Universitat Autònoma de Barcelona

Effect of the housing and feeding system on the welfare and productivity of pregnant sows

MÈMORIA PRESENTADA PER NÚRIA CHAPINAL i GÓMEZ

PER ACCEDIAR AL GRAU DE DOCTOR DINS DEL PROGRAMA DE DOCTORAT DE PRODUCCIÓ ANIMAL DEL DEPARTAMENT DE CIÈNCIA ANIMAL I DELS ALIMENTS

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“The greatness of a nation and its moral progress can be judged by the way its animals are treated”

(Mahatma Gandhi)

ABSTRACT

The new EU directives on the protection of pigs (*Sus scrofa*) make necessary the development of appropriate group housing systems on a welfare and productivity basis. The general objective of this study was the comparison among two different commercial group housing systems and conventional stalls for pregnant sows by assessing behavioural, physiological and performance measures.

One hundred and eighty pregnant sows, from first to ninth parity, were selected on a commercial farm and used in three different replicas (60 sows per replica). Sows were housed from day 29 of pregnancy to 1 week before parturition in conventional stalls (STALL), in groups of 10 with trickle feeding (TRICK) and in groups of 20 with an unprotected electronic sow feeder (FITMIX; 20 sows per housing system per replica). All the sows had been previously stall-housed and were equally feed-restricted. Sows were observed on 11 non-consecutive days during 4 h a day. General activity and stereotypies were measured by scan-sampling observation (10-min intervals) in all the systems. Blood samples were obtained twice a replica and levels of haptoglobin (Hp) and pig-MAP were determined to assess physical stress. Backfat depth, liveweight and reproductive performance were also considered. In the two group housing systems, aggressions were recorded by continuous behaviour sampling and a dominance rank (RI) was thereafter calculated. In FITMIX, data on feeding behaviour recorded by the system from 25 non-consecutive feeding cycles were analyzed. Number of visits to the feeder, duration of the visits and feeder occupation was analyzed on a daily and hourly basis to determine over-time and circadian feeding patterns. The establishment of a feeding order was also assessed.

Overall, group housing sows with FITMIX appeared to increase resting behaviour and decrease oronasofacial stereotypies to a higher extent than with TRICK. Both group housing systems reduced considerably the performance of sham-chewing. Gilts showed a lower general activity and performance of stereotypies than older sows in all the systems. In general, Hp and pig-MAP levels and productivity measures did not differ among systems. However, incidences such as lameness or vulva injuries were more often detected in group housing systems.

Frequency of aggressions, intensity and proportion of resolution were higher in FITMIX, yet intense physical contact was unusual in both systems. Conflicts in FITMIX were largely for feeding whereas in TRICK, they occurred mainly in the resting area. However, proportion of aggressions for drinking was higher in TRICK. Correlation between RI and liveweight was stronger in FITMIX, although correlation between RI and parity was similar in the two systems. Gilts got less involved in aggressions, although they received more aggressions than they initiated in both group housing systems. Forty-six per cent of the FITMIX sows, mostly gilts and subordinates, needed assistance to adapt to the feeding system. Eventually, 8.3% of the FITMIX sows failed to adapt and had to be removed.

FITMIX sows made several visits to the feeder to get their daily ration, although daily feeder occupation seemed to be shorter compared to literature on protected ESF. Daily feeder occupation per sow appeared to decrease over time. Within each feeding cycle, maximum activity around the feeder was observed in the hours following the start of the cycle, so that activity was very low in the latter half of the cycle. A relatively stable feeding order was quickly established and maintained over the experiment and it highly correlated with RI. High-ranking sows fed earlier and made as many visits as low-ranking sows but longer and thus, they occupied the feeder for longer.

In conclusion, well-managed group-housed sows seemed to increase resting behaviour and decrease stereotypies at similar productivity and tissue damage levels than conventional stalls. Sequential feeding appeared to make FITMIX a more competitive feeding system than TRICK. In terms of efficiency, FITMIX appeared to be a good system for medium-sized stable groups of sow, although optimization of the feeder efficiency may take several weeks. However, the establishment of a rank-related feeding order may ameliorate disturbance around the feeder and help stockmanship to detect problems. Taking everything into account, it can be suggested that group housing systems can be a good alternative to stalls provided that management is appropriate. Higher quality stockmanpeople may be required for early detection and solution of problems, particularly to prevent excessive aggression and ensure adaptation in sequential feeding systems. Nevertheless, long-term effects of group housing systems on welfare should be further assessed before recommendations are made.

RESUM

Les noves directives de la UE sobre la protecció dels porcs (*Sus scrofa*) fan necessari el desenvolupament de sistemes d'allotjament en grup apropiats des del punt de vista del benestar i de la productivitat. L'objectiu general d'aquest estudi fou la comparació entre dos sistemes comercials d'allotjament en grup i les gàbies convencionals per a truges gestants, mitjançant mesures de comportament, fisiològiques i productives.

Cent vuitanta truges gestants, de primer a novè part, se seleccionaren d'una granja comercial i foren emprades en tres rèpliques diferents (60 truges per rèplica). Les truges foren allotjades del dia 29 de gestació a una setmana abans del part en gàbies convencionals (STALL), en grups de 10 amb un sistema d'alimentació de caiguda lenta (TRICK) i en grups de 20 amb un dispensador de pinso electrònic sense protecció (FITMIX; 20 truges per sistema d'alimentació i rèplica). Totes les truges havien estat prèviament allotjades en gàbies i foren alimentades de forma igualment restringida. Les truges s'observaren 11 dies no consecutius durant 4 h al dia. En tots els sistemes, els nivells d'activitat general i d'estereotípies es mesuraren mitjançant la tècnica d'observació *scan-sampling* a intervals de 10 minuts. S'obtingueren dues mostres de sang per rèplica i es determinaren els nivells d'haptoglobina (Hp) i pig-MAP per valorar el grau d'estrès físic. El gruix de greix dorsal, el pes viu i els resultats reproductius també foren considerats. En els dos sistemes d'allotjament en grup, s'enregistraren les agressions mitjançant observació contínua i posteriorment es calculà l'ordre de dominància (RI). Al sistema FITMIX, s'analitzaren les dades de comportament alimentari enregistrades automàticament durant 25 cicles alimentaris no consecutius. El número de visites al dispensador, la duració de les visites i l'ocupació del dispensador s'analitzaren per dia i per hora per determinar els patrons de comportament alimentari i la seva evolució circadiària i al llarg del temps. També es determinà l'establiment de l'ordre d'accés al dispensador.

En general, l'allotjament de les truges en grup amb FITMIX incrementà el descans i disminuí les estereotípies oronasofacials en major mesura que l'allotjament en grup amb TRICK. Ambdós sistemes d'allotjament en grup reduïren considerablement la masticació en buit. Les primípares mostraren uns nivells d'activitat general i d'estereotípies menors que les truges adultes en tots els sistemes. Els nivells d'Hp i de pig-MAP, i les mesures productives no diferiren entre sistemes. En canvi, les incidències com coixeses o ferides de vulva foren més freqüents en els sistemes d'allotjament en grup.

La freqüència, la intensitat i la proporció de resolució de les agressions foren més altes al sistema FITMIX, tot i que el contacte físic intens fou inusual en ambdós sistemes. Els conflictes al sistema FITMIX foren principalment per menjar, mentre que al sistema TRICK es produïren principalment a la zona de descans. Tanmateix, la proporció d'agressions per beure fou major al sistema TRICK. La correlació entre l'RI i el pes viu fou major al sistema FITMIX, tot i que la correlació entre l'RI i el número de part fou similar en ambdós sistemes. Les primípares participaren menys en agressions, tot i que en reberen més que n'iniciaren en ambdós sistemes. El 46% de les truges del sistema FITMIX, majoritàriament primípares i subordinades, necessitaren ajuda per adaptar-se al sistema d'alimentació. Finalment, el 8,3% de les truges del sistema FITMIX no s'adaptaren i foren eliminades.

Les truges del sistema FITMIX feren diverses visites al dispensador per obtenir la seva ració diària, tot i que l'ocupació diària del dispensador fou menor que la citada a la literatura referent als sistemes d'alimentació electrònica amb protecció (ESF). L'ocupació diària disminuí al llarg del temps. Dins de cada cicle alimentari, la màxima activitat al voltant del dispensador s'observà a les hores immediates al seu inici, de manera que l'activitat fou molt baixa en la segona meitat del cicle. Un ordre d'accés al dispensador relativament estable i correlacionat amb l'RI s'establí ràpidament i es mantingué durant l'experiment. Les truges dominants accediren al dispensador més aviat i feren un número de visites similar a les truges subordinades però de major duració i per tant, ocuparen el dispensador durant més temps.

En conclusió, els sistemes d'allotjament en grup augmentaren el descans i disminuïren les estereotípies mantenint uns nivells de productivitat i de dany tissular similars als de les truges en gàbies. El sistema FITMIX presentà major competitivitat que el sistema TRICK a causa de l'alimentació seqüencial. El sistema FITMIX fou eficient en grups estables de mida mitjana, tot i que l'optimització de l'eficiència no s'assolí fins al cap d'uns dies. D'altra banda, l'establiment d'un ordre d'accés al dispensador correlacionat amb l'ordre de dominància podria disminuir el conflicte per menjar i ajudar al personal a detectar problemes. Tenint en compte tots els factors, l'allotjament en grup podria ser una bona alternativa a les gàbies sempre que el maneig sigui l'adequat. Un personal més qualificat podria ser necessari per la detecció precoç i la solució dels problemes, sobretot per prevenir l'agressivitat excessiva i assegurar l'adaptació en sistemes d'alimentació seqüencial. Malgrat tot, els efectes a llarg termini dels sistemes d'allotjament en grup sobre el benestar haurien de ser avaluats prèviament a llur recomanació.

RESUMEN

Las nuevas directivas de la UE sobre la protección de los cerdos (*Sus scrofa*) hacen necesario el desarrollo de sistemas de alojamiento en grupo apropiados desde el punto de vista del bienestar y la productividad. El objetivo general de este estudio fue la comparación entre dos sistemas comerciales de alojamiento en grupo y las jaulas convencionales para cerdas gestantes, mediante medidas de comportamiento, fisiológicas y productivas.

Ciento ochenta cerdas gestantes, de primer a noveno parto, se seleccionaron en una granja comercial y se repartieron en tres réplicas diferentes (60 cerdas por réplica). Las cerdas se alojaron desde el día 29 de gestación a una semana antes del parto en jaulas convencionales (STALL), en grupos de 10 con un sistema de alimentación de caída lenta (TRICK) y en grupos de 20 con un dispensador de pienso electrónico sin protección (FITMIX; 20 cerdas por sistema de alimentación y réplica). Todas las cerdas habían estado previamente alojadas en jaulas y se alimentaron de forma igualmente restringida. Las cerdas se observaron 11 días no consecutivos durante 4 h al día. En todos los sistemas, los niveles de actividad general y de estereotipias se midieron mediante la técnica de observación *scan-sampling* a intervalos de 10 minutos. Se obtuvieron dos muestras de sangre por réplica y se determinaron los niveles de haptoglobina (Hp) y pig-MAP para valorar el grado de estrés físico. El espesor de tocino dorsal, el peso vivo y los resultados reproductivos también fueron considerados. En los dos sistemas de alojamiento en grupo, se registraron las agresiones mediante observación continua y posteriormente se calculó el orden de dominancia (RI). En el sistema FITMIX, se analizaron los datos de comportamiento alimentario registrados automáticamente durante 25 ciclos alimentarios no consecutivos. El número de visitas al dispensador, la duración de las visitas y la ocupación del dispensador se analizaron por día y por hora para determinar los patrones de comportamiento alimentario y su evolución circadiana y a lo largo del tiempo. También se determinó el establecimiento del orden de acceso al dispensador.

En general, el alojamiento de las cerdas en grupo con FITMIX incrementó el descanso y disminuyó las estereotipias oronasofaciales en mayor medida que el alojamiento en grupo con TRICK. Ambos sistemas de alojamiento en grupo redujeron considerablemente la masticación en vacío. Las primíparas mostraron unos niveles de actividad general y de estereotipias menores que las cerdas adultas en todos los sistemas. Los niveles de Hp y de pig-MAP, y las medidas productivas no difirieron entre sistemas. En cambio, las incidencias como cojeras o heridas de vulva fueron más frecuentes en los sistemas de alojamiento en grupo.

La frecuencia, la intensidad y la proporción de resolución de las agresiones fueron mayores en el sistema FITMIX, aunque el contacto físico intenso fue inusual en ambos sistemas. Los conflictos en el sistema FITMIX fueron principalmente por comer, mientras que en el sistema TRICK se produjeron principalmente en la zona de descanso. Asimismo, la proporción de agresiones en el bebedero fue mayor en el sistema TRICK. La correlación entre el RI y el peso vivo fue mayor en el sistema FITMIX, a pesar de que la correlación entre el RI y el número de parto fue similar en ambos sistemas. Las primíparas participaron menos en agresiones, aunque recibieron más que las que iniciaron en ambos sistemas. El 46% de las cerdas del sistema FITMIX, mayoritariamente primíparas y subordinadas, necesitaron ayuda para adaptarse al sistema de alimentación. Finalmente, el 8,3% de las cerdas del sistema FITMIX no se adaptaron y fueron eliminadas.

Las cerdas del sistema FITMIX hicieron diversas visitas al dispensador para obtener su ración diaria, aunque la ocupación diaria del dispensador fue menor que la citada en la literatura referente a los sistemas de alimentación electrónica con protección (ESF). La ocupación diaria disminuyó a lo largo del tiempo. En cada ciclo alimentario, la máxima actividad alrededor del dispensador se observó en las horas inmediatas a su inicio, de manera que la actividad fue muy baja en la segunda mitad del ciclo. Un orden de acceso al dispensador relativamente estable y correlacionado con el RI se estableció rápidamente y se mantuvo durante el experimento. Las cerdas dominantes accedieron al dispensador más temprano e hicieron un número de visitas similar a las cerdas subordinadas pero de mayor duración, por lo que ocuparon el dispensador durante más tiempo.

En conclusión, los sistemas de alojamiento en grupo aumentaron el descanso y disminuyeron las estereotipias manteniendo unos niveles de productividad y de lesión tisular similares a los de las cerdas en jaulas. El sistema FITMIX presentó mayor competitividad que el sistema TRICK a causa de la alimentación secuencial. El sistema FITMIX se mostró eficiente en grupos estables de tamaño medio, aunque la optimización de la eficiencia no se alcanzó hasta al cabo de unos días. Por otra parte, el establecimiento de un orden de acceso al dispensador correlacionado con el RI podría disminuir el conflicto por comer y ayudar al personal a detectar problemas. Teniendo en cuenta todos los factores, el alojamiento en grupo podría ser una buena alternativa a las jaulas siempre que el manejo sea el adecuado. Un personal más cualificado podría ser necesario para la detección precoz y la solución de los problemas, sobre todo para prevenir la agresividad excesiva y asegurar la adaptación en sistemas de alimentación secuencial. No obstante, los efectos a largo plazo de los sistemas de alojamiento en grupo sobre el bienestar deberían ser evaluados previamente a su recomendación.

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CHAPTER 1

Literature review

1. THE SCIENTIFIC ASSESSMENT OF ANIMAL WELFARE

"Animal welfare" is not a term that arouse in science to express a scientific concept. Rather it arouse in society to express ethical concerns regarding the treatment of animals. However, because science plays an important role in interpreting and implementing social concerns over the quality of animal life, animal welfare was adopted as a subject of scientific research and discussion. This adoption has led to a remarkably protracted debate on how to conceptualize, in a scientific context, a concept that is fundamentally rooted in values. When scientists attempt to assess animal welfare, they need to ensure that their scientific measures reflect the socially constructed meaning of the term (Tannenbaum 1991; Sandøe 1992; Fraser 1995; Stafleu *et al* 1996).

It is generally accepted that there are three broad approaches used by scientists in studying animal welfare: the "nature of the species", the "feelings-based" and the "functioning-based" approaches (Duncan & Fraser 1997).

The first approach calls for animals to be raised in a manner that suits "the nature" of the species or such that the animal performs its full repertoire of behaviours. Performance of the full behavioural repertoire has been widely criticized as a criterion for welfare (Dawkins 1980). Certain behaviours are adaptations to cope with adverse circumstances, such as hiding from predators. Therefore, the environments that bring out these behaviours tend to reduce welfare rather than increase it. Moreover, it is difficult to define a specific concept of "nature" because animals can readily adapt their behaviours to new environments and be very successful in the new mode of living. Evolution favours not simply a repertoire of actions that are performed with a characteristic frequency, but a series of conditional rules whereby the animal uses certain types of behaviour in response to certain circumstances. Understanding these conditional rules may be more useful in assessing quality of life (Fraser *et al* 1997b) than a generalized concept of "nature".

The "feelings-based" approach defines animal welfare in terms of the subjective experiences of the animals (feelings, emotions), and emphasizes the reduction of negative feelings (suffering, pain, etc.) and/or promotion of positive ones (comfort, pleasure, etc.)(Duncan 1993, 1996). Relevant research methods include measures of animals' preferences and motivations, plus behavioural and physiological indicators of emotional states. There is widespread agreement that subjective experiences such as suffering and contentment are important for an animal's welfare. However, developing an understanding of such experiences involves additional logical steps and assumptions, all of which are open to questioning and revision (Dawkins 1990). Consequently, some scientists prefer to use more traditional measures based on the functioning of the body (Gonyou 1993; McGlone 1993).

The "functioning-based" approach defines animal welfare in terms of the normal or satisfactory biological functioning of the animal, in the sense of health, growth and reproduction, that is, biological fitness. The definition that underpins this approach is "the welfare of an individual is its state as regards its attempts to cope with its environment" (Broom 1986). This definition refers to both the cost of coping attempts and the extent of success (Figure **1**). Attempts to cope include the functioning of body repair systems, immunological defences, physiological stress response and a variety of behavioural responses. The biological cost of these responses includes adverse effects on the animal's ability to grow, reproduce and remain healthy (Barnett *et al* 2001). This definition of welfare has been broadened to incorporate animal emotions as they would have evolved on the basis of their survival values and contribution to biological fitness (Broom 2001).

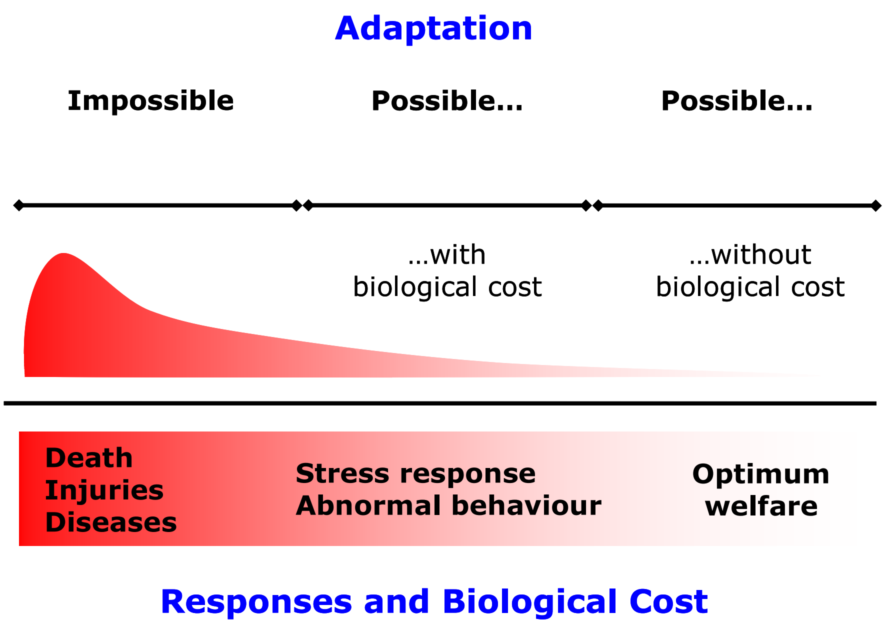

Figure 1 Responses, biological cost and extent of success in coping attempts (adapted from Broom & Johnson 1993).

Broom and Johnson (1993) stated that the assessment of welfare should be carried out in an objective way that is independent of moral considerations. Moreover, welfare varies over a range, from very good to very poor, and it should be measured using a variety of indicators (Curtis 1987; Duncan 1987), since there are various methods for coping with the environment and various consequences of failure to cope. Objective measures of poor welfare should include those which indicate some reduction in the fitness of the individual and those which quantify the difficulty which the individual has in coping with adversity (Table 1). After the welfare has been measured, ethical decisions about whether or not the situation is tolerable can be taken. It is important that the process of welfare assessment and the process of ethical judgment be separate (Broom 1991). However, although many of the "functioning-based" measures are straightforward to quantify, there is much debate about the link between biological functioning and the animal's welfare. It is specifically difficult to draw conclusions if different measures fail to agree.

Table 1 Measures of poor welfare (adapted from Broom & Johnson 1993).

- **Mortality**
- **Reduced life expectancy**
- **Reduced ability to grow or produce**
- **Impaired reproduction**
- **Body damage**
- **Disease**
- **Immunosupression**
- **Physiological changes associated to stress response (e.g. increases in heart rate and cortisol levels)**
- **Abnormal behaviours**

These three approaches of animal welfare are by no means mutually exclusive; indeed, advocates of any one sometimes seem to assume that their own approach of welfare would encompass the others, inasmuch as they are important or knowable (Fraser 2003). An example of a comprehensive approach would be the *Five Freedoms* (Table 2) recently modernized by the Farm Animal Welfare Council (1997), which has been used by some authors as a practical tool for welfare assessment (e.g. Gonyou 2001 for the assessment of stall and group housing systems for sows). Nonetheless, the three approaches represent three different areas of emphasis which can lead scientists to use quite different criteria in assessing animal welfare. It is possible that different sets of values will lead to different welfare assessment tools yielding different conclusions, each correct within the given value assumptions (Fraser 2003). A recent example is the disagreement in the welfare assessment of stall-housed pregnant sows carried out by the Scientific Veterinary Committee (1997) created by the European Union and a group of Australian scientists (Barnett *et al* 2001). The European reviewers concluded that the welfare of sows is jeopardised by gestation stalls, given (1) that affective states and an ability to behave in a relatively natural way are inherently important for animal welfare, and (2) that is better to include such considerations in assessing welfare than to limit welfare assessment to scientifically controversial measures. At the same time, the Australian reviewers concluded that gestation stalls are not necessarily bad for sow welfare, given a relatively restrictive definition whereby welfare boils down to the biological functioning of the animal, and assuming that welfare assessment should be restricted to measures that enjoy high credibility in scientific circles. In doing so, however, they may have sacrificed capturing some of the widely held social meaning of the term. Therefore, in assessing animal welfare at the farm and group level, we should attempt not the impossible goal of eliminating value assumptions from animal welfare assessment, but the achievable goal of making value assumptions more explicit so that disagreements can be traced correctly to the underlying value differences (Fraser 2003).

Table 2 Five Freedoms (Farm Animal Welfare Council 1997).

1. **Freedom from thirst, hunger and malnutrition** – by ready access to fresh water and a diet to maintain full health and vigour.
2. **Freedom from discomfort** – by providing a suitable environment including shelter and a comfortable resting area.
3. **Freedom from pain, injury and disease** – by prevention or rapid diagnosis and treatment.
4. **Freedom to express normal behaviour** – by providing sufficient space, proper facilities and companions of the animals own kind.
5. **Freedom from fear and distress** – by ensuring conditions that avoid mental suffering.

2. WELFARE IMPLICATIONS FOR HOUSING PREGNANT SOWS

2.1. Current situation

A remarkable change in animal agriculture has occurred since 1950, whereby certain traditional, semi-outdoor production methods were largely replaced by more industrialised ones. In the case of pregnant sows, group housing was replaced by tethers or stalls. Housing sows in stalls is still a common practice all around the world. About 70% of the sows are stall-housed at some stage during pregnancy in Europe, about 60-70% in USA, 62% in Australia and 49% in New Zealand (Barnett *et al* 2001). This system predominates because it minimises aggression and permits individual feeding and management at low capital cost.

The Scientific Veterinary Committee (1997) reported that stalls have also advantages for welfare. It prevents stress and injuries associated to fighting, each sow is certain to have the full ration of feed available to it, sows can all feed at the same time, care-taking is made easier and signs of morbidity, such as feed refusals or vulva discharge, are easy to detect and can be treated appropriately. However, they concluded that some serious welfare problems persist even in the best stall-housing systems. The major disadvantages for sow welfare are indicated by high levels of stereotypies, of unresolved aggression and of inactivity associated with unresponsiveness, weaker bones and muscles, more likelihood of extreme physiological responses, of urinary tract infections associated with inactivity and worse cardiovascular fitness than group-housed sows.

Group housing systems ease most of the disadvantages of stalls because sows have more exercise, more control over their environment, more opportunity for normal social interactions and better potential for the provision of opportunities to root or manipulate materials. The major disadvantage of group housing is stress and injuries such as bites to the vulva or skin associated to fighting, fact that could lead to embryo loss in extreme cases. Moreover, detection of health problems and individual feeding (at least in some systems) is more difficult. In general, better stockmanship is necessary to prevent these adverse effects.

With the review made by the Scientific Veterinary Committee in hand, the European Union adopted a ban on the gestation stalls as of 2013, by means of the

Council Directive 2001/88/EC of 23 October 2001 amending Directive 91/630/EC laying down minimum standards for the protection of pigs. Some of the most important aspects in this legislation are shown in Table 3.

Table 3 European standards for the protection of pregnant sows (Council Directive 2001/88/EC of 23 October 2001 amending Directive 91/630/EC).

- **Sows and gilts shall be kept in groups from 4 weeks after the service to 1 week before the expected time of farrowing.** The pen must have sides greater then 2.8 in length (2.4 m when less than 6 animals are kept in the group). Sows and gilts raised on holdings of fewer than 10 sows and those that are particular aggressors, which have been attacked or which are sick or injured may be kept individually, provided that they can turn around easily in their boxes.
- **The total unobstructed floor area available to each gilt after service and to each sow must be at least 1.64 m^2 and 2.25 m^2 respectively.** When these animals are kept in groups of less than 6 individuals the area must be increased by 10%, and when they are kept in groups of 40 or more individuals the area may be decreased by 10%.
- **A part of the area equal to 0.95 m^2 per gilt and 1.3 m^2 per sow must be of continuous solid floor of which a maximum of 15% is reserved for drainage openings.**
- **When concrete slatted floors are used for pigs kept in groups, the maximum width of the openings must be 20 mm and the minimum slat width must be 80 mm.**
- **The feeding system must ensure that each individual can obtain sufficient food even when competitors are present.**
- **To satisfy their hunger and given the need to chew, all dry pregnant sows and gilts must be given a sufficient quantity of bulky or high-fibre food as well as high-energy food, and they shall have permanent access to manipulable material.**
- **Stockmanship shall receive instructions and guidance focused on welfare aspects.** Appropriate training courses are available.

2.2. Assessment of welfare in pregnant sows

As commented before, scientists can approach animal welfare from different viewpoints and attribute various degrees of importance to the different welfare concerns. For a comprehensive approach, behaviour, physiologic function, health and production indices should be used to evaluate the effects and appropriateness of the different housing systems for pregnant sows (Scientific Veterinary Committee 1997; Barnett *et al* 2001; Task Force on the Housing of Pregnant Sows 2005). However, welfare assessment results from different studies on sow housing systems are difficult to interpret. First of all, there are a number of potential confounding variables relating to sow housing that make comparison between systems difficult. Some of these variables are feeding system, flooring type, bedding, stall or pen design, space allowance, stable[1] *vs* dynamic[2] social groups, group size and level of stockmanship (McGlone *et al* 2004a; Task Force on the Housing of Pregnant Sows 2005). Secondly, it should not been assumed that the method of housing is the major determinant of animal welfare. The quality of stockmanship can have a major influence (Rushen & de Passillé 1992). And finally, obtaining clear replication is often difficult. Replication is especially necessary in group housing systems because social status and individual pen social dynamics is very important (McGlone et al 2004a; Task Force on the Housing of Pregnant Sows 2005). As a result, statements should be made only in relation to the specific conditions used in each experiment.

2.2.1. Behaviour

The best indicators of long-term problems for pigs are frequent measurements of abnormalities of behaviour (Broom 1996). However, the meaning of "abnormal" is frequently left unspecified (Mason 1991a). Broom and Johnson (1993) defined abnormal behaviours as those which differ in pattern, frequency or context from those which are shown by most members of the species in conditions which allow a full range of behaviour. The most widely recorded abnormal behaviours in pregnant sows are stereotypies and excessive aggressive behaviour (Broom 1996).

