0.13	−0.38 †	0.02	−0.03	−0.39 †	−0.32
	GD	−0.27	0.14	−0.27	0.05	−0.22	−0.17
Eating concentrates	D	−0.08	0.20	−0.14	0.06	0.37 †	0.30
	GD	−0.05	0.08	−0.02	−0.16	0.20	0.02
Grooming with the drum can	D	0.07	0.14	0.51 *	−0.21	0.31	0.33
	GD	0.11	−0.08	0.38 †	−0.08	0.40 †	−0.19
Investigating a drum can	D	−0.25	−0.28	0.01	−0.17	0.03	−0.14
	GD	−0.11	0.01	0.41 †	−0.12	0.44 *	−0.11

Significant correlations at †P<0.10, *P<0.05 and **P<0.01

[z] D: enriched pen using a drum can; GD: enriched pen using a drum can with an artificial turf

[y] REA: area of rib eye muscle; BBT: beef belly thickness; SFT: subcutaneous fat thickness; ER: extraction rate; BMS No.: number of beef marbling standared; DCW: dressed carcass weight

Discussion

Behavioral measurements

The steers continued to access the drum cans for 3 months after installation. They did not access the drum cans frequently right after installation, suggesting that the drum can was perceived as a novel object. In our previous study with pigs (Ishiwata et al., 2002), it was found that the pigs displayed investigation of the box that we gave them to provide an escape area from fighting, just after installation. Herskin et al. (2003) have found that a novel feeding method, even with the usual food, temporarily decreased duration of eating in dairy cows.

Drum cans were continuously used in manners of eating, investigating, and grooming as we had expected. In most of the previous studies on environmental enrichment (Schaefer et al., 1990; Jones et al., 2000; Wilson et al., 2002; Pelley et al., 1995), the long-term persistence of animal's interest in provided devises is not clear. The installation of drum cans in this study increased the frequencies of active behaviors especially eating. Since steers were fed restricted amount of concentrates during the early fattening stage, the increment behavior is eating hay. In both pens with a drum can installed, more steers ate hay at the drum can after they finished eating concentrates at the feeding alley, rather than at the trough. This suggests that the drum can was more attractive for steers to eat hay than the usual trough. This is also supported by the fact that the drum can was used more frequently by dominant steers. Pelley et al (1995) have demonstrated that steers like to access bale straw because they can destroy it and display their natural foraging behavior. In the present study, bale hay provided in the drum can might make it easier for steers to destroy the bale, because the height of the drum can fitted the height of the steers' jaw.

Redbo and Nordblad (1997) have reported that restrictive allowance of roughage increase and develop oral stereotypy. Although the number of steers that displayed tongue rolling was not different between the pens in this study, steers in the control pen licked bars of the pen more frequently than in the other pens with a drum can installed. This suggests that installation of the drum can improved the environment of the pens.

On the comparison of behaviors of steers in a pen and pasture in Chapter 2, it was suggested that the steers in a pen environment might perform more the oral behaviors such as self-grooming, allogrooming, licking objects and tongue rolling other than eating to compensate for the lack of occurrence of feeding behaviors. In this study, eating behavior encouraged by installing the drum cans reduced licking objects in the oral behaviors other than eating. However, grooming behaviors as the oral behaviors other than eating were not affected by increased eating. In relatively small environment, the steers would also perform self-grooming and allogrooming to keep social communication and their body clean. Although it was expected that using the turf for grooming could decrease self-grooming, the effect of the turf was not shown in the frequency of self-grooming.

After removal of drum cans, some behavioral changes were found in eating, investigating bars and resting, especially in the pen with the drum can installed around the artificial turf that was put. These results suggest that the drum can with an artificial turf was more attractive than the simple drum can. The drum can with the artificial turf promoted grooming behavior and investigating behavior at the drum can more than at the simple drum can. Bayne et al. (1991) have found that singly-housed rhesus monkeys displayed higher level of stereotyped behavior after removal of enrichment devices than they did in the period prior to adding these devices. In the present study, behavior of investigating bars increased after removal of the drum can, especially in the pen with the drum can installed around the artificial turf that was put.

All temperament scores were not different between pens. This agrees with the reports on pigs that enrichment did not affect the ease of handling (Hill et al., 1998; Day et al., 2002).

Physiological parameters

Some physiological parameters reflected changes in behaviors induced by installation of the drum can. As dopaminergic activities cause opiate induction and self-narcotisation, increase of plasma dopamine concentrations in the pen with a drum can is especially noteworthy. This might be due to so-called social facilitation in which steers were given some positive stimulus which activated by eating with familiar peers at an attractive feeder. Decrease of serum triglyceride concentration in the pen with a drum can might reflect promoted fat metabolism by this increased activity.

In the present study, stress-related hormones (cortisol, adrenalin and noradrenalin) were not affected in their concentrations by enrichment. Veissier et al (1997) have demonstrated that enrichment did not affect neuroendocrine responses to stress, despite the fact that calves spent more time licking their lips and tongue rolling under socially and physically deprived conditions. On the other hand, Redbo (1998) has shown in dairy heifers that the higher their stereotypy level, the lower the cortisol response of them. In addition, there were some reports that pigs in an enriched pen have higher baseline cortisol concentrations (Jong et al., 1998; 2000), and pigs in a barren pen have a blunted circadian rhythm in cortisol (Jong et al., 2000). These studies indicate that a hypothalamo-pituitary-adrenal axis in barely housed pigs is less sensitive to environmental stress. Beattie et al. (2000b) and Jong et al. (1998) have also found the difference of cortisol responses to acute stress between pigs from barren and enriched environments. Thus pen environment in the present study was not likely to be so bare even in the control pen. This interpretation is emphasized by no differences in the incidence of a stereotyped behavior like tongue rolling between pens.

After removal of the drum cans, increase of serum total cholesterol concentrations in the pens installed with a drum can was shown during the middle fattening stage. Increase of blood cholesterol is known to lead to improved beef marbling score (JLIA, 2000).

Productive traits

Although the average body weight was not different between pens, eating hay at a drum can correlated with daily gain. Eating hay from and grooming with a drum can was affected by social rank especially in the pen with a drum can installed around an artificial turf. Higher ranking steers more frequently ate hay and rubbed their heads and necks at the drum can than did the lower ranking steers. Hasegawa et al. (1997) have reported that the eating behavior of the subordinate heifers were interrupted by an attack of dominants. It is conceived that this kind of social disturbance of eating should occur around a drum can, resulting in variations in the weight gain of steers. As for the interrelation of ease of handling with weight gain, more restless steers on the scale had better growth in both pens with a drum can installed. I cannot, however, find the reason of this.

The positive effects of enrichment by installing drum cans improved carcass characteristics of steers such as beef belly thickness, beef marbling score and subcutaneous fat thickness. Behavioral facilitation of eating from and grooming with a drum can in the early fattening stage activated animal mentioned before, and improved their final productivity. Beattie et al. (2000a) and Klont et al. (2001) have reported the positive effect of environmental enrichment on the meat quality of pigs, but only the short-term effect of social enrichment on growth has been reported in beef cattle (Loerch and Fluharty, 2000). Thus this would be the first report demonstrating that facility enrichment in the early fattening stage can have long-term subsequent effects and improve carcass characteristics of beef cattle.

Conclusions

Installing a drum can as an environmental enrichment in the early fattening stage of steers improved their final productivity. Although social factors affected steers' success to access the drum can, the drum can kept the steers attracted and promoted their growth by encouraging their eating and grooming with it for several months after installation. Some physiological parameters reflected these positive changes in behaviors during installation. In addition, behavioral and physiological positive effects lasted even after removal of the drum can and improved the final carcass characteristics of beef cattle.

CHAPTER 4

Choice of attractive conditions by beef cattle in a Y-maze just after release from restraint

Objectives

As results of Chapter 3, it was shown that the environmental enrichment did not affect the steers' responses to a human handling such as weighing on the scale. In the enriched pens, however, more restless steers during human handling had better growth rate.

For beef cattle that have usually minimal contact with human, being handled by human under isolated from peers and restricted condition should be more stressful. So, the causations of difficulty in handling and the way to moderate cattle's stress were investigated by determining the attractiveness of beef cattle to different conditions immediately after release from restraint. In this chapter, the Y- maze test was used to determine the reactions of the subject animals that were allowed to choose the conditions voluntarily.

In experiment 1, the reactions of cattle that were given a choice in the relative positive conditions such as peers, food and bare condition were determined. In experiment 2, the reactions of the cattle that were given a choice in the relative aversive conditions such as human having different posture and position, and novel object were determined. In experiment 3 and 4, whether sheep that were familiar to the cattle were as attractive as conpecific peers was determined even though they were different species.

Materials and methods

Animals and test procedure

One hundred and eighty nine Angus heifers, averaging 12 months of age and 391.5±33.0 kg, were used in experiment 1 and 2. Total 157 Angus heifers, average 9 months of age were used in experiment 3 and 4. The heifers were born in 2002 (experiment 1 and 2) and 2003 (experiment 3 and 4) and reared at pasture at the Agricultural Research Centre Trangie, New South Wales, Australia. The Y-maze was constructed barred metal fence panels 1.6 m in height and covered with hessian sheets to minimize the effect of outside distraction. It consisted of a forcing pen, single file race (0.9×11.8 m), a crush (0.9×2.75 m), a choice area and two choice pens (6.5×8.5 m each). The floor of the choice area and the choice pens was bare earth. Each choice pen was divided into three equal-sized sectors marked out on the ground with rope (Fig. 4-1).

Animals were used once only during the testing procedure. Before testing, the animals were kept in the holding pens adjoining the forcing pen. Each animal was then moved down the race and into the crush individually by one handler. The test animal was contained in the crush for two minutes without restraint in the head bail, which was simply used as the front gate of the crush to contain the animal. For the first approximately 30 seconds out of the two minutes, the handler stood in the front of the animal. During containment, the behavior of test animal was rated on five point scale of Grandin (1993). The ratings were: (1) clam, no movement; (2) slightly restless; (3) squirming, occasionally shaking the crush; (4) continuous, very vigorous movement and shaking of the crush; (5) rearing, twisting of the body and struggling violently.

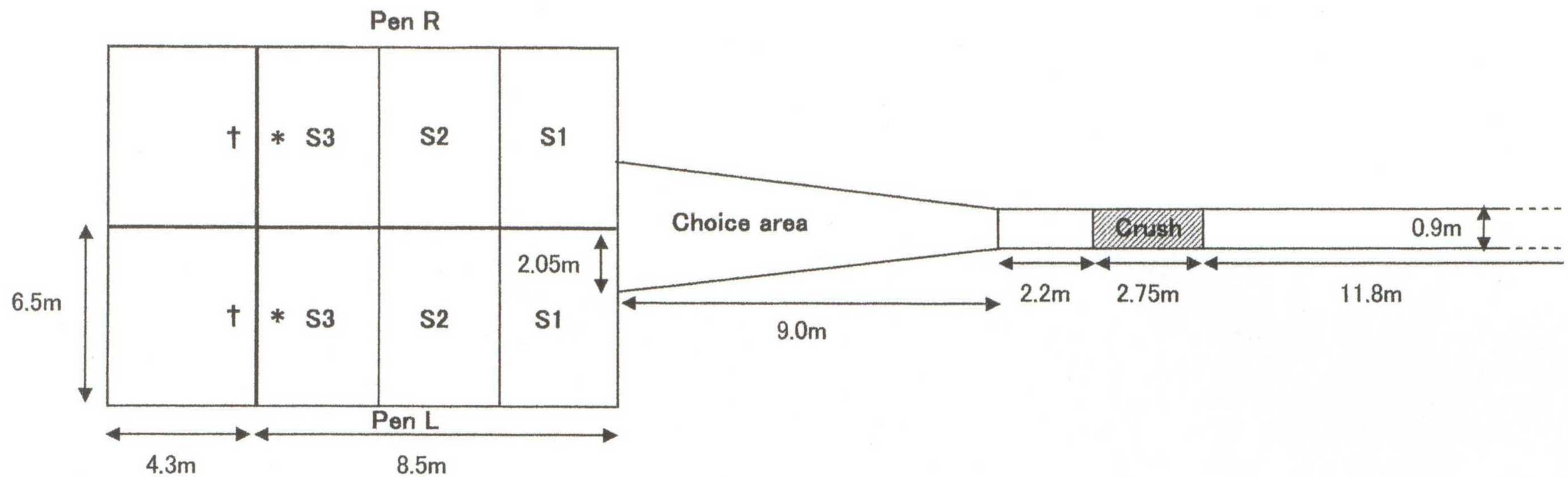


Fig. 4-1. The layout of the Y-maze. The test field and the choice area were surrounded by fences 1.6 m high. The asterisk indicates the position of the choice stimulus when this was food, the seated human of the human standing inside the pen and the dagger indicates the position of the human standing outside the pen.

After the two minutes of containment, the head bail was opened and the animal was released from restraint. All animals were allowed to voluntarily leave the crush, and they were never touched by the handler. After the animal left the crush, the animal could enter the choice area from where it could choose one of the two pens. If the animal entered neither of the two pens within five minutes, the handler entered the choice area near the exit of the crush and walked slowly behind the animal until it entered one of the choice pens. This handler walked along the center line of the choice area in order to avoid influencing the choice made by the test animal. The choice pattern (voluntarily/forced) was recorded. Choice was defined as all feet of the animal entering one or other of the choice pens. Following its original choice, the animal remained undisturbed for five minutes, during which time it could freely enter either of the choice pens, the choice area or crush.

From the time of its release from the crush until the completion of the test, the behavior of the animal was recorded on video tape. From this tape, the time spent walking, standing, investigating the ground, investigating the side of the pen, self-grooming, rubbing against the sides of the pen and staying near the crush entrance were determined. Also recorded were the pen first chosen (side and treatment) and the latency to choose. These measurements were common to both experiments.

Experiment 1

Each heifer was given one of the following choice combinations:

(i) n=34, a pen containing three familiar heifers (Peers) (Fig. 4-2 (a)) vs. a pen with a pile of hay (Food) on a metal rack measuring 1.2 m×0.65m×0.65m (Fig. 4-2 (b)).

(ii) n = 34 a pen containing three familiar heifers (Peers) vs. a bare pen (Bare) (Fig. 4-2 (c)).

(iii) n = 35, a pen with hay (Food) vs. the bare pen (Bare).

The familiar heifers were selected from the animals already tested. They stayed in a pen measuring 6.5 m×4.3 m adjacent to the test pen separated by a barrier through which they could have visual and physical contact with the test animal (Fig. 4-1). As well as the behaviors described above, time spent engaged in social contact (sniffing and licking peers), eating hay, investigating hay and grooming with hay were also measured, depending on the choice combination offered. The time spent in each sector (S1, S2 and S3) was also recorded.

The test took place over the course of the day, so some of the animals were tested using each choice combination in the morning and some in the afternoon. The time of each combination was allocated randomly during the morning tests and during the afternoon tests. In any one choice pairing, the on which the choices appeared were equally allocated to the right and left pens. During tests involving food, the heifers to be tested were kept in the pasture adjacent to the test facility to prevent their motivation for hay from changing as a result of time off feed.