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[1] Stable or static group: Sows are grouped together once and no additional sows are added to the group for the remained of the gestation

[2] Dynamic group: new sows are added to the group on a regular basis to replace those removed for farrowing

2.2.1.1. *Stereotypies*

Definition

Stereotypies are generally defined as unvarying, repetitive behaviour patterns that have no obvious goal or function (Odberg 1978). Stereotypies such as bar-biting, sham-chewing, drinker-pressing, repetitive rooting or nosing in a trough (Figure 2) may be exhibited by sows housed both individually and in pens, although they are more often observed in the former (Jensen 1988; Arellano *et al* 1992; Broom *et al* 1995; Vieuille-Thomas *et al* 1995). Sows show some form of oronasofacial (ONF) behaviour in all environments – indoors and outdoors and in pens and stalls. Some repetitive ONF behaviour does appear to have a purpose, such as chewing bedding or grass. However, some apparently does not, and it is this behaviour that has been classified as stereotypy (Dailey & McGlone 1997).

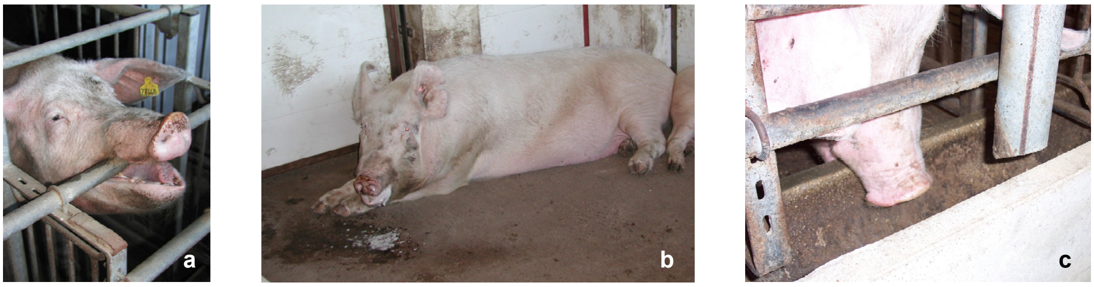

Figure 2 Bar-biting (a), sham-chewing (b) and repetitive nosing in a trough (c) are stereotypies frequently exhibited by pregnant sows.

Epidemiology

The proportion of sows in a housing condition which show stereotypies varies from none in complex environments (Stolba & Wood-Gush 1989) to 100% in restrictive ones(Cronin 1985). Likewise, the proportion of the day that sows spend engaged in stereotypic behaviour varies considerably among studies, from less than 1% (Morris *et al* 1993) to as high as 26% (Spoolder *et al* 1995) or 46% (Cronin & Wiepkema 1984). Considerable variation among individual sows has also been reported (from 0% to 61% in Appleby & Lawrence 1987).

Causes

Feeding motivation

Causes of stereotypies have not been totally elicited yet. They are likely to result in a complex way from a number of interacting processes (Lawrence & Terlouw 1993; Rushen *et al* 1993). In the case of sows, they are specifically related to heightened feeding motivation resulting from feed restriction (Lawrence *et al* 1988; Lawrence & Terlouw 1993). Pregnant sows suffer from chronic hunger, and the intake of too small a meal increases the underlying feeding motivation rather than inducing satiety, at least in the short term. As a result, sows persist on feeding-related behaviour in the postfeeding period directed toward available, alternative stimuli such as pen surfaces. Therefore, stereotypies occur largely after the meal (Rushen 1984; Rushen 1985; Jensen 1988; Terlouw *et al* 1991; Terlouw & Lawrence 1993). Indeed, stereotypies are reduced if energy intake is increased (Appleby & Lawrence 1987; Terlouw *et al* 1991; Bergeron & Gonyou 1997), specially when feed is provided *ad libitum* (Bergeron *et al* 2000; de Leeuw & Ekkel 2004). They can sometimes be reduced by providing dietary fibre (Robert *et al* 1993; Brouns *et al* 1994; Ramonet *et al* 1999; Bergeron *et al* 2000; de Leeuw & Ekkel 2004). However, this is not always successful (McGlone & Fullwood 2001), indicating that the amount and type of fibre have an important effect on satiety (Robert *et al* 1993; Ramonet *et al* 1999). It is also important that fibre is provided in a way that increases the feeding time and allow the expression of feeding/foraging behaviour (Fraser 1975; Brouns *et al* 1994; Bergeron *et al* 2002). Therefore, reduction in the performance of stereotypies is more likely when a foraging substrate such as straw, which also provides dietary fibre, is supplied (Fraser 1975; Spoolder *et al* 1995; Whittaker *et al* 1998). Consequently, it appears that feed intake by itself or feeding motivation is not the only main cause of stereotypies. Furthermore, although sows are not fed *ad libitum*, they are always fed over maintenance and never underfed (Close & Cole 2000). Moreover, it does not seem that enhanced feeding motivation due to feed restriction but some other non-specific processes are responsible for the long-tem persistence and repetition of stereotypies (Lawrence & Terlouw 1993; Haskell *et al* 1996).

Environmental constraint

Environmental constraint on feeding behaviour has also been proved to be necessary for the development of stereotypies. In fact, sows that are maintained under extensive conditions fed restrictedly do not exhibit stereotypies (Stolba & Wood-Gush 1989). The strongly motivated feeding behaviour is highly modified or "channelled" by restrictive environments into the few simple behavioural elements allowed by the available incentives (Rushen *et al* 1993; Lawrence & Terlouw 1993). "Channelling" is a prerequisite for sensitization to occur, whereby repeated stimulation of the underlying neural elements lead to the behaviour being more easily elicited and maintained (Dantzer 1986).

Behavioural arousal

Stereotypies seem also facilitated by the excitatory effect of behavioural arousal. The behavioural arousal is a non-specific motivational factor affecting the general activity of the animal (Rushen *et al* 1993; Lawrence & Terlouw 1993) which may arise as the result of frustrating a highly motivated behaviour (Odberg 1978). An increased arousal seems to be associated with frustration caused by a predicted insufficient meal (Haskell *et al* 1996) and seems to influence in stereotypies by preventing the animal from rest (Terlouw *et al* 1992).

Other factors

Other factors that may influence are stress (Mason 1991a), social facilitation (sows are more likely to develop stereotypies if their neighbours already perform them; Appleby *et al* 1989) and individual predisposition (Mason 1991b).

Changes of stereotypies over time

Development of stereotypies from normal behaviour is a continuum. Stereotypies become more invariable and inflexible with time. Established stereotypies are also elicited by a broad range of events such as an increase in the general arousal, no longer by the original causal stimulus alone. This fact is known as "emancipation". They are much more difficult than developing stereotypies to discourage or interrupt by changing the environment. They also may lose some elements of the original behaviour pattern, that is, they are "abbreviated" due to cumulative repetition and the rapidity with which they are performed (Mason 1993).

Stereotypies and poor welfare

Although some early research indicated that stereotypic behaviour may help sows cope with aversive environment (Cronin & Wiepkema 1984), they are widely considered as indicators of poor welfare (Mason 1993; Broom & Johnson 1993; Wechsler 1995; Mench & Mason 1997), whether they have a function or not. Mason (1991a) defined stereotypies as a sign of poor welfare from three main reasons: the type of environments in which they develop; the type of behaviour patterns from which they develop; and the type of factors that increase the performance of existing, established stereotypies.

Stereotypies often develop in situations of low stimulus input, physical restraint and inescapable fear or frustration (Mason 1991a). These are situations that behavioural and physiological data indicate to be aversive and stressful (Duncan & Wood-Gush 1972; Dawkins 1990). Indeed, a behavioural sign of aversion or internal conflict, such as an attempt to escape or a redirected activity, is sometimes the very source from which a stereotypy develops. Furthermore, once well established, stereotypies are often elicited on exposure to a stressor, or to barren conditions (Mason 1991a).

An example that makes evident that stereotypies are indicators of poor welfare is the stereotypic pacing displayed by laying hens if no nest material is available. At the time when a nest would normally be built, the hen walks up and down in the cage in a repetitive way, indicating frustration of nesting behaviour (Duncan 1970; Wood-Gush 1972). Providing the hen with a preformed nest or removing the oviduct so that no egg is laid does not prevent these behaviours (Wood-Gush 1963; Hughes *et al* 1989).

2.2.1.2. *Aggressive behaviour*

Description of aggressive behaviour in pigs

Group housing allows more freedom of movement and expression of normal behaviours. Aggression, which is the most overt component of agonistic behaviour, is an integrated part of the normal behavioural repertoire of a social species like the pig. Aggression can be defined as the behaviour that results in harm, displacement or removal of other individuals (adopted from Berkowitz 1981). Agonistic behaviour includes also features of behaviour involving escape or passivity as well as aggression (Fraser & Broom 1990). Under confinement conditions, where animals have limited possibilities to avoid or escape from aggressors, aggression may become abnormally excessive, and therefore threatening and deleterious to both production and welfare (Hagelsø-Giersing & Studnitz 1996). Domestic pigs appear to have retained the same fighting tactics as the wild boar (Signoret *et al* 1975). Aggression is based on threats, pressing and pushing, thrusts and bites and is usually performed in a parallel or anti-parallel position (Figure 3), directed at the head and shoulder region of the animal (Jensen 1980). It also includes chasing, which normally stops when the victim flees. The animals seem to respond to each others' signals, which mean that components of agonistic behaviour other than aggression, such as submission signs and avoidance behaviour play an important role (Jensen 1982; McGlone 1985). Much of the overt aggression seen with domestic pigs occurs in two situations: a brief period of fighting when mixing unfamiliar pigs, and a long-term competition that occurs over feed and other resources (Fraser 1984). Both situations are important in sows because they are frequently mixed during their reproductive life and feed is a limited resource as they are feed-restricted.

Figure 3 Anti-parallel position is adopted by pigs in order to minimise the number of bites they receive, so that bites are largely directed at the head and shoulder region.

Situations that causes aggression in pregnant sows

Mixing unacquainted sows

The mixing of unacquainted sows causes intense aggression and great exertion that result in a dominance hierarchy or social rank (Meese & Ewbank 1973). However, the frequency of aggressions decreases drastically within the first 24-48 hours (Barnett *et al* 1992; Arey & Franklin 1995) and the hierarchy is relatively stable in some days (van Putten & van de Burgwal 1990; Arey 1999). The cost of the establishment of the hierarchy is very high in terms of energy, time and lesions (Langbein & Puppe 2004), although it has the function of reducing this cost in the long-term, by predetermining the order of access to resources (Hagelsø-Giersing & Studnitz 1996). Social rank in sows has been shown to be positively correlated with age, liveweight and parity (Martin & Edwards 1994; Arey 1999). There is more fighting at mixing between pigs of equal sizes than those which are less evenly matched (Rushen & Pajor 1987; Rushen 1988; Andersen *et al* 2000), because opponents have difficulties with determining relative strength or fighting ability (Enquist & Leimar 1983). However, not all the dominance relationships between pairs of individuals (dyads) are established by fighting (Moore *et al* 1993; Erhard *et al* 1997; Arey & Edwards 1998; Arey 1999). Therefore, pigs are probably able to assess their opponent's dominance ability using some form of status signalling and thereby physical assessment is not always necessary (Turner & Edwards 2004).

Several management options have been proposed to reduce overt aggression at mixing sows although most of them resulted in contradictory effects (Arey & Edwards 1998). Commercial experience has suggested that aggression is reduced when sows are mixed into larger groups (Edwards *et al* 1993). Although an increase in aggressive interactions would be expected as a function of the number of dominance relationships to settle (Arey & Edwards 1998), large groups seem to adopt a more energetically efficient social strategy (Turner & Edwards 2004). In addition, effective avoidance of aggressors is more likely in large pens with greater dimensions and more mates to hide among (Broom *et al* 1995). Therefore, providing a mixing environment with non-slip flooring and adequate space or barriers to facilitate escape and avoidance is highly recommended (Arey & Edwards 1998). Reducing feeding motivation of sows at the time of mixing by providing feed *ad libitum* has also been reported to reduce aggression

(Barnett *et al* 1994; Edwards *et al* 1994). However, the presence of straw does not seem to have any effect (Botermans 1989) although it may reduce fighting-related lameness by improving foothold (Muirhead 1983; Svendsen *et al* 1990). However, as dominance aggression cannot be completely avoided, repeated mixing should be minimized and carried out before or after the embryo implantation period to avoid detrimental effects on welfare and production (Simmins 1993). Supervising the process to ensure no individual receives excessive aggression is also essential.

Competition for limited resources

Once established, dominance relationships are maintained and reinforced through non-aggressive interactions and infrequent aggressive behaviours and threats (McGlone 1986; Mendl 1995). Sows have been reported to remember the identity and the dominance status of group members over a period of 4-6 weeks of separation (Spoolder *et al* 1996; Arey 1999). However, a higher level of aggression may be necessary if resources are restricted. One of the major challenges in group housing of sows is to minimize the competitive aggression at feeding. A feeding system that functions well is a system where all individuals are allowed access to feed and may complete their ration without being displaced by others (Andersen *et al* 1999). Several commercial options will be commented later. Providing sows with wet feed or roughage have been reported to reduce feeding-related aggression in some of these feeding systems (van Putten & van de Burgwal 1990; Gjein & Larssen 1995a; Andersen *et al* 2000; Jensen *et al* 2000).

Aggression in confined sows

Nevertheless, sow aggression is not limited to group housing. Sows kept in stalls often show aggressive behaviour towards their neighbours (Barnett *et al* 1987; Broom *et al* 1995). Such aggressive interactions in confined sows will not normally result in injury but they involve fear, frustration and social stress as they cannot be satisfactorily resolved (Scientific Veterinary Committee 1997).

2.2.2. Physiology

2.2.2.1. *The stress response*

Definition

Physiological changes associated with the stress response have been widely used as indicators of welfare (Dantzer & Mormede 1983; Broom & Johnson 1993) owing to the belief that if stress increases, welfare decreases. Modern use of the word "stress" in physiology comes from Seyle (1950) who noted that increased pituitary-adrenocortical activity was a non-specific response to various challenges and used the word to describe the physiological reaction itself. Nowadays, "stress" has a negative connotation, often describing the animal's state when it is challenged beyond its behavioural and physiological capacity to adapt to its environment (Fraser *et al* 1975).

Hypothalamic corticotrophin releasing factor (CRF) is thought to be a common mediator of the observed effects of stress (Vale *et al* 1981; Koob & Heinrichs 1999). Secretion of CRF causes activation of both the sympathetic nervous system and the hypothalamic-pituitary-adrenal axis (HPA). Therefore, elevated CRF directly or indirectly causes the release of cathecolamines, opioids, adrenal corticotrophin releasing hormone (ACTH), glucocorticoids and other proteins. Changes in these hormones may lead to elevated heart rate and blood pressure, mobilization of nutrients, immunosuppression and changes in behaviour such as stereotypies and so on (Dantzer 1986; Dunn & Berridge 1990; Salak-Johnson *et al* 2004).

Many questions remain about how the environment impinges upon the nervous, endocrine and immune system and the interaction among these systems. Most studies have focused on the effects of acute rather than chronic stress on these systems. Due to efficient feed-back mechanisms, chronic stress is generally not measurable by changes in HPA or sympathetic activity. Chronic stress may, however, affect regulation of these systems, which becomes apparent when the animal is subjected to acute stress (Terlouw *et al* 1997). Most research to date indicates that the above mentioned physiologic measures of stress are similar for pregnant sows housed in stalls and in groups (McGlone et al 2004a; Task Force on the Housing of Pregnant Sows 2005).

The use of cortisol as an indicator of stress

The primary glucocorticoid secreted by the adrenal cortex in pigs is cortisol. Cortisol has been the most common physiological parameter used to measure farm animal welfare (Terlouw *et al* 1997). Elevated blood, saliva or urine cortisol is clearly a sensitive measure of acute stress (Broom & Johnson 1993), but its use as a measure of long-term welfare is arguable, especially where values do not differ between systems. There are many arguments against the use of occasional measures of cortisol to evaluate welfare related to different methods of housing animals (Rushen 1991; Rushen & de Passillé 1992; Broom & Johnson 1993):

- Housing conditions may intermittently elicit adrenal cortex responses but random samples may miss these. Moreover, the release of cortisol exhibit both diurnal and ultradian variation. Therefore, regular sampling over hours or days in catheterized animals would be required to assess chronic stress. Mean daily levels do not seem a useful measure. The pattern of the secretory episodes, e.g. the frequency, duration and amplitude, gives more useful information. A test of adrenal function has also been proposed as an alternative. It is based on the assumption that chronic stress results in a hyper-reactivity of the adrenal cortex, so that cortisol responses to an acute stressor or to ACTH are exaggerated (Broom 1988). However, results are also controversial since the HPA axis may react in very different ways to chronic stress.
- Adrenal cortex response to short-term stressors often adapts when they are repeated frequently. A continuing response indicates that a problem still exists, but the disappearance of the response does not mean that the problem has been solved.
- Sampling itself may cause an increase in blood or saliva cortisol, as it takes only 2 minutes to become evident. Urine needs a longer time lag.
- Cortisol can also increase following behavioural events such as sexual or nursing behaviour, events which seem unlikely to involve suffering.

2.2.2.2. *The acute phase response*

Definition

The first reaction of the body to immunological stress is the innate, non-specific response preceding the specific immune reactions. The acute phase response (APR) is a prominent systemic reaction of the organism to local or systemic disturbances in its homeostasis caused by infection, inflammation, tissue damage or stress. This defence mechanism is characterized by systemic reactions like fever, hormonal changes, alterations of appetite patterns, muscle catabolism or changes in the concentrations of acute phase proteins (APP). APP are mainly synthesized in the liver, and most of them are glycoproteins. Their expression is regulated by proinflammatory cytokines, mainly by IL-6 type cytokines (Baumann & Gauldie 1994; Gabay & Kushner 1999). The production of APP is also stimulated by ACTH and glucocorticoids (Gruys *et al* 1994). Figure 4 summarizes the induction and regulation network of APP synthesis.

The magnitude and type of change as well as the kinetic of the response can differ among APP. It also depends on the species in question and the extent of tissue damage. The concentration of most of them increases (positive APP) whereas some others (negative APP) show a decrease in their basal levels in response to challenge. Some APP are present at very low concentration in normal state and may show increases up to 100 fold. The maximum serum concentration is typically reached within 24 to 48 h after the initiation of the stimulus. A decline is seen within four to seven days if no further stimulus occurs. If stimulus persists, such as in chronic inflammation, increased serum concentrations of APP are observed, although the increase is lower than after an acute stimulus (Petersen *et al* 2004).

The use of acute phase proteins as indicators of tissue damage

Monitoring health on the farm

APP are used in clinical medicine as a non-specific diagnostic tool in the detection, prognosis and monitoring of treatment during infection and inflammation (Kushner & Mackiewicz 1987). A similar application in veterinary medicine has been proposed. APP are also likely to be used as markers for clinical and subclinical diseases, as their increase occurs before the clinical signs are evident (Harding *et al* 1997). Therefore, APP analysis may be used in the future to help monitor health on the farm for optimal productivity and welfare (Eckersall 2000).

Potential indicator of stress

APP have been proposed as potential indicators of stress (Piñeiro *et al* 2001; Chen *et al* 2003; Saco *et al* 2003; Murata *et al* 2004). APP analysis appears to have some advantages over cortisol measurement. APP are likely to remain increased when animals are under chronic stress, their measurement is not affected by acute stress caused by sampling and they seem to be less subject to individual variability and circadian fluctuations (Saco *et al* 2003). However, the effect of stress on serum concentrations of these proteins remains controversial, as it is difficult to distinguish the effect of stress from the effect of tissue damage (Petersen *et al* 2004).

Aid in the meat inspection

An additional use in slaughterhouse has been suggested. APP may be an aid in meat inspection, in the detection of carcasses of potential risk for public health as well as in the evaluation of meat quality (Eckersall 1992; Saini *et al* 1998; Hiss *et al* 2003).

Standardization of APP analysis

However, before all this applications are reached, it seems necessary to establish common criteria for APP measurement. As a first step, standardization of routine diagnostic assays for animal APP among laboratories has been proposed (Eckersall *et al* 1999). This process is under way in Europe, where it is seen as a practical advance toward the creation of a standardized "acute phase index" (Skinner 2001). Owing to future technological developments, fully automated, simultaneous and rapid measurement of multiple APP may soon be realised.

Applications of the APP analysis in the pig

In the case of pigs, two of the major APP are haptoglobin (Hp) and pig-MAP (pig major acute phase protein). Hp is the most widely used in pigs, mainly due to the greater availability of methods for its quantification (Piñeiro *et al* 2003).

Both Hp and pig-MAP blood concentrations have been shown to increase due to natural and experimental respiratory infections (e.g. Hall *et al* 1992; Heegaard *et al* 1998; Agersø *et al* 1998; Asai *et al* 1999; Magnusson *et al* 1999; Segales *et al* 2004). In post-weaning pigs, Hp has been used as a predictor of weight gain (Eurell *et al* 1992) and it has been related to decreased feed intake (Dritz *et al* 1996).

In slaughter pigs, Hp has been detected lower in herds of high health status and higher in pigs with clinical signs of lameness, respiratory disease, tail and ear bites (Petersen *et al* 2002a,b) or lesions recorded at slaughter (Chen *et al* 2003; Geers *et al* 2003). High levels of Hp have also been recorded in pigs from farms with poor housing and management conditions, even in those animals without clinical symptoms (Lipperheide *et al* 1998; Geers *et al* 2003).

Increases in Hp and pig-MAP have also been related to stress caused by long transport (Piñeiro *et al* 2001; Saco *et al* 2003) rather than short transport (Hicks *et al* 1998; Gymnich *et al* 2001; Chen *et al* 2003; Saco *et al* 2003), the latter being better monitored by cortisol (Bradshaw *et al* 1996; Geverink *et al* 1998; Hicks *et al* 1998; Chen *et al* 2003; Saco *et al* 2003). No changes in Hp or pig-MAP concentrations have been reported after four hours of cold or heat (Hicks *et al* 1998) or in pigs fed disorderly (Piñeiro *et al* 2005). Therefore, APP concentrations seem to change in response to stress involving tissue damage (physical stress) yet there is no evidence of the effect of psychological stress itself.

Therefore, APP and especially Hp determinations have been shown to be a useful tool for health monitoring during the integrated pig production process, allowing recognition of performance and welfare reducing conditions. Unfortunately, there is a lack of literature about how housing and management conditions affect APP levels in pregnant sows.

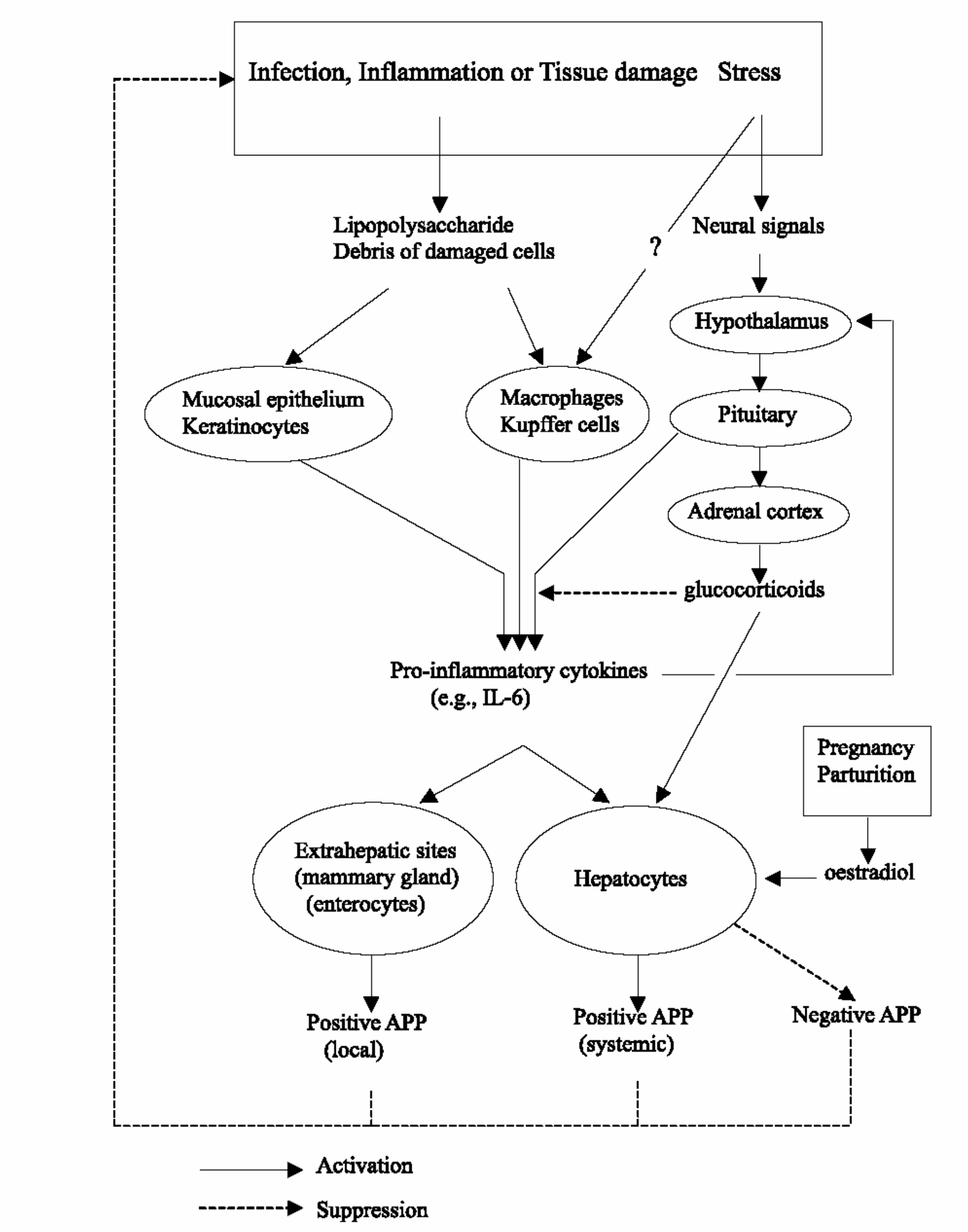

Figure 4 Induction and regulation network of acute phase protein (APP) synthesis in animals subjected to internal or external challenge (Murata *et al* 2004).

2.2.3. Health

On modern pig units where disease is controlled well, no housing systems for pregnant sows have substantial levels of disease and there are no major differences in disease incidence between the various systems for confined or group-housed sows. Only non-infectious or less infectious problems, such as lameness and injuries are more obviously related to environmental conditions (Scientific Veterinary Committee 1997; Task Force on the Housing of Pregnant Sows 2005).

2.2.3.1. *Body injuries*

Body injury rate has been reported to be higher for sows housed in groups than for sows housed in stalls (Gjein & Larssen 1995a; Anil *et al* 2003). However, severe injuries are unusual in well-managed groups (Hodgkiss *et al* 1998). Decubital ulcers on the shoulder or back are the main lesion in stall-housed sows (Figure 5a). They are produced during sow recumbency because of inadequate dimensions of the stall in relation to the size of the sow. Aggressions are the main cause of body injuries in group-housed sows (Gjein & Larssen 1995a; Anil *et al* 2003; Figure 5b). Consequently, as sow weight and body dimensions increase, injury rate also increases in stall-housed sows but it decreases in group-housed sows (Hodgkiss *et al* 1998; Anil *et al* 2003). Sows with increased liveweight are likely to be the dominants in the group (Arey 1999), which rarely receive aggressions from other group members.

Figure 5 Decubital ulcers (a) and scratches from aggressions (b) are frequent in stalled and group-housed sows respectively.

2.2.3.2. *Vulva biting*

Vulva biting is one of the most concerning aggression-related injuries in group-housed sows (Figure 6). Feeding systems which do not allow sows to feed simultaneously, such as electronic sow feeders (ESF), are more likely to present this problem (Rizvi *et al* 1998). Sows are forced to queue and, consequently, the vulva becomes an easy target for the aggressive behaviour elicited by the frustration of waiting yet being hungry and not getting satiated after the visit to the feeder (van Putten & van de Burgwal 1990; Kroneman *et al* 1993a). Several management techniques, such as providing sows with roughage (van Putten & van de Burgwal 1990; Gjein & Larssen 1995a; Jensen *et al* 2000) have been reported to reduce feeding-related aggression. Simultaneous feeding systems can also present vulva biting if the rear of the sow is unprotected or if the supply of water or access to it is limited (Rizvi *et al* 1998).

Figure 6 Vulva biting in group-housed sows**.**

2.2.3.3. *Lameness*

Lameness incidence seems to be related to both housing system and flooring type (Scientific Veterinary Committee 1997). Several studies suggest that spatial restriction in confined sows facilitates lameness compared to group-housed sows (e.g. Bäckström

1973; Tillon & Madec 1984; Peet 1990; Svendsen *et al* 1990). However, in some of these studies, group-housed sows were on bedded floor whereas confined sows were on concrete or slats. On the other hand, there are several studies that suggest that when housed on the same flooring type, sows in group present a higher lameness incidence (Backus *et al* 1991, 1997; Gjein & Larssen 1995b). Fighting seems to be one of the major causes of lameness in group (Gjein & Larssen 1995c).

2.2.4. Production

It is a reasonable assumption that serious welfare problems will be apparent in reduced production (Broom 1991). Some of the production measures that have been used to evaluate sow housing systems are body condition parameters (liveweight, backfat depth) and reproductive performance (weaning-to-oestrus interval, farrowing rate, litter size/weight). However, when all sows in a well-managed housing system are considered, the mean differences are found to be small although the effect on certain sows may be large (Scientific Veterinary Committee 1997). Rushen and de Passillé (1992) suggested that production measures should be based on individual performance if information about animal welfare is to be obtained. Moreover, the copying systems of animals have evolved to minimise effects on reproductive success. Hence, if there are differences among systems, even a small effect may indicate considerable welfare problems (Scientific Veterinary Committee 1997).

2.2.4.1. *Body condition*

Body condition can be reliably estimated from backfat depth and liveweight measures (Figure 7). It is important that each sow gets the appropriated amount of feed so that mobilization of body reserves over the reproductive cycle are minimized and reproduction is not jeopardized (Dourmad *et al* 1994). A sufficient body condition is also important for thermal isolation and to avoid ulcers caused by stall/pen fittings (Vieuille-Thomas *et al* 1995). Backfat depth measurement is easy and can be used to adjust individual feed allocation (Dourmad *et al* 2001). When average liveweight or backfat depth figures are used, well managed stall and group-systems usually show similar results (Cronin *et al* 1996; Harris *et al* 2001; Boyle *et al* 2002). However, Broom *et al* (1995) reported that average liveweight after four pregnancies was lower for stall-housed than for group-housed sows. The suggested reason was the larger amount of time that the stall-housed sows spent performing energetically costly stereotypies (Cronin 1985). On the other hand, there is concern about how group feeding can affect the homogeneity of the batch. Subordinate sows have been reported to gain less weight in some competitive feeding methods due to uneven feed distribution among sows (Brouns & Edwards 1994). Therefore, the election of a feeding system that provides each individual with the appropriate ration, regardless the presence of competitors is of paramount importance.

Figure 7 Body condition can be reliably estimated from liveweight and backfat depth measures, the latter being easily measured by ultrasounds**.**

2.2.4.2. *Reproduction*

Ovarian function depends on a finely balanced control of the hypophyseal-ovarian axis by hormones. It is well established that elevated peripheral concentrations of cortisol due to stress can disrupt hormonal events with the consequent modification of the animal's ability to express normal oestrus periods. There are also concomitants effects on ovulation rates and the ability of fertilized eggs to survive and get implanted. Therefore, some of the stress manifestations are failure to show oestrus, poor conception rates and reduced litter size (Varley 1991). Implantation occurs between the 12th and 28th day of pregnancy (Hughes & Varley 1980) and it is widely considered as a time of high risk. Mixing sows in group housing systems may cause social stress (Arey & Edwards 1998). As a result, it is advised to mix sows either on weaning and then keep them in the same group over the first 4 weeks of pregnancy (Simmins 1993) or after the 4th week of pregnancy (Scientific Veterinary Committee 1997; Barnett *et al* 2001).

It is always difficult to make comparisons of systems as many management variables can affect performance and bias results. Nevertheless, farm surveys (Meat and Livestock Comission 1994) and several studies (Broom *et al* 1995; den Hartog *et al* 1996; Signoret & Vieuille-Thomas 1996) corroborate that reproductive performance from well-managed stalls and group housing systems can be similar. Some early studies found better results from sows in stalls than in groups, especially if they were fed with electronic sow feeders (Lynch *et al* 1984; den Hartog *et al* 1993). However, equipment and management understanding have improved in the last years. Hence, reproductive performance has been reported to be even better in group-housed sows with electronic sow feeders than in stall-housed sows (Bates *et al* 2003). However, social status has been reported to have an effect in reproductive performance. Sows in the middle positions of the social rank have been found to have lower performance due to a higher level of stress in some studies (Mendl *et al* 1992; Nicholson *et al* 1993) although not in others (Pritchard *et al* 1997).

3. GROUP HOUSING: ALTERNATIVE SYSTEMS AND MANAGEMENT

There are multiple and flexible alternatives to stall housing. Most of the common group housing systems were already described in the last century (den Hartog *et al* 1996; Scientific Veterinary Committee 1997; Edwards 1998) although they have been improved. On the other hand, there are different management options as well within each system. There is no single ideal system, as location, farm system, standards of stockmanship, capital availability and personal preference will all influence the selection. Producers must decide what they want to achieve in group housing and select the system and management program that will most likely achieve those goals. Each system has the ability to operate satisfactorily if correctly managed, but also the potential to give rise to major welfare problems if management is poor. It is the people looking after the system, rather than the system itself, which will ultimately determine the health, welfare and reproductive performance of the sows.

Most classifications of group housing systems are based on how the animals are fed. No doubt this preoccupation with feeding is related to one of the primary reasons for the initial change to stalls, that is, control over individual feed intake. I will continue to classify group housing systems by feeding type, but I will also examine social management, which is essential to operate satisfactorily any group housing system. Table 4 summarizes the most common commercial feeding systems and the typically recommended social management for each one.

3.1. Group housing systems: feed control

Control of feed intake must be viewed at three levels (Gonyou 2003). The first is achieving an appropriate **average feed intake** in the sows, although there is no control over individual intake. The second level of control achieves **equal intake for all individuals**, but it does not allow individual feeding. The final level of control is the ability to feed **different amount to each animal**. A well-designed and managed stall system can theoretically achieve this highest level of control. However, in practice, stall-housed sows are often fed identical amounts until a problem in animal condition is noted and adjustments are made. It is usually possible for sows fed in a trough within their stalls to steal significant amounts of feed from a timid neighbour. Inter-stall aggression is common in stall systems (Broom *et al* 1995) and is generally related to feed access.

In all group housing system, some animals (5-10%) may fail to adapt to the competition of the group. These animals may need to be removed and kept separately for special attention to safeguard their welfare and performance (Edwards 1998).

3.1.1. Appropriate average feed intake

3.1.1.1. *Floor feeding*

Floor feeding is one of the simplest and cheapest feeding systems for group-housed sows (Edwards 1998). It consists on spreading the total allowance of feed from the group, either by hand or automatically (dump feeding or spin feeding). This system has two intrinsic limitations regarding to feeding; uncontrolled variation in individual feed intake and the potential for excessive feed-associated aggression. The automatic systems are more recommended as they throw out the feed over a wider area. In this way, feeding-related competition is reduced and a more even distribution of the feed is achieved. Problems can be also ameliorated by providing more space or by exerting social control.

So far, the most common social management has been matching sows of similar size and body condition in small, stable groups. However, the alternative of forming large groups of variable sized animals may also be a viable option (see below on social management). Contrarily to expected, feeding the sows in a straw area has been found to increase feeding-related aggression (Whittaker *et al* 1999).

3.1.2. Equal intake for all individuals

3.1.2.1. *Short stall systems*

These systems consists on head and shoulder barriers along the trough (typically 0.45 to 0.90 m long) to separate each feeding place, leaving much greater free space for the remainder of the pen. They are a low-cost option for stall systems conversion (Petherick *et al* 1987). Conventional stalls can be easily reconverted in feeding places by reducing the overall length and giving the sows access to the central or rear passages. The part of the cubicle which is cut-off may be used to make a gate to subdivide the sows into small groups.

All sows within a pen are fed the same amount as it is not possible to predetermine which animal will enter each stall. The longer the feeding place, the higher the proportion of sows which are able to consume the correct amount of feed. Since sows cannot be fully enclosed while feeding, the possibility of feed poaching by fast eating sows and increased aggression exists.

3.1.2.2. *Improvements to short stall systems: trickle feeding and wet feeding*

One way in which these problems have been minimised is by using trickle feeding or biofix system (de Wit 1996) rather than delivering the feed in a single drop. In this system, all sows are fed simultaneously by a slow release of feed into each short stall. Feed delivery rate is matched to feed intake rate of the slowest sow in the group (Hoofs 1990). Differences in feed intake rate cannot be expressed and thus, no feed will accumulate for another sow to steal. It is important to group sows according to size (what helps match their feed intake rate) and body condition, and keep the group stable. In this way, a relatively even distribution of feed can be achieved.

Short stall systems have also been reported to improve when combined with a wet feeding system (Andersen *et al* 1999), which has the advantage of providing greater dietary bulk from the additional water consumed with the feed.

3.1.3. Individual control of feed intake

3.1.3.1. *Individual feeding stalls*

True individual control of feed intake is only possible if sows are individually confined during feeding. The simplest method to achieve this is to use individual feeding stalls (Edwards 1998). Sows are allowed into the stalls, usually being locked in for protection, during feeding. Typically all animals are fed the same amount, but individuals can receive additional feed by hand. While confined for feeding, sows can be inspected and easily handled.

However, this system is very expensive in terms of cost and occupation of the building. This cost can be reduced if several groups use one set of feeding stalls sequentially, although there is an associated increase in labour requirements. The system can be automated with electronically controlled gates to allow different groups to gain access to the feeding stalls at different times of the day and differential rations can be fed to individuals electronically identified by an earmark transponder (Morris-Hurnik system, Morris *et al* 1993).

3.1.3.2. *Free access stall system*

The best way to reduce capital cost of individual feeding stalls is by doubling up the use of the feeding stalls as a free access lying area, what is known as cubicle or free access stall system (Edwards 1998). Whilst it is desirable to have manual or sow operated back gate, this is often deemed unnecessary in practice with carefully matched sows in small stable groups on similar feed requirements. However, the limited free space means that mixing unfamiliar sows in such systems should be avoided whenever possible.

3.1.3.3. *Electronic sow feeders (ESF)*

An alternative to individual feeding stalls for achieving individual control of feed intake is the electronic sow feeder (ESF). In this system, animals must feed sequentially at one or more feeding stations controlled by a central computer. Each individual is identified on entry to the station by an electronic transponder carried on an ear tag. A programmed individual ration of feed is then dispensed to that animal, which is protected while eating by a specialised crate with gates operated by the sow itself or by the computer. A single feeding station can be shared by as many as 40-60 sows, and very large groups of animals can be consequently kept in low cost, unspecialised housing.

The system resets on a daily basis to allow animals to have access to another day's ration. Identification of the sows that have not finished their ration in the previous day is provided. This information must be used by stockpeople for early identification and resolution of any problems (Bressers *et al* 1993).

Since many animals have to use the feed station sequentially, this is obviously a focus of activity and design features and management factors are important to minimise the aggression that can result (Jensen *et al* 2000; Brooks 2003). Providing sows with roughage have been proved to reduce feeding-related aggression (van Putten & van de Burgwal 1990; Gjein & Larssen 1995a; Jensen *et al* 2000). Regular checking and maintenance is also vital as any mechanical faults soon give rise to increased aggression within the group.

To minimise the number of sows which fail to feed, it is important to have a systematic training programme for animals before they encounter the competition of the large group. Therefore, labour input may be higher in the beginning but reduced later (den Hartog *et al* 1993). However, a qualitatively change in management is required, that is, stockmanship must be qualified and trained in order that the system operates satisfactorily.

3.1.3.4. *Alternative to protected ESF: Fitmix*

Fitmix is a relatively new type of ESF which lacks of protective crate. It has the same management possibilities as the conventional ESF, but only protects the face of the sow while feeding (National Committee 2002). It was first designed for its space efficiency and building flexibility and it is therefore a good option for reconvertion of farms with stalls.

The lack of protection while feeding makes sows divide their feed dose over significantly more visits than what is normally seen in conventional ESF, where sows may be directly or indirectly forced to finish their ration in a single visit (Eddison & Roberts 1995). However, if stable groups are used, a relatively constant feeding order is established and feeding-related aggression is reduced (Hunter *et al* 1988).

3.2. Social management

Social management should attempt to reduce regrouping aggression, the social tension within a group on an ongoing basis, and, as noted above, may be used to achieve some degree of control over feed intake in those systems where individual control of feed intake is not possible. Social management includes a number of techniques, but the major considerations are the frequency of regrouping, sorting and group size (Gonyou 2003). Management possibilities will be highly conditioned by herd size.

3.2.1. Frequency of regrouping

Some degree of regrouping will occur in all systems. A typical breeding group (all females bred close in time) will include sows that have been weaned and bred on their first oestrus, late or repeat breeders, and replacement gilts. These three subgroups are usually unfamiliar to each other but may find they are grouped together for gestation. If animals are grouped together once, and no additional animals are added to the group for the remained of the gestation, it is called **stable** or **static** group.

The alternative to static groups is **dynamic** grouping, whereby new sows are added to the group on a regular basis to replace those removed for farrowing. Aggression related to the frequent regrouping may be deleterious for both welfare and productivity (Simmins 1993). However, dynamic grouping is necessary to maintain large groups, unless the overall herd size is very large.

3.2.2. Sorting

Sorting sows is probably necessary to operate systems where individual control of feed intake is not possible. They are usually sorted by size and body condition. In this way, they are indirectly sorted by nutritional requirements and feed intake rate. Otherwise, smaller sows which are usually less dominant and slower eaters will often not obtain their fair share of feed and finish the gestation in a less than ideal body condition. Gilts are recommended to be kept in separate groups throughout their first gestation in all the systems regardless the degree of feed control. Because of size difference and lack of experience, they are likely to be frequently attacked and thus, unable to adapt, especially in complex systems such as ESF.

3.2.3. Group size

Group size may vary from a few up to several hundred of animals. It depends on herd size and decisions made on static *vs* dynamic management, sorting and feeding system. A fairly common management approach using ESF is to operate dynamic groups of mature sows in groups of more than 200 animals which share several feeder stations. The feeder stations are programmed to sort animals out when they are ready to move to farrowing. Fitmix is typically managed with static groups, variable in size. Systems where individual control of feed intake is not possible are typically managed with small static groups, often less than 10 sows.

Adoption of large groups involves a lower capital cost in terms of space and facilities, but management may be more difficult. However, research on immature pigs (Turner & Edwards 2004) and commercial experience on sows (Edwards *et al* 1993) indicate that aggression in large groups is lower on an individual basis on the day of regrouping than in small groups and is often minimal on subsequent days. Therefore, increasing group size seems to mitigate regrouping aggression in dynamics groups. In addition to the above-mentioned large dynamic groups in ESF, large group management may have applications to other feeding systems, such as floor feeding systems, although it should be properly assessed before adoption as a standard practice. In North America and Australia, it is increasing the use of large, simple, tent-like shelters (ecoshelters or hoop barn systems) that house large groups of pregnant sows, in combination with different feeding systems and straw bedding (Barnett *et al* 2001; Honeyman 2002).

Table 4 Summary of the different feeding systems attending to their feed control, indicating the most typically recommended social management.

Systems and variants	Feed control	Social management		
		Frequency of regrouping	Sorting by size	Group size
Floor feeding[1] - Manual feeding - Dump feeding - Spin feeding	Average feed intake	Stable	Recommended	Up to 10
Short stall systems[1] - Drop feeding - Trickle feeding - Wet feeding	Equal feed intake	Stable	Recommended	Up to 10
Individual feeding stalls[1] - Manually operated - Morris-Hurnik system	Individual control	Stable	Not necessary[2]	Up to 10
Free access stalls - Manually operated - Sow operated	Individual control	Stable	Not necessary [2]	Up to 10
Electronic sow feeders (ESF) - Conventional (with protective crate) - Fitmix	Individual control	Dynamic (conventional) Stable (Fitmix)	Not necessary [2]	Up to 200+ (conventional) [3] Up to 50 (Fitmix)

[1] Some of these systems are also used in large dynamic groups of sows, especially in ecoshelters or hoop barn systems

[2] Separation of gilts throughout their first gestation is highly recommended also in the systems were individual control is possible

[3] One feeder for approximately every 50 sows (it may vary depending on the design and the building layout)

4. CONCLUSIONS AND IMPLICATIONS OF GROUP HOUSING PREGNANT SOWS *VS* CONFINEMENT IN STALLS

Given the number of variables to consider and the large methodological differences in the published studies, it is difficult to rank systems for overall welfare. The most recent reviews on housing systems for pregnant sows carried out by researchers from Europe (Scientific Veterinary Committee 1997), Australia (Barnett *et al* 2001) and North-America (Task Force on the Housing of Pregnant Sows 2005) reached different conclusions because of different criteria for assessing animal welfare. The European reviewers concluded that welfare is better when sows are kept in groups whereas the Americans concluded that no one system is better than others, even though both groups tried to integrate the three welfare approaches (see page 1). The Australian reviewers concluded that both individual and group housing can meet the welfare requirement of pigs, by restricting themselves to the "functioning-based" approach. However, some specific conclusions can be drawn for different variables of welfare by integrating the three reviews approaches. This may allow identifying some specific problems and try to find solutions, since the three reviews agree in the difficulty of calculating and comparing overall welfare in very different systems.

4.1. Behaviour

4.1.1. Stereotypies and opportunity for foraging behaviour

The three reviews agreed that stereotypies are a more concerning issue in stalls than in group housing systems, despite being performed in all the systems. Restricted feeding and lack of opportunity for productive foraging appear to be more important than restriction of movement and housing system *per se*. The Europeans considered the higher potential for the provision of opportunities to root or manipulate materials as one of the advantages of group housing systems. However, the Americans and Australians remarked that environment in pens is often not complex enough to allow the expression of foraging behaviour, because of inadequate pen design or lack of manipulable material. The three reviews agreed that such circumstances also may lead to the development of stereotypies in groups, although the Europeans suggested that the incidence would still be lower than in stalls.

4.1.2. Opportunity for exercise

The three reviews agreed that limitation of space and movement in stalls has some adverse effects on welfare and it is probably one of the aspects more related to public concern. Sows in stalls have reduced muscle tone and mass, reduced bone strength and reduced agility from inactivity, which lead to impaired manoeuvrability in postural changes and consequently lameness and decubital ulcers.

Both Europeans and Americans related restricted movement to lack of control over the environment and impossibility to avoid stressful components of it. On the other hand, the Europeans assumed that group-housed sows have more exercise. However, the Americans and the Australians remarked that sows rarely use the opportunity for exercise if the environment is not complex enough to allow exploratory behaviour, and feed and water are readily available and close to the lying area. The Australians suggested two solutions to overcome the lack of exercise in sows: 1) the use of indoor large groups or extensive systems, where sows are forced to have exercise because of separation of feeding and lying area, and 2) the improvement of stalls design so that sows can turn around.

4.1.3. Social and aggressive behaviour

The three reviews agreed that sows prefer to have social contact with other pigs and that, when provided with sufficient space and environmental complexity, aggression is rare whereas affiliative behaviour is common. However, in both stalls and indoor group housing systems aggression is a problem. Stalls prevent from injuries caused by overt aggression but sows are likely to suffer from fear and frustration due to the incapacity to resolve agonistic interactions. On the other hand, sows in pens can resolve agonistic interactions but there is a risk of pain and injury, especially if the feeding system is too competitive. Initial designs of ESF were those which caused more welfare problems related to aggression. The three reviews also agreed that adequate design and management can reduce aggression in both stalls and group housing systems. Obviously, the management challenge is greater in group housing systems, where feeding management, social management and providing opportunities for avoiding attacks are of paramount importance.

4.1.4. Overall impact of behaviour measures on welfare

It was, in part, evidence of the animals' affective states, natural behaviour and abnormal behaviour that led the European reviewers to conclude that serious welfare problems occur even in the best stall systems. They defined the stalls as "aversive" and "frustrating" taking into account studies of preferences and considering natural and abnormal behaviours as inherent important variables.

However, the Australians reviewers suggested that affective states and behaviour play a role in animal welfare as they would have evolved on the basis on their survival values and contribution to biological fitness. They can be only instrumentally important or inherently important but so closely tied to biological functioning that can be adequately captured by "functioning-based" measures. The Australians reviewers did not look to evidence of negative affective states as primary criteria of welfare problems. Furthermore, they attributed most of the behavioural problems to inadequate physical design of the housing system and management rather than the housing system *per se*.

The American reviewers made a more conservative assessment, avoiding balancing different behavioural aspects with each other or with other aspects as health or production, and concluded that all the systems have shortcomings that should be specifically solved.

4.2. Physiology

The availability of physiological data from the scientific literature is rather limited for gestating sows kept in different housing environments. Moreover, the majority of the studies use cortisol as their primary physiological measurement, although its use in the assessment of chronic stress has been criticized. Indeed, the three reviews also focused their assessment in cortisol measurements. All of them concluded that physiologic measures of stress are generally similar for sows housed in stalls and in groups. The Australians insisted on the importance of design features on chronic stress in all the systems. Both the Americans and the Australians also pointed out that stress may be more pronounced in low-rankings individuals within a group.

4.3. Health

The three reviews agreed that body and vulva injuries are more frequent in groups than in stalls. Injuries caused by pen fittings decrease in groups whereas those related to aggression increase. Hence, good management is essential.

All of them also agreed that lameness is more related with floor type, bedding and pen design than housing systems *per se*. It is largely related to restricted space and movement in stalls and to aggression in group. Consequently, it is a potential issue in all the systems, although the Europeans concluded than in well-managed herds, the problem is worse in stalls.

4.4. Production

The three reviews concluded than productivity appears to be very similar in stalled and group-housed sows if well-managed. Therefore, the quality of stockpeople may have a more important effect on the differences among herds than the housing system *per se*. The Australians and the Americans mentioned that some early designs of ESF that worked with dynamic sows showed worse reproductive results than stalls. On the other hand, the Europeans remarked that when all sows in a housing system are considered, the mean differences between systems are found to be small but the effect on certain sows is large. There may be problems for some sows from group housing and for rather more sows from confined conditions. In general, the coping systems of animals have evolved to minimise effects on reproductive success, so if there are differences between systems, even a small effect may indicate considerable welfare problems.

4.5. General conclusion

Taking all these aspects into account, group housing pregnant sows may be better on a welfare basis as it allows freedom of movement and social interactions. However, the same group housing systems, when they fail to work well, lead to problems, especially in the areas of aggression, injury and uneven body condition. When they lack manipulable material or complexity in the environment, sows in groups are also unable to forage. Furthermore, housing systems cannot be considered in isolation of other important factors that influence animal welfare. High quality stockmanship, feeding systems that minimize competition and environmental features that allow sows to occupy their time and escape from aggressive group mates are essential. Important genetic differences also exist in temperament and affect how well sows function in different housing systems. There are also individual differences within a particular breed. A housing system that works well for more dominant animals may not be favourable for less dominant sows.

Furthermore, effects on society must also be considered. Different sow housing systems may have different impacts on environmental nutrient burden, food safety, and worker health and safety.

To address animal welfare in the long term, advantages of current group housing systems should be retained while making improvements to overcome problems identified.

CHAPTER 2

Objectives

The general objective of this study was the comparison among two different commercial group housing systems (trickle feeding and Fitmix) and conventional stalls for pregnant sows on a welfare and productivity basis. This general objective can be divided in the next specific objectives:

Chapter 3: "Evaluation of welfare and productivity in pregnant sows kept in stalls or in two different group housing systems"

1. To assess and compare the general activity and the performance of stereotypies among the two group housing systems and stalls
2. To assess and compare the degree of tissue damage by determining the levels of acute phase proteins among the two group housing systems and stalls
3. To assess and compare the evolution of liveweight and body condition among the two group housing systems and stalls
4. To assess and compare the reproductive performance among the two group housing systems and stalls

Chapter 4: "Aggressive behaviour in two different group housing systems for pregnant sows"

5. To assess and compare the level and characteristics of aggressive interactions between the two group housing systems
6. To assess and compare the dominance rank and its relation to other variables between the two group housing systems
7. To assess and compare the process of adaptation to the two group housing systems

Chapter 5: "Feeding behaviour patterns in group-housed pregnant sows fed with an unprotected electronic sow feeder (Fitmix)"

8. To study the efficiency of an unprotected feeder
9. To study the evolution of the feeding behaviour over time
10. To study the circadian evolution of the feeding behaviour
11. To study the establishment of a feeding order and its relation to social rank

CHAPTER 3

"Evaluation of welfare and productivity in pregnant sows kept in stalls or in two different group housing systems"

Abstract

One hundred and eighty pregnant sows (*Sus scrofa*), from first to ninth parity, were selected on a commercial farm and used in three different replicas (60 sows per replica). Sows were housed from day 29 of pregnancy to 1 week before parturition in conventional stalls, in groups of 10 with trickle feeding or in groups of 20 with an unprotected electronic sow feeder (Fitmix; 20 sows per housing system per replica). All the sows were equally feed-restricted. Behaviour, acute phase proteins (APP) plasma levels and productivity were assessed. General activity and stereotypies were measured by scan-sampling observation at different times of the day on 11 non-consecutive days. Overall, group housing sows with Fitmix appeared to increase resting behaviour and decrease oronasofacial stereotypies to a higher extent than with trickle feeding ($P < 0.001$). Both group housing systems reduced considerably the performance of sham-chewing ($P < 0.001$). Gilts showed a lower general activity and performance of stereotypies than older sows in all the systems ($P < 0.001$). In general, APP levels and productivity measures did not differ among systems. However, incidences such as lameness or vulva injuries were more often detected in group housing systems. Removal of animals was higher in sows with Fitmix than in the other systems. In conclusion, well-managed group-housed sows seem to increase resting behaviour and decrease stereotypies at similar productivity and tissue damage levels. However, higher quality stockmanship may be required for early detection and solution of problems in group housing systems. Nevertheless, long-term effects of group housing systems on welfare should be further assessed before recommendations are made.

1. INTRODUCTION

In 2013, only group housing of pregnant sows from day 29 of pregnancy to 1 week before parturition will be allowed in the EU Member States. This will affect management, feeding and welfare. The widely used stalls permit individual feeding and management at low capital cost and avoid overt aggressions. However, the restriction of movement and the impossibility to perform normal feeding and social patterns of behaviour cause welfare problems such as development of stereotypies, chronic stress, lameness and decubital ulcers. Housing the sows in group could improve some of these problems. Several studies suggest that stereotypies in sows fed the same restricted diet are lower when housed in pens (Jensen 1988; Broom *et al* 1995; Vieuille-Thomas *et al* 1995). Nevertheless, group housing also presents some disadvantages. Individual feeding becomes more difficult and supervision more laborious, although the most important welfare problem seems to be stress and injuries caused by aggressions, particularly, after mixing and for feed access. It is thus important that group housing systems are designed and managed so that welfare is good.

For the evaluation of welfare in different housing systems, different indicators should be taken into account (Broom 1996), including measures of behaviour, stress and performance. Nevertheless, assessment of chronic stress in housing systems is difficult. Cortisol measurements have been used in several studies (Barnett *et al* 1992; Mendl *et al* 1992; Broom *et al* 1995), although there may be some interpretation problems (Rushen & de Passillé 1992). Acute phase proteins (APP) have been proposed as indicators of chronic stress (Piñeiro *et al* 2001; Chen *et al* 2003; Saco *et al* 2003; Murata *et al* 2004), although further research should be done.

There are few studies that compare different indicators of welfare in conventional stalls and modern commercial group housing systems (den Hartog *et al* 1993; Broom *et al* 1995). In this study, sows housed in stalls were compared to those in group with Fitmix (an unprotected type of electronic sow feeder), and to those in group with trickle feeding. Fitmix permits individual automatic rationing although sows have to feed one at a time, which may lead to the establishment of a feeding order. With trickle feeding, sows are fed simultaneously the same ration. However, competition for feed access is reduced by using partial barriers and by synchronizing feed delivery and feed intake rate. The experiment was repeated during three replicas in different seasons.

Behavioural observations, acute phase proteins (APP) plasma levels, body condition evolution and reproductive success were used as indicators of animal welfare and productivity.