Experiment 2

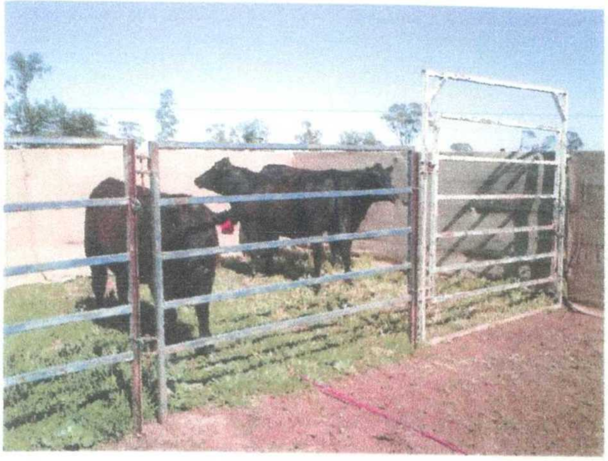
Another 86 heifers were given each one of the following choice combinations:

(i) n=29, a pen with a familiar handler standing inside (STI) (Fig. 4-2 (d)) vs. the pen with a novel object (NO) (Fig. 4-2 (e)). Standing inside means that the human was inside the choice pen, standing at the mid-point of the side opposite the entry gate.

(ii) n=29, a pen with the same human standing outside the pen (STO) (Fig. 4-2 (f)) vs. the pen with the novel object (NO). Standing outside means that the human was standing outside the choice pen in the position where the animals has been in the Peer choice.

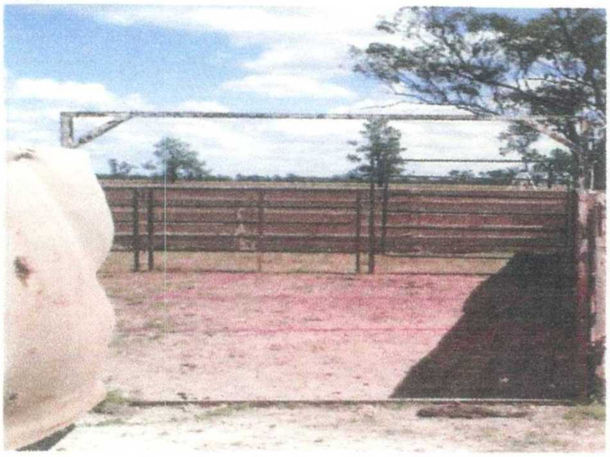
(iii) n=28, a pen with the same human sitting inside (SI) (Fig. 4-2 (g)) vs. the pen with a

(a)

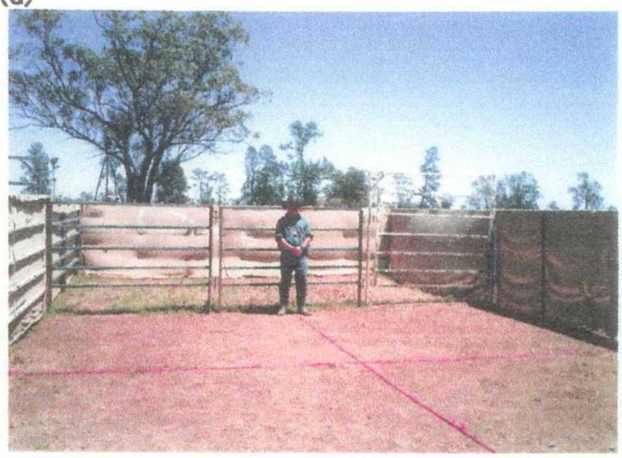


(b)

(c)

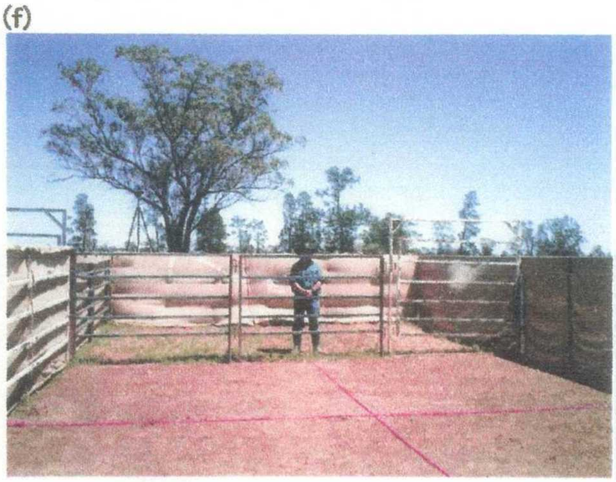


(d)



(e)

(f)



(g)

Fig. 4-2. Choice stimuls in a test pen.
(a) Peers presented as three familiar cattle.
(b) Food presented as hay on a metal rack.
(c) Bare presented as a bare pen.
(d) STI presented as a familiar handler standing inside.
(e) Novel object (NO) presented as an orange-painted tire.
(f) STO presented as a familiar handler standing outside the pen.
(g) SI presented as a familiar handler sitting inside.

novel object (NO).

The novel object was an orange-painted tire 40.6 cm in diameter suspended by rope 50 cm above the ground at the mid-point of the side opposite the entry gate. The familiar handler was the same parson leading the test animal to the crush before the test and standing in the front of the test animals during the restraint. As well as the behaviors common to both experiments we also measured time spent sniffing and licking novel object and time spent interacting with the human. The time spent in each sector (S1, S2 and S3) was also recorded.

Experiment 3

Another 90 heifers were given each one of the following choice combinations:

(i) n=30, a pen containing three familiar heifers (Peers) vs. a pen containing six sheep (Sheep).

(ii) n=30, a pen containing three familiar heifers (Peers) vs. a bare pen (Bare).

(iii) n=30, a pen containing six sheep (Sheep) vs. a bare pen (Bare).

Twelve Merino young ewe averaging 10 months of age were used in experiment 3 and 4. The sheep used as a choice were born in 2003 and reared at pasture at the NSW Agricultural Research Centre Trangie, Australia. The six sheep were selected from twelve animals alternately. They stayed a pen measuring 6.5 m×4.3 m adjacent to the test pen separated by a barrier through which they could have visual and physical contact with the test animal (Fig. 4-1). As well as the behaviors described in experiment 1, time spent engaged in social contact with sheep was also measured, depending on the choice combination offered.

Experiment 4

Another 67 heifers were given each one of the following choice combinations:

(i) n = 19, a pen containing three familiar heifers (Peers) vs. a pen with the same novel object as experiment 2(NO).

(ii) n = 22, a pen containing six sheep (Sheep) vs. a pen with the novel object (NO).

(iii) n = 26, a bare pen (Bare) vs. a pen with the novel object (NO).

Statistical analysis

The numbers of heifers choosing each pen and the number of heifers choosing voluntarily or after force were analyzed using the chi-square test. The latency to first choice was analyzed using the Mann-Whitney U test. The latency to choose each pen on each combination of choices was analyzed using the Kruskal-Wallis test or a one-way factorial ANOVA. If effects were significant, post-hoc testing was performed with Scheffé's F-test. The behavior score in the crush was analyzed using the Student's t-test or Mann-Whitney U test.

Three periods of behavior of the animals were distinguished. These were behavior in the choice area before the animal was making its first choice, behavior in the choice pens and behavior in the choice area after the animal made its first choice. The effect of combination of choices on the duration of behaviors in each pen and choice area was analyzed using the one-way ANOVA. If the effect was significant, post-hoc test was performed with Tukey's HSD.

Comparisons between the numbers of times each pen was entered were made using the Wilcoxson Matched Pairs test. The time spent in each pen and choice area was analyzed using one-way ANOVA or the Kruskal-Wallis test. If effects were significant, post-hoc testing was performed with Scheffé's F-test.

The effect of pen and location within the pen (S1, S2 and S3) on the time spent in each sector per the total duration of staying in each pen was analyzed using two-way ANOVA. If effects were significant, post-hoc testing was performed with Tukey's HSD.

Results

Experiment 1

The percentage of heifers choosing the pen containing other animals was significantly greater than that of heifers choosing the bare pen (χ^2=5.76; P<0.05) (Fig. 4-3 (a)), the percentage of heifers choosing other animals tended to be greater than that of heifers choosing food (χ^2=2.94; P<0.10) (Fig. 4-3 (a)) and there was no significant difference between the percentage of heifers choosing food and the bare pen (χ^2=0.26; P>0.10) (Fig. 4-3 (a)). The latency to choose a particular choice condition (Peers, Food or Bare) was not significantly affected by the choice condition on the other side of Y-maze. However, latency (±SD) to choose was significantly longer when the choice combination was 'Food vs. Bare' (153.8±128.2 s) than when it was 'Peers vs. Food' (57.8±72.7 s) or 'Peers vs. Bare' (71.1±88.5 s) (both P<0.01). Furthermore, very few heifers had to be forced to choose when the choice combination was 'Peers vs. Food' (χ^2=30.12; P<0.01) or 'Peers vs. Bare' (χ^2=19.88; P<0.01), but when the combination was 'Food vs. Bare' (χ^2=1.40; P>0.10), 40% of heifers had to be forced to choose (Fig. 4-3 (b)). The behavior score in the crush was not significantly related to any of the choice parameters.

In the choice area before choosing for the first time, heifers given the choice of 'Food vs. Bare' spent significantly less time walking (both P<0.05) and spent significantly more time near the entrance to the crush (both P<0.05) than the heifers given the choices of 'Peers vs. Food' and 'Peers vs. Bare'(Fig. 4-4 (a)). None of the other behaviors differed between the combinations of choices.

When Peers was one of the choices, heifers entered the Peers pen significantly more times

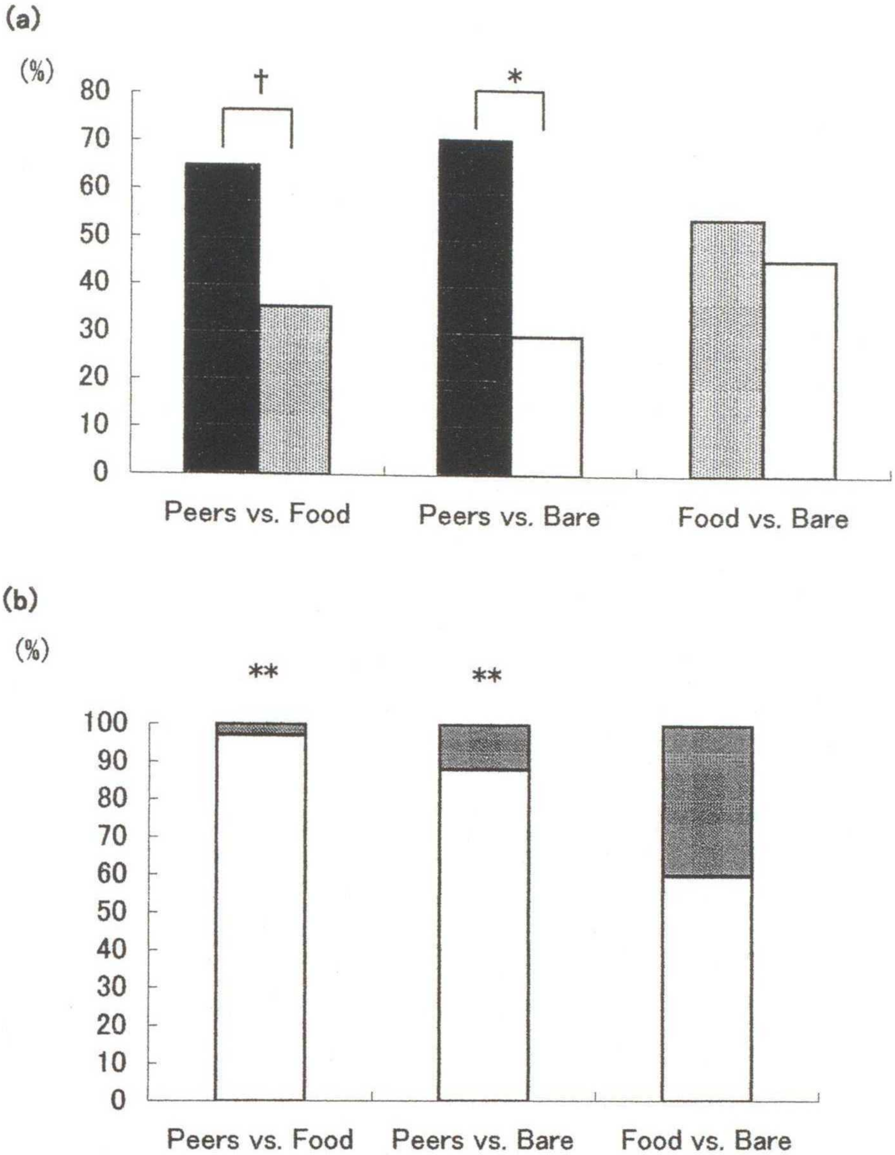


Fig. 4-3 (a) Percentage of heifers choosing peers, food or the bare pen and **(b)** percentage of heifers choosing voluntarily (clear bars) or forced (shaded bars) when presented with three combinations of choice (Peers vs. Food, Peers vs. Bare and Food vs. Bare) in a Y-maze. Probability levels are indicated by †P<0.10, * P<0.05 and ** P<0.01.

than they entered the Food ($P<0.05$) or Bare pen ($P<0.01$) (Fig. 4-4 (b)). However, when the choice was 'Food vs. Bare', there was no difference in the number of times heifers entered either pen (Fig. 4-4 (b)). In fact, when the choice was 'Food vs. Bare', heifers spent significantly more time in the choice area than in either of the choice pens (both $P<0.01$) and, when the choices were 'Peers vs. Food' and 'Peers vs. Bare', the heifers spent more time in the choice area than in the Food ($P<0.05$) or Bare pens ($P<0.01$) (Fig. 4-4 (c)).

While in the pen with peers, if the alternative choice was the bare pen, heifers spent significantly more time investigating the ground than when the alternative choice was food ($P<0.05$) (Fig. 4-5 (a)). The other behaviors were not significantly different between the combinations of choices. When heifers were in the pen with food, heifers spent significantly more time investigating food when the alternative choice was the bare pen than when the alternative choice was peers ($P<0.05$) (Fig. 4-5 (b)). There were no other significant differences. In the bare pen, there were no significant differences between peers and food as the alternative choices. In the choice area during the time after the heifers had made their first choice, the heifers given the choice of 'Food vs. Bare' spent significantly more time at the entrance of the crush than the heifers given the other combinations of choice (both $P<0.05$) (Fig. 4-5 (c)). No other behaviors were significantly different between the combinations of choices.