2. METHODS

2.1. Animal, housing, feeding and general management

One hundred and eighty Large White x Landrace pregnant female pigs[3] (*Sus scrofa*) from first to ninth parity (Table 1) were selected on a commercial farm on the 29th day of pregnancy. All sows had been previously stall-housed during their productive live, that is, from weeks to years depending on their parity. They were used in three different replicas (60 sows per replica). After being weighed and their backfat depth measured, they were housed in three different housing systems with different feeding systems in the same building until a week before the expected parturition date. The first replica took place from mid January to early April, the second one from late April to mid July and the third one from late July to mid October.

In each replica, the sows were randomly assigned to a housing and feeding system. Twenty sows were housed individually in conventional part-slatted stalls (STALL; 2.15 m x 0.60 m). These sows were given wet feed once daily at 700h and water was available *ad libitum* in the trough. This was the system used routinely on the farm and all the sows had been kept like that before the experiment. Twenty more sows were housed in two pens (10 sows per pen) with trickle feeding (TRICK; Rotecna, Spain). Each pen had 10 feeding places with shoulder length barriers along the feed trough (1m x 0.60 m). These sows were fed simultaneously once daily at 700h at an average delivery rate of 156 g min^{-1}. Water was provided *ad libitum* from a drinker per pen. The other 20 sows were housed in a single pen with an unprotected electronic sow feeder (FITMIX; Mannebeck, Germany). Sows were identified by an earmark transponder and offered the individually allocated amount of wet feed. They were fed one at a time in a single feeder without a protective crate. Each daily feed cycle started at 700h. The

[3] Hereafter, all experimental female pigs will be refereed to as sows irrespective of their parity number, unless otherwise indicated

feeder had a lateral access to the feed leftovers in order to decrease aggressive behaviour towards the sow that was being fed. Water was provided *ad libitum* from a single drinker. The resting area was divided by two protecting walls (1 m x 1.8 m). These two group housing systems had part-slatted floor without bedding and space allowance was 2.3 m^2 per animal without taking into account the space occupied by the feeding places or the feeder. One thermometer was situated next to each housing system in order to measure daily maximum and minimum temperature. The pens were illuminated by both natural daylight and artificial lighting with lights switched on at 600h and off at 2200h. The same stockpeople cared for all the animals.

Table 1 Distribution of the parity number in the different groups.

	Replica 1			Replica 2			Replica 3		
	Gilts	Young adults[1]	Old adults[2]	Gilts	Young adults[1]	Old adults[2]	Gilts	Young adults[1]	Old adults[2]
STALL	6	6	8	6	8	6	6	9	5
TRICK	6	6	8	6	7	7	6	8	6
FITMIX	6	6	8	6	8	6	6	8	6

[1] Sows from second to fourth parity

[2] Sows from fifth parity on

All the sows were restrictedly fed with concentrated feed (143 g crude protein, 90 g crude fat, 80 g crude fibre, 63 g ash and 12.25 MJ ME per kg). The quantity offered to STALL and FITMIX sows were 2.3 kg/day/gilt and 2.5 kg/day/sow until day 90 of pregnancy and from then on, 2.8 kg/day/gilt and 3 kg/day/sow. TRICK sows were offered 25 kg/day/pen until day 90 of pregnancy and 30 kg/day/pen from then on. The rations were corrected using backfat depth measures when necessary.

2.2. General experimental protocol

Sows were weighed on days 1 and 15 of the experiment and on the day they left the pregnancy facilities to the farrowing crates. The same days and also on days 31 and 65 of the experiment, backfat depth was measured by ultrasounds (RENCO LEAN-METER®). After each measurement, feed allocation was corrected if backfat depth was lower than 14 mm or higher than 20 mm.

FITMIX sows followed a training program during the first fortnight to learn how to use the feeder. Lateral access for the feed leftovers was also cancelled. From day 5 to 8, sows that already knew how to feed were moved out of the pen from 1200h to 1600h in order to leave just the sows that had learning problems. On days 5 and 8, space allowance was reduced and assistance was offered when a sow approached the feeder. Sows were compensated for the missed shares of feed once the training period was finished.

Behaviour was observed 3 days per system during the first two weeks of the experiment (considered the adaptation phase) and then 1 day per week per system until the week before leaving to the farrowing crates. In the first and second replicas, from 6 to 10 sows per system were blood sampled in the 3-5th and 8-10th week of the experiment in order to determine the level of two APP, haptoglobina (Hp) and pig-MAP (pig major acute phase protein).

Feed offered, water use (drunk and spilt) and temperature (minimum and maximum) were recorded every day. Incidences like death, abortions, lameness or vulva injuries were also noted. Pregnancy was reconfirmed by ultrasounds on day 55 of the experiment. Sows were removed to conventional farrowing crates one week before the expected farrowing date. Parturition was hormonally induced following the farm routine. Reproductive performance was assessed.

2.3. Behavioural observations

For observation purposes, a number was sprayed on the neck, back and flanks of each group-housed sow before each observation day. Interruptions by farm staff were minimized on the observation days. Sows were observed during four periods each day: one period of 30 minutes before feeding (from 630h to 700h, period 1), two 60-minute periods, separated by a 30-minute rest, starting at 700h for FITMIX and after feeding for STALL and TRICK (period 2 and period 3) and one 90-minute period in the afternoon (from 1415h to 1545h, period 4). The observers (one for STALL and FITMIX, one for each pen for TRICK) were situated in the nearest corridor to the feeding area. A ten-minute interval scan-sampling technique was used (Martin & Bateson 1993). Hence, 28 scan samples were recorded per system on each observation day. Posture, activities and location in the pen were recorded (Table 2).

2.4. Blood biochemistry

Haptoglobin and Pig-MAP were analysed by radial immunodiffusion (Mancini *et al* 1965). The assays were performed by the Department of Biochemistry and Biology, Science School, Universidad de Zaragoza (Lampreave *et al* 1994; Gonzalez-Ramon *et al* 1995).

2.5. Measures of reproduction

Several measures of reproduction were taken at parturition. These included the number of piglets born alive, dead or mummified, the total weight of piglets born and the total weight of piglets born alive.

2.6. Data analyses

For the analyses of behavioural data, the experiment was divided into two phases. The two first weeks were considered the adaptation phase (phase A) and were analysed apart from the rest of the experiment (phase B). Diurnal evolution of the behavioural data was just analysed in phase B. To make the comparison of the different activities between groups easier, some behaviours were regrouped. Therefore, a new category of behaviour called "interaction with the floor and the equipment" (IFE) was created which included floor, bar and trough manipulation and feeder interaction. To have a general idea about the level of stereotypes in each group, all the categories of activities except eating were considered together as oronasofacial behaviours (ONF). As a result, the categories of activities compared between groups were: sham-chewing, IFE, drinking and ONF. For the analysis of the parity effect, sows were divided in three groups: gilts, young adults (from second to fourth parity) and old adults (from fifth parity on).

Statistical analyses were performed using the statistical package SAS (1999). Measures of productivity, reproduction (except the number of piglets born alive, dead or mummified) and biochemistry were analysed using the MIXED procedure. The replica was specified as a random effect. The least-square means of fixed effects (LSMEANS) adjusted to Tukey's honestly significance difference was used as a test of multiple comparisons. Levene's homogeneity of variance test was also computed. The number of piglets born alive, dead or mummified and all the behavioural data (count data) were analysed using the GENMOD procedure (Cameron & Trivedi 1998). The least-square means of fixed effects (LSMEANS) adjusted to Bonferroni's honestly significance difference was used as a test of multiple comparisons. In all cases, the accepted significance level was $P < 0.05$.

Table 2 Recorded behaviours and locations.

Category of behaviour or location	Description (when necessary)	Systems where recorded
Posture		
Lying		All
Standing	Immobile or walking	All
Sitting		All
Activity		
Drinking	Manipulating the drinker or apparently ingesting water	All
Sham-chewing	Continuous chewing while no feed is present in the mouth	All
Floor manipulation	Nosing, rubbing or licking the floor	All
Bar manipulation	Nosing, rubbing, licking or biting any metal component of the stall or pen other than the feeding pipe	STALL, TRICK
Trough manipulation	Nosing, rubbing, licking or biting the trough or the feeding pipe	STALL, TRICK
Eating	Ingesting the allocated feed	FITMIX
Feeder interaction	Nosing, rubbing, licking or biting any component of the feeder without getting other feed than leftovers from another sow	FITMIX
Location		
Feeding area	In the feeding places (at least head and shoulders inside) or in the vicinity of the electronic feeder	TRICK, FITMIX
Resting area	Other than the feeding area	TRICK, FITMIX

3. RESULTS

3.1. Environmental conditions

The average minimum : maximum temperatures (ºC) in the pregnancy facilities during the three replicas were 13 : 18, 20 : 27 and 21 : 27 respectively

3.2. Behaviour

Behaviour data showing among-systems comparisons in phase A and B are shown in Figure 1, 3 and 5 and diurnal evolutions in phase B are shown in Figure 2, 4 and 6.

3.2.1. Posture

Both in phase A and B, FITMIX sows were observed lying a higher proportion of scan samples than STALL and TRICK sows ($P < 0.001$). Differences in phase B were only observed in period 1 and 2 ($P < 0.001$).

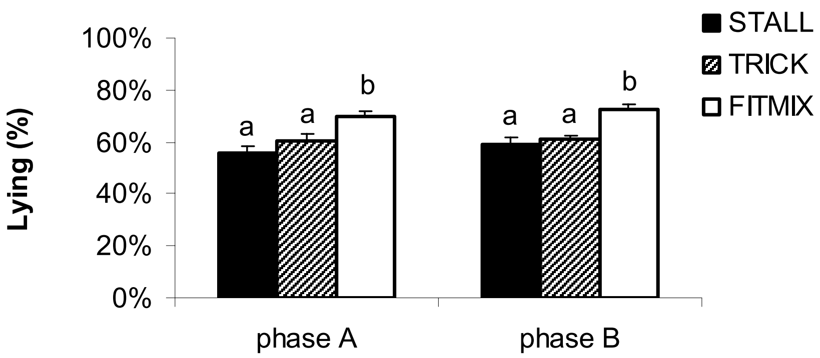

Figure 1 Mean proportion (%) of scan samples that sows were observed lying during phase A and B. Error bars denote one s.e. If letters above columns are different, $P < 0.05$.

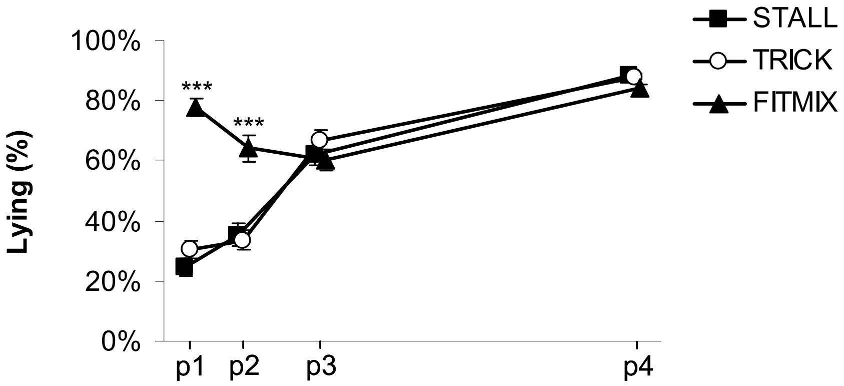

Figure 2 Mean proportion (%) of scan samples that sows were observed lying during four different daily periods (p) in phase B. Error bars denote one s.e. *** $P < 0.001$.

3.2.2. Activities

Both in phase A and B, STALL sows were observed performing sham-chewing a higher proportion of scan samples than TRICK and FITMIX sows ($P < 0.001$). Differences in phase B remained during the four daily periods ($P < 0.001$). FITMIX sows were observed interacting with the floor and the equipment (IFE) a lower proportion of scan samples than STALL sows in phase A ($P < 0.05$) and than TRICK sows in phase B ($P < 0.05$). In phase B, FITMIX sows performed less IFE than TRICK sows in period 1 ($P < 0.001$), less than STALL and TRICK sows in period 2 ($P < 0.001$) but more than TRICK sows in period 4 ($P < 0.001$). In phase A, FITMIX sows were observed drinking a lower proportion of scan samples than TRICK and STALL sows ($P < 0.001$) whereas in phase B, FITMIX sows were observed drinking less frequently than STALL sows and these less than TRICK sows ($P < 0.001$). No differences among systems were found in period 1 whereas FITMIX sows performed these behaviour less frequently than both TRICK and STALL sows in period 2 and less than TRICK sows in period 3 and 4 ($P < 0.001$). Overall, STALL sows were observed performing non-feeding oronasofacial behaviours (ONF) a higher proportion of scan samples than TRICK sows and these a higher proportion than FITMIX sows in both phases ($P < 0.001$). Differences in ONF among systems in each period are shown in Figure 4.d.

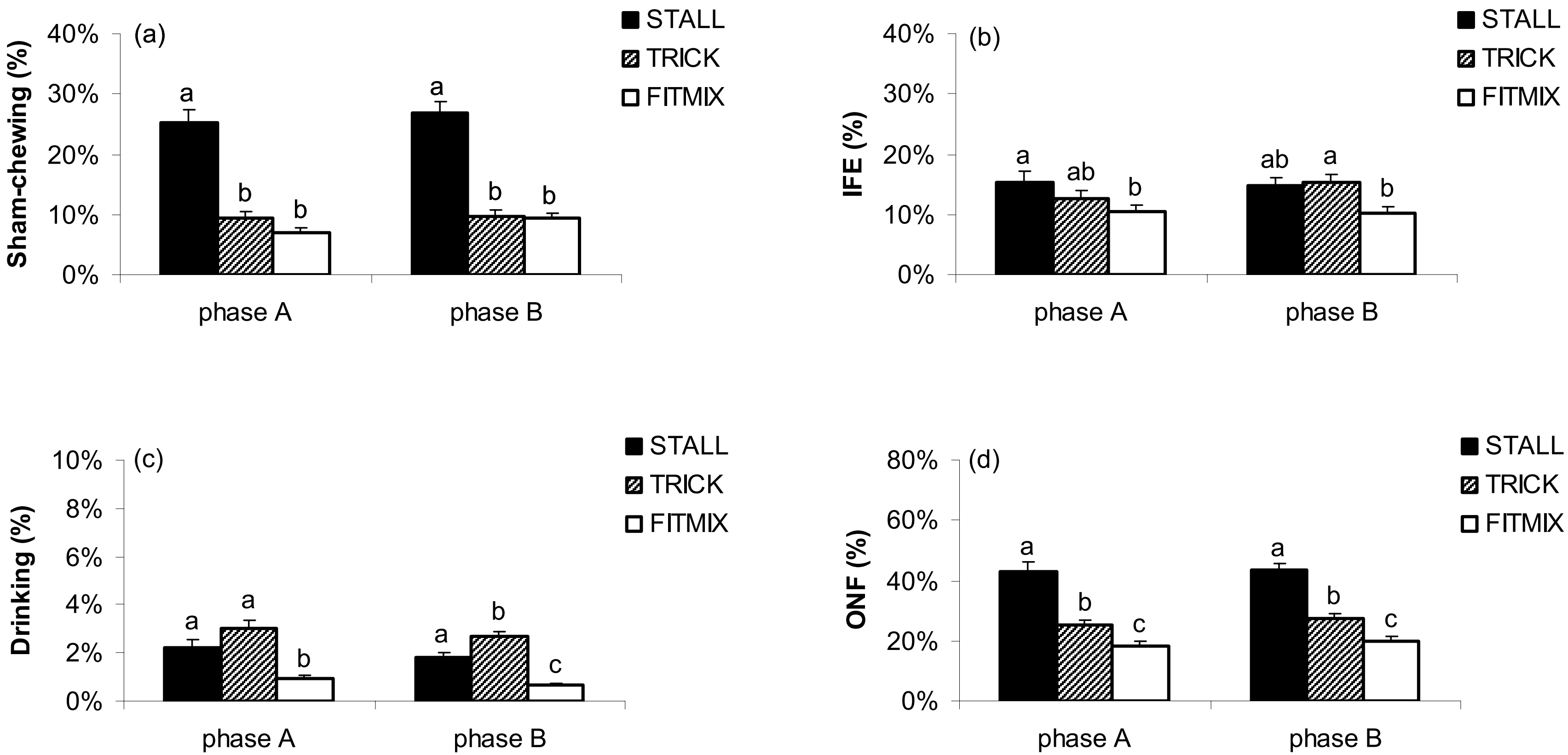

Figure 3 Mean proportion (%) of scan samples that sows were observed: a) sham-chewing, b) interacting with the floor and the equipment (IFE), c) drinking or d) performing non-feeding oronasofacial behaviours (ONF) during phase A and B. Error bars denote one s.e. If letters above columns are different, $P < 0.05$.

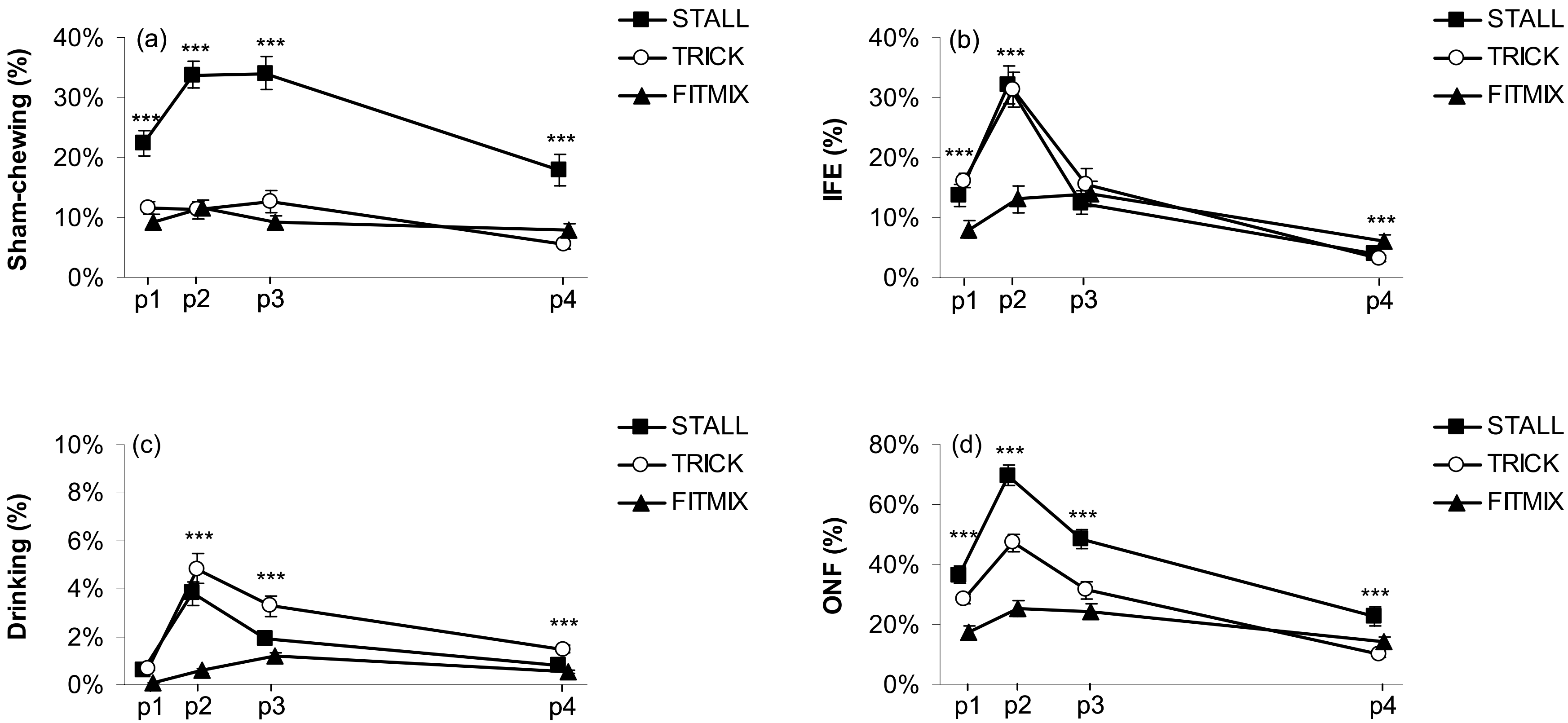

Figure 4 Mean proportion (%) of scan samples that sows were observed: a) sham-chewing, b) interacting with the floor and the equipment (IFE), c) drinking or d) performing non-feeding oronasofacial behaviours (ONF) during four different daily periods (p) in phase B. Error bars denote one s.e.*** $P < 0.001$.

3.2.3. Location in the pen

Both in phase A and B, TRICK sows were observed in the feeding area a higher proportion of scan samples than FITMIX sows ($P < 0.05$ for phase A and $P < 0.001$ for phase B). Differences in phase B were due to period 1 and 2 ($P < 0.001$). However, FITMIX sows were observed more frequently in the feeding area than TRICK sows in period 4 ($P < 0.001$).

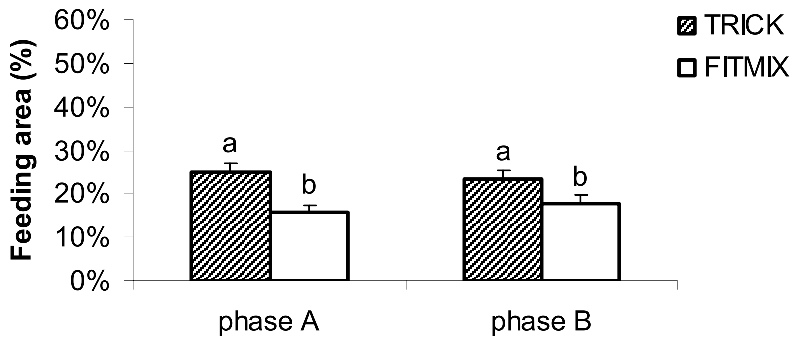

Figure 5 Mean proportion (%) of scan samples that sows were observed in the feeding area during phase A and B. Error bars denote one s.e. If letters above columns are different, $P < 0.05$.

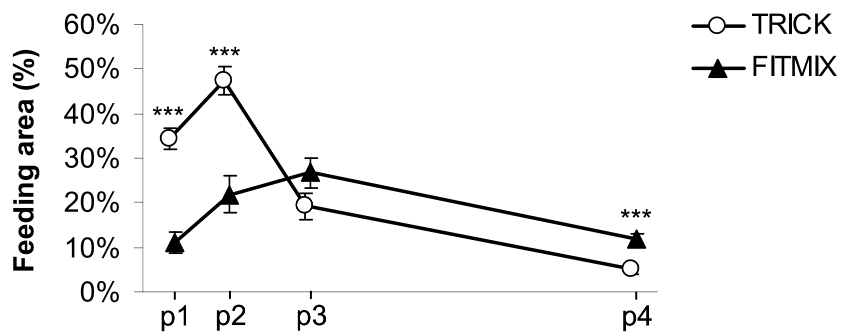

Figure 6 Mean proportion (%) of scan samples that sows were observed in the feeding area during four different daily periods (p) in phase B. Error bars denote one s.e. *** $P < 0.001$.

3.2.4. Parity effect

Both in phase A and B, gilts were observed lying a higher proportion of scan samples than young adults and these a higher proportion than old adults ($P < 0.001$). Differences were not found in period 4. Gilts were also observed performing sham-chewing a lower proportion of scan samples than both young and old adults in all the occasions ($P < 0.001$). They were observed performing IFE a lower proportion of scan samples than old adult in phase A ($P < 0.01$) and a lower proportion than young adults and these a lower proportion than old adults in phase B ($P < 0.001$). There was no parity effect for drinking-related behaviours. When analyzing ONF behaviours in phase A, gilts were observed performing these behaviours a lower proportion of scan samples than both young and old adults but just in STALL and TRICK ($P < 0.05$). There were no differences among systems for gilts, either. In phase B, gilts were observed performing ONF a lower proportion of scan sampling than both young and old adults just in period 2 and 3 ($P < 0.001$). Old adults were observed in the feeding area a higher proportion of scan samples than gilts in phase A ($P < 0.001$) and a higher proportion of scan samples than gilts and young adults in phase B ($P < 0.001$).

3.3. Blood biochemistry

No differences were found in pig-MAP plasma levels either among systems or between the two samples. A general decrease in time was found in haptoglobin plasma levels ($P < 0.001$) although there were no differences among systems.

3.4. Productivity and reproduction

Average daily water use per animal was higher in STALL than in the group housing systems ($P < 0.001$). Weekly evolution of daily water use is shown in Figure 7. The average daily amount of feed offered per animal was 2.61 kg/sow/day in both STALL and TRICK and 2.56 kg/sow/day in FITMIX. No differences were found among systems.

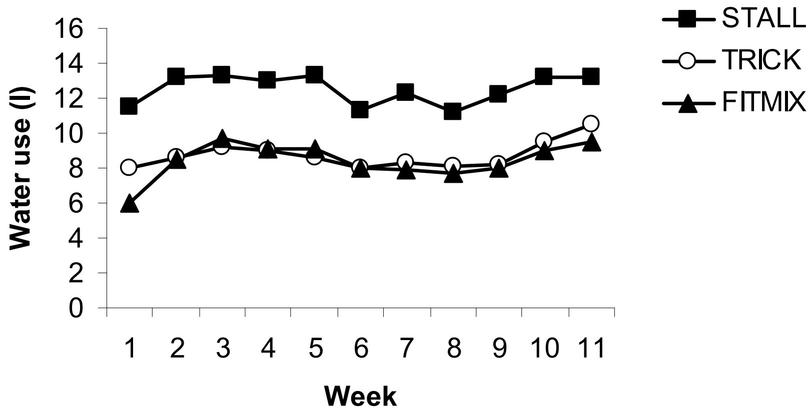

Figure 7 Weekly evolution of average daily water use per sow.

No differences were found among systems in any of the three liveweight measurements. Liveweights did not differ from the first to the second measurement in any of the systems but they did in the third measurement in all the systems as expected ($P < 0.001$). No differences among systems were found in any of the backfat depth measurements or their variability. Average evolution of backfat depth is shown in Figure 8.

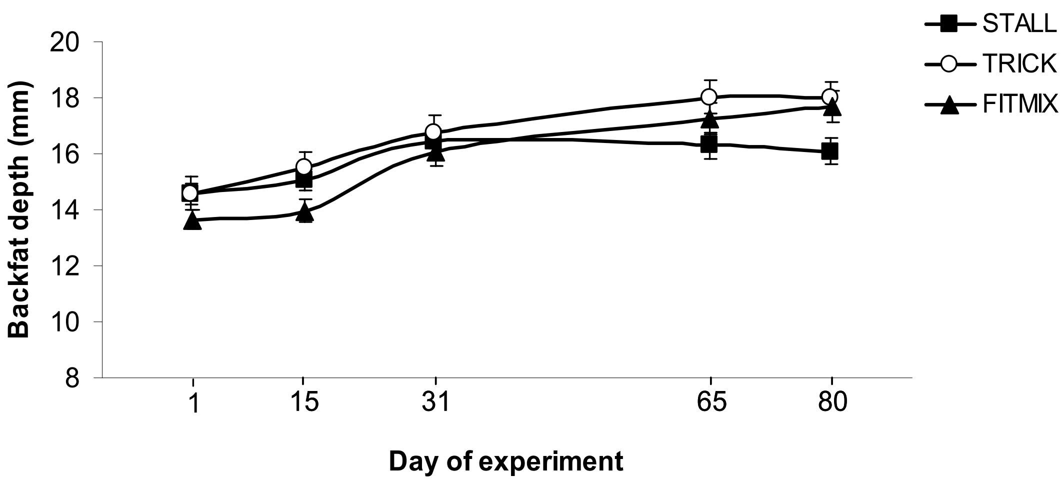

Figure 8 Mean backfat depth of sows on days 1, 15, 31, 65 and 80 of the experiment. Error bar denote one s.e.

Few reproductive differences were found. The number of piglets born dead per litter was lower in FITMIX than from the other systems (STALL = 1.24, TRICK = 1.04 and FITMIX = 0.54, s.e. = 0.18, $P < 0.01$). Parity affected the mean piglet birth weight so that gilts produced lighter piglets than young adults (gilts = 1.42, young adults = 1.56 and old adults = 1.51, s.e. = 0.04, $P < 0.05$). There were no differences in number of piglets born alive or mummified, total weight of piglets produced or total weight of piglets born alive.

3.5. Incidences

The number of sows that were removed in each system and the causes of removal are shown in Table 3. All the failures to farrow (sows which returned to cycle, were detected not pregnant by ultrasound or aborted) occurred in the third replica. Three of the six sows that failed to feed were also lame. Five of them were considered to have failed to adapt to the feeding system, because difficulties to feed arose right after entering the system. All of them belonged to replica 2 or 3. A total of eight TRICK and seven FITMIX sows were observed lame. One STALL, five TRICK and five FITMIX sows were vulva injured.

Table 3 Removed sows according to cause.

	STALL	TRICK	FITMIX
Sudden death	-	1	1
Detected not pregnant	2	2	4
Abortion	-	-	1
Failure to feed	-	-	6
Total removed sows	2	3	12

4. DISCUSSION

4.1. Behaviour measures

Several measures of behaviour suggest that STALL sows found the conditions more difficult than those housed in groups, especially than FITMIX sows. FITMIX sows spent more time lying. These differences were due to a higher activity (mainly standing) of STALL and TRICK sows immediately before and after feeding. Expecting the scheduled meal may induce frustration and stress in a hungry animal and raise the general level of activity or excitement, i.e. arousal (Haskell *et al* 2000). In this context, arousal is defined as a non-specific motivational factor affecting the general activity of the animal (Lawrence & Terlouw 1993; Rushen *et al* 1993) which may arise as the result of frustrating a highly motivated behaviour (Odberg 1978). Therefore, the level of standing and activity is often used as a measure of arousal (Terlouw & Lawrence 1993). Similar increases in general activity before feeding had been previously described (e.g. Terlow *et al* 1991; Terlouw & Lawrence 1993; Terlow *et al* 1993). However, FITMIX did not appear to increase the general arousal before feeding. That is important taking into account that the feeding cycle started at the same time at which the other systems were fed, the sows were able to hear the increase in general activity and vocalization in the adjacent pens and they were equally feed-restricted. Nevertheless, sows remained lying at the same level as in period 4. Ingestion of an insufficient meal has been suggested to be also an arousing stimulus (Lawrence & Terlouw 1993; Terlouw *et al* 1993). Thus, the diurnal pattern of activity usually follows meals schedule (Jensen 1988; Backus *et al* 1991; Robert *et al* 1993). After feeding, STALL and TRICK sows remained at the same level of activity as when expecting the meal and FITMIX sows increased the level. FITMIX sows fed mainly in period 2 and 3 and feeding-related increase in general activity was maintained over these two periods. Differences among systems were not found in period 3 and 4. Therefore, FITMIX appeared to provide a most favourable environment for resting. The greater space allowance per pen in FITMIX may have also facilitated the physical exercise and reduced biomechanical stress on the sow, providing more agility and comfort (Marchant & Broom 1996). Terlouw *et al* (1991) and Terlouw & Lawrence (1993) also found that feed-restricted sows spent more time lying when group-housed than when stall-housed.

STALL sows performed more non-feeding ONF behaviours than TRICK and FITMIX sows. Sham-chewing is largely considered as a self-directed stereotypy (Terlouw *et al* 1991; Lawrence & Terlouw 1993; Mason 1993; Broom *et al* 1995) whereas drinking behaviour is considered a stereotypy if it persists after metabolic requirements are fulfilled (Rushen 1984; Terlouw *et al* 1991; Douglas *et al* 1998). Interaction with the floor and the equipment are more controversial. Whereas bar-biting is also largely considered a stereotypy (Terlouw *et al* 1991; Mason 1993; Lawrence & Terlouw 1993; Broom *et al* 1995), manipulation of the trough, the feeder or the floor resembles feeding behaviour. Despite this matter of interpretation, it seems that a higher level of ONF behaviour reflects a higher feeding motivation and probably a higher arousal that prevents sows from resting (Lawrence & Terlouw 1993). Therefore, persistent non-feeding ONF behaviours may be indicative of, or precursors to, stereotypies (Haskell *et al* 1996), especially considering the absence of feed while observing.

The level of ONF behaviours increased after feeding in all the systems. The ingestion of an insufficient amount of feed seemed to specifically facilitate the performance of theses behaviours by enhancing the feeding motivation and arousal instead of reducing these motivations by inducing satiety (Terlouw *et al* 1993; Lawrence & Terlouw 1993). Stereotyped ONF behaviours do not in general occur before feeding or at other times because the motivational feeding system is not sufficiently primed for low incentives to elicit feeding responses (Lawrence & Terlouw 1993). The higher level of ONF behaviours in STALL and TRICK sows before feeding may have been reflecting a heightened arousal that also prevented them from lying. Rushen (1984) and von Borell & Hurnik (1991) suggested that the animals than spent more time standing where the same that spent more time performing stereotypies. The level of ONF behaviours in FITMIX sows did not decrease from period 2 to 3 due to sequential feeding of animals yet it did in STALL and TRICK sows, although levels in STALL sows remained higher than in the other systems. Several studies suggest that stereotypies are performed mainly 2-3 hours following the ingestion of meal (Rushen 1985; Jensen 1988; Terlouw *et al* 1993). In period 3 and 4, there were no differences in the level of ONF behaviours between TRICK and FITMIX sows, despite the different pattern of feeding.

Sham-chewing is probably the most detrimental stereotypy because is considered to be in a more advanced stage of development. Stereotypies develop in a continuous way from normal behaviour patters that become altered and performed out of context. They lose variability and flexibility with time due to environmental restriction in the variety of allowed behaviours. Environment-directed stereotypies may develop into self-directed stereotypies (Mason 1993). Therefore, sham-chewing may be a good indicator of environmental restriction. The level of sham-chewing was always higher in STALL sows. It increased after feeding but, opposite to IFE and drinking behaviour, remained high also in period 3. This pattern of behaviours agrees with the sequence previously suggested by several studies (Rushen 1985; Jensen 1988; Terlouw & Lawrence 1993). Drinking and manipulating the trough and the floor show a peak within the first hour whereas persistent drinking behaviour and sham-chewing are usually expressed over longer periods. Moreover, sham-chewing is often performed when animals are lying (Broom & Potter 1984; Fraser & Broom 1990), as appeared to happen in period 3. The low levels of sham-chewing in TRICK and FITMIX are important especially because all the sows had already been stall-housed for some weeks (in the case of gilts) to years. Therefore, most of the animals may have developed stereotypies previously to the start of the experiment. Long-established stereotypies are very difficult to abolish, or even diminish, improving the environment because they are somehow independent of extrinsic factors (Mason 1991a). Terlouw & Lawrence (1993) could not diminish the level of stereotypies by increasing the amount of feed offered to sows that had been feed-restricted over three parities, either stall or group-housed, although feed restriction seems to be the main factor involved in the stereotypies. However, Stolba & Wood-Gush (1989) observed that pigs of different ages and sexes in semi-naturals conditions did not perform stereotypies although the adults had been previously reared in conventional housing systems and they were feed-restricted.

FITMIX sows were those which interacted less with the floor and the equipment. This could be due to a lower feeding motivation and arousal although it may have been affected by the fact that FITMIX sows had less available, alternative stimuli such as bars to where redirect their feeding motivation (Lawrence & Terlouw 1993). Anyway, this lack of environmental stimuli did not cause an increase in self-directed stereotypies.

In general, TRICK sows were those more frequently observed performing drinking behaviour although STALL sows used more water. However, the amount of water acquired from the trough/drinker was quite similar between the three systems. TRICK sows consumed dry feed. As they were fed simultaneously, they tried to gain access to the drinker all at the same time after the meal, due to both thirst and social facilitation (Forkman 1996). However, they had to drink sequentially. As a result, high levels of drinking behaviour where sustained also in the period 3. Furthermore, the drinker may have been understood as a resource of limited access (because of its spatial distribution) and thus needed to be defended in a social organized group (Turner *et al* 2000). Therefore, the drinker became an incentive stimulus in this system compared to the other systems where sows acquire water from the meal and, in the case of FITMIX, finish feeding sequentially.

Overall, we can suggest that FITMIX sows performed fewer stereotypies than TRICK sows and these less than STALL sows despite being equally feed-restricted and all of them having long-established stereotypies due to previous restrain. Therefore, although the level of feed restriction has been proposed as the main factor in the development of stereotypies (Terlouw *et al* 1991), environmental restriction and thus type of housing and feeding system also seems to affect. Broom *et al* (1995) found very similar results to us when comparing sows housed in stalls, in small groups with individual feeding stalls and in larger groups with electronic sow feeder (ESF) with protective feeding crate. Stall-housed sows performed much more stereotypies than group-housed sows. When comparing the two different group housing systems, oral stereotypies were slightly lower in sows with ESF. Nevertheless, the animals used in this study were gilts that had not been kept in stalls before and thus could not have long-establish stereotypies caused by long-term restraining. Jensen (1988) and Vieuille-Thomas *et al* (1995) also found that feed-restricted adult sows performed fewer stereotypies when housed in groups than in stalls. However, it is not clearly specified the conditions where the sows were kept before the study. It can be concluded that housing conditions have an effect in the expression of ONF behaviours, which can be largely considered as stereotypies. However, the exact role of a particular environment is still not clear. Various factors may be affecting in a different way, such as nature of the substrates available during the individual's life, pattern of feed distribution and animal's perception of space and resources available and of their limitation (Vieuille-Thomas *et al* 1995).

Occupancy of the feeding area was higher for TRICK sows than FITMIX sows although TRICK sows were not observed while eating, contrarily to FITMIX sows. Differences were due to periods immediately before and after TRICK sows were fed. Increased arousal and feeding motivation made TRICK sows stand in the feeding places interacting with the fixtures while expecting the predicted meal and once it was finished.

Overall, old sows showed a more altered behaviour than gilts in all the systems. The older the sows, the longer they had previously been in stalls. Von Borell and Hurnik (1991) found that the time sows spent standing and sitting was positively correlated with age and was significantly higher for sows classified as stereotyped. Broom *et al* (1995) also found that feed-restricted stall-housed sows increased the level of activity and stereotypies over four pregnancies. Therefore, the parity effect found in the three systems appears to be more a consequence of the past conditions than of the experimental ones.

4.2. Physiological measures

APP levels did not show any difference among systems. Although APP have been proposed as stress indicators by several authors (Piñeiro *et al* 2001; Chen *et al* 2003; Saco *et al* 2003; Murata *et al* 2004), the effect of stress on serum concentrations of these proteins remains controversial, as it is difficult to distinguish the effect of stress from the effect of tissue damage (Petersen *et al* 2004). APP concentrations will change in response to stress involving tissue damage (physical stress), such that likely to occur in long transport (Piñeiro *et al* 2001; Saco *et al* 2003) or diseases (Chen *et al* 2003). However, there is no evidence of the effect of psychological stress itself. No changes in Hp or Pig-MAP concentrations have been reported after short transports (Hicks *et al* 1998; Gymnich *et al* 2001; Saco *et al* 2003), four hours of cold or heat (Hicks *et al* 1998) or in pigs fed disorderly (Piñeiro *et al* 2005). Therefore, according to APP levels, there were no differences in the degree of tissue damage among systems. However, further research should be done in order to find physiological indicators of psychological stress.

4.3. Productivity and reproduction

There were no differences in any measure of weight or backfat depth among systems. Broom *et al* (1995) found that stall-housed sows had a lower weight than those group-housed at the end of the fourth pregnancy and suggested that it was due to the large amount of time spent performing energetically costly stereotypies. We did not find any difference although STALL sows spent more time engaged in ONF behaviours. Sows in all systems increased backfat over the pregnancy as expected and any group was more affected than the others by uneven feed intake. There is a great concern about this particularly in systems like TRICK were dominant sows are likely to eat a larger amount of feed than their subordinates.

Few reproductive differences were found. The number of piglets born dead was lower in FITMIX sows. This may have been caused by a lower farrowing time (Fraser *et al* 1997a) due to a higher chance of exercise in FITMIX sows, since the total space per pen was larger (Vestergaard & Hansen 1984).

4.4. Incidences

Adaptation failure (8.3%) was in the common range of 5-10 % proposed by Edwards (1998) for competitive feeding systems. However, difficulties of adaptation to the feeder may be eased by training the sows before the first time they are introduced in a pen with FITMIX.

Likelihood of detecting lameness was not the same for all the systems, since any particular procedure was carried out to detect locomotive problems. Detecting a STALL sow lame was very unlikely because we could not see them walking. Assessing lameness in TRICK sows was easier than in FITMIX because they stood up and walked simultaneously at feeding time. In FITMIX, lameness that did not prevent sows from feeding may have gone unnoticed. Several studies suggest that spatial restriction in confined sows facilitates lameness compared to group-housed sows (e.g. Bäckström 1973; Tillon & Madec 1984; Peet 1990; Svendsen *et al* 1992). However, in some of these studies, group-housed sows were on bedded floor whereas confined sows were on concrete or slats. On the other hand, there are several studies that suggest that when housed on the same kind of floor, sows in group present more lameness incidence

(Backus *et al* 1991, 1997; Gjein & Larssen 1995b). Fighting seems to be one of the major causes (Gjein & Larssen 1995c). Most of the lame sows in both systems were detected in the beginning of the replica. Therefore lameness may have been caused largely by fighting performed during the first hours after mixing.

Five sows were vulva injured in both TRICK and FITMIX and one in STALL. These results are somehow surprising because vulva injuries are normally caused by bites. Vulva bites are considered as an aggressive act and not a redirected exploratory behaviour. Sequential feeding systems are more likely to present this problem since hungry sows have to queue (van Putten & van de Burgwal 1990; Kroneman *et al* 1993a). Incidence in FITMIX in this experiment was lower than those reported by Backus *et al* (1991; 20%), Gjein & Larssen (1995a; 15.2%) or van Putten & van de Burgwal (1990; 10%) after using different management techniques to reduce feeder-related aggression. Rizvi *et al* (1998) reported that feeding systems with individual separations like TRICK usually leave the rear of the sow exposed to vulva biting. Anyway, vulva biting is more unlikely because sows are fed simultaneously and restrained and therefore feeding-related aggression related is lower. Number of sow per drinker was also described by the author as an influencing factor. In TRICK, although there were fewer sows per drinker than in FITMIX, the access was more restricted because they were thirsty simultaneously, and therefore, they had to queue. The surprising vulva injury in a STALL sow may have been caused by a reason other than biting, such as sitting when the vulva was edematous, or by contact with the stall. It may have also been a bite produced in one of the manipulations, such as weighting. Nevertheless, vulva injuries are not likely to have long-term effects and hence do not cause any decrease in reproductive performance (Rizvi *et al* 1998).

5. CONCLUSIONS AND ANIMAL WELFARE IMPLICATIONS

The largest amount of information about the welfare of the sows was obtained from the measures of behaviour, particularly measures of activity and stereotypies. Measures of aggressive behaviour are still unpublished. Stereotypies are related to poor welfare because they developed in situation of stress, frustration or lack of control. They reflect a past or present difficulty to cope with the environment. Sows used in this experiment were likely to have long-established stereotypies as the fact that older sows were more affected in all the system indicates. Long-established stereotypies are usually reluctant to change by enriching the environment. Therefore, the decrease in stereotypies level in group-housing systems could already be considered as a welfare improvement. FITMIX was the system which more increased time spent resting and more decreased time spent performing stereotypies. Somehow, sows may have perceived the environment provided as more comfortable and less restrictive. Therefore, design of the pen and feeding management seems to be important once housing sows in groups is decided.

On the other hand, sows can be group-housed at levels of tissue damage and average performance similar to stall-housed sows, providing that management is favourable. High quality stockmanship is essential in order to detect and solve promptly any incidence or adaptation problem in group housing systems. The more comfortable stockpeople feel, the more reliable the system will be.

According to our results, welfare of pregnant sows seems to be improved when they are group-housed. However, further research should be done on long-term effects of group housing on measures of behaviour, physiology and performance. Social behaviour should also be considered (see Chapter 4).

CHAPTER 4

"Aggressive behaviour in two different group housing systems for pregnant sows"

Abstract

One hundred and twenty pregnant sows (*Sus scrofa)*, from first to ninth parity, were selected on a commercial farm and used in three different replicas (40 sows per replica). Sows were housed from day 29 of pregnancy to 1 week before parturition in either groups of 10 with trickle feeding (TRICK) or groups of 20 with an unprotected electronic sow feeding (FITMIX; 20 sows per housing system per replica). Aggressive interactions were recorded on eleven non-consecutive days, 4 hours per day and dominance rank (RI) was subsequently determined. Frequency of aggressions, intensity and proportion of resolution were higher in FITMIX ($P < 0.001$), yet intense physical contact was unusual in both systems (4.5% of the total interactions). Conflicts in FITMIX were largely for feeding (82% *vs* 19% for FITMIX and TRICK respectively, $P < 0.001$) whereas in TRICK, they occurred mainly in the resting area (14% *vs* 57% for FITMIX and TRICK respectively, $P < 0.001$). However, proportion of aggressions for drinking was higher in TRICK (3.5% *vs* 23% for FITMIX and TRICK respectively, $P < 0.001$). Correlation between RI and liveweight was stronger in FITMIX ($r_s = 0.29$ and 0.57 for TRICK and FITMIX respectively, $P < 0.001$), although correlation between RI and parity was similar in the two systems ($r_s = 0.42$ and 0.47 for TRICK and FITMIX respectively, $P < 0.001$). Forty-six per cent of the FITMIX sows, mostly gilts and subordinates, needed assistance to adapt to the feeding system. Eventually, 8.3% of the FITMIX sow failed to adapt and had to be removed. In conclusion, sequential feeding appeared to make FITMIX a more competitive feeding system. Therefore, a higher management quality is required to prevent excessive aggression and ensure an easy adaptation of the animals to this system.

1. INTRODUCTION

Individual confinement of pregnant sows was spread over the world since it permits individual feeding and avoids overt aggressions. However, concern about the restriction of movement and the high incidence of abnormal behaviours has forced the replacement of the stalls by group housing systems in the EU member estates. Although group housing obviously lessens confinement related reduction of welfare (e.g. Jensen 1988; Broom *et al* 1995; Vieuille-Thomas *et al* 1995; Marchant & Broom 1996), it inevitably introduces a risk of aggressive behaviour. The welfare's consequences of the social stress and physical injuries caused by aggression have been widely reported (Arey 1998). Dominance aggression for the establishment of the hierarchy is probably instinctive and it is minimised after the first days (Barnett *et al* 1992; Brouns & Edwards 1994; Hagelsø-Giersing & Studnitz 1996). A stable hierarchy has the function of predetermining the order of access to resources so that large fighting can be minimized through the use of threat, submission and avoidance (Hagelsø-Giersing & Studnitz 1996). However, high levels of competitive aggression can be perpetuated if resources such as feed, water or space are limited either in quantity, distribution or temporal availability (Turner *et al* 2000), thus compromising the welfare of the subordinates (Cs.eerly & Wood-Gush 1990).Therefore, one of the major challenges in group housing is to find feeding systems where all individuals are allowed to access to feed and may complete their ration without being displaced by others (Andersen *et al* 1999). Different systems allow different feed control (Gonyou 2003): average feed intake (e.g. floor feeding), equal intake for all individuals (e.g. trickle feeding) or individual intake (e.g. individual feeding stalls and electronic sow feeders). Electronic sow feeders (ESF) have been quite studied in the last decades (e.g. Edwards *et al* 1988; Hunter *et al* 1988; van Putten & van de Burgwal 1990; Mendl *et al* 1992; Bressers *et al* 1993; Simmins 1993; Jensen *et al* 2000; Bates *et al* 2003) although few studies compare these systems with others of lower feed control but probably with some other advantages for welfare (Broom *et al* 1995). For instance, the sequential feeding in ESF may increase the risk of competitive aggression because of repeated frustration of the sows' feeding motivation. Competition is in turn aggravated by social facilitation (Jensen *et al* 2000). Therefore, systems which allow simultaneous feeding should be taken into account.

In this study, we compare social behaviour in two modern commercial feeding systems for group-housed sows of different feed control: a relatively new type of ESF without protective feeding crate (FITMIX) and trickle feeding (TRICK). FITMIX permits individual automatic rationing, although sows have to feed one at a time, probably establishing a feeding order if groups are stable. In TRICK, sows are fed simultaneously the same ration. However, competition for feed access is reduced using partial barriers and synchronizing feed delivery and feed intake rates. The experiment was repeated during 3 replicas in different seasons. The aim of this study was to compare between the two systems: a) the frequency, intensity and distribution of aggressive interactions, b) the correlation between dominance rank and other variables and c) the adaptation difficulties.

2. METHODS

2.1. Animal, housing, feeding and general management

One hundred and twenty Large White x Landrace female pigs[4] (*Sus scrofa*) from first to ninth parity were selected on a commercial farm, being on the 29th day of pregnancy. They were used in three different replicas (40 sows per replica). All sows had been previously stall-housed during their productive live, that is, from weeks to years depending on their parity. After being weighed and their backfat depth measured, they were group-housed with two different feeding systems in the same building until a week before the expected parturition date. The first replica took place from mid January to early April, the second one from late April to mid July and the third one from late July to mid October.

In each replica, the sows were randomly assigned to one of the feeding system. Twenty sows were housed in two pens (10 sows per pen) with trickle feeding (TRICK, Rotecna, Spain). Each pen had 10 feeding places with shoulder length barriers along the feed trough (1m x 0.60m). These sows were fed simultaneously once daily at 700 h at an average delivery rate of 156 g/min. Water was provided *ad libitum* from a drinker per pen. The other 20 sows were housed in a single pen with an unprotected electronic sow

[4] Hereafter, all experimental female pigs will be refereed to as sows irrespective of their parity number, unless otherwise indicated

feeder (FITMIX; Mannebeck, Germany). Sows were identified by an earmark transponder and offered the individually allocated amount of wet feed. They were fed one at a time in a single feeder without a protective crate. Each daily feed cycle started at 700 h. The feeder had a lateral access for the leftovers that the sows dropped while eating in order to decrease aggression towards the sow that was using the feeder. Water was provided *ad libitum* from a single drinker. The resting area was divided by two protecting walls (1 m x 1.8m). The two systems had part-slatted floor without bedding and space allowance was 2.3 m^2 per animal without taking into account the space occupied by the feeding places or the feeder. One thermometer was situated next to each system in order to measure daily maximum and minimum temperature. The pens were illuminated by both natural daylight and artificial lighting with lights switched on at 600 h and off at 2200 h. The same stockpeople cared for all the animals.

All the sows were restrictedly fed with concentrated feed (143 g crude protein, 90 g crude fat, 80 g crude fibre, 63 g ash and 12.25 MJ ME per kg). The quantity offered to the FITMIX animals was 2.3 kg/day/gilt and 2.5 kg/day/sow until day 90 of pregnancy and from then on, 2.8 kg/day/gilt and 3 kg/day/sow. TRICK animals were offered 25 kg/day/pen until day 90 of pregnancy and 30 kg/day/pen from then on. The rations were corrected using backfat depth measures when necessary.

2.2. General experimental protocol

Sows were weighed on days 1 and 15 of the experiment and on the day they left the pregnancy facilities to the farrowing crates. The same days and also on days 31 and 65 of the experiment, backfat depth was measured by ultrasounds (RENCO LEAN-METER®). After each measurement, feed allocation was corrected if backfat depth was lower than 14 mm or higher than 20 mm.

FITMIX sows followed a training program during the first fortnight to learn how to use the feeder. Lateral access to the feed leftovers was cancelled. From day 5 to 8, sows that already knew how to feed were moved out of the pen from 1200 h to 1600 h in order to leave only the sows that had learning problems. On days 5 and 8, space allowance was reduced and assistance was offered when a sow approached the feeder. An extra training day was allowed in replica 3 after the experience of the previous replicas. Sows were compensated for the missed shares of feed once the training period was finished.

Behaviour was observed 3 days per system during the first two weeks of the experiment (considered the adaptation phase) and then 1 day per week per system until the week before leaving to the farrowing crates.

Incidences like lameness or vulva injuries were also noted. Pregnancy was reconfirmed by ultrasounds on day 55 of the experiment. Sows were removed to conventional farrowing crates one week before the expected farrowing date. Parturition was hormonally induced following the farm routine. Reproductive performance was assessed.

2.3. Behavioural observations

For observation purposes, a number was sprayed on the neck, back and flanks of each sow in group before each observation day. Interruptions by farm staff were minimized on the observation days. Sows were observed during four periods each day: one period of 30 minutes before feeding (from 630 h to 700 h), two 60-minute period, separated by a 30-minute rest, starting at 700 h for FITMIX and after feeding for TRICK and one 90-minute period in the afternoon (from 1415h to 1545h). The observers were situated in the nearest corridor to the feeding area. Two people observed simultaneously TRICK sows (one per pen) whereas one person and one digital camera (SONY DCR-TRV950E) were needed to record the feeding area in FITMIX. Continuous behaviour sampling (Martin & Bateson 1993) was used to record all the aggressive interactions that occurred during the observation periods. Each interaction was scored (Table 1) and the identity of the sows involved and the location in the pen (feeding area, drinker or other) were noted. When possible, the sow that initiated the encounter and the sow that won were identified.

In TRICK, some other behavioural measures were recorded out of the observation periods: time that took all the sows to entry the feeding places since the beginning of the feed delivery and final distribution of the sows in the feeding places. Displacements and voluntary changes of position during the feeding time were also registered.

Table 1 Aggressive interactions score.

Aggressive interactions score	
No physical contact	One sow threats another sow without making contact
Mild physical contact	One sow bites or knock with the head another sow
Intense physical contact	Escalation of previous score or when two sows take part in an aggressive encounter involving parallel or inverse parallel pressing frequently accompanied by bites in rapid succession. This score includes the interactions likely to cause physical damage

2.4. Data analyses

For the analyses of behavioural data, the experiment was divided into two phases. The first two weeks were considered the adaptation phase (phase A) and were thus analysed apart from the rest of the experiment (phase B). For the analysis of the parity effect, sows were divided in three groups: gilts, young adults (from second to fourth parity) and old adults (from fifth parity on).

Statistical analyses were performed using the statistical package SAS (1999). Data from behavioural sampling were analysed using the GENMOD procedure (Cameron & Trivedi 1998). The least-square means of fixed effects (LSMEANS) adjusted to Bonferroni's honestly significance difference was used as a test of multiple comparisons.

The aggressive interactions between pairs throughout the experiment were used to determine the dominance rank of the individuals within each group. Various method were examined (see Langbein & Puppe 2004 for a review), but found to correlate highly and hence the rank index (RI) described by Lee *et al* (1982) and Nielsen *et al* (1995a) was chosen. RI conferred to each animal ranks from 1 (if the animal is subordinate to all other animals in the group) to the number of animals in the group (if the animal is dominant to all others animals in the group). A Spearman's rank order correlation coefficient (PROC CORR Spearman) was used to determine which variables correlated to RI and adaptation ability.

3. RESULTS

3.1. Level of aggression

A total of 2185 aggressive interactions in TRICK and 6667 in FITMIX were analysed. Sows from FITMIX were involved in more aggressive interactions per hour (initiated, received and total) than sows from TRICK. In both systems, there was an increase in the frequency of aggression in phase B (Table 2).

Table 2 Mean frequency (± s.e.) of initiated, received and total aggressive interactions in which sows were involved per hour in each system (S) and phase (Ph).

	TRICK		FITMIX		*P*		
Aggressive interactions	**Phase A**	**Phase B**	**Phase A**	**Phase B**	**S**	**Ph**	**S*Ph**
Initiated	0.68±0.06	0.96[1]±0.07	2.38±0.46	3.07[1]±0.42	***	***	ns
Received	0.68±0.05	0.97[1]±0.05	2.38±0.27	3.06[1]±0.32	***	***	ns
Total	1.37±0.08	1.93±0.09	4.76±0.58	6.13±0.67	***	***	ns

[1] Little differences between frequencies of initiated and received aggressive interactions within the same system are due to removal of some animals

*** $P < 0.001$; ns = not significant

Parity effect was analysed in phase B (Figure 1). Old adult sows initiated aggressive interactions more frequently than young adults and gilts in both systems ($P < 0.001$). When analysing frequency of received aggressive interactions, no parity effect was found in TRICK whereas old adults received aggressive interactions more frequently than gilts in FITMIX ($P < 0.05$). In both systems, gilts received more aggressions per hour than they initiated ($P < 0.001$) whereas old adults initiated more aggressions than they received ($P < 0.05$; Wilcoxon signed rank test). No differences between frequency of initiated and received aggressions were found in young adults.