The effect of interaction of pen and the time spent in each sector was significant ($P<0.001$). In the pen containing peers, heifers spent significantly longer in the sector closest to the other animals than in the other sectors (both $P<0.05$) (Fig. 4-6). In the bare pen, the reverse was true wherein animals spent significantly more time in the sector closest to the entry gate (both $P<0.05$). In the pens containing food, the animals spent equal amounts of time in the sector closest to the food and the sector closest to the entry gate, and the heifers

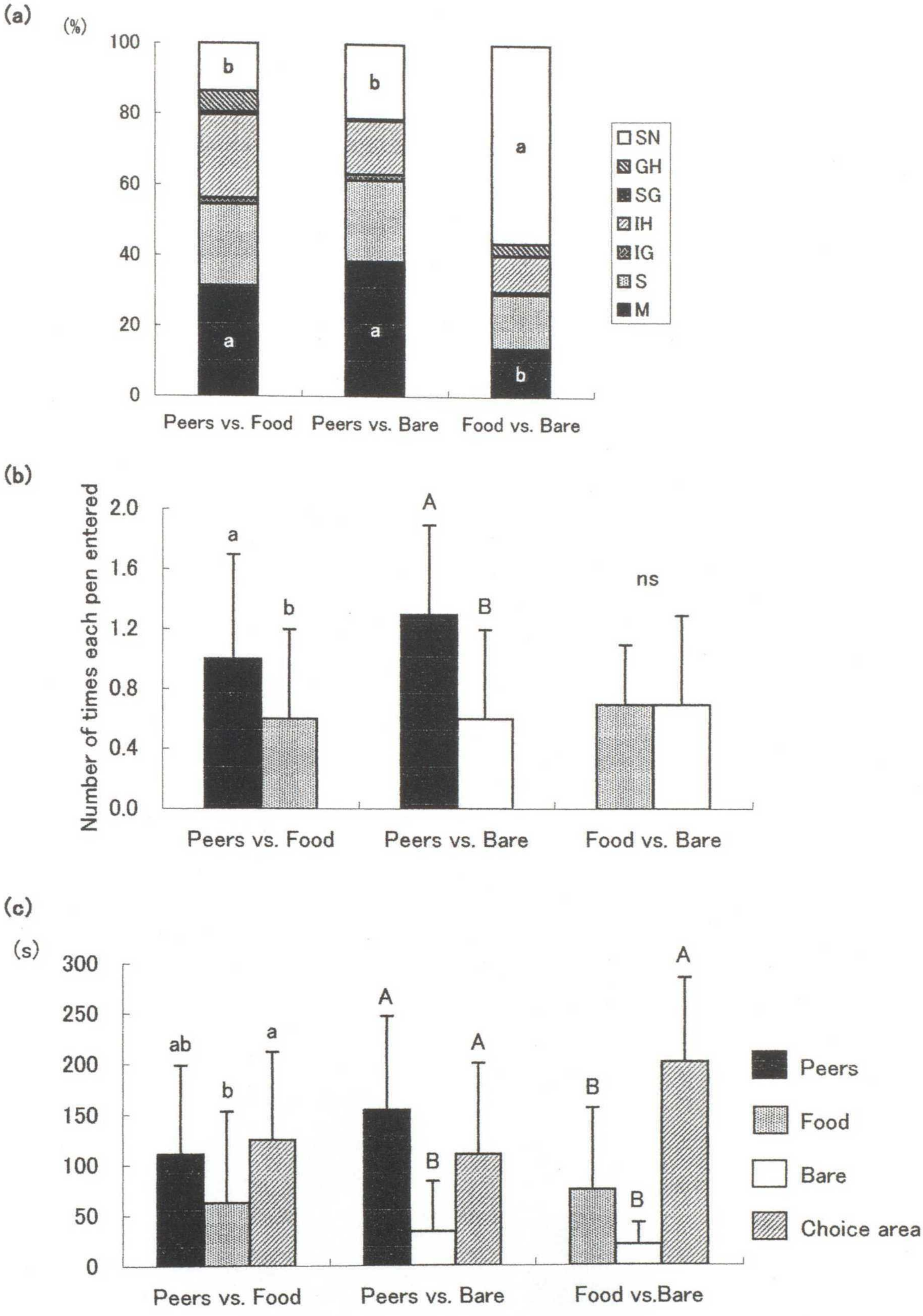


Fig. 4-4 (a) Behavior of heifers in the choice area before choosing, **(b)** mean (±SD) number of entries into the pen containing peers, food or nothing and **(c)** mean (±SD) length of time heifers spent in the pen with peers, the pen with food, the bare pen or the choice area after choosing when presented with three choice combinations (Peers vs. Food, Peers vs. Bare and Food vs. Bare) in a Y-maze. SN = standing near crush; GH = grooming the sides of the choice area; SG = self-grooming; IH = investigating the sides of the choice area; IG = investigating ground; S = standing; M = moving. Different letters indicates significant difference; a, b = $P<0.05$, A, B = $P<0.01$.

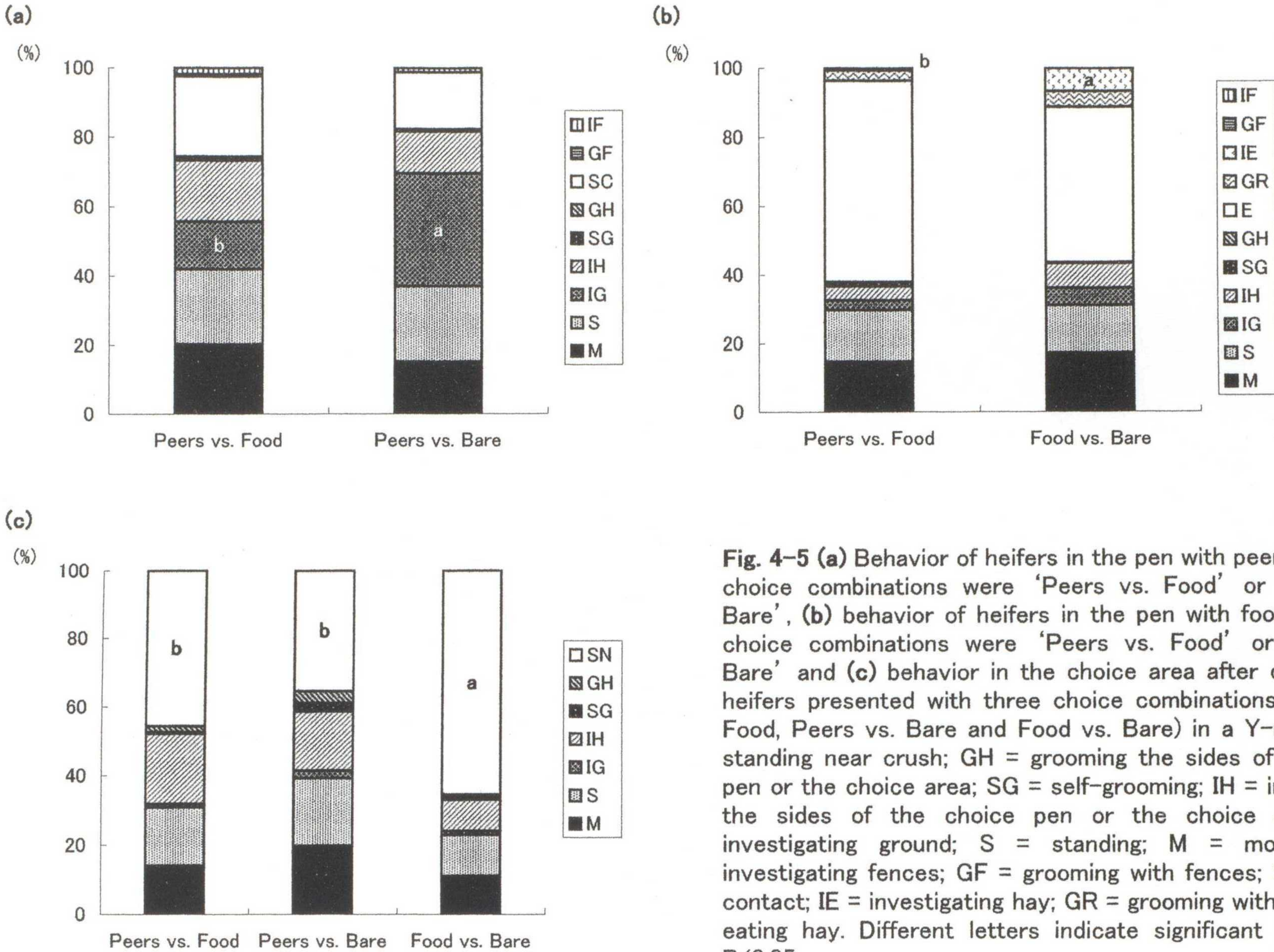


Fig. 4–5 (a) Behavior of heifers in the pen with peers when the choice combinations were 'Peers vs. Food' or 'Peers vs. Bare', **(b)** behavior of heifers in the pen with food when the choice combinations were 'Peers vs. Food' or 'Food vs. Bare' and **(c)** behavior in the choice area after choosing by heifers presented with three choice combinations (Peers vs. Food, Peers vs. Bare and Food vs. Bare) in a Y–maze. SN = standing near crush; GH = grooming the sides of the choice pen or the choice area; SG = self–grooming; IH = investigating the sides of the choice pen or the choice area; IG = investigating ground; S = standing; M = moving; IF = investigating fences; GF = grooming with fences; SC = social contact; IE = investigating hay; GR = grooming with a rack; E = eating hay. Different letters indicate significant differences, $P<0.05$.

spent the least amount of time in the sector in the middle of the pen (both P<0.05) (Fig. 4-6). The heifers spent significantly longer in the sector furthest from the entry gate when their peers were in the pen than when food was in the pen (P<0.05) and significantly longer there when food was in the pen than when the pen was empty (P<0.05) (Fig. 4-6). The converse was true for the sector closest to the entry gate in that the heifers spent significantly less time in this sector when food and peers were in the pen than when the pen was bare(both P<0.05) (Fig. 4-6).

Experiment 2

The percentage of heifers choosing the pen with the novel object was significantly greater than the number of heifers choosing the human being, regardless of the position or posture of the human (χ^2=9.97, 12.45, 7.00, STI, STO and SI, respectively; all P<0.01) (Fig. 4-7 (a)). There were no significant differences in latency to choose between any of the choice combinations. Very few of the heifers had to be forced to choose when the human was inside the pen, either standing (χ^2=18.24; P<0.01) or seated (χ^2=11.57; P<0.01) but, when the human was standing outside the pen (χ^2=1.69; P>0.10), 38% of the heifers had to be forced to choose (Fig. 4-7 (b)). The mean behavior score (±SD) in the crush of the heifers choosing the human sitting inside the pen (2.93±0.61) tended to be higher than that of the heifers choosing the novel object (2.36±0.64) (P=0.05).

The only significant difference in behavior in the choice area before choosing was the greater time spent investigating the sides of the choice area in the heifers given the choice of the human standing inside the pen and the novel object than in the heifers given the choice between the seated human and the novel object (P<0.05) (Fig. 4-8 (a)).

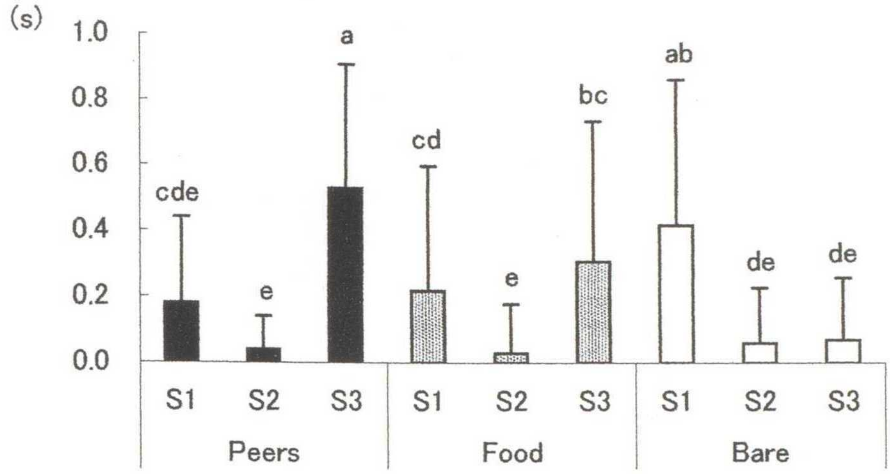
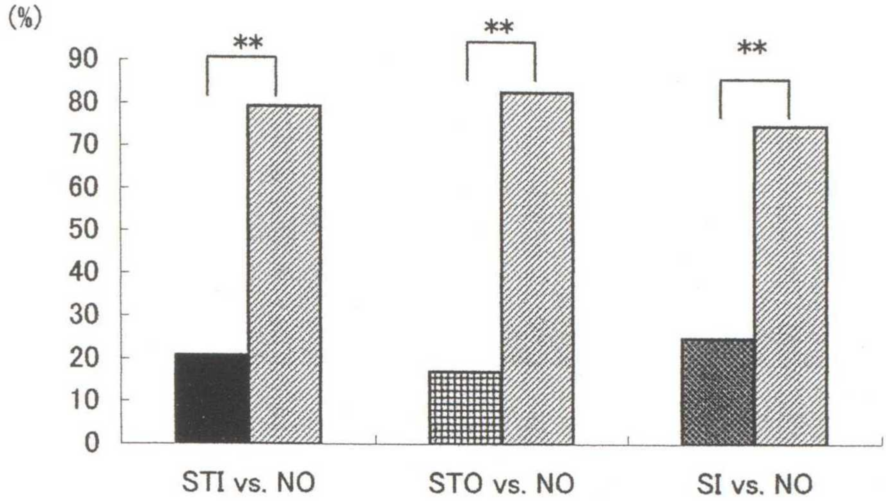


Fig. 4-6. Mean (±SD) time spent in the sector closest to the entry gate (S1), the sector furthest from the entry gate (S3) and the intermediate sector (S2) while in the pen with peers, the pen with food and the bare pen by heifers presented with three choice combinations (Peers vs. Food, Peers vs. Bare and Food vs. Bare) in a Y-maze. Different letters indicate significant differences, P<0.05.

(a)



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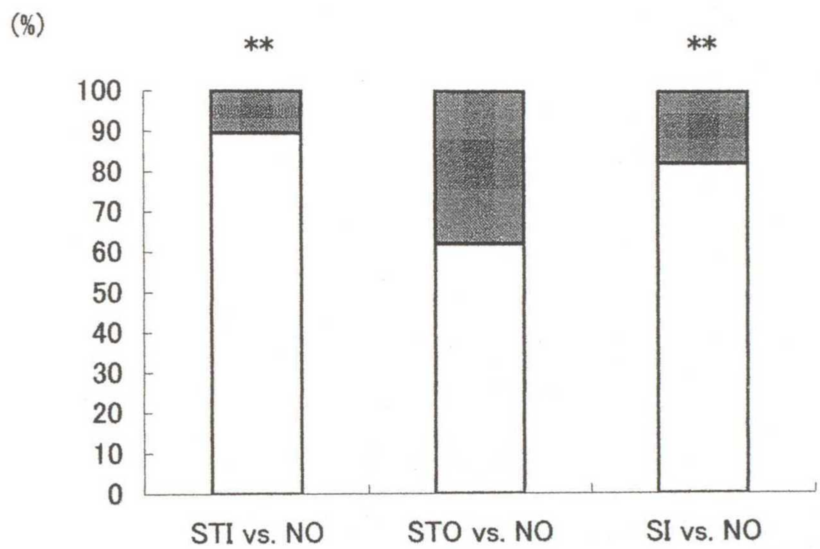


Fig. 4-7 (a) Percentage of heifers choosing a human standing inside the pen, a human standing outside the pen, a human sitting inside the pen and a novel object and **(b)** percentage of heifers choosing voluntarily (clear bars) or forced (shaded bars) when presented with three combinations of choice (Human standing inside pen vs. Novel object, Human standing outside pen vs. Novel object and Human sitting inside pen vs. Novel object) in a Y-maze. Probability levels are indicated by ** P<0.01.

In the choice combinations where the human being was standing, heifers entered this pen significantly fewer times than the pen containing the novel object (both $P<0.01$) but, when the human was seated, there was no difference between the number of times the animals entered the pen with the human or that with the novel object (Fig. 4-8 (b)). However, regardless of the choice combination, the time spent in the choice area was longer than that spent in either choice pen (all $P<0.01$) (Fig. 4-8 (c)). There were no differences in the behavior of the animals while inside the choice pens or in the choice area after making their initial choice.
The interaction between choice stimulus and the time spent in each sector was not significant. However, the effect of sector was significant ($P<0.001$) in that heifers spent longer in the sector closest to the entry gate (0.55±0.46 s) than in the intermediate sector (0.05±0.17 s) or the sector closest to the human or the novel object (0.06±0.17 s) (both $P<0.05$).

Experiment 3

The percentage of heifers choosing the pen containing other animals was significantly greater than that of heifers choosing the bare pen ($\chi^2=4.80$; $P<0.05$) (Fig. 4-9 (a)). However, there was not significant difference between the percentage of heifers choosing other animals and sheep ($\chi^2=2.13$; $P>0.10$), and those of heifers choosing sheep and the bare pen ($\chi^2=0.00$; $P>0.10$) (Fig. 4-9 (a)). The latency to choose a particular choice condition (Peers, Sheep or Bare) was not significantly affected by the choice combinations of the Y-maze. No heifers had to be forced to choose. The behavior score in the crush was not significantly related to any of the choice parameters.

In the choice area before choosing for the first time, heifers given the choices of 'Sheep vs. Bare' spent significantly more time standing than the heifers given the choices of 'Peers vs.

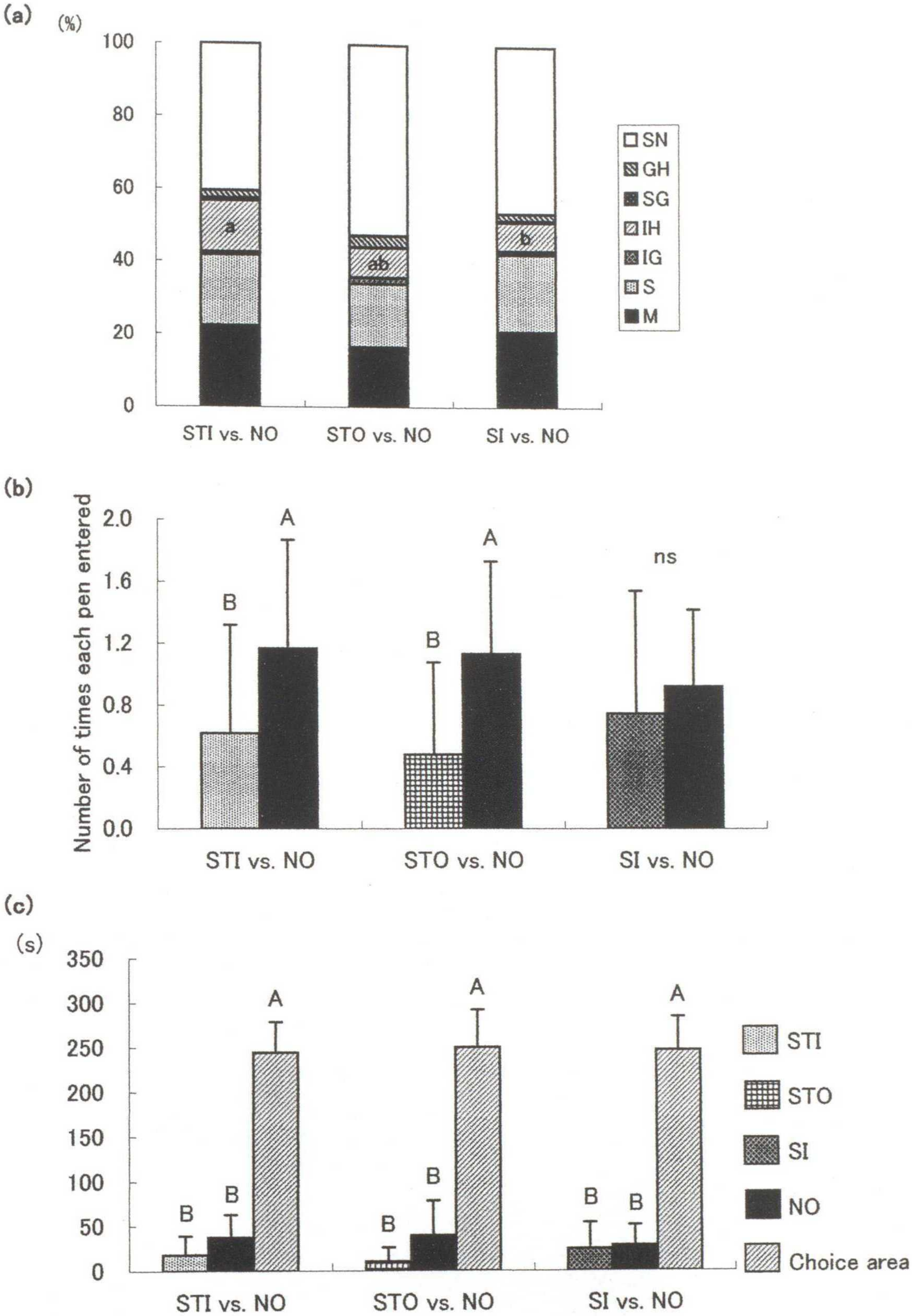


Fig. 4-8 (a) Behavior in the choice area before choosing, **(b)** mean (±SD) number of times each choice pen was entered and **(c)** mean (±SD) length of time heifers spent in the pen a human standing inside the pen, the pen a human standing outside the pen, the pen a human sitting inside the pen, the pen with the novel object or the choice area after choosing of heifers presented with three combinations of choice (Human standing inside pen vs. Novel object, Human standing outside pen vs. Novel object and Human sitting inside pen vs. Novel object) in a Y-maze. SN = standing near crush; GH = grooming the sides of the choice area; SG = self-grooming; IH = investigating the sides of the choice area; IG = investigating ground; S = standing; M = moving. Different letters indicates significant difference; a, b = $P<0.05$, A, B = $P<0.01$.

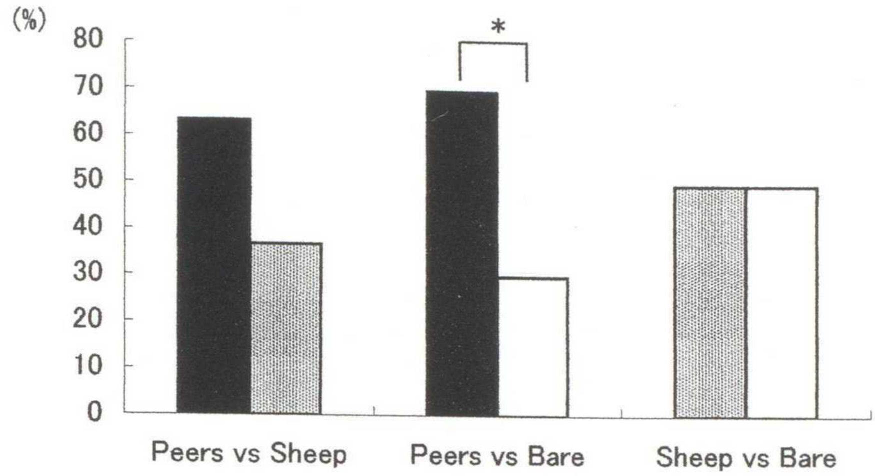
Bare' ($P<0.05$) (Fig. 4-9 (b)). None of the other behaviors differed between the combinations of choices.

When Peers was one of the choices, heifers entered the Peers pen significantly more times than they entered the bare pen ($P<0.05$) and heifers tended to enter the Peers pen more times than they entered the Sheep pen ($P<0.10$) (Fig. 4-10 (a)). However, when the choice was 'Sheep vs. Bare', there was no significant difference in the number of times heifers entered either pen (Fig. 4-10 (a)). In fact, when the choice was 'Sheep vs. Bare', heifers spent significantly more time in the choice area than in either of the choice pens (both $P<0.01$) (Fig. 4-10 (b)), however heifers spent significantly more time in Sheep pen than in the bare pen ($P<0.05$) (Fig. 4-10 (b)). When the choice was 'Peers vs. Sheep', heifers spent significantly more time in Peers pen than in Sheep pen or the choice area (both $P<0.01$) (Fig. 4-10 (b)), and when the choice was 'Peers vs. Bare', heifers spent significantly less time in the bare pen than in Peers pen or the choice area (both $P<0.01$) (Fig. 4-10 (b)).

When heifers were in the pen with sheep, if the alternative choice was the bare pen, heifers spent significantly more time walking than when the alternative choice was peers ($P<0.05$) (Fig. 4-11 (a)). In the choice area during the time after the heifers had made their first choice, the heifers given the choice of 'Sheep vs. Bare' spent significantly more time at the entrance of the crush than heifers given the choice of 'Peers vs. Sheep' and 'Peers vs. Bare'(both $P<0.05$) (Fig. 4-11 (c)). No other behaviors were significantly different between the combinations of choices. When heifers were in the pen with peers and the bare pen, any behavior was significantly different between the combinations of choices.

The effect of interaction of pen and the time spent in each sector was significant ($P<0.001$). In the pen containing peers, heifers spent significantly longer in the sector closest to the other animals than in the other sector (both $P<0.05$) (Fig. 4-12). In the pen containing

(a)



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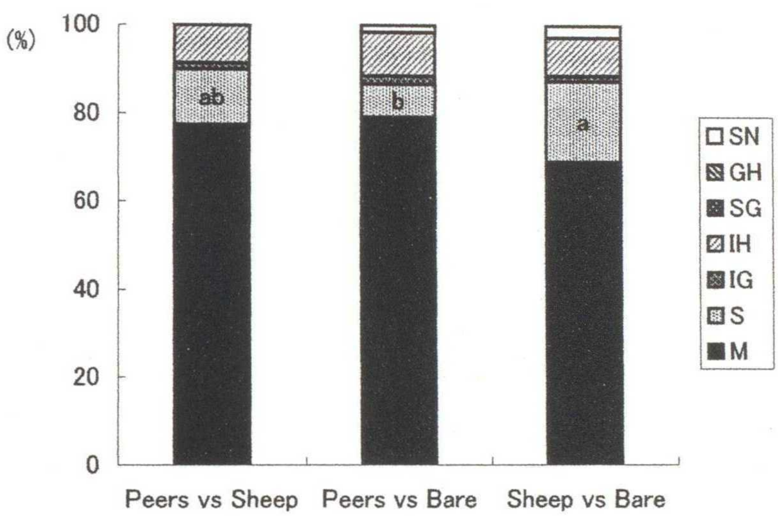


Fig. 4-9 (a) Percentage of heifers choosing peers, sheep or the bare pen and **(b)** behavior of heifers in the choice area before choosing when presented with three combinations of choice (Peers vs. Sheep, Peers vs. Bare and Sheep vs. Bare) in a Y-maze. Probability levels are indicated by * $P<0.05$. SN = standing near crush; GH = grooming the sides of the choice area; SG = self-grooming; IH = investigating the sides of the choice area; IG = investigating ground; S = standing; M = moving. Different letters indicates significant difference, $P<0.05$.

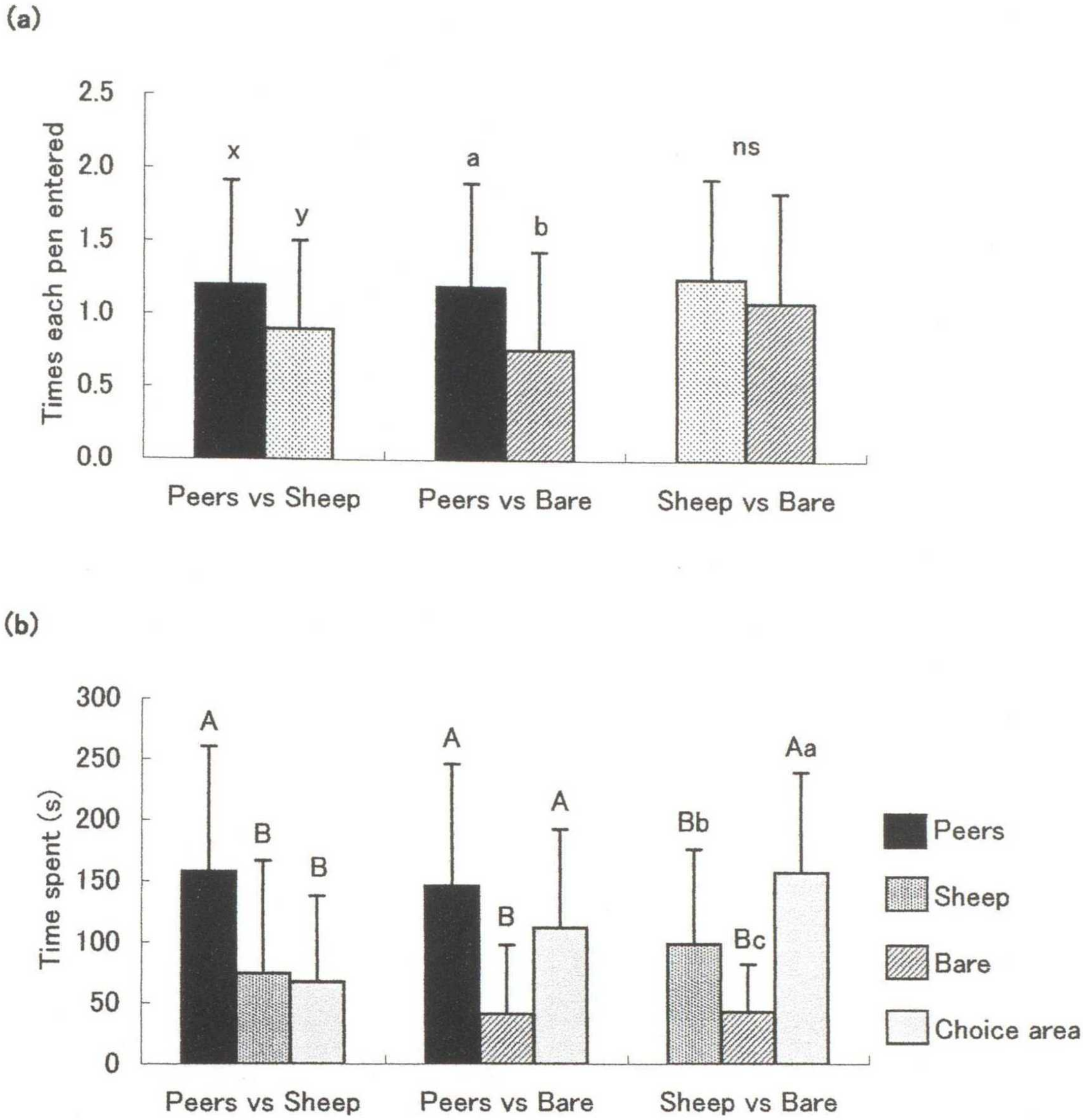
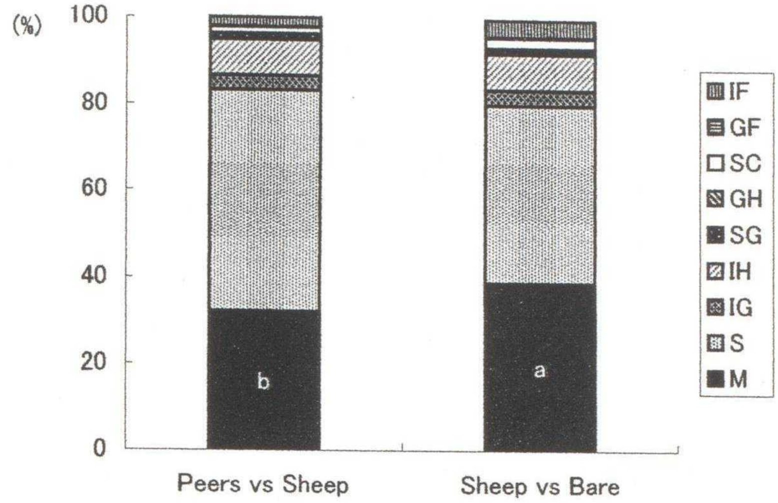