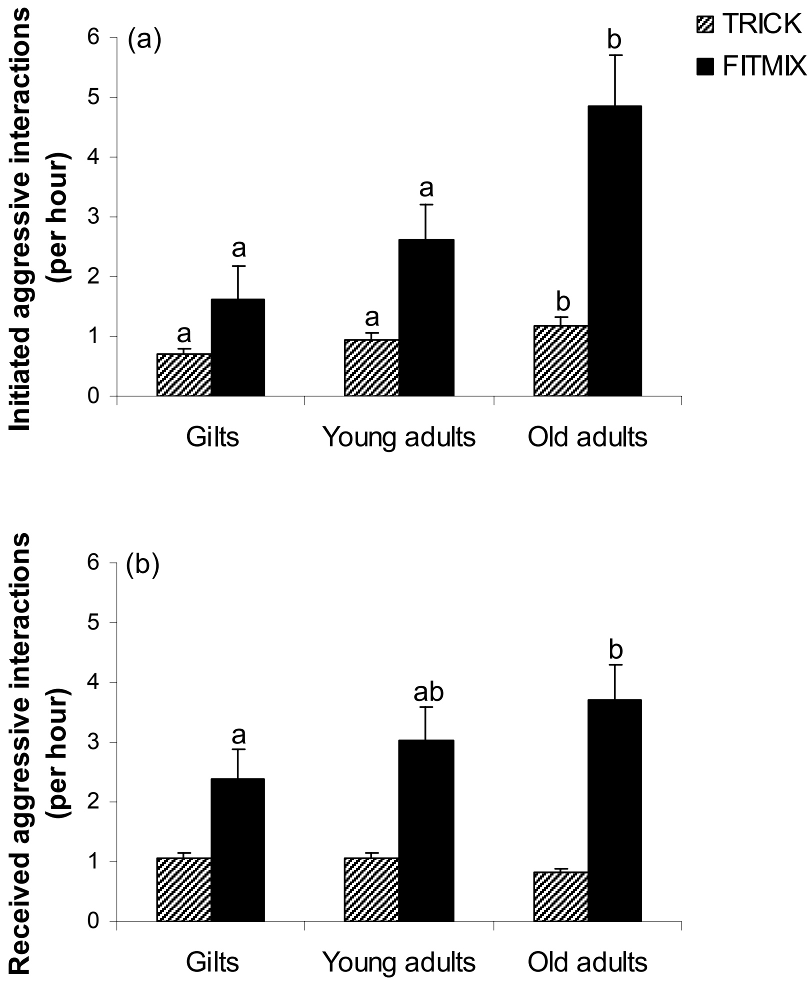

Figure 1 Mean frequency per hour of aggressive interactions that sows of each parity initiated (a) and received (b) during phase B. Errors bars denote one s.e. If letters above columns within the same system are different, $P < 0.05$.

3.2. Intensity score

Most of the aggressions in TRICK and FITMIX were without or with mild physical contact (Figure 2). Sows from TRICK interacted more frequently without contact than sows from FITMIX in both phases whereas sows from FITMIX interacted more frequently with mild physical contact than sows from TRICK also in both phases ($P <$ 0.001).There were no differences between phases in any of the systems in interactions without or with mild physical contact. However, although there were no differences between systems in the proportion of aggressions with intense physical contact, there was a decrease in phase B in both systems (*P* < 0.001 for TRICK, *P* < 0.01 for FITMIX).

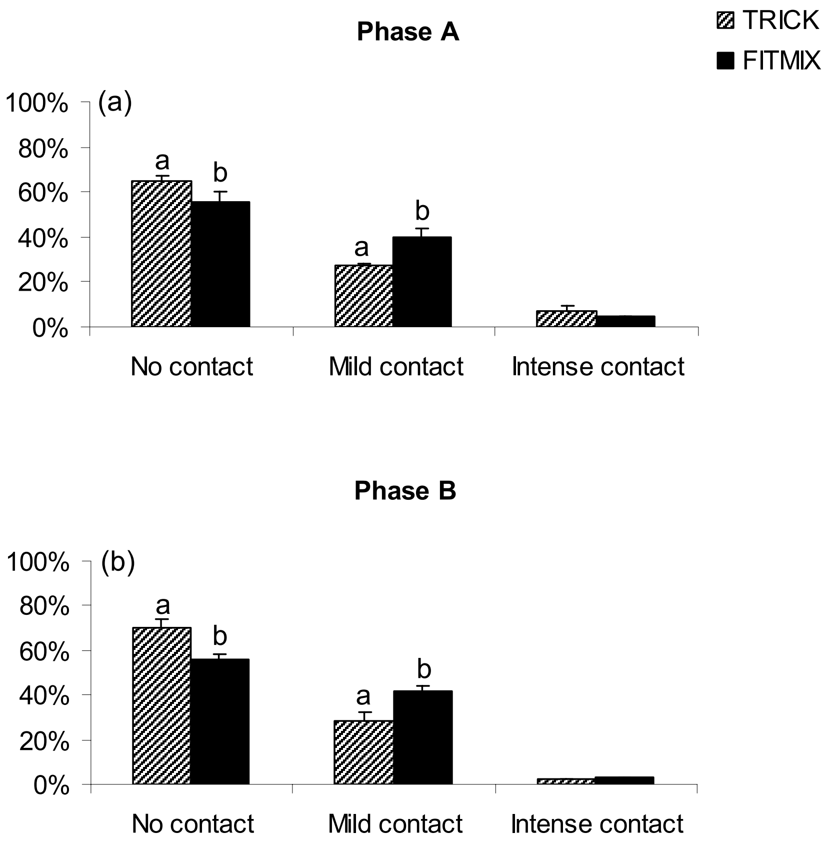

Figure 2 Distribution (%) of aggressive interactions in each intensity score in phase A (a) and B (b). Each column represents the mean of the three replicas. Errors bars denote one s.e. If letters above columns within each intensity score are different, P < 0.001.

3.3. Location of aggressions in the pen

A higher proportion of aggressions occurred in the feeding area in FITMIX than in TRICK whereas a higher proportion of aggressions occurred around the drinker in TRICK than in FITMIX in both phase A and B (*P* < 0.001; Figure 3). There was a significant although not very important increase in phase B in the proportion of aggressions that occurred in the feeding area in both systems (*P* < 0.001) and in the proportion of aggressive interaction that occurred around the drinker just in TRICK, which was almost doubled (*P* < 0.001).

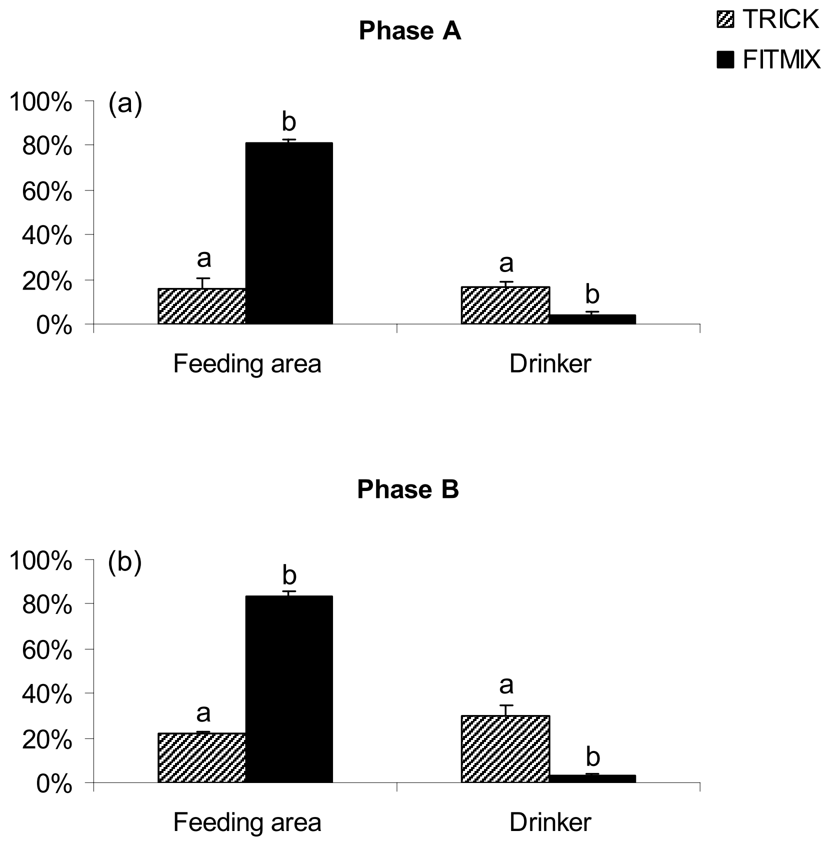

Figure 3 Distribution (%) of aggressive interactions in different locations of the pen in phase A (a) and B (b). Each column represents the mean of the three replicas. Errors bars denote one s.e. If letters above columns within each location are different, $P < 0.001$.

3.4. Outcome

The proportion of aggressions with a clear outcome was higher in FITMIX than in TRICK (P < 0.001; Figure 4). No differences between phases were found in any system.

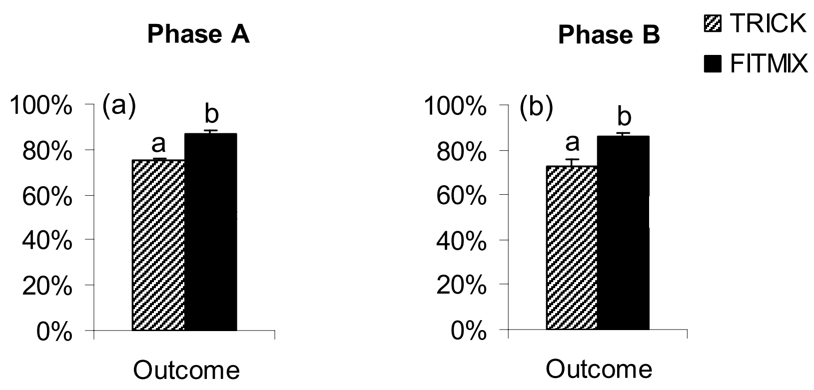

Figure 4 Proportion (%) of aggressive interactions with a clear outcome in phase A (a) and B (b). Each column represents the mean of the three replicas. Errors bars denote one s.e. If letters above columns are different, P < 0.001.

3.5. Rank index

Correlation was found between rank index (RI) and several variables in both systems, although they were higher in FITMIX (Table 3). However, sows from seventh parity on appeared to start loosing dominance status in FITMIX (Figure 5). No correlations were found between RI and backfat depth or any measure of reproduction in any system.

Table 3 Spearman rank correlation coefficient (r_s) between the rank index (RI) and several variables where correlation was found.

	TRICK		**FITMIX**	
	r_s	*P*	r_s	*P*
Parity	0.42	***	0.47	***
Initial liveweight	0.29	*	0.57	***
Final liveweight	0.46	***	0.57	***
Frequency of total aggressive interactions	0.10	ns	0.55	***
Frequency of initiated aggressive interactions	0.53	***	0.74	***

*** $P < 0.001$; * $P < 0.05$; ns = not significant

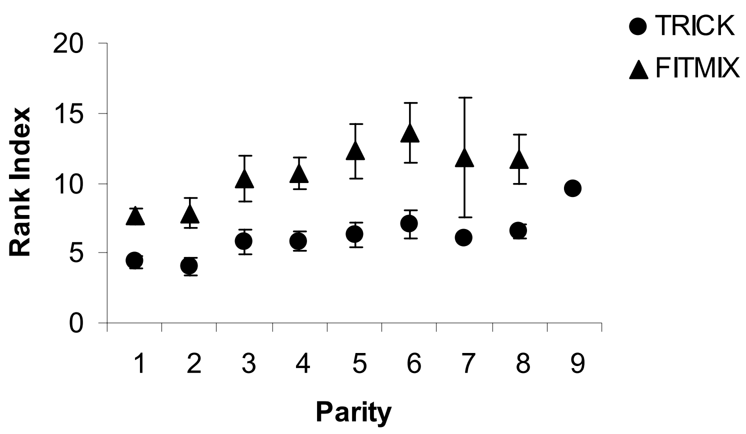

Figure 5 . Mean rank index (RI) that sows from each parity scored. Errors bars denote one s.e.

3.6. Displacements and voluntary changes of position in TRICK

A total of 123 displacements and 162 voluntary changes of position were observed throughout the three replicas. The evolution of displacements and voluntary changes of position in replica 1 was very different from the subsequent replicas (Figure 6). Since displacements can be considered as aggressive interactions, they were taken into account to estimate mean frequencies of aggressive interactions.

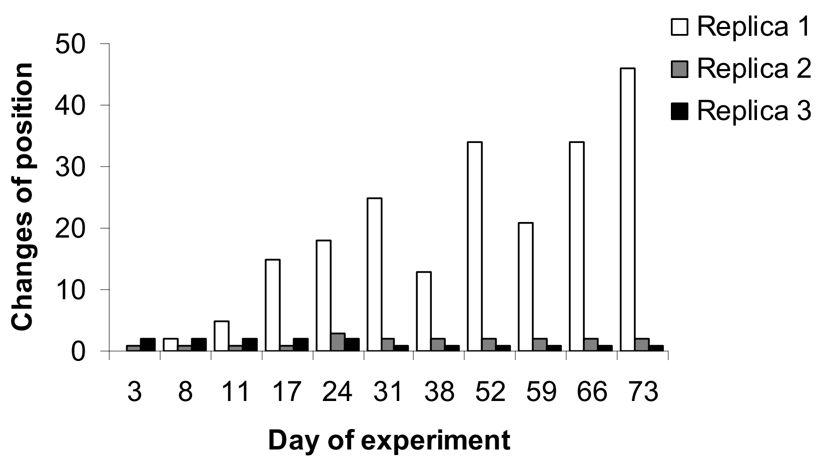

Figure 6 Evolution of changes of position (displacements and voluntary changes) in each replica in TRICKLE. The two pens of each replica (20 sows) are considered together in each column. Errors bars denote one s.e.

3.7. Adaptation process

Sows from TRICK were able to enter a feeding place each since the very beginning of the experiment. Time spent in entering the feeding place was insignificant compared to the time unit used. Feeding places appeared to be randomly chosen everyday.

On the contrary, sows from FITMIX had some adaptation problems (Figure 7). Only 63.33% of the sows learnt how to use the feeder without assistance. Sows were considered to have learnt the mechanism of the feeder once they were able to eat at least 10% of their ration. Only one sow failed to demonstrate how to use the feeder after the training program although the fact that it was lame may have seriously effected. However, four more sows (two of them gilts) had to be removed because they failed to feed evenly in group conditions despite learning how to use the feeder during the training program.

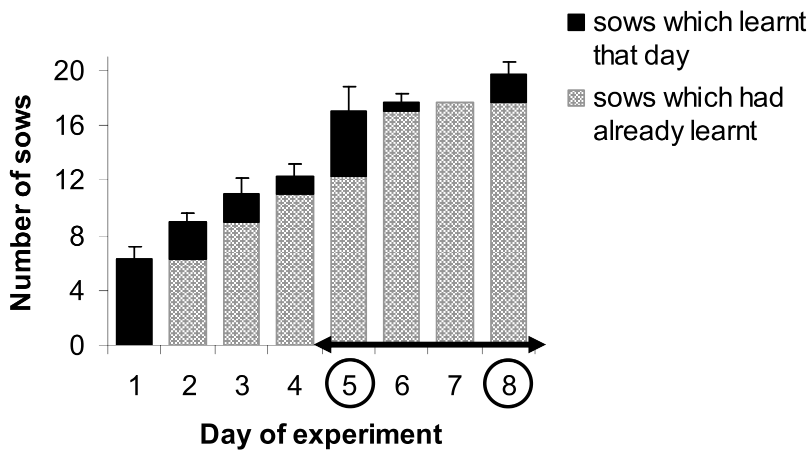

Figure 7 Evolution of the adaptation process in FITMIX. The arrow represents the days the training program was performed and the circles the days within the training program that assistance was offered. Errors bars denote one s.e.

Correlation was found between the day when sows learnt to use the feeder and parity (r_s = -0.40, $P < 0.05$) and RI (r_s = -0.35, $P < 0.05$). However, Figure 8 shows that sows from seventh parity on started losing their adaptation skills. On the other hand, the fact that quite a lot of sows learnt how to use the feeder the first day makes it difficult to find a correlation between the day when sows learnt to use the feeder and RI. As a result, it was decided to divide sows into high-ranking (RI ≤ 10) and low-ranking sows (RI > 10) and the adaptation period into two periods, the first four days (without assistance) and the last following four days (the training program). The percentage of sows that learnt before the training program started was much higher in high-ranking sows than in low-ranking sows (86.4 % *vs* 51.4 %, $P < 0.001$). Likewise, 61.1% of the gilts needed assistance to learn in contrast to 31.8% of young adults and 20% of old adults.

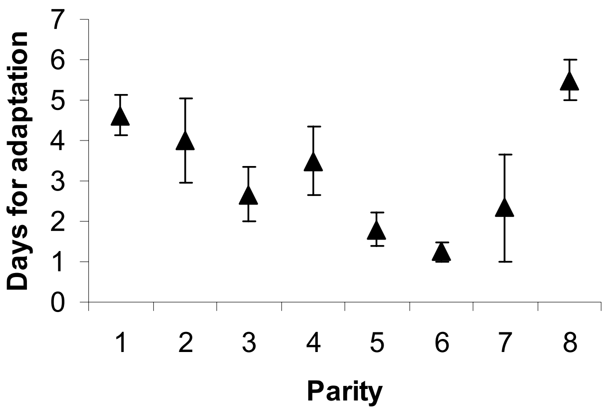

Figure 8 Mean time (days) that sows from each parity needed to learn how to use the feeder in FITMIX.

3.8. Incidences

Lameness and vulva injuries incidence were very similar between groups. A total of 5 sows and 3 gilts in TRICK and 3 sows and 4 gilts in FITMIX were observed lame. In FITMIX, one of the sows and two of the gilts had to be eventually removed because lameness prevented them from feeding. Five sows in TRICK and four sows and one gilt in FITMIX were vulva injured. Other incidences like death or farrowing failure are commented in Chapter 3.

4. DISCUSSION

Despite the quick reduction in the frequency and intensity of aggressions after mixing (Barnett *et al* 1992), several days are necessary to achieve a relatively stable hierarchy, particularly when sows have to compete for resources (Oldings *et al* 1992; van Putten & van de Burgwal 1990; Arey & Edwards 1998). Consequently, results found in phase A in our experiment need to be interpreted with caution. Since significant differences between systems found in phase A were also found in phase B, we will focus the discussion in phase B. In phase B, hierarchy can be considered to be relatively stable (although hierarchies have to be understood as a dynamic organization). As a result, we suggest that data from phase B can provide more reliable information about the impact of the different housing and feeding systems on welfare in the longer term.

4.1. Aggressive interactions

FITMIX seemed to be a more competitive feeding system than TRICK, since a rather high level of virtually harmless interactions was maintained, mainly around the feeder. This fact may be largely attributed to two factors: defensibility of the feeder and sequential feeding in FITMIX. Defensibility of a resource is a good predictor of aggressive competition among animals (Grant 1993). Some of the important environmental factors influencing defensibility are the clumping of resources in space and in time, the predictability of their arrival in space and time, and the number of potential competitors present (Fraser *et al* 1995). Feed in FITMIX was offered in a single, regular feeding site in a defensible structure. Furthermore, it was the only resource available at the same time and the number of potential competitors was not high enough to dilute the effectiveness of aggression. Therefore, it was understood as a resource easy to monopolized and thus worthy to compete for. In addition, restricted animals become synchronized in all their active behaviours and social facilitation is very important, particularly in the acquisition of feed, since it is the only important event along the day (Petherick *et al* 1987; Hagelsø-Giersing & Studnitz 1996). However, sows had to eat sequentially in FITMIX. This made hungry sows queue around the feeder, what is known to induce frustration of the feeding motivation and therefore, restlessness and aggression (Meunier-Salaun *et al* 2001; Zonderland *et al* 2004). Hunter *et al* (1988) reported that, after finishing their rations in protected ESF, some frustrated sows kept on competing for non-feeding visits with other sows that were still waiting in the queue. In such a situation, sows have to attack by the rear and a certain degree of physical contact may become necessary. Vulva bites have been reported to become a risk in ESF (van Putten & van de Burgwal 1990; Rizvi *et al*, 1998), although similar vulva injuries incidences were found in both systems in our study.

On the contrary, defending feed may have become uneconomical in TRICK and therefore the level of aggression was lower. The resource was not concentrated since there was a feeder per sow and the physical barriers between them made it difficult for a sow to defend more than one location (Petherick *et al* 1987; Barnett *et al* 1992). Furthermore, since feed was provided to all individuals at the same time and at a low rate, a sow had to leave its own feeder in order to compete with others and potentially lose the feed that came meanwhile. As a result, there were more aggressions while expecting the meal (predictability is another of the factors that enhances defensibility) and once the feed in the trough was finished (but sows were still highly motivated) than displacements during the actual ingestion of feed.

However, feeding regime in TRICK may have influenced drinker-related activity. TRICK was supposed to avoid expression of individual variability in feed intake rate and thus sows finished their meal simultaneously. Besides, dry diet was provided. As a result, the drinker was the only source of water and was mostly demanded at a certain time of the day. It became a defensible structure to compete for, despite being *ad libitum*. Sequential drinking may have been one of the main reasons why vulva injuries were as high in TRICK as in FITMIX (Rizvi *et al* 1998). Anyway, most of the aggression occurred out of the feeding or drinking area. Although space allowance per sow was the same in both systems, total space per pen was lower in TRICK and no specific areas were delimited. Therefore, aggression may have occurred just by proximity (McBride 1971) and because performing active behaviour without disturbing those animals which were resting may have become more difficult (McGlone & Newby 1994; Turner *et al* 1999). Nevertheless, resources did not seem to be limited enough to elicit overt aggressive competition. Lower intensity of interactions may have also made the observer difficult to determine their outcome.

Frequency of aggression increased in phase B in both systems and a higher proportion were due to competition for resources. The proportion of aggressions with intense physical contact significantly declined, although they were infrequent in both phases. In phase A, individuals may have been still establishing the nature of the relationships with each other (dominance aggression) whereas in phase B they were mainly defending the resources (competitive aggression; Hagelsø-Giersing & Studnitz 1996). Hierarchy was supposed to be more stable in phase B, and therefore the order of access to limited resources also more established. As a result, individuals with similar fighting ability and thus similar potential for resource monopolization may have tried to acquire the resource at the same time (Andersen *et al* 2004) and thus, a constant level of low intensity aggression may have been required (Turner *et al* 2004).

4.2. Dominance rank

Overall, more correlations and higher were found between RI and other variables in FITMIX than in TRICK. These results may be somehow affected by the fact that much less interactions were observed in TRICK and thus used for RI calculation. Although the number of interactions observed exceeded the minimum number suggested by Drickamer *et al* (1999), more relationships between pairs of animals remained undetermined in TRICK than in FITMIX. The dominance index assigned to an animal has been reported to be severely affected when a large number of relationships cannot be determined for this animal (Brouns & Ewards 1994; Langbein & Puppe 2004).

Moreover, when competition is high, correlations are supposed to increase between RI and all the animal features that enhance the likelihood of gaining access to the resources, such as parity, experience or liveweight (Andersen *et al* 2000). Liveweight is considered the best known indicator of resource holding potential in the pig and other species, especially in groups with a large weight asymmetry (Rushen 1987; Andersen *et al* 2000). Although asymmetry was similar in both systems, FITMIX sows may have taken more advantage from a high initial weight when defending the resources as they were more limited (Andersen *et al* 2000; Turner *et al* 2000). The correlation between RI and liveweight in FITMIX was slightly weaker than that found by Arey (1999) in one of his experiments (r_S=0.63, $P < 0.001$). However, the author determined the relative dominance rank of sows by a paired feed displacement test and indeed, liveweight is more important in such a competitive context than in the pen situation. Correlations are also supposed to be stronger in this kind of test because all dyadic relationships can be determined (Brouns & Edwards 1994). However, the correlation found between liveweight and dominance rank by Arey (1999) in his first experiment was smaller than ours (r_s=0.39, $P < 0.05$).

Regardless to being obviously correlated with liveweight, parity is usually related to both social and feeding experience (Hunter *et al* 1988). None of the sows in our experiment had previous experience in group housing. Therefore, the parity effect found in this experiment would be expected to be largely due to correlation between parity and liveweight. However, similar correlations between parity and RI were found in both systems, although correlation between liveweight and RI was weaker in TRICK. More interactions in TRICK should be gathered to try to explain this controversy. Correlations between RI and parity were weaker than those found by Arey (1999; r_s=0.63, $P < 0.001$). In addition to the different methodology of data collection, another reason may be that Arey (1999) used sows from first to sixth parity. We observed in our experiment that sows from seventh parity on seemed to start losing dominance status. Sows have been reported to increase in body dimensions up to sixth parity (McGlone *et al* 2004b). Therefore, sows from seventh parity on may have lost fighting ability compared to younger sows of similar weight. However, there were too few experimental sows of such a high parity (four in TRICK and five in FITMIX) to draw conclusions.

The differences in aggressive behaviour between gilts and older sows are closely related to dominance rank. In agreement to a number of studies (Jensen 1982; Mendl *et al* 1992; Fraser *et al* 1995; Andersen *et al* 1999, 2000; Turner *et al* 2004), old adults initiated a higher proportion of interactions than gilts in both systems, since they had higher success likelihood. On the contrary, gilts were more passive and tried to avoid attacks, because fighting were uneconomical for them. Even so, gilts received more interactions than they initiated in both systems. In FITMIX, older sows also received more interactions than gilts. The reason for that may be found in the feeding order established in sequential feeding systems, which has been found to correlate with parity and dominance rank (Hunter *et al* 1988). Older dominant sows of similar strength or fighting ability probably tried to gain access to the feeder close in time, engaging in competitive aggression to reaffirm their position and control the resource, instead of avoiding fights (Andersen *et al* 2000). Besides, early feeding dominant sows in protected ESF have been reported to eat their ration at a time and proceed to compete with sows close in the feeding order for non-feeding visits (Hunter *et al* 1988; Eddison

& Roberts 1995). On the other hand, old sows in TRICK may have attacked in a more indiscriminate or random way, just due to proximity or disturbance, since no parity effect was found in the frequency of received interactions in TRICK.

Consequently, RI correlated with frequency of initiated aggressive interaction in both systems but only in FITMIX with frequency of total aggressive interactions. Mendl *et al* (1992) also found a relationship between the dominance rank and both the frequency of aggression and the proportion of aggressive initiation in group-housed gilts fed with protected ESF. In several species, dominance rank is often thought to be somehow related to the level of aggressive behaviour an animal exhibits or the number of aggressive interactions it is involved in (Reinhardt *et al* 1987; Orgeur *et al* 1990; Barroso *et al* 2000). However, they have not been proved to be as useful in pigs as in other species when calculating a dominance index (Langbein & Puppe 2004).

RI had no effect on backfat depth or any of the reproduction measures as it had been previously reported (Pedersen *et al* 1993; Arey 1999). Some other authors found that socially intermediate sows were those with worse reproductive performance (Mendl *et al* 1992; Nicholson *et al* 1993).

4.3. Adaptation to the feeding system

TRICK sows did not show important adaptation problems as expected (de Wit 1996; National Committee 2002). The frequency of changes of position per day was much lower in replica 2 or 3 than in replica 1. Hulbert & McGlone (2006) compared drop *vs* trickle feeding in groups of five sows and found higher frequencies of changes of position in trickle feeding, which were also higher than our results in replica 2 and 3. In our case, a possible explanation for this variability among replicas may be that although sows received the same basic ration throughout the experiment, they may have felt more restricted in winter due to an increase in their energy requirements. They may have increased their feed intake rate due to a higher feeding motivation (Broom *et al* 1995; Nielsen *et al* 1999). Consequently, sows may have perceived the relative delivery rate as lower, and this may have caused frustration among faster eaters and encouraged them to move to other places to look for feed (Hoofs 1990; Edwards 1998; de Wit 1996). Therefore, regular adjustment of delivery rate seems very important to keep the synchrony with intake rate. This is easily achieved if sows are matched for size, body condition and parity (Edwards 1998). A common recommendation is to keep gilts in separate groups throughout their first gestation (Gonyou 2003). However, this higher frequency in changes of position did not affect productive measures, not even affected backfat variability (see Chapter 3).