Fig. 4-10 (a) Mean (±SD) number of entries into the pen containing peers, sheep or nothing and **(b)** mean (±SD) length of time heifers spent in the pen with peers, the pen with sheep, the bare pen or the choice area after choosing when presented with three choice combinations (Peers vs. Sheep, Peers vs. Bare and Sheep vs. Bare) in a Y-maze. Different letters indicates significant difference; x, y = $P<0.10$, a, b, c = $P<0.05$ and A, B = $P<0.01$.

(a)



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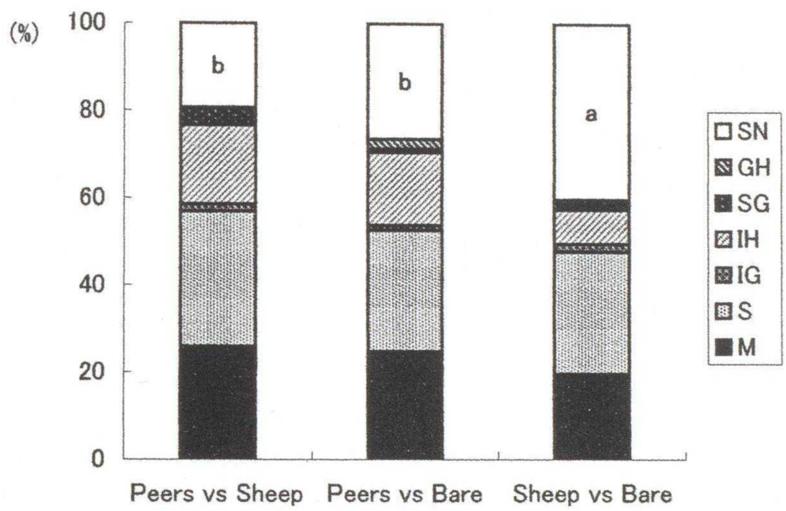

Fig. 4-11 (a) Behavior of heifers in the pen with sheep when the choice combinations were 'Peers vs. Sheep' or 'Sheep vs. Bare' and **(b)** behavior of heifers in the choice area after choosing by heifers presented with three choice combinations (Peers vs. Sheep, Peers vs. Bare and Sheep vs. Bare) in a Y-maze. SN = standing near crush; GH = grooming the sides of the choice pen or the choice area; SG = self-grooming; IH = investigating the sides of the choice pen or the choice area; IG = investigating ground; S = standing; M = moving; IF = investigating fences; GF = grooming with fences; SC = social contact. Different letters indicate significant differences, $P<0.05$.

sheep, the animals spent equal amounts of time in the sector closest to the sheep and the sector closest to the entry gate, and the heifers spent the least amount of time in the sector in the middle of the pen (both $P<0.05$) (Fig. 4-12). In the bare pen, heifers spent the most amount of time in the sector closest to the entry gate ($P<0.05$) (Fig. 4-12).

Experiment 4

The percentage of heifers choosing either pen was not significantly different in any choice combination; $\chi^2=2.58$, $\chi^2=0.18$ and $\chi^2=2.46$; all $P>0.10$, Peers vs. NO, Sheep vs. NO and Bare vs. NO, respectively (Fig. 4-13 (a)). The latency to choose a particular choice condition (Peers, Sheep, Bare or NO) was not significantly affected by the choice combinations of the Y-maze. No heifers had to be forced to choose. The behavior score in the crush was not significantly related to any of the choice parameters. In the choice area before choosing for the first time, No behavior differed between the combinations of choices.

When the choice was 'Peers vs. NO', heifers entered the Peers pen significantly more times than they entered the NO pen ($P<0.01$) (Fig. 4-13 (b)). However, when the choice was 'Sheep vs. NO' or 'Bare vs. NO', there was no difference in the number of times heifers entered either pen (Fig. 4-13 (b)). When the choice was 'Peers vs. NO', heifers spent significantly less time in the NO pen than in the Peers pen or the choice area (both $P<0.01$), however heifers spent significantly more time in the Peers pen than in the choice area ($P<0.05$) (Fig. 4-13 (c)). When the choice was 'Sheep vs. NO' or 'Bare vs. NO', heifers spent significantly more time in the choice area than in either of the choice pens (all $P<0.01$) (Fig. 4-13 (c)).

When heifers were in the pen with peers and sheep, heifers spent significantly more time

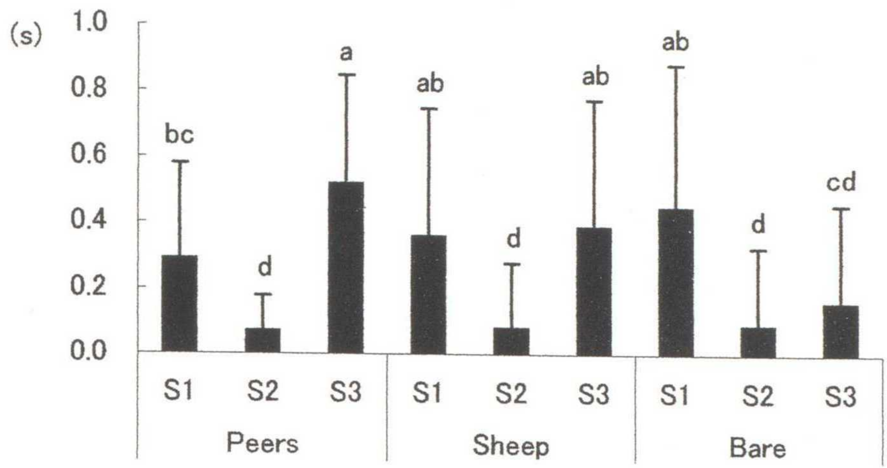

Fig. 4-12. Mean (±SD) time spent in the sector closest to the entry gate (S1), the sector furthest from the entry gate (S3) and the intermediate sector (S2) while in the pen with peers, the pen with sheep and the bare pen by heifers presented with three choice combinations (Peers vs. Sheep, Peers vs. Bare and Sheep vs. Bare) in a Y-maze. Different letters indicate significant differences, $P<0.05$.

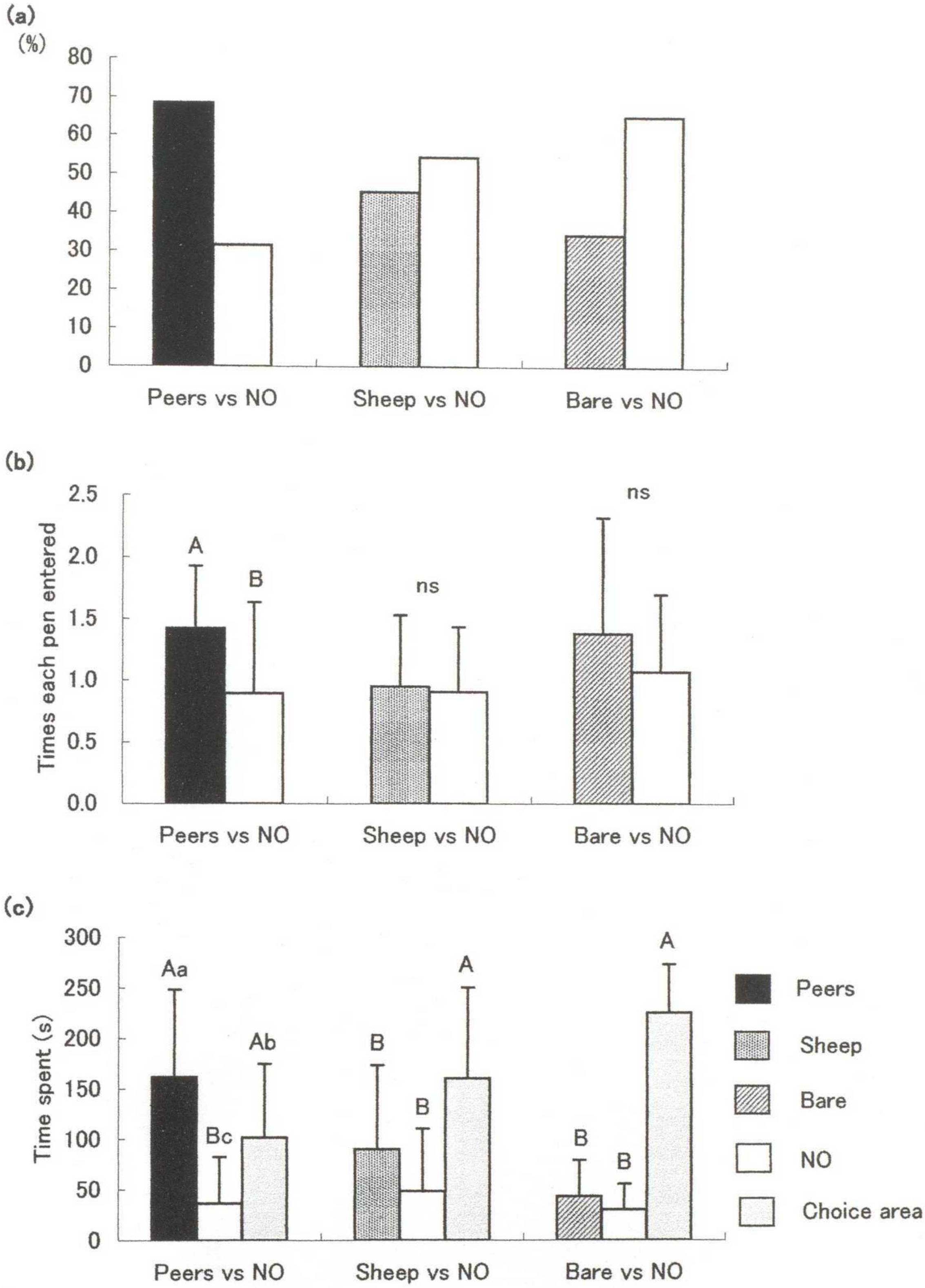

Fig. 4-13 (a) Percentage of heifers choosing peers, sheep, the bare pen or the novel object, **(b)** mean (±SD) number of entries into the pen containing peers, sheep, nothing or the novel object and **(c)** mean (±SD) length of time heifers spent in the pen with peers, the pen with sheep, the bare pen, the novel object or the choice area after choosing when presented with three choice combinations (Peers vs. NO, Sheep vs. NO and Bare vs. NO) in a Y-maze. Different letters indicates significant difference; a, b, c = $P<0.05$ and A, B = $P<0.01$.

performing social contact with peers than with sheep (P<0.05) (Fig. 4-14 (a)). In the choice area during the time after the heifers had made their first choice, the heifers given the choice of 'Peers vs. NO' spent significantly less time at the entrance of the crush than the heifers given the other combinations of choice (P<0.05) (Fig. 4-14 (b)).

The effect of interaction of pen and the time spent in each sector was significant (P<0.001). In the pen containing peers, heifers spent significantly longer in the sector closest to the other animals than in the other sectors (both P<0.05) (Fig. 4-15). In the pen containing sheep, the animals spent equal amounts of time in the sector closest to the sheep and the sector closest to the entry gate (P<0.05) (Fig. 4-15). Heifers spent significantly longer in the sector closest to the entry gate than in the sector in the middle of the pen (P<0.05) (Fig. 4-15). In the bare pen or the pen with a novel object, heifers spent significantly more time in the sector closest to the entry gate than in the other sectors (all P<0.05) (Fig. 4-15).

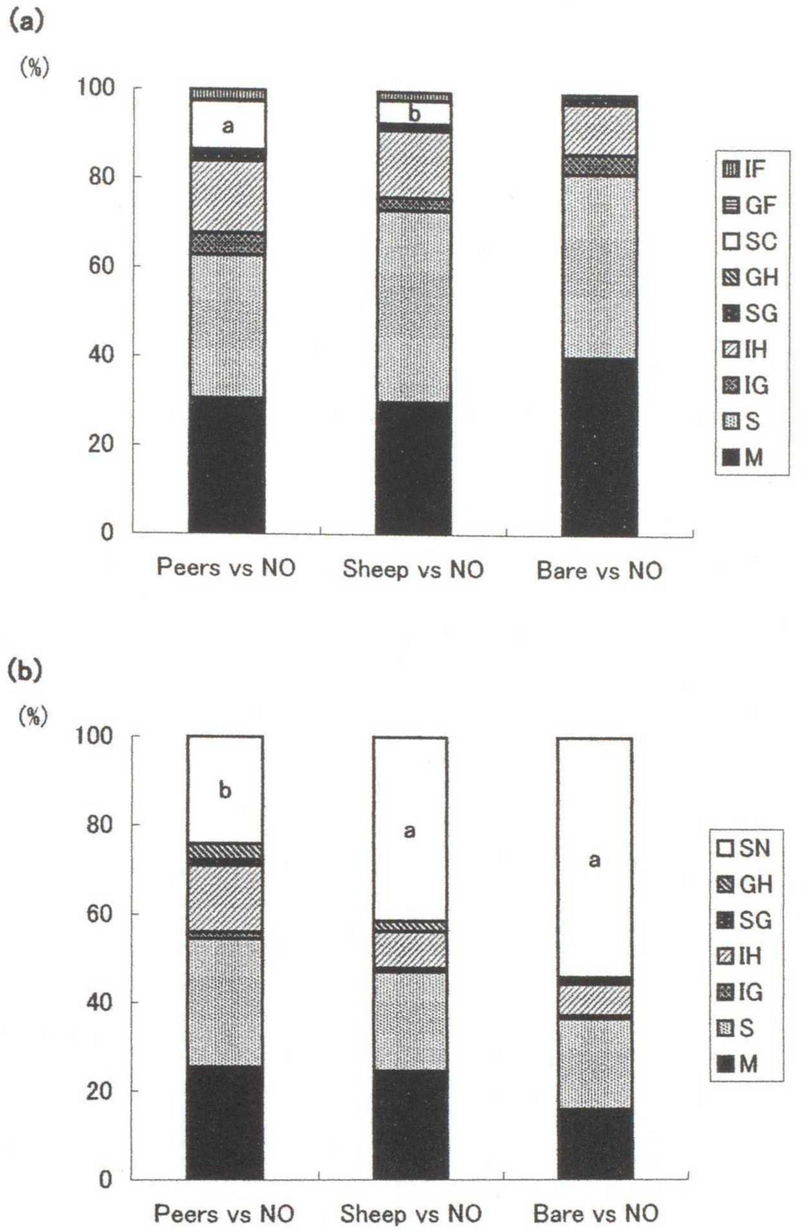

Fig. 4-14 (a) Behavior of heifers in the pen with peers, the pen with sheep and the bare pen and **(b)** behavior of heifers in the choice area after choosing by heifers presented with three choice combinations (Peers vs. NO, Sheep vs. NO and Bare vs. NO) in a Y-maze. SN = standing near crush; GH = grooming the sides of the choice pen or the choice area; SG = self-grooming; IH = investigating the sides of the choice pen or the choice area; IG = investigating ground; S = standing; M = moving; IF = investigating fences; GF = grooming with fences; SC = social contact. Different letters indicate significant differences, $P<0.05$.

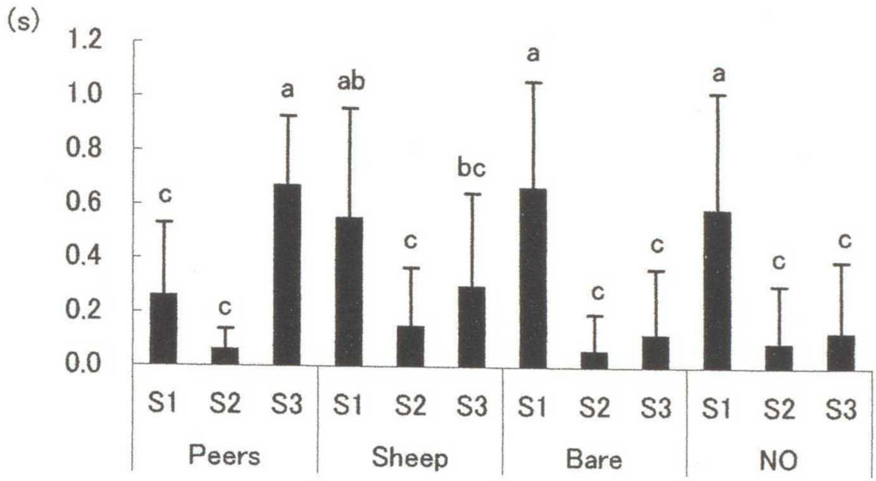

Fig. 4-15. Mean (±SD) time spent in the sector closest to the entry gate (S1), the sector furthest from the entry gate (S3) and the intermediate sector (S2) while in the pen with peers, the pen with sheep, the bare pen and the pen with the novel object by heifers presented with three choice combinations (Peers vs. NO, Sheep vs. NO and Bare vs. NO) in a Y-maze. Different letters indicate significant differences, P<0.05.

Discussion

Experiment 1 and 2

Experiment 1 clearly demonstrated the preference of the heifers for their peers compared to food or a bare pen. Experiment 2, however, did not show a preference for any of the choices but rather a lower aversion for the novel object and the seated human compared to the standing human. None of the behaviors measured during the choice test in either experiment were related to the behavior of the animals while contained in the crush.

The preference of the heifers for peers in Experiment 1 was demonstrated by their initial choice, their readiness to choose and their behavior during the test after they had made their first choice. As regards their first choice, heifers chose peers over the bare pen, with food intermediate between these two. Readiness to choose was shown by their lower latency to choose when peers were one of the choices and by the fact that very few animals had to be forced by the human handler to choose. Finally, once the heifers had made their choice, they spent less time in the choice area, they entered the pen with the peers in it more times and, when in the pen with peers, spent more time in the sector of the pen closest to the other animals.

While our study suggests the desire of heifers to return to the company of other familiar animals following handling, other studies have shown the influence of the presence of peers while handling procedures are being conducted. Gringnard et al. (2000) showed that the visual presence of peers calmed the behavior of calves during handling in a novel environment. Furthermore, the presence of peers decreased distress behavior of heifers in a novel object test (Boissy and Le Neindre, 1990) and novel environment test (Veissier and Le Neindre, 1992), while Boissy and Le Neindre (1997) reported that separation from peers induced behavioral and physiological responses to stress. In addition, in farmed red deer, there was a report that they preferred staying next to unfamiliar deer to staying next to an empty pen (Abeyesinghe and Goddard, 1998). These studies suggest the importance of peers when their presence is forced by the conditions of the experiment. Our study indicates the importance of peers as shown voluntarily by the experimental heifers.

While not shown as clearly as the preference for peers, food appeared to be more attractive for heifers than the bare pen. One possibility is that the animals may not have been hungry enough to be highly attracted to the hay, as we took care to ensure that there was not a great difference in time off feed for animals tested later in the day compared to animals tested earlier. It is also possible that feeding using a novel feeder in novel test pen provoked a reaction to novelty rather than a desire to eat as suggested by the results of Herskin et al. (2003). The inhibition of feeding in a novel environment has also been used to evaluate the response to novelty by Boissy and Buissou (1988), Veisser and Le Neindre (1992) and Boissy and Buissou (1995). However, Pajor et al. (2003) have reported that heifers chose bucket feeding more than control in their Y-maze test. In their experiment, the bucket contained molasses-flavored calf starter and was held by a human handler while the control was a human standing side on to the animal. In our study, the heifers were alone in the choice area and test pen. Finally, Dumont and Boissy (2000) reported that a sheep in small group would not leave its group to reach a preferred feeding site located further away.

When the pen with peers was not one of the two choices, the heifers spent more time at the entrance of the crush. It was possible that this could have been due to attraction caused by visual contact with the other heifers that the test animal could see in the holding pen, approximately 15m from the entrance of the crush. This reinforces the idea that peers were the most attractive for heifers.

Experiment 2 showed that the presence of the human was initially more aversive than the novel object since animals were more likely to make the novel object their first choice in preference to the human. However, once they had made this choice and the animals were able to move freely between the two pens and the choice area, they were as likely to enter the pen with the seated human as they were to enter the pen containing the novel object. However, when the human was standing, even standing outside the pen, the animals were likely to enter this pen than the pen with the novel object. In other studies the responses of cattle to humans have been determined, the human was either sitting stationary on a stool (Hemsworth et al., 1996), standing in the test pen (Veissier and Le Neindre, 1992; de Passillé et al., 1995, 1996) or interacting with the test animal in such situations in the docility test (Le Neindre et al., 1995; Grignard et al., 2000, 2001), restraint test (Boivin et al., 1992a, b, 1994) and the sorting test (Boivin et al., 1992a, b, 1994). Behavioral responses to a human in different postures have never been determined in cattle, although those to a motionless human and stroking or handling human have been determined in the situation that animals were restrained (Grignard et al., 2000, 2001).

In some of the previous studies on cattle, the test animals have been observed to interact with the human. In those where the human was standing, heifers were observed to sniff a human (Veissier and Le Neindre, 1992) and de Passillé et al. (1995, 1996) reported that calves made contact with the human without vocalizing. In the case of a sitting human, few cattle were observed to approach within 1 and 2 m, although most cattle approached within 4 m (Hemsworth et al., 1996). In our study, no heifers made contact with the human. There was also no difference between the human standing inside or outside the pen, and only one heifer entered the sector closest to the human, which corresponded to an approach distance of 2.8 m.

It is possible that this lack of difference is related to the early experiences of the heifers, since Morita et al. (2001) and Uetake et al. (2003) have shown that animals lose their aversion to humans who work inside their enclosure than compared to those who work outside.

The fact that our heifers entered the pen with the human sitting inside as many as the pen with a novel object indicates that the animals perceived the seated human as less of a threat. Hemsworth et al. (1986) and Miura et al. (1996) have reported that pigs are far more likely to approach a squatting or lying human than a standing one. They interpreted this as indicating that relatively large objects are threatening to pigs. Also, Kendrick and Baldwin (1989) have shown that a human on all fours is less aversive to sheep than a standing human.

However, relative to cattle, humans may not pose such a size threat to them as they do for pig and sheep. A suggestion has been made by Rushen et al. (1999b) that wariness of humans may result from their propensity for quick or unpredictable movements in addition to the relative size. It is possible that, in our study the sitting human might be perceived to be less able to evoke fear, resulting in the heifers perceiving the sitting human and the novel object as equally and lowly aversive. However, the heifers chose the pen with human sitting inside firstly had higher behavior score in the crush, so it is that they had a strong sense of curiosity.

Experiment 3 and 4

Experiment 3 and 4 showed that the preference of the heifers for their peers compared to a bare pen or a novel object. The more heifers chose the pen with peers over the bare pen as is the case with the result in experiment 1. If the pen with peers was not one of the choices, the heifers spent more time near the entrance of the crush in the choice area. The heifers were away from sheep, a bare pen and a novel object. It was also shown that peers were the most attractive condition for heifers in these experiments. Hagen and Broom (2003) have reported that cattle could discriminate between individual familiar conspecifics.

The heifers spent more time performing social contacts with their peers than with sheep. The heifers spent more time in the pen with peers than the pen with sheep. It should be shown that sheep had less attractiveness for heifers. Sheep were not as attractive as familiar conspecific peers, even though the heifers could see sheep in the pasture.

However, there was not significant difference between the proportions of heifers choosing the pen with peers and the pen with sheep. Furthermore, the time spent in the pen with sheep was longer than the time spent in the bare pen. Abeyesinghe and Goddard (1998) have reported that the presence of sheep was not shown a high degree of alert behavior nor a strong avoidance by farmed red deer. They have suggested that the sheep were not as threatening as other farm animals such as pigs and cattle. The presence of sheep might be not threatening for cattle as well as deer. The proportion of heifers choosing the pen with sheep was also not significantly different from that of choosing the bare pen or the pen with a novel object. Sheep might have almost the same attractive level as a barn pen and a novel object for heifers.

Conclusions

After a period of restraint in the crush accompanied by close human proximity, peers were the most attractive condition for heifers, whereas human presence, particularly a standing human, was the least attractive. It therefore appears that the causes of flightiness and difficulty in handling are separation from peers and human proximity. Furthermore, sheep were neither attractive condition nor aversive condition for heifers. It was found that sheep can not replace conpecific peers. We recommend that cattle should be returned to their peers as soon as possible after restraint and that humans should not approach them needlessly even just standing outside their enclosure.

CHAPTER 5

General discussion

The themes of this thesis were to devise the methods to assess the holistic environments for beef cattle in the following three contexts or relationships: (1) the relationship between cattle and barn and pasture conditions in the concept of environmental enrichment; (2) the relationship between cattle and human; (3) the relationship between cattle and their peers (Fig. 5-1).

Firstly, beef cattle's surroundings in the context of the relationship between cattle and barn and pasture conditions in the concept of environmental enrichment were assessed in Chapter 2 and 3. In Chapter 2, cattle showed the notable ethogram that adapted to each living conditions. Although animals reared in an intensive pen environment spent less time of eating than the animals reared in extensive pasture environments. Total proportion of oral behaviors in the intensive environment was not different from that in the extensive environment. The cattle in a pen might change objects of oral behavior to adapt the environment and behave appropriately as ruminants. Cattle spend more time of grazing on the grassy pasture environment, while the cattle in a pen should spend more time of grooming, licking and tongue rolling to compensate the short time of eating high-quality feed. In the pasture environment, the time spent grazing was diversified according to the quality and quantity of grasses there. Cattle that could ingest high-quality grasses spent less time of grazing. Thus cattle could easily adapt themselves to the different environments by changing the proportion of some behaviors in their ethogram.