On the contrary, FITMIX had some adaptation difficulties, as also expected without a previous training procedure (Edwards 1998; National Committee 2002; Brooks 2003). Whereas some animals readily learned how to use the feeder, some others needed assistance. Modern production systems like ESF rely on the cognitive abilities of livestock to learn and remember how to use unfamiliar equipment. The introduction of previously stall-housed sows in a pen with ESF is a great learning challenge for them. They have to locate the feed resources and work out how to operate the mechanism that releases the feed before they receive their first meal after mixing. Therefore, spatial memory and operant conditioning abilities are very important (Held *et al* 2002). Pigs are supposed to readily learn operant procedures (Dantzer 1978) and they are more easily motivated by feed deprivation than other species (Lawrence *et al* 1988; Kilgour *et al* 1991; Bergeron *et al* 2000). Learning and recalling the procedure is reinforced by the most valuable reward, that is, feed. Social learning is also very important when behavioural synchronization is so strong. True imitation is not always necessarily. A demonstrator may simply draw observers' attention to the right part of the pen. Subsequently, the observer may investigate that part more intensely, acquiring the same response as the demonstrator by conventional operant conditioning. Such a process is called stimulus enhancement (Nicol 1996). However, cognitive abilities as well as social learning may be impaired by stress and fear produced after mixing unfamiliar sows in a new environment which they can neither predict nor control (Wiepkema & Schouten 1990; Nicol 1996; Mendl 1999). This may be the reason why low-ranking sows and gilts were those which needed more assistance in FITMIX. Optimal behaviour tactics seem to depend on dominance rank or relative competitive ability and resource distribution (Barta & Giraldeau 1998). Therefore, subordinates sows may choose to wait until dominant animals are resting. There is thus a conflict between social facilitation and fear of encountering a dominant animal (Brouns & Edwards 1994; Fraser *et al* 1995). Gilts had more difficulties in learning and probably cognitive immaturity had some effect (Held *et al* 2002). However, FITMIX gilts appeared to adapt quite well when assisted separately. Therefore, fear and social stress may have had a more important role. Therefore, it is highly recommended to keep gilts separately throughtout their first gestation, or at least, to train them separately before entering the new group.

Another factor that may have affected adaptation in FITMIX is lameness, since it affects movement and competitive abilities and thus access to the feeder. Lameness also seems to affect gilts more severely (Kroneman *et al* 1993b). In contrast, lame sows in TRICK could anyway acquire their ration. Although similar incidence of lameness was found in both systems, none of the lame sows had to be removed in TRICK.

Assistance to sows once they were in the pen was quite effective. The proportion of removed sows was in the acceptable range (5-10%) proposed by Edwards (1998). However, a systematic training programme for sows, and particularly gilts, in a training pen before they encounter the competition of the new group is highly recommended. Training increases predictability and controllability of the environment and thereby increases the feeling of safety and reduces stress and aggression (van Putten & van de Burgwal 1990). The longer the period of training, the shorter the time they need to become accustomed to the feeder in a new environment (Bressers *et al* 1993). Moreover, recent research has proved that experience through one gestation in Fitmix is enough to maintain the learning process until the next gestation (Buisan *et al* 2006).

5. CONCLUSIONS AND ANIMAL WELFARE IMPLICATIONS

Level of aggression appeared to be higher in FITMIX than in TRICK. Sequential feeding in a single, defensible structure made this feeding system more competitive. Therefore, a maintained level of low intensity aggression may have been necessary to reaffirm the priority of access to the feeder. As a result, stronger correlations were found in FITMIX between rank index and variables that contribute to fighting ability. Simultaneous feeding at a low rate reduced feeding-related aggression in TRICK, although increased drinking-related competitiveness. Nevertheless, most of the interactions in TRICK were in the resting area, suggesting a lack of total space and delimitation of the area. Parity was correlated to rank index in both systems. Therefore, although gilts were those less involved in aggression, they generally received more aggression than initiated. Despite not being severely attacked, they may have suffered from fear and behaviour restriction in presence of dominants. This was evident in

FITMIX, where social factors clearly affected adaptation to the system. As a result, we suggest that gilts should be kept apart throughout their first gestation in group housing systems. This would give them the opportunity to adapt easily to complex systems such as FITMIX in a more favourable environment. Previous training of sows in an adapted training pen would facilitate adaptation of sows in all cases and would improve welfare of sows after mixing. In conclusion, FITMIX demands a higher management quality to prevent excessive aggression and ensure an easy adaptation of the animals. However, welfare cannot be assessed just by social factors. Other measures such as resting behaviour, stereotypies, physiological indicators of stress and productivity are necessary to rank systems for overall welfare, as systems may differ in many aspects. Long-term and individual evaluation of welfare within a group should be performed before statements about a system are made.

CHAPTER 5

"Feeding behaviour patterns in group-housed pregnant sows fed with an unprotected electronic sow feeder (Fitmix)"

Abstract

Sixty pregnant sows from first to eighth parity were selected on a commercial farm and used in three different replicas. Sows were housed from day 29 of pregnancy to one week before parturition in stable groups of 20 with FITMIX. The feeding cycle was updated once a day at 700 h. Data recorded by the system from 25 non-consecutive feeding cycles were analyzed. Sows made several visits to the feeder to get their daily ration, although daily feeder occupation seemed to be shorter compared to literature on protected ESF. Daily feeder occupation per sow appeared to decrease over time ($P < 0.001$). Within each feeding cycle, maximum activity around the feeder was observed in the hours following the start of the cycle, so that activity was very low in the latter half of the cycle. A relatively stable feeding order was quickly established and maintained over the experiment ($W > 0.80$, $P < 0.001$) and it highly correlated with dominance rank ($r_s = 0.80$, $P < 0.001$). High-ranking sows fed earlier and made as many visits as low-ranking sows but longer and thus, they occupied the feeder for longer ($P < 0.01$). In conclusion, FITMIX appeared to be an efficient feeding system for medium-sized stable groups of sow, although optimization of the feeder efficiency may take several weeks. The lack of protection while feeding made sows split their ration in several visits. However, the establishment of a rank-related feeding order may ameliorate disturbance around the feeder and help stockpeople to detect problems.

1. INTRODUCTION

Electronic Sow Feeders (ESF) were first developed back in the 1980's (Lambert *et al* 1983; Edwards *et al* 1984). They allow sows to be housed as a group but fed as individuals, usually in a feeding crate where they are protected from other sows. The daily ration for the individual sow can be determined and is delivered when the sow enters the feeding crate and is identified by the computer controlling the system. Therefore, ESF overcome the lack of control over individual feeding intake intrinsic to other group housing systems. Moreover, they record information on feeding behaviour, such as time, size and duration of each visit to the feeder. This information used to be patiently collected manually or by video recordings, fact that limited the extent of feeding behaviour research. However, the equipment used in the last century's studies had design faults that only became apparent with the commercial adoption of the systems. In addition, many of the published studies involved housing designs and group sizes that had no relation, or relevance, to the systems that are now used on commercial units. Fortunately, ESF have been improved in the last years and are currently highly recommended (Brooks 2003). However, specific studies on feeding behaviour of group-housed sows fed with ESF were largely done before these improvements (Hunter *et al* 1988; Edwards *et al* 1988; Bressers *et al* 1993; Eddison & Roberts 1995). Detection of patterns in the use of a feed station by sows may help supervision because deviations from such patterns may be related to the occurrence of disease, oestrus or reproductive or other problems.

ESF are mainly used with large dynamic groups, thus making difficult to detect stable feeding patterns in time (Bressers *et al* 1993). Moreover, ESF usually limit behaviour variability. Some designs force the sows to eat their daily ration in a single visit (walk-through layout, Brooks 2003). In some other designs, no limitation upon the number of visits is imposed but sows are so protected while feeding that most of them finish their whole ration in a single visit (Eddison & Roberts 1995). Fitmix is a relatively new type of ESF that has the same management possibilities as conventional ESF, but it just protects the face of the sow while eating. Consequently, sows are likely to split their ration in several visits to the feeder. As it usually works with stable groups, a feeding order is supposed to be established, thereby limiting competition for feeding.

The present study used data recorded by Fitmix from three different stable groups of pregnant sows to detect: a) variations in the feeding patterns over time, b) circadian variations in the feeding pattern and in the occupation of the feeder, c) the establishment of a consistent feeding order and d) relations of the dominance rank to the feeding pattern and the feeding order.

2. MATERIAL AND METHODS

2.1. Animal, housing, feeding and general management

Sixty Large White x Landrace female pigs[5] (*Sus scrofa*) from first to ninth parity were selected on a commercial farm, on the 29th day of pregnancy. They were used in three different replicas (20 sows per replica). All sows had been previously stall-housed during their productive live. They were housed in stable groups until a week before the expected parturition date (a total of 11 weeks). The first replica took place from mid January to early April, the second one from late April to mid July and the third one from late July to mid October.

The sows were kept in a part-slatted pen without bedding. Space allowance was 2.3 m^2 per sow without considering the space occupied by the feeder. The resting area was divided by two protecting walls (1 m x 1.8m). Illumination was by both natural daylight and artificial lighting with lights switched on at 600 h and off at 2200 h. A thermometer registered the daily maximum and minimum temperature.

There was a single electronic feeder (FITMIX, Mannebeck, Germany) and a single drinker in the pen. FITMIX enables to allocate an individual ration to each sow. However, sows are not protected by a crate while feeding but just by a short fence that covers their face. Feed is offered in mash consistency and comes directly from a nozzle into the sow's mouth (Figure 1), with no need for a trough. Sows get identified by an earmark transponder through the aerial and if they have feed claims, a conveyor carries feed through the nozzle. The feeder has a lateral access for the leftovers that the sows

[5] Hereafter, all experimental female pigs will be refereed to as sows irrespective of their parity number, unless otherwise indicated

may drop while eating in order to decrease aggression towards the sow that is using the feeder.

Each daily feeding cycle started at 700 h. All the sows were restrictedly fed with concentrated feed (143 g crude protein, 90 g crude fat, 80 g crude fibre, 63 g ash per kg and 12.25 MJ ME) that was mixed with water in the feeder. The basic rations were 2.3 kg/day/gilt and 2.5 kg/day/sow until day 90 of pregnancy and from then on, 2.8 kg/day/gilt and 3 kg/day/sow. Rations were individually corrected using backfat depth measures when necessary. A report was emitted by the system before starting the next feeding cycle in order to detect those sows that had not finished the allocated ration. Water was provided *ad libitum*.

Sows followed a training program during the first fortnight to learn how to use the feeder. FITMIX has a learning aide that makes acquiring feed from the nozzle easier by changing some technical parameters. Lateral access to the feed leftovers was cancelled. Furthermore, from day 5 to 8, sows that already knew how to feed were moved out of the pen from 1200 h to 1600 h in order to leave just the sows that had learning problems. On day 5 and 8, space allowance was reduced and assistance was offered when a sow approached the feeder. Sows were compensated for the missed shares of feed once the training period was finished.

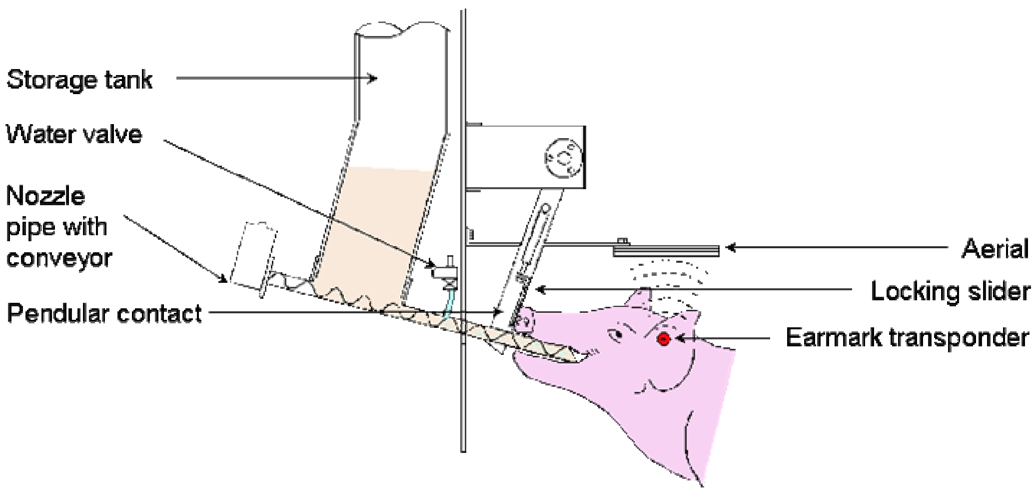

Figure 1 Functioning of FITMIX

2.2. Data collection

Each time the system identified a transponder, a record was saved by means of a computer interface (MILAN, Mannebeck, Germany). Initial and final times of each identification were recorded. Feed intake in each identification could not be recorded due to technical problems.

Data from the first two weeks were discarded because it was considered as the adaptation time for the sows and the learning aide was working. Twenty-five non-consecutive feeding cycles evenly distributed in the next 9 weeks (from 2 to 4 per week) were chosen for the data analysis, avoiding those days were lost of data or excessive disruption occurred.

Data were filtered to detect misidentified transponders, negative or exaggerated durations, or negative interval between records (Eissen *et al* 1998; Casey *et al* 2005). Durations equal to 0 seconds were not discarded. Eissen *et al* (1998) and Casey *et al* (2005) only discarded visits of duration equal to 0 when feed intake was recorded. We did not have feed intake information but there was no reason to think that durations equal to 0 seconds were more likely an error than for instance 1 second.

We detected that transponder identification was frequently interrupted while the animal was under the aerial. Tough head movements due to competition or simply head turns while feeding from the nozzle may have been the reason. As a result, the system saved several records for each visit the sows made to the feeder. In order to analyze the data properly, successive records belonging to the same visit needed to be grouped. For this purpose, a visit made by an animal was considered as finished when a new animal was identified (van der Mheen, personal communication). However, overestimation of the duration of the visit could happen at low-activity times, since an animal could make a visit to the feeder, go resting and make another visit without any other animal visiting the feeder in between. Therefore, a threshold was set to classify as errors those visits with duration longer than expected. A histogram for the duration of the visits was used to identify the point in the tail of the distribution where the frequency showed a substantial decrease (Casey *et al* 2005).

In order to describe the feeding patterns of sows both over time and within the feeding cycle, several variables were used: a) number of visits per feeding cycle (number of daily visits) and per hour within each feeding cycle, b) duration of the visits,

c) feeder occupation per feeding cycle (daily feeder occupation) and per hour within each feeding cycle and d) feeding order of sows within each group. The duration of the visits was calculated in two different ways: a) the final visit time minus the initial visit time (estimated duration) and b) the sum of the duration of the different records grouped into each visit (recorded duration). Therefore, feeder occupation was calculated as the sum of both estimated and recorded duration of the visits (estimated and recorded feeder occupation respectively). Two criteria were also used to determine the feeding order within each group for each feeding cycle: a) the initial time of the first visit and b) the 10th percentile of the initial times of the visits for each sow.

Feeding behaviour of group-housed sows may be affected by dominance rank (Brouns & Edwards 1994). The dominance rank of the sows within each group had been previously determined by calculating the rank index (RI) described by Lee *et al* (1982) and Nielsen *et al* (1995a). The aggressive interactions between pairs recorded by direct observation and video recording throughout the experiment were used for this purpose (see Chapter 4).

2.3. Data analyses

Statistical analyses were performed using the statistical package SAS (SAS 1999). For the analyses of feeding behaviour over time, each replica was divided into three three-week periods. The individual sow was considered the experimental unit. The data for the number of daily visits were analyzed using the GENMOD procedure. The least-square means of fixed effects (LSMEANS) adjusted to Bonferroni's honestly significance difference was used as a test of multiple comparisons. The data for the duration of visits and daily feeding occupation were transformed to a logarithm scale and analyzed using the MIXED procedure. The least-square means of fixed effects (LSMEANS) adjusted to Tukey's honestly significance difference was used as a test of multiple comparisons. The replica was specified as a random effect. Circadian patterns for the number of visits, duration of visit and feeder occupation were estimated for each three-week period by calculating the means for each hour of every feeding cycle. The feeding cycle * replica was considered the experimental unit. Comparison of the hourly means for each period was carried out using the GENMOD procedure for the number of visits and the MIXED procedure for the logarithm of both the duration of the visit and the feeder occupation.

The stability of the feeding order was estimated using Kendall's coefficient of concordance, W (Siegel & Castellan 1988). A value of 1 for W indicates that all feeding orders were identical, and a value of 0 indicates that feeding order was random.

Spearman's rank order correlation coefficient (PROC CORR Spearman) was used to calculate RI correlation to feeding behaviour variables and feeding order.

3. RESULTS

The average minimum:maximum temperatures (ºC) in the three replicas were 13:18, 20:27 and 21:27 respectively.

Some sows had to be removed from the experiment due to several causes (see Chapter 3). The evolution of group size from period 1 to 3 for each replica is shown in Table 1. Some sows were already removed during the adaptation period. The data from the three sows that were removed from the experiment in period 1 in replica 3 were discarded for the analyses of all the variables but feeder occupation.

We did not detect any misidentified transponders, negative or exaggerated durations, or negative interval between records. After grouping records into visits, there were a total of 29759 visits (29672 visits after discarding data from the animals removed early in the experiment). Visits of duration equal to 0 accounted for the 3% of the total. Visits longer than 1 h (0.1% of the total) were considered as an error and their duration was substituted by the average duration.

Table 1 Evolution of group size from period 1 to 3 for each replica.

	Period 1	**Period 2**	**Period 3**
Replica 1	19	19	19-18
Replica 2	18	18	18
Replica 3	19-16	16-13	13-12

3.1. Evolution of feeding behaviour over time

The period effect on the number of daily visits, duration of visit and daily feeder occupation is summarized in Table 2.

Table 2 Least squares means for the effect of period on number of daily visits, duration of visits and daily feeder occupation.

	Period 1	Period 2	Period 3	s.e.	*P*
Number of daily visits (number/sow/feeding cycle)	23.8	22.0	24.7	2.23	ns
Duration of visit (sec)	65.6	68.8	66.6	6.23	ns
Daily feeder occupation (sec/sow/feeding cycle)	1281.8 ^{a}	1147.8^{b}	1199.5^{b}	75.23	***

ns, *** = not significant, $P < 0.001$

^{a,b,c} Within a row, means without a common superscript letter differ significantly

3.2. Circadian pattern of feeding behaviour

Since no period effect was found on the circadian pattern of the number of visits, duration of visit or the feeder occupation, data from the three periods were combined in and Figure 2 and Figure 3. Most of the visits were made in the hours following the start of the feeding cycle, so that activity around the feeder was very low in the latter half of the feeding cycle. However, there was a significant increase in the proportion of visits in the last hour ($P < 0.001$), that is, the previous hour to the start of the next cycle. The duration of visit decreased significantly one hour after the feeding cycle was updated ($P < 0.001$) and it lost any pattern when the activity around the feeder decreased to minimal levels. Circadian evolution of the feeder occupation was similar to evolution of the number of visits, so that occupation was irrelevant in the latter half of the feeding cycle. Differences between the estimated and recorded feeder occupation were relevant at high-activity times.

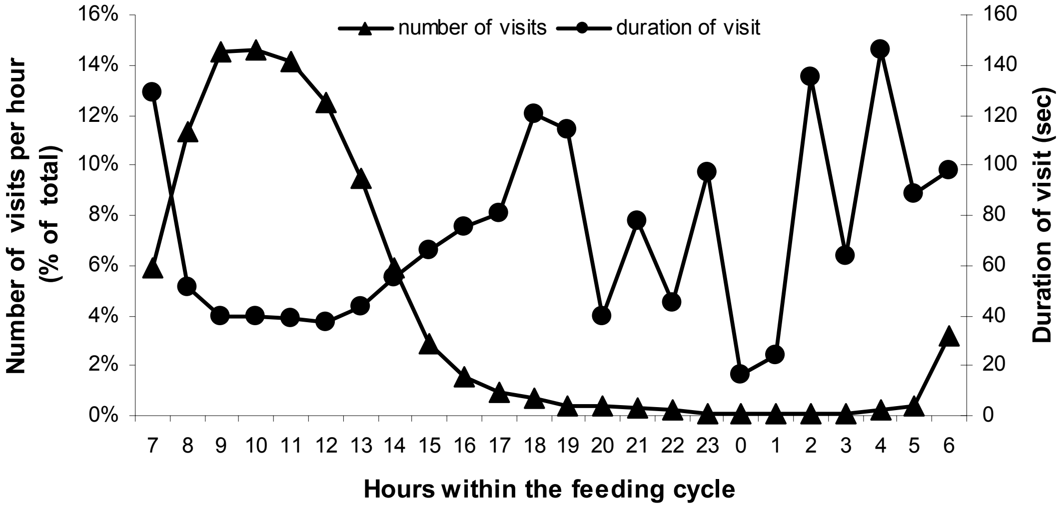

Figure 2 Proportional distribution of visits over the feeding cycle (% of total,) and average duration of visit per hour (seconds).

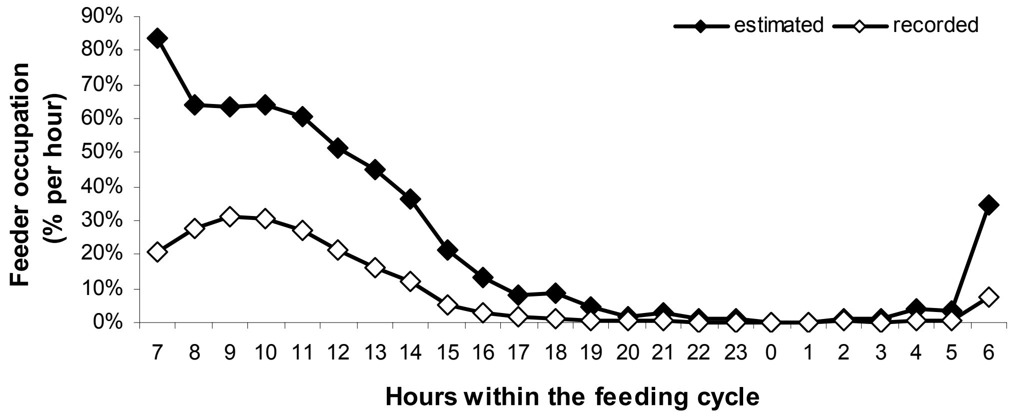

Figure 3 Percent of estimated and recorded feeder occupation per hour.

3.3. Consistency of the feeding order

Calculation of Kendall's coefficient of concordance (W) indicated that the feeding order was stable in each replica, no matter which criterion was used, and both overall and within each period (overall $W > 0.80$, per period $W > 0.77$, $P < 0.001$). Indeed, the two criteria highly correlated ($r_s = 0.96$, $P < 0.001$). The 10th percentile was selected as the criterion for further analyses because concordance was slightly higher and because it seemed to reflect more accurately the observed pattern. It may happen that by chance a sow made a visit to the feeder before the usual first one in the order. Even so, this opportunist sow was likely to be readily displaced by the usual first one. It was also observed that sows usually made several visits close in time after the first one.

Since the feeding order was relatively stable, the mean position in the feeding order was calculated for each sow. Positions were corrected when group size was smaller than 19 sows. Mean standard deviation was of 1.86 positions both for sows in the earlier and the later half of the feeding order. However, the mean standard deviation for the first and last position seemed to be smaller than for the others (0.44 and 0.62 respectively, whereas all the others were > 1).

3.4. Effects of dominance rank on feeding behaviour

Correlations among rank index (RI), feeding behaviour variables and mean position in the feeding order are summarized in Table 3. Correlations between feeding behaviour variables and RI were found to be weak. Therefore, sows were divided into high-ranking (RI ≥ 10, n=26) and low-ranking sows (RI < 10, n = 27). High-ranking animals presented longer duration of the visit (106.5 *vs* 61.6 sec, s.e. = 10.96, $P < 0.01$) and daily feeder occupation (1391.3 *vs* 1021.9 sec, s.e. = 98.72, $P < 0.01$) yet no differences were found in the number of daily visits. Correlations between feeding order and feeding behaviour variables were also weak. However, the average duration of the visit and daily feeder occupation were higher for the earlier half of the feeding order (DUV = 106.4 *vs* 64.9, s.e. = 11.31, $P < 0.01$; DFO = 1470.9 *vs* 976.4, s.e. = 92.32, $P < 0.01$) yet no differences were found in the number of daily visits.

Table 3. Correlations (r_s) between feeding behaviour variables and rank index (RI)

	RI	NDV	DUV	DFO
Rank Index (RI)	-			
Number of daily visits (NDV)	-0.09 ns	-		
Duration of the visit (DUV)	0.56 ***	- 0.70 ***	-	
Daily feeder occupation (DFO)	0.29 ***	0.40 ***	0.29 ***	-
Feeding Order	-0.87 ***	0.08 **	- 0.24 ***	- 0.22 ***

ns, **, *** = not significant, $P < 0.01$, $P < 0.001$

4. DISCUSSION

4.1. General feeding behaviour

Feeding behaviour patterns in group-housed pigs have been reported to be affected by a great number of factors, such as group size (Nielsen *et al* 1995a; Hyun & Ellis 2002), group management (stable *vs* dynamic groups in pregnant sows; Hunter *et al* 1988; Bressers *et al* 1993), feed allowance (restriction *vs ad libitum*; Brouns & Edwards 1994), provision of straw or bulk material (van Putten & van de Burgwal 1990; Jensen *et al* 2000; van der Mheen *et al* 2004), equipment design especially related to the level of protection to the visiting animal (Edwards *et al* 1988; Gjein & Larssen 1995a; Nielsen *et al* 1995b) and building layout (Brooks 2003). All these factors affect social competition, that together with social facilitation and inherent photoperiodicity are the main constrainers of feeding behaviour in group-housed pigs (Nielsen *et al* 1995a). Indeed, experimental designs may differ considerably, thus making comparisons among different studies complicate. Furthermore, most of the studies are carried out either in groups of sows with ESF that provide a protective crate or in groups of growing pigs that are fed *ad libitum* yet at different level of protection to the feeding pig. There is, as yet, a lack of published data on feeding behaviour of group-housed pregnant sows fed with unprotected ESF such as FITMIX. Consequently, comparison of our results with other studies must be done with caution.

Comparison is even a bit more difficult in our case, because feeding and non-feeding visits could not be differentiated. However, we were able to check by the daily automatic report that very rarely a sow did not finish their whole ration. Moreover, non-feeding visits have been considered as feeding behaviour by some authors (Ramaekers 1996; Eissen 2000). They have been related to foraging behaviour as well as social behaviour to defend, after all, the feeder (Young & Lawrence 1994; Nielsen *et al* 1995a). Moreover, they must be considered when estimating the average daily occupation per sow to determine the feeder capacity. As a result, we suggest that the need to draw the distinction between feeding and non-feeding visits is not essential to study the pattern of feeder use. Non-feeding visits have been reported to be shorter than feeding ones since they reflect attempted feeder displacements (Nielsen *et al* 1995a). Non-feeding visits may be the reason why some of the visits in our study were extremely short (3% of the visits lasted 0 sec).

4.2. Evolution of feeding behaviour over time

Overall, the number of daily visits per sow in our study was higher than that reported by others using protected ESF with protective crate, as it was expected. Edwards *et al* (1988) found a much lower number of daily visits per sow using different feeder designs (from 3.9 to 7.2 on average) for 38 group-housed sows, assuming that sows ate their entire ration in a single visit. However, daily feeder occupation per sow was higher than in our study (from 25.4 to 29.7 min on average). Whereas the single feeding visit lasted from 10.9 to 12.6 min, the non-feeding visits lasted from 1.6 to 3.6 min on average. Sows fed from FITMIX seem to divide their ration over significantly more visits than what is normally seen with protectedl ESF (National Committee 2003), where most of the sows eat their ration in a single visit (Eddison & Roberts 1995). This is probably caused by the fact that the unprotected feeding point cause more disturbances to the sows during their feed intake. Growing pigs have also been reported to make a higher number of smaller visits to achieve the same daily feed intake when the feeder design did not completely protect the feeding pig (Morrow & Walker 1994; Nielsen *et al* 1995b). The sows in our study were able to eat a slightly higher ration than sows in Edwards *et al* (1988) in less total time despite the need to make more visits. This may have been caused by a shorter non-feeding time in FITMIX rather than an increased feed intake rate since the latter is limited by the speed of the nozzle. FITMIX is not supposed to offer feed reward to non-feeding visitors since the feeding sow drops very little feed and this is redirected to the side instead of remaining in a trough. Moreover, most of the sows may not dare to revisit the feeder after finishing their ration as it happens in protected ESF (Hunter *et al* 1988). Therefore, too much protection may limit feeder efficiency. On the other hand, van der Mheen *et al* (2004) recorded more daily visits per sow with Fitmix than in the present study. The fact that the groups were dynamic and larger may have caused higher disturbance around the feeder. In fact, they reduced the number of daily visits from 54 to 45 by providing roughage, thereby reducing disturbances around the feeder and enhancing its efficiency.