In inadaptable environments, it is known that the proportion of a part of the normal

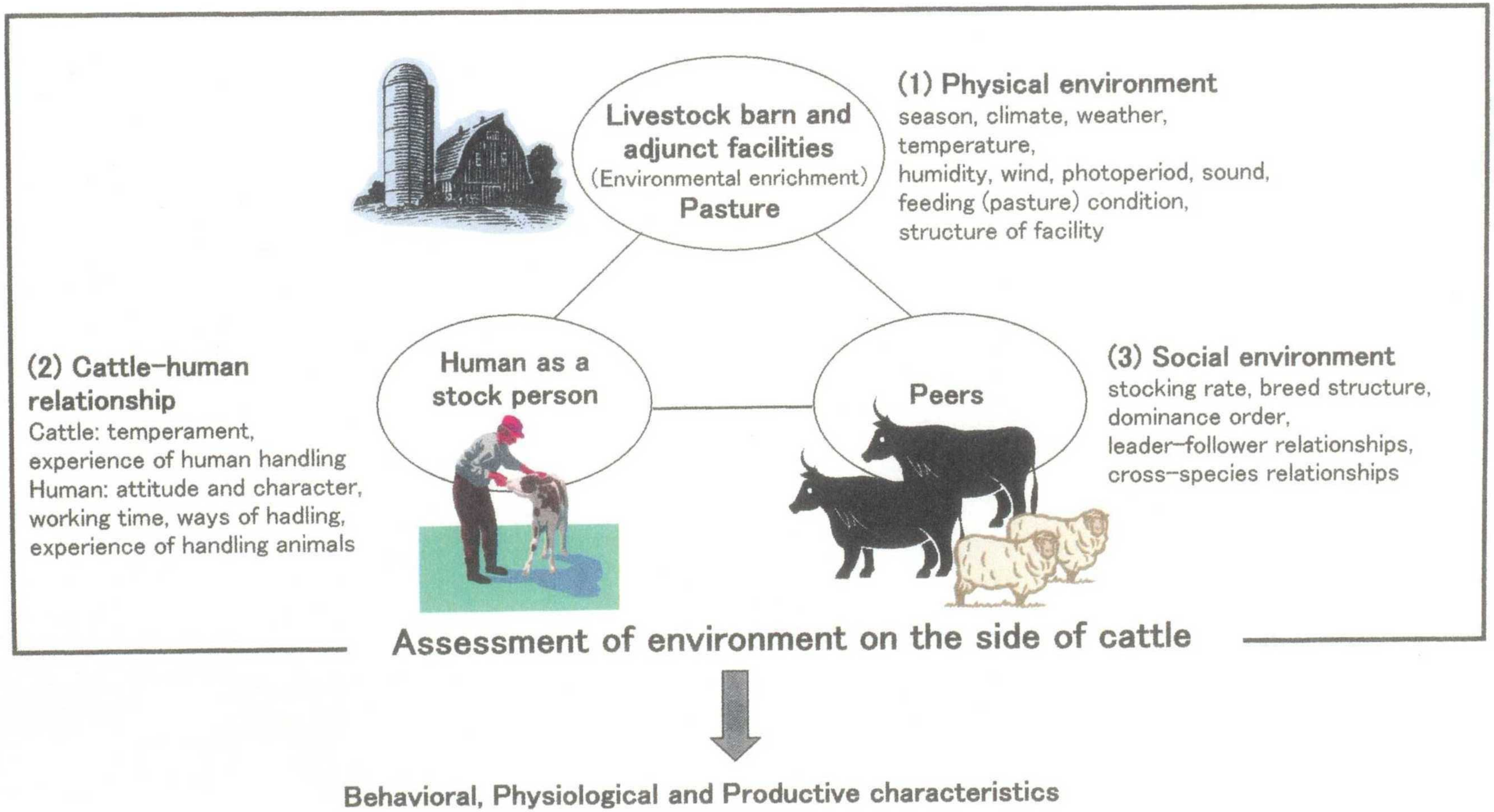

Fig. 5-1. Three contexts of beef cattle's surroundings: (1) the relationship between cattle and livestock barn and pasture conditions in the concept of environmental enrichment; (2) the relationship between cattle and human; (3) the relationship between cattle and their peers.

behaviors increase and the sequence of activity is repeated. In cattle, stereotypies are shown particularly in intensive housing situations and often relate to oral behaviors, such as bar-biting and tongue rolling (Phillips, 2002c). It should be caused by the fact that oral behavior is one of the most important behaviors for cattle as domestic herbivores. In cattle grazing in a pasture, it has been reported that maximum grazing times and biting rates normally occur at about 10 - 12 hours per day and 65 - 70 bite per minute, respectively. Longer grazing times (13 hours per day) have also been recorded on sparsely vegetated rangeland (Phillips, 1993). Sward grasping behavior has been observed normally 30000 to 40000 times per day (Phillips, 2002c). In Chapter 2, the proportion of cattle grazing in a pasture environment was 42.6 - 61.5% from dawn till dusk, whereas that of cattle eating in a pen environment was 22.3 – 32.9%. In addition, the proportion of cattle performing grazing related behavior like walking while grazing was 54.4 – 73.4%, but penned cattle did not spend the comparative time to manipulate and process feed. It has been known that restricted allowance of roughage and feeding of a diet with high levels of concentrate can increases oral stereotypies (Redbo et al., 1996; Redbo and Nordlad, 1997). And furthermore, oral stereotypy such as tongue rolling has been observed in tethered cattle having few social contacts (Redbo, 1990; Sato et al., 1994). Therefore, tongue rolling is now believed to be the result of long-term frustration caused by suppressed feeding and boring environment (Seo et al., 1998).

In an intensive pen in Chapter 2 and the control pen in Chapter 3 of this thesis, no stereotypy was observed as a result of restricted feeding. However, installing a drum can as an environmental enrichment encouraged eating behavior and reduced licking objects (Chapter 3). This result might support the finding in Chapter 2 that the other oral behaviors except tongue rolling are performed to compensate for the lack of feeding behaviors. However, the environmental enrichment conducted in this thesis had no effect on grooming behaviors. It has been known that grooming is primarily a body care activity but it has nutritional, communicative and psychological function (Phillips, 2002b). Cattle in relatively small environment might perform more self-grooming and allogrooming to keep social communication than cattle in an extensive outdoor environment.

The positive effects of enrichment by installing drum cans in Chapter 3 were shown not only behavioral characteristics but also physiological and productive characteristics. The performance of the normal appetitive behavior brings a change in physiological parameters. It has also been shown that nonnutritive sucking by providing a dummy teat can affect digestive hormone secretion (de Passillé et al., 1993). In the other farm animals, especially in pig, the environmental enrichment has influenced physiological parameter (Beattie et al., 2000b) and meat quality (Beattie et al., 2000a). It was found that tethered cattle almost stopped performing stereotypies after animals were released onto pasture or loose barn (Redbo, 1990, 1992). On the contrary, it is reported that animals resumed high levels of stereotypies after the re-tethering post-grazing (Redbo, 1990, 1992, 1993).

As results of Chapter 2 and 3, the following findings were observed: (1) the beef cattle's surroundings in the context of the relationship between animals and barn facilities conditions could be assessed by researching whether animals can perform important oral behaviors with an appropriate proportion or not; (2) the environmental enrichment should improve cattle's environment to make cattle perform oral behaviors appropriately. The positive effects of such environmental enrichment could be shown on not only behaviors but also physiological and productive characteristics, and could improve animals' welfare.

Secondly, beef cattle's surroundings in the context of the relationship between cattle and human were assessed in Chapter 3 and 4. In Chapter 3, it was found that a treatment of environmental enrichment had no effect on the steers' responses to the following human handling at weighing on the scale, at sampling blood, at recording ultrasonic images and at measuring body size. Hill et al. (1998) and Day et al. (2002) have also reported that the enrichment does not improve the ease of handling in pigs. From here onwards, the relationship between cattle and human could be different from the relationship between cattle and other surroundings like the facilities. However, as for the interrelation between the ease of handling and the productivity, more restless steers on the scale had better growth in the enriched pens. The environmental enrichment to improve cattle's stocking environment in this study had a positive effect on their productivity, but more nervous cattle had better growth rate in enriched pens.

The effects of human presence and handling on the productivity have been reported on dairy cows (e.g. Purcell et al., 1988; Hemsworth et al., 1995; Breuer et al., 1997), pigs (e.g. Paterson and Pearce, 1992; Seabrook and Bartle, 1992; Hemsworth, 1993), chickens (e.g. Jones and Hughes, 1981; Barnett et al., 1994; Hemsworth et al., 1994) and dairy goat (e.g. Lyons, 1989). In dairy cattle that have intimate relationships with humans though daily milking, it is known that more friendly cows have less fear of humans and yield a higher amount of milk (Albright, 1993), and also have the lower cortisol concentrations in their milk and the lower Flinch-Step-Kick responses (Hemsworth et al., 1989). On the other hand, the presence of an aversive handler during milking can reduce milk yield by increasing residual milk (Rushen et al., 1999a). Stock persons' attitudes to their animals and personality could affect the productivity of dairy cows (Seabrook, 1984).

As for beef breeds, they usually have fewer contacts with humans and are less approachable than dairy breeds (Murphey et al., 1980). In beef cattle, many opportunities for positive interactions with human have been replaced by the mechanical devices like when stock persons feed their animals. On the other hand, many aversive tasks associated with managing animals, such as catching and restraint for administration of medication, foot care and transport, still require human invitation.

So, in Chapter 4, the responses to human in beef cattle reared in pasture environment were investigated just after released from restraint in a crush with the isolation from peers. The cattle were given one of the choices including the following three pens: a pen with a familiar handler standing inside the pen, a pen with the same human standing outside the pen and a pen with the same human sitting inside the pen. In these choices, the aversiveness to human was shown by the test procedure that the cattle could choose either pen voluntarily. Regardless of position or posture of the human, the presence of the human was aversive for the cattle just after released from restraint in a crush. Particularly a standing human was more aversive than a sitting human. It appears that the flightiness and difficulty in handling can be dependent on human proximity in the beef cattle that are reared in a pasture and have minimal contact with human.

The effects of human handling on approach-avoidance responses to human have been studied on cattle (Boissy and Bouissou, 1988; Hemsworth et al., 1996a), pigs (Tanida et al., 1994; Hemsworth et al., 1996a, b) and sheep (Hargreaves and Hutson, 1990; Mateo et al., 1991). In these studies, gentle handling consists of some physical contact, such as stroking or brushing, or giving food rewards. These kinds of handling have shown to reduce the level of fearfulness of animals to human. And furthermore, the presence of a human after gentle handling has also shown to temper the influence of social isolation in a novel environment (Price and Thos, 1980; Boivin et al., 1997). Cattle with few opportunities of human handling are indicated that they seldom approached the human standing over a fence.

As results of Chapter 3 and 4, possible causations of beef cattle's flightiness and difficulty in human handling were clearly determined. And furthermore, these results made it possible to provide useful information on how to overcome aversive effects of restraint and handling as soon as possible afterwards.

Thirdly, beef cattle's surroundings in the context of the relationship between cattle and their peers were assessed in Chapter 4. Cattle are social species so that the existence of their peers is important for their psychological stability. It has been shown that even aggressive males preferred to sleep in close proximity to their familiar cage mates in mice (Van Loo et al., 2004). As a result of the choice test in Chapter 4, it was shown that peers were the most attractive condition even in cattle. The attractiveness of peers was stronger than that of food. In cattle under range conditions, social cohesiveness with fluctuations in food and water availability affects their distribution patterns (Howery et al., 1998). The presence of familiar animals (Boissy and Dumont, 2002) and the size of social group (Dumont and Boissy, 2000) also influence the choice of grazing location in sheep. Grazing away from peers would bring social animals the fear of isolation (Sibbald and Hooper, 2004). In Chapter 4, when a pen with peers was not one of the two choices, more cattle did not choose with willingness.

The deprivation of social contact has negative effects in cattle. It has been shown that separation from peers induces behavioral and physiological stress responses (Boissy and Le Neindre, 1997). Calves kept in isolation have shown excessive behavioral reactions (Veissier et al., 1997), and have been observed more tongue-playing, grooming and other behaviors with tongue-movement (Kerr and Wood-Gush, 1987; Seo et al.,1998). In addition, more hair balls in the rumen caused by excessive self-grooming were found in calves kept in individual housing (Bokkers and Koene, 2001).

Conversely, providing peers makes cattle less afraid of the situation when animals are in a novel area (Veissier and Le Neindre, 1992). The presence of peers decreases distress behavior of cattle in a novel object test and escaping from an unusual noise (Boissy and Le Neindre, 1990). It is shown that cattle can discriminate between individual conspecifics with their familiarity (Hagen and Broom, 2003). Animals are not only aware of the presence of peers, but also aware of their emotional state (Bouissou et al., 2001). Cattle seem perceive that peers are under stress from olfactory signals contained in urine (Boissy et al., 1998).

Furthermore, in Chapter 4, it was shown that peers were more attractive than sheep as different spices. The cattle preferred to stay in close proximity to their peers compared to sheep. It has been reported that deer chose to maintain closer to their conspecifics, even though they were unfamiliar (Abeyesinghe and Goddard, 1998). Although sheep are not fearful animals for cattle, it was suggested in this thesis that the presence of sheep was not enough comfort for cattle even if they are familiar.

As results of Chapter 4, strong attractiveness of peers just after social isolation was shown. The applicability of the choice test in which cattle can move freely was also shown to determine the intensity of cattle's interest or motivation to their kept environment.

In conclusion, this thesis made it possible to devise some methods to assess the facilities and social environment for beef cattle. In the present diversified farming systems used for beef cattle, assessing their surroundings from animals' side should be useful to adapt farm facilities to the systems and to modify the stock person's practices accordingly. This should also make it possible to improve their welfare and performance. In future, it would need to assess the adaptability of animals to their surroundings individually as well as at the level of breed.

Summary

In Chapter 1, general objectives of this thesis were discussed in consideration of the previous studies conducted.

In Chapter 2, behaviors of young beef cattle reared in intensive pen environment were compared with those of cattle reared in extensive pasture environment. Total of 122 steers in pens and 1136 steers in pasture were observed from dawn till dusk over 6 days in each farm. The proportion of steers performing oral behaviors was greater in Farm A, B and C04 of the pasture environment than that in Farm JB of the pen environment ($P<0.05$). However, the proportion of steers performing oral behaviors in Farm F1 of the pen environment was not significantly different from that in all farms of the pasture environment. The proportion of steers eating was less in the farms of the pen environment than in Farm A and B that had sparsely vegetated pastures ($P<0.05$). The proportions of steers performing the oral behaviors other than eating and drinking were greater in Farm F1 than in the other farms ($P<0.05$). The proportion of steers performing allogrooming in Farm JB was greater than that in the other farms of the pasture environment ($P<0.05$). In the pen environment, the proportion of steers performing the oral behaviors other than eating and drinking increased approximately 2 h after dawn and after eating in the morning and afternoon. On the other hand, in the pasture environment, the proportion of steers performing the other oral behaviors was totally lower than that in the pen environment. Although the level of oral behaviors of beef cattle was affected by nutritional quality and quantity of food, total proportion of the oral behaviors was not different between the intensive and extensive environments. Cattle reared in an intensive pen environment performed more oral behaviors other than eating compared with cattle in an extensive environment. However, the level of the oral behaviors other than eating was enough

to compensate for the lack of feeding behaviors.

In Chapter 3, the effects of environmental enrichment on behavioral, physiological and productive characteristics were evaluated. Seventy-one Japanese Black X Holstein steers were allocated to three pens in two repetitive experiments. Pen C (n=11 and 12) consisted of a feeding alley for grain feed, a trough for dry hay, a water bowl and a resting space as a control pen. Pen D (n=12 and 12) was enriched with a drum can that can hold hay. Pen GD (n=12 and 12) was further enriched with a drum can that was placed around an artificial plastic turf for grooming. The drum cans were removed after 5 mo of onset of installation. Behavioral observations were made for 2 h at 10 min intervals after feeding on three successive days in each month of 10 mo. Agonistic interactions were also continuously observed for 1 h after feeding to assess the dominance order (DO). Sampling blood and measuring body weight were performed bimonthly. The steers accessed the drum can frequently for 3 mo after installation (1st, 2nd, 3rd month vs. 4 month, all $P<0.05$). The frequency of total eating of grain feed and hay was higher in Pen D and GD than in Pen C (both $P<0.01$), while it became the lowest in Pen GD after removal of the drum can (both $P<0.05$). Grooming at the drum can was observed more frequently in Pen GD than in Pen D ($P<0.05$). After they finished eating the grain feed, they ate hay at the drum can rather than at the trough (for both pens $P<0.01$). Plasma dopamine concentrations were higher in Pen D than in Pen C ($P<0.05$), and serum triglyceride concentrations were higher in Pen C than in Pen GD ($P<0.05$) during the installation period of the drum can. After removal of the drum can, serum total cholesterol concentrations became higher in Pen D and GD than in Pen C (both $P<0.05$). The ADG correlated positively with the frequency of eating hay at the drum can in Pen D ($r_s=0.52$, $P<0.01$). In Pen GD, the frequency of access to the drum can correlated negatively with DO ($r_s= -0.59$, $P<0.01$). Carcass belly fat was thicker in Pen D and GD than in Pen C (both

P<0.01). In Pen GD, the frequency of eating hay (r_s= 0.79, P<0.01) and grooming at the drum can (r_s=0.63, P<0.05) correlated positively with the marbling score. Although social factor affected the steers' access to the drum can, installing it in the early fattening stage encouraged the steers to eat and groom there and resulted in better carcass characteristics through the prolonged physiological positive effects.

In Chapter 4, the attractiveness of different conditions to beef cattle was determined. Total 346 Angus heifers were individually allowed to enter a choice area after 2 minutes of restraint in a crush and to choose between two pens. After the test animal chose one or either pen, the animal could freely access both test pens and the choice area for a further 5 minutes.

In experiment 1, each heifer was given one of the following choices: pen with 3 familiar animals (Peers) vs. pen with a pile of hay on a metal rack (Food) (n=34); Peers vs. the bare pen (Bare) (n=34) and Food vs. Bare (n=35). More heifers chose Peers over Bare (χ^2=5.76; P<0.05). And more heifers tended to choose Peers over Food (χ^2=2.94; P<0.10), whereas Food and Bare did not differ. The latency to choose either pen was shortest (P<0.01) and they spent less time staying near the crush (P<0.05) if Peers was one of the choices. After choosing, more heifers entered the Peers pen than the Food (P<0.05) and Bare (P<0.01) pen. Peers were the most attractive condition, and food had almost the same attractive level as a bare pen for heifers.

In experiment 2, another 86 heifers were given each one choice: pen with a familiar handler standing inside (STI) vs. the pen with a novel object (NO) (n=29); pen where the handler stands outside the pen (STO) vs. NO (n=29); pen where the handler sits inside (SI) vs. NO (n=28). Fewer heifers chose the pen with the human (χ^2=9.97, 12.45, 7.00, STI, STO and SI, respectively; all P<0.01). Except for the choice of 'STO vs. NO', the number of heifers choosing either pen voluntarily was larger than that of heifers not choosing 5 minutes after release (both P<0.01). The number of times the NO pen was entered was larger than for STI and STO (both P<0.01), although the numbers of times the SI and NO pens were entered was not different. More heifers avoided the human, especially the standing human outside the fence. In conclusions, just after handling with restraint, returning cattle in the group of peers and not approaching cattle needlessly should moderate their stress.

In experiment 3, another 90 heifers were given each one choice: pen with three familiar animals (Peers) vs. pen with six sheep (Sheep) (n = 30); Peers vs. Bare (n = 30); Sheep vs. Bare (n = 30). More heifers chose Peers over Bare (χ^2=4.80; P<0.05), whereas Peers and Sheep, and Sheep and Bare did not differ. The latency to choose either pen was not different on each combination of choices. The heifers given the choices of 'Sheep vs. Bare' spent more time standing than the heifers given the choices of 'Peers vs. Bare' (P<0.05). After choosing, more heifers entered the Peers pen than the Bare (P<0.05) and Sheep pens (P<0.10). The time spent was longer in the Peers pen than in the Sheep pen and the choice area on the choice of 'Peers vs. Sheep' (P<0.01).

In experiment 4, another 67 heifers were given each one choice: Peers vs. pen with the same novel object as experiment 2 (NO) (n = 19); Sheep vs. NO (n = 22); Bare vs. NO (n = 26). The proportion of heifers choosing either pen was not significantly different in any choice combination. More heifers entered the Peers pen than the NO pen (P<0.01). On the choice of 'Sheep vs. NO', the time spent in the choice area was longest (P<0.01). The heifers given the choice of 'Peers vs. NO' spent less time standing near the crush than the heifers given the other choices (P<0.05). The response of heifers to sheep was changed by the existence of peers. Sheep were neither attractive condition nor aversive condition for heifers. It was found that sheep could not serve for conpecific peers. In conclusions, just after handling with restraint, returning cattle in the group of peers and not approaching cattle needlessly should be useful to moderate their stress.

In Chapter 5, it was suggested that this thesis made it possible to devise some methods to assess the facilities and social environment for beef cattle. In the present diversified farming systems used for beef cattle, assessing their surroundings from animal's side should be useful to adapt farm facilities to the systems and modify the stock persons' practices accordingly. This should also make it possible to improve their welfare and performance.

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肉用牛における飼育環境の総合評価と環境エンリッチメントの方策に関する研究

農業における技術進歩により農作物の生産量が増加したことに伴い、肉牛における生産システムも放牧から集約的な舎飼に変わり、牛の成長を早め生産高を増やすようになった。しかし近年では、放牧が見直され、また家畜福祉を考慮することによって、生産物に付加価値が付けられるようになった。このような流れを受けて、肉牛の飼育システムは一層多様化し、人と牛との関わり方など牛の福祉や生産性に影響を及ぼす要因も多様化している。

そこで、本研究では、現在の肉牛を取り巻く飼育環境を、環境エンリッチメントという動物福祉を向上させる新しい概念を取り入れた畜舎や放牧地のような施設環境と、仲間同士の関わりに人との関わりを含めた社会環境の観点から、総合的に評価することを目的とした。実験 1 では、牛の常同行動と関係のある Oral Behavior に注目し、集約的にペン飼育された肉牛の行動を、粗放な環境で放牧された牛の行動と比較した。実験 2 では、肉牛の飼育ペンに改良したドラム缶飼槽を設置し、肉牛の行動・生理・生産性における環境エンリッチメントの効果を検討した。実験 3 では、上記の物理的な要因に加え、肉牛の飼育環境における社会的な要因を検討するため、管理作業での拘束直後に肉牛が好む条件を選択試験により調べた。

実験 1 では、122 頭の舎飼牛（農家 F1 と JB）と 1136 頭の放牧牛（農家 A、B、C03、C04、D、E）を対象に、それぞれ 10 分間隔と 15 分間隔の走査サンプリングで、日出から日没までの行動を各農家 3 回ずつ観察した。Oral Behavior を発現した牛の頭数割合は、放牧である農家 A と B、C04 で、舎飼である農家 JB よりも大きかった ($P < 0.05$)。しかし、舎飼である農家 F1 の Oral Behavior をした牛の頭数割合と、放牧でのすべての農家の Oral Behavior をした牛の頭数割合には差がなかった。舎飼において摂食行動をした牛の頭数割合は、放牧地の植生がまばらであった農家 A や B よりも小さかった ($P < 0.05$)。摂食と飲水を除く Oral Behavior を行なった牛の頭数割合は、農家 F1 において他の農家よりも大きかった ($P < 0.05$)。農家 JB でも相互グルーミングをした牛の頭数割合が、すべての放牧農家よりも大きかった ($P < 0.05$)。舎飼において、摂食と飲水を除

く Oral Behavior を行なった牛の頭数割合は、朝夕の摂食後と日出の約 2 時間後に増加した。一方、放牧においては、摂食と飲水を除く Oral Behavior を行なった牛の頭数割合は、全体的に小さかった。Oral Behavior の割合は、餌の質や量によって影響を受けたが、Oral Behavior の総発現頭数割合は、舎飼と放牧で差がなかった。舎飼の牛は、放牧牛に比べ、摂食を除く Oral Behavior をより多く行なった。これらのことから、舎飼の牛は、口を使う身繕いや探査、舌遊びをすることで、少ない摂食行動による Oral Behavior の不足分を補っていると考えられた。

実験 2 では、黒毛和種×ホルスタイン種の F1 去勢雄牛 71 頭を、2 回反復して、3 種類の閉鎖追い込み式ペン：通常の飼槽のみの対照群（C 群：n = 11, 12)、乾草が入るドラム缶を設置したドラム缶群（D 群：n = 12, 12)、同ドラム缶の側面に人工芝を巻き付けた身繕いドラム缶群（GD 群：n = 12, 12）において 5 ヵ月間飼育した。ドラム缶設置 5 ヵ月後にドラム缶を除去した。ドラム缶設置 10 ヵ月後まで、毎月 3 日間ずつ、朝夕の給飼後 2 時間に 10 分間隔で行動を観察した。また社会的順位を推定するため、給飼後 1 時間に敵対行動を連続観察した。採血と体重測定は隔月で行なった。ドラム缶利用回数は、設置 2、3 ヵ月後が、直後、1、4 ヵ月後よりも多かった（$P < 0.05$)。GD 群では、社会的順位の高い個体ほどドラム缶利用回数が多かった（$r_s = -0.59$, $P < 0.01$)。設置期間中の採食回数は、両処理群が C 群よりも多かったが（$P < 0.01$)、除去後には GD 群で最も少なくなった（$P < 0.05$)。設置期間中は、ドラム缶での身繕い行動が、GD 群で D 群よりも多くみられた（$P < 0.05$)。設置期間中には、血清中性脂肪濃度が GD 群で C 群よりも低く（$P < 0.05$)、除去後も GD 群が C、D 群よりも低かった（$P < 0.05$)。また設置期間中は、血漿ドーパミン濃度が D 群で C 群よりも高かった（$P < 0.05$)。除去後は血清総コレステロール濃度が D 群で最も高く、GD 群も C 群より高かった（$P < 0.05$)。設置期間中は、D 群においてドラム缶での採食回数が多い個体ほど増体が良くなった（$r_s = 0.52$, $P < 0.01$)。枝肉成績では、ばら厚が両処理群で C 群よりも厚かった（$P < 0.01$)。GD 群では、ドラム缶での採食回数（$r_s = 0.79$, $P < 0.01$）・身繕い回数（$r_s = 0.63$, $P < 0.05$）が多い個体ほど BMS ナンバーが高くなった。ドラム缶は、設置 3 ヵ月後まで長期に

採食・身繕い・探査を誘起し続け、特に乾草の採食を促進した。肥育前期の環境エンリッチメントによるこれらの行動上の効果は、生理指標にも反映され、中期以降の脂肪蓄積を促進し、枝肉成績を向上させた。

実験3では、放牧飼育されている346頭のアンガス種若雌牛を以下の4つの試験に供試した。テスト牛を1頭ずつ枠場で2分間拘束した後、解放し2つのペンのどちらかを選択させた。選択ペンは開放されており、最初の選択後の5分間は、牛は両方の選択ペンと選択エリアを自由に移動できた。試験1では、3頭の馴染みのある牛のいるペン（仲間ペン）と乾草の入った餌台のあるペン（乾草ペン）の選択（n = 34)、仲間ペンと何も無いペン（空のペン）の選択（n = 34)、乾草ペンと空のペンの選択（n = 35）をさせた。空のペンより、仲間ペンを最初に選択した牛の割合が大きかった（$P < 0.05$)。また、乾草ペンより仲間ペンを選択する牛の割合が大きい傾向がみられた（$P < 0.10$)。乾草ペンと空のペンの選択では選択した割合に差がみられず、選択潜時が最も長くなった（$P < 0.01$)。仲間ペンに入った回数は、乾草（$P < 0.05$）および空のペン（$P < 0.01$）に入った回数より多かった。試験2では、ペン内に立っている人のいるペン（人（立）ペン）と新奇物としてオレンジ色のタイヤを設置したペン（新奇物ペン）の選択（n = 29)、柵越しに立っている人のいるペン（人（外）ペン）と新奇物ペンの選択（n = 29)、ペン内に座っている人のいるペン（人（座）ペン）と新奇物ペンの選択（n = 28）をさせた。人のいるペンより、新奇物ペンを選んだ牛の割合が大きかった($P < 0.01$)。人（立）ペンおよび人（座）ペンと新奇物ペンとの選択では、自発的に選択した牛の割合が大きかった（$P < 0.01$）が、人（外）ペンと新奇物ペンとの選択では、両選択パターンの割合に差がなかった。人（立）および人（外）ペンよりも、新奇物ペンに入った回数の方が多かった（$P < 0.01$）が、人（座）ペンと新奇物ペンとの選択では、両ペンに入った回数に差がなかった。試験3では、仲間ペンと6頭の羊のいるペン（羊ペン）の選択（n = 30)、仲間ペンと空のペンの選択（n = 30)、羊ペンと空のペンの選択（n = 30）をさせた。仲間ペンと羊ペンの選択と羊ペンと空のペンの選択では、最初の選択頭数割合にペン間で差がみられなかった。しかし空のペンより仲間ペンを最初に選択した牛の頭数割合が大きかっ

た（$P < 0.05$）。羊ペンと空のペンの選択を与えられた牛は、仲間ペンと空のペンの選択を与えられた牛よりも、選択中に佇立する時間割合が大きかった（$P < 0.05$）。仲間ペンに入った回数は、空のペンに入った回数よりも多かった（$P < 0.05$）。仲間ペンと羊ペンの選択では、仲間ペンでの滞在時間が長かった（$P < 0.01$）。試験 4 では、仲間ペンと新奇物ペンの選択（$n = 19$）、羊ペンと新奇物ペンの選択（$n = 22$）、空のペンと新奇物ペンの選択（$n = 26$）をさせた。いずれの選択ペンにおいても、最初に選択した牛の頭数割合に差はみられなかったが、仲間ペンに入った回数のみが、新奇物ペンに入った回数よりも多かった（$P < 0.01$）。羊ペンや空のペンと新奇物ペンとの選択では、選択エリアでの滞在時間が最も長かった（$P < 0.01$）。選択エリアでの行動では、選択肢に仲間ペンが含まれていないときに枠場付近で佇立する割合が大きかった（$P < 0.05$）。牛にとって仲間の存在が最も強い誘引条件であり、羊は仲間のような誘引条件でも、人のような嫌悪条件でもないことが明らかになった。したがって、仲間からの一時的な隔離を伴う枠場作業後には、牛を速やかに仲間の牛と一緒にし、人は不必要に接近しないことが、管理作業由来のストレス緩和方法として有効であると考えられた。

以上の結果から、肉牛での物理的な施設環境は、牛にとって重要な Oral Behavior を適切な割合で行なうことができるか否かを調査することで評価でき、環境エンリッチメントによって、Oral Behavior を適切に発現できるような環境に改善すべきであるといえる。また、牛が自由に動くことができる選択試験の適用が、社会環境に対する牛の関心やモチベーションの強さを評価する有効な方法であることも確認された。結論として、本研究で用いた方法により、肉牛を取り巻く飼育環境を、施設環境と社会環境から総合的に評価することができた。このような牛側からの環境評価は、現在の多様化した肉牛の生産システムにおいて、畜舎施設や管理作業を改善する上で大いに役立ち、それによって肉牛の福祉を向上し、生産性を改善することが可能になると考えられる。