Daily feeder occupation per sow seemed to be higher in the first period although no significant differences were found in either the number of daily visits or duration of visit. However, these variables are highly affected by group size. Since group size in the third replica varied considerably over time, it was decided to analyze the other two replicas separately. The number of daily visits was found to be higher and the duration of visit shorter in the first period. Therefore, despite allowing a two-week adaptation period before collecting data, sows proved to be less efficient in the first period. They made a higher number of shorter visits and occupied the feeder for longer to achieve a similar ration, that is, the non-feeding time was longer in the first period than in the others. Therefore, sows seemed to need more than two weeks to completely adapt to the functioning of the feeder and get the maximum efficiency.

4.3. Circadian pattern of feeding behaviour

Sows showed an increase in the feeding activity at the feeding cycle start time that overlaid any photoperiodicity effect (Feddes *et al* 1989). Activity remained very low during the latter half of the feeding cycle, before starting a gradual increase again in anticipation of the beginning of the next feeding cycle. All sows must have fed in the earlier half of the feeding cycle. This pattern of activity resembles to that found by Edwards *et al* (1988) and makes evident the great effect of social facilitation in restricted sows even in competitive systems (Hagelsø-Giersing & Studnitz 1996). Jensen *et al* (2000), in a study on four commercial herds of pregnant sows kept in dynamic groups with protected ESF, found that irrespective of the time of day that the feeding cycle started there was an immediate increase in the feeding activity that lasted for several hours. Even so, day time apparently continued to be a potent trigger of activity. Therefore, in herds where feeding start time was out of phase with the normal diurnal pattern of activity, peaks of activity at the start and at the end of day time were still evident. In our case, a peak at the end of the day would have been probably reflected in an increase in the number of non-feeding visits due to the foraging behaviour inherent to sows, enhanced by permanent hunger. Therefore, FITMIX proved to promote resting.

Although maximum occupation (49 min/h) was achieved in the first hour after the start of the feeding cycle, the number of feeding visits was higher in the following hours yet they were shorter. Sows which ate during the first hour were able to displace contestants so that they occupied the feeder continuously in longer visits. Subsequent sows in the feeding order were more easily intimidated and displaced from the feeder so that sows took turns in shorter visits. The frequency of aggressions for access the feeder was calculated from 700h to 800h and from 830 to 930 h from direct observation and video recording carried out once a week (see Chapter 4) and it was found higher from 830 to 930 h (62.33 *vs* 88.58 aggressions per hour respectively, $P < 0.01$, Wilcoxon signed rank test). Therefore, occupation of the feeder is not directly related to competition. Number of visits and duration are more directly related to competition (Young & Lawrence 1994; Hyun *et al* 1997). When occupation of the feeder increases due to an increase in the duration of the visits, competition is lower than when the increase is due to an increase in the number of shorter visits. In a sense, occupation is reduced when competition is increased because feeder occupation per animal decreases (Botermans *et al* 1997). Obviously, when occupation is low, competition is, too.

The feeder was not operating at full capacity even at the times of the day of maximum activity. This fact is also reflected in the daily feeder occupation per sow. In theory, the number of sows would need to be increased considerably to force sows to use the feeder at night (Walker 1991; Nielsen *et al* 1995a). However, occupation proves to be difficult to estimate in unprotected ESF. Transponder identification may be interrupted while the animal is occupying the feeder even if the transponder remains under the antenna. The visitor may make rough movements while eating from the nozzle, turn up the head to threaten contestants or even fight so close to the feeder that no other sow could take its place in the feeder. Although the transponder would be no longer under the antenna in the latter cases, the sow would be preventing other sows from using the feeder and thus occupying it. If we considered just the recorded occupation, we would be underestimating the occupation of the feeder and therefore, overestimating its capacity. We are aware that, by applying the decided visit criterion, we may be overestimating the occupation of the feeder at low activity times yet not at high activity times. At high activity time, occupation may be even underestimated to a lesser extent. An example would be if a new sow attempted to displace the feeding sow and after fighting for some seconds in front of the "vacated" feeder, the new one managed to get access to it. However, we suggest that the risk can be assumed without altering the magnitude of the results. Nevertheless, a validation of the system should be done for the sake of accuracy. Meanwhile, capacity of the system should be assessed by combination of percent of occupation and total visits per hour, and allowing always a reasonable margin for the benefit of the doubt.

4.4. Feeding order and dominance rank

In agreement to other studies (Hunter *et al* 1988; Edwards *et al* 1988), stable groups of sows were able to quickly establish and maintain a fairly consistent feeding order. The order was already established in period 1 although sows were not completely adapted in terms of efficiency as mentioned before. The order was maintained over 9 weeks. The studies mentioned above observed the sows up to two weeks and hence, it was not clear whether these sows could maintain the stable feeding order over longer periods of time. Bressers *et al* (1993) studied dynamic groups of sows and found that, although the feeding order was not random within subgroups of sows entered together to the pen, it did not remain stable over a period of several weeks. However, the feeding order was relatively stable between subgroups, as also stated van Putten & van der Burgwal (1990). As a result, feeding order seems to be more consistent in stable groups. The establishment of a feeding order brings several advantages. First of all, queues around the feeder are reduced to 2 or 3 animals on average at high activity times (Hunter *et al* 1988; Edwards *et al* 1988 for groups of 19-20 sows). From 10-min scan-sampling carried out once a week (see Chapter 3) we could estimate the queue at different times of the day and results were very similar (0.85 ± 0.12; 2.82 ± 0.09; 3.64 ± 0.08; 1.02 ± 0.06 for 630 to 700 h, 700 to 800 h, 830 to 930h and 1415 to 1545 h respectively, expressed as mean ± s.e.). The reduction of the queue around the feeder is important to reduce disturbances and aggression among frustrated hungry sows, particularly in form of vulva biting (van Putten & van de Burgwal 1990). We found a lower incidence of vulva biting than in other studies with more protective systems (see Chapter 3). As a result of this disturbance amelioration and the improvement in controllability and predictability of the environment, chronic stress may be reduced (Barnett & Taylor 1997). And finally, a stable feeding order may allow stockpeople to detect health problems or even oestrus because of deviations from the usual order. This would be an additional aide to the daily list of sows with uneaten feed (Bressers *et al* 1993).

Feeding order was highly correlated to dominance rank, that is, high-ranking sows were the first to get access to the feeder when the feeding cycle started, as it was already reported by Hunter *et al* (1988). The first one was the most constant in its position. In addition, high-ranking sows were found to visit the feeder as many times as low-ranking sows but in longer visits and hence, they occupied the feeder for longer. The most dominant sows appeared to make some long feeding visits in the first hour following the start of the feeding cycle. After finishing their ration, they probably revisited the feeder, thus causing disturbance and an increase in the frequency of shorter visits in the following hours. Low-ranking sows waited to feed later in the day. They needed a higher number of shorter visits to finish their ration since they may have been continuously interrupted. Since they made the same number of visits on average as high-ranking sows, they may have hardly revisited the feeder after finishing their ration and therefore, they occupied the feeder for shorter.

5. CONCLUSIONS

The lack of protection while feeding in FITMIX made sows split their ration in several visits. On the other hand, this fact also seemed to increase efficiency by reducing non-feeding occupation of the feeder. Optimization of the feeder efficiency took several weeks. However, a rank-related feeding order was quickly established and maintained over time. The establishment of a feeding order may ameliorate disturbances around the feeder and help stockpeople to detect problems. Nevertheless, these conclusions should not be extrapolated to different ESF designs, larger group sizes or dynamic groups.

CHAPTER 6

General discussion

1. INDICATORS OF ANIMAL WELFARE

Assessing overall welfare in different housing systems is very difficult. Systems may score very differently depending on the emphasis that is given to each welfare indicator. Different welfare indicators may fail to agree within a system. Moreover, management is likely to affect welfare more than the housing system itself and several management options are possible for each system. Hence, drawing general conclusions about the appropriateness of a system is virtually impossible. Each single situation must be analyzed accurately before decisions are made.

1.1. BEHAVIOUR

1.1.1. GENERAL ACTIVITY AND STEREOTYPIES

FITMIX was the system that presented the lowest level of general activity and stereotypies. This may indicate a lower level of arousal and feeding motivation (Haskell *et al* 2000). Therefore, this system appeared to increase resting behaviour. A higher total space per pen and division of the resting area may have contributed to a highest comfort. The pen also provided fewer stimuli such as bars where to redirect feeding motivation. Moreover, feeding time may have lost to some extent the role of unique important event of the day owning to sequential and ordered feeding. Lack of synchronization in feeding activity may have weakened the effect of social facilitation in stimulating the performance of general activity and stereotypies.

However, the different feeding pattern in FITMIX may have somehow altered the results. The ingestion of an insufficient meal has been reported to elicit an increase in general activity and in the performance of stereotypies that may last 2 or 3 hours (Jensen 1988; Terlouw *et al* 1993). Therefore, observational periods probably comprised the more critical hours in STALL and TRICK sows. However, not all FITMIX sows were observed long enough after their meal, due to sequential feeding. Quite a few sows, largely adults likely to perform stereotypies, ate in period 2 and 3, as they were high activity periods. Although the number of sows in postprandial period increased from period 2 to 3, there was not a corresponding increase in either the level of general activity or oronasofacial stereotypies. In period 4, when some sows were likely to be still in postprandial period, activity and stereotypies level were again minimal. Results would have been more accurate if observations had been prolonged for some hours and quantitative differences between FITMIX and the other systems may have been shortened. However, an increase in the level of activity and stereotypies between period 3 and 4 high enough to make differences between FITMIX and STALL disappear is unlikely. On the other hand, sham-chewing was so low in both group housing systems that was not even affected by the period of the day.

TRICK also decreased performance of sham-chewing in comparison to STALL, despite not reducing general activity or performance of environment-directed stereotypies to the same extent as FITMIX. Sham-chewing is the stereotypy that better indicates environment restriction because it is in a more advanced stage of development (Mason 1991a). In our case, STALL sows presented much higher levels of sham-chewing than group-housed sows. Likewise, TRICK and FITMIX were likely to have developed sham-chewing and other stereotypies prior to the experiment because they had been stall-housed for long. The fact that gilts performed less stereotypies than older sows in the three systems is an evidence that stereotypies are likely to increase with confinement time. Taking into account that long-established stereotypies are very difficult to diminish by improving the environment (Mason 1991a), the reduction in sham-chewing performance in both group housing systems can be considered as a great achievement.

The increase in drinking-related activity that TRICK sows showed is difficult to interpret since several factors may have been involved. The feeding regime (dry feed distributed simultaneously) made the single drinker be demanded by all the sows at the same time of the day. Therefore, drinking-related activity was enhanced by both competition and social facilitation (Forkman 1996). Furthermore, the drinker may be understood as an incentive where to redirected feeding motivation after an insufficient meal. Hence, it is difficult to distinguish between social factors and environmental restriction.

1.1.2. AGGRESSIVE BEHAVIOUR

1.1.2.1. *General level of aggression*

Aggressions in STALL sows were observed just sporadically and thus it was not found necessary to include them in the statistical analyses. Perhaps, interactions between sows were too subtle to be clearly detected by the observer since physical contact was almost impossible. Although incapacity to resolve interactions has been reported to cause psychological stress (Barnett *et al* 1987), this cannot be assessed by any of the measurement carried out in this experiment.

FITMIX was the most competitive feeding system because sows had to feed sequentially from a single defensible structure. As a result, frequency of feeding-related aggression was higher than in the other systems, involved more physical contact and were more decisive. The establishment of a feeding order related to the dominance rank probably reduced the frequency of aggression, especially vulva biting, by reducing the number of animals queuing. However, sows of similar strength or fighting ability probably tried to gain access to the feeder at the same time. Therefore, physical contact may have been necessary to reaffirm priority of access to the feeder. In addition, sows attacked by the rear, making threats and submission signs less effective. However, fights likely to cause injuries were seen as occasionally as in TRICK. The determination of a lesion score may have been interesting to prove that degree of physical injury was similar in the two group housing systems. Incidence of lameness and vulva bites, often related to aggression, and level of tissue damage were also similar in the two group housing systems.

Simultaneous feeding at low rate in feeding places seemed to be an efficient strategy to reduce competition for feeding. As a result, TRICK seems to be a good system to allow restricted sows to eat together, as they would chose, minimizing harmful aggressions and ensuring a fairly even distribution of feed.

1.1.2.2. *Dominance rank*

Correlations between rank index and variables that favour individuals in competition were higher in FITMIX. However, these correlations are not a good indicator of hierarchy strength or stability. Strength and stability can be determined by complex calculus if enough information is gathered (Langbein & Puppe 2004). In our case, higher correlations may indicate a higher degree of competitiveness for the resources in FITMIX.

Degree of competition also affects the number of recorded interactions and thus, the method of determination of the dominance rank. The lower the number of interactions recorded, the more likely to find undetermined dyads. The rank index assigned to an animal can be severely affected when a large number of relationships cannot be determined for this animal (Brouns & Edwards 1994; Langbein & Puppe 2004). A common approach to overcome the problem of a lack of interactions in already stable groups is to force animals to show overt aggressive behaviour, e.g. when valuable resources are restricted. The paired feed competition test has been broadly used for sows (Brouns & Edwards 1994; Arey 1999). Brouns & Edwards (1994) found that the index obtained with this paired test highly correlated with that determined from observed interactions in the group situation when the number of observed interactions in the group was high enough. However, these kind of paired contests have been criticized because they not always deliver a reliable image compared to real dominance relationships within the whole group (Craig 1986). Instead, Langbein & Puppe (2004) suggested short-term restricted resource availability to encourage aggressive encounters but observed in the entire group and within their normal home pen. Nevertheless, both options would result in the determination of a “competitive order” for a specific context instead of a general dominance order. The “competitive order” should be validated in terms of its measurements of priority of access as well as its generality before it can be regarded as a dominance measure (Syme 1974). Therefore, observing animals in real conditions is the best option to study dominance in groups. An option in TRICK may be observing sows just after feeding during more days to collect interactions around the drinker, despite being time spending. Forcing a competitive situation that is not inherent to the system is not a good alternative if assessment of the system itself is the main aim of the experiment.

Rank index correlated with parity in both systems. Gilts were subordinate to most of the adult sows and although they were less involved in aggression, they received more attacks than they initiated. Therefore, they were more likely to feel fear and find movement and behaviour restricted in both systems (Scientific Veterinary Committee 1997) and therefore, they should be carefully supervised for the sake of their welfare.

1.1.2.3. *Adaptation to competitive systems*

In TRICK, sows did not presented adaptation problems. Gilts were more likely to get some of their ration stolen since they ate more slowly, especially in replica 1, where number of displacements was higher. However, the allocated ration was based on adult requirements and therefore, body condition was not deteriorated in the short term.

In FITMIX, most of the gilts and subordinates got adapted to the system after being assisted separately. Therefore, learning problems were due to social factors rather than immature cognitive abilities. Even so, they had to wait for longer to get their ration and were more easily disturbed when feeding. Therefore, the more complex and competitive the system is, the worse consequences social stress may have.

1.1.2.4. *Impact of aggressive behaviour on animal welfare*

How detrimental is aggression to welfare is not totally clear. Obviously the welfare of the victims of severe aggressions is jeopardized. Apart from pain and injuries, subordinates often feel fear and restriction of movement and behaviour as mentioned before. Therefore, it is very important for their welfare to ensure that they have adequate opportunities to escape and hide from other pigs, by providing enough space and structures to hide behind (Scientific Veterinary Committee 1997). This facilitates the resolution of the conflicts at a lower cost in terms of time, energy and injuries (Fraser *et al* 1995). Dominant animals may be more frequently involved in aggression since fighting is worthy for them and therefore they are also at high risk of injury. However, aggressive behaviour may be rewarding for them through the attainment of something perceived as desirable. Insofar as the mediate cause is frustration, fear or other negative experiences, excessive aggression can be seen as a definite indicator of suboptimal conditions and therefore of reduced welfare (Hagelsø-Giersing & Studnitz 1996). On the other hand, aggression is a natural and instinctive behaviour in pigs and is not possible to completely eliminate it, as it has been seen to happen even in individual confinement. Therefore, the aim of good management is to minimize aggression, specially avoiding injuries and excessive attacks to particular animals.

1.2. PHYSIOLOGY

The three systems showed similar levels of APP, indicating that FITMIX did not lead to a higher level of tissue damage. That tissue damage is likely to happen in all commercial systems is obvious. Stall-housed sows find difficulties in lying down due to space restriction and lack of muscle and bone development, which may lead to decubital ulcers. In groups, fighting can also lead to physical damage, lameness and increased physical effort. However, there is not, as yet, a reliable method to assess psychological stress in the long term. Cortisol has been reported to be a valid indicator of psychological acute stress (Broom & Johson 1993). However, its use in the determination of chronic stress has been highly criticised (Rushen 1991; Rushen & de Passillé 1992; Broom & Johnson 1993). Psychological stress is very likely in both individual and group housing due to fear and repeated frustration of the animal motivations and behavioural needs. Although HPA axis is involved in APP regulation (Gruys *et al* 1994), no study has succeeded in proving their validity as a psychological stress indicator (Piñeiro *et al* 2005). Therefore, an effort should be done in the scientific community to find an indicator to detect psychological stress before physical detriment is caused.

1.3. PRODUCTION

It is a reasonable assumption that serious welfare problems will be apparent in reduced performance. However, copying systems of animals have evolved to minimise effects on reproductive success. Therefore, a good performance level does not mean that welfare is good. If performance is reduced, the exact cause should be discovered before it can be assumed to indicate welfare problems. Variations in performance can be due to many factors and some of them are not related to welfare, such as genetic background (Rushen & de Passillé 1992). Performance of well-managed herds of sows is very similar if only profitability of the enterprise as a whole is considered. Measures should be based on the performance of individual animals. Therefore, a good performance level should be taken as a prerequisite in any housing system before further assessing welfare by other means.

The fact that performance measures were similar in the three systems in our study does not provide much information in the ranking of the systems on a welfare basis. Long-term assessment over several parities may give us more accurate information. However, incidence of stillborn piglets was lower in FITMIX. This may be caused by a lower farrowing time (Fraser *et al* 1997a) due to a higher chance of exercise in FITMIX since the total space per pen was larger (Vestergaard & Hansen 1984). Therefore, improved bone strength and muscle tone as a result of group housing can be beneficial to sows during farrowing. Boyle *et al* (2002) reported that group housing during gestation resulted in improved manoeuvring ability and comfort of sows in the farrowing crate with beneficial implications for skin health. However, these sows were more restless during farrowing and in early lactation than sows kept in stalls during pregnancy. Some other studies also found group-housed gilts and sows during pregnancy more restless and stressed than stall-housed ones on introduction to farrowing crates and during farrowing (Marchant & Broom 1993; Lawrence *et al* 1994; Beattie *et al* 1995; Harris & Gonyou 1998; Boyle *et al* 2000). Increased movement during farrowing increases the probability of piglets being crushed (Weary *et al* 1996; Thodberg *et al* 1999) and has been associated with aggression towards piglets (Harris *et al* 2001) and savaging (Beattie *et al* 1995). Boyle *et al* (2002) found similar reproductive performance for sows kept in groups or in stalls during pregnancy, whereas Cronin *et al* (1996) reported a higher litter size in group-housed sows but also a higher neonatal mortality. Therefore, impact of group housing during pregnancy on subsequent welfare in farrowing crates is controversial.

1.4. OVERALL ASSESSMENT OF ANIMAL WELFARE

Taking into account that no relevant differences were found among systems in the level of tissue damage and performance measures, conclusions should be drawn from behavioural measures. The Scientific Veterinary Committee (1997) of the European Union concluded that some serious welfare problems persisted even in the best stall-housing systems attending to a) the animals' affective states (specially fear, lack of control and frustration), b) the opportunity to carry out natural behaviours and c) the level of abnormal behaviour as indicative of poor welfare, without assuming that these aspects would necessarily affect "functioning-based" variables such as growth, reproduction, injury and health. Group housing *per se* allows foraging behaviour within the restriction of the complexity of the environment, social interactions and exercise. According to abnormal behaviours, both group housing systems in our study reduced to minimal levels long-established sham-chewing and FITMIX also reduced environment-directed stereotypies and increased resting behaviour compared to STALL. In addition, levels of stereotypes in these group housing systems are expected to be even lower once they are commercially adopted as sows will have not been stall-housed for such a long time prior to being housed in groups, as happened in the present study. On the other hand, aggressive interactions can be considered as a natural behaviour providing that is not excessive, as it was the case. However, affective states are very difficult to assess scientifically because of a lack of understanding of the underlying biology (Rushen & de Passillé 1992). It is not possible to know if behavioural and social deprivation in stalls causes more suffering that competition in groups. However, attending to the opportunity of natural behaviour and movement, and the level of abnormal stereotypies, it is concluded that group housing system is a good alternative to stalls in order to improve overall welfare.

Nevertheless, welfare of pregnant sows is largely focused in housing systems, because this is the focus of legislation, sometimes ignoring that other factors such as stockmanship quality may have a greater effect. The welfare of group-housed sows is not automatically better than that of stall-housed sows. If the group housing system is not managed correctly, the change is merely in the type of welfare problems encountered. Appropriate design ensures that the system has the potential to be adequately managed, but it does not guarantee the management. In a well-designed group housing system, welfare concerns can be addressed, although they cannot all be eliminated.

1.5. MANAGEMENT TECHNIQUES TO IMPROVE WELFARE IN TRICKLE FEEDING AND FITMIX

1.5.1. Sorting sows by size

Breeding sows may differ in size by a factor of two or more, a degree of variation uncommon in any other phase of production, and consequently fighting ability may highly differ within the group, too. Therefore, it is suggested to keep gilts apart to guarantee their adaptation in competitive systems and an appropriate achievement of feed in systems were individual control of the intake is not possible.

Moreover, sorting by size is recommended in TRICK to adjust the single ration to the requirements of all the sows and avoid high differences in feed intake rate. Even if the immediate postmixing aggression levels may be higher in uniform groups, size uniformity minimises the undesirable consequences for welfare of impaired distribution of feed. On the other hand, a certain degree of asymmetry may help to reduce the cost of establishing the dominance rank and the feeding order in FITMIX (Andersen *et al* 2000), providing that gilts are kept separately.

1.5.2. Improving pen design by increasing group size

The pen design is specially restricted in TRICK by the recommendation of keeping sows in small evenly-sized groups (which limits total space per pen) and the necessity to fit as many feeding places as animals. Therefore, it is often difficult to delimit the pen by means of walls so that sows can hide behind. Feeding places may be used for this purpose (Barnett *et al* 1992) but they leave the rear of the sow completely exposed. Small groups also offer less opportunity to hide among other animals in order to avoid aggressions.

ESF permits establishing larger groups in more spacious pens. However, medium-sized stable groups are recommended in FITMIX due to lack of a protective crate while feeding. Stable groups establish a feeding order that reduce disturbance around the feeder. Increasing group size may suppose the use of dynamic groups that could cause disruption in the feeding order, although it seems to reduce aggression in an individual basis. Capacity of feeders should be carefully estimated.

Therefore, increasing group size to improve pen design and facilitate avoidance behaviour and comfort should be properly assessed to ensure that feeding system efficiency is not at risk before being recommended as a standard practice.

1.5.3. Previous training in FITMIX

A systematic training program should be carried out before mixing unacquainted sows in a pen with FITMIX so that they can learn in a less stressful situation and are capable to eat since the first day after mixing into the new group. This can be done by providing a small training pen and giving them uncontested access to one of the feeders for a period of the day. Some transformations can be done in the functioning of the system in order to facilitate the achievement of feed. Sows which not readily use the feeder must be patiently assisted until they understand its function and feed consistently without aid. Once systems are adopted in farm, labour input would be increased just at the start of the productive lives of sows, as they can remember how to use the feeder after being several weeks without using it (Buisan *et al* 2006).

1.5.4. Provision of roughage

The provision of roughage in the lying area has been proposed by several authors to reduce aggression related to sequential feeding (van Putten & van de Burgwal 1990; Gjein & Larssen 1995a; Jensen *et al* 2000). It increases satisfaction of feeding motivation and reduces pressure on the feeder so that competition is reduced. On the contrary, provision of roughage in simultaneous feeding system seems to increase competition for access to the roughage, thereby increasing aggression (Krause *et al* 1997; Whittaker *et al* 1999) due to synchrony of roughage-directed behaviour and general activity.

2. FEEDING BEHAVIOUR

Feeding behaviour is highly frustrated in all housing systems for pregnant sows, not only because of an insufficient meal but also because of the way this meal is offered. All feeding systems designs are an attempt to overcome competitiveness for feeding which would lead to uneven distribution of the ration. Feeding sows in stalls is likely to be frustrating for the sow since they do not have even to move to find the feed. Consequently, foraging behaviour is totally thwarted. Trickle feeding is not a natural way of feeding sows, either. Feed intake rate and thereby feeding time is imposed by delivery rate. As the feed is delivered at a rate at which the slowest sow can consume, fast eaters are forced to eat more slowly than they would. On the other hand, ESF force sows to eat sequentially rather than simultaneously as they would choose. However, when feed is restricted in quantity or spatial distribution, a conflict is likely to arise between social facilitation (wish to eat at the same time) and social dominance (fear of encroaching into the social space of a dominant individual which may provoke an attack) (Brouns & Edwards 1994). As feed is always available in ESF, low-ranking sows may prefer to wait until dominant sows are resting and therefore, the establishment of a feeding order is beneficial for them. This tactic cannot be adopted by subordinates in simultaneous feeding systems and therefore design must ensure that all sows can eat together and acquire their ration. Although ESF may present some problems associated to sequential feeding, it is probably the most accepted commercial system due to high feeding control, management versatility and economic profitability (Brooks 2003). Moreover, ESF record useful information for the study of feeding behaviour of restricted pregnant sows, essential to improve equipment design and management.

2.1. FEEDING PATTERN IN FITMIX COMPARED TO PROTECTED ESF

Conventional ESF provide a feeding crate to reduce disturbance to the visiting sow yet conflicts usually occurs in the queue. Some ESF design force and others promote feeding the entire ration in a single visit preventing any variability in feeding behaviour. Sows have been reported to adopt an unpredictable variable feeding pattern if no limitation upon the number of visits to the feeder is imposed, although they tend to eat their entire ration in a single visit if protection is provided (Eddison & Roberts 1995). Therefore, expression of individuality is restricted by competition and the possibility of getting isolated.

The main difference between FITMIX and conventional ESF is the lack of a protective crate in FITMIX. This makes necessary the use of a nozzle rather than a trough where feed is dropped. The nozzle may not seem a natural way to feed sows. However, it reduces the amount of feed dropped while eating, which is diverted to a lateral access. Therefore, non-feeding visits are not rewarding and feeding sows is less frequently disturbed than if there were a trough. However, to ensure a proper leaning of the mechanism of the nozzle, the lateral access is cancelled by a horizontal board during the first fortnight.

The lack of a protective crate made FITMIX sows split their ration in several visits and reduce the non-feeding occupation of the feeder, in comparison to protected ESF. High-ranking and low-ranking sows made the same number of visits. High-ranking sows revisited the feeder after finishing their meal, interrupting low-ranking sows. However, number of visits and occupation of the feeder decreased after several weeks. This means that high-ranking sows decreased their non-feeding visits and therefore low-ranking sows could finish their meal in fewer visits, too. This decrease may be related to the fact that lateral access was not available until the third week, and it took the sows some days to understand its function. Therefore, the lack of protection may make FITMIX an efficient system by reducing non-feeding occupation of the feeder, in addition to its space efficiency and building flexibility. Furthermore, FITMIX does not impose any restriction in the expression of social interactions necessary to reaffirm the priority of access to resources.

2.2. THE EFFECT OF SOCIAL MANAGEMENT ON FEEDING PATTERNS

FITMIX sows were managed in stable groups of 20 sows not evenly sized. This social management may have influenced in some aspects of the observed feeding patterns. The fact that FITMIX sows were kept in stable groups facilitated the establishment of a consistent feeding order, related to the dominance rank. Therefore, asymmetry in size may have also facilitated its establishment. The establishment of a feeding order has been reported to have several advantages. First of all, queue around the feeder is reduced, thereby ameliorating disturbance around the feeder and incidence of vulva biting (van Putten & van de Burgwal 1990). Chronic stress is also supposed to be reduced (Barnett & Taylor 1997) by improving controllability and predictability of the environment (van Putten & van de Burgwal 1990). It also allows animals to get their meal every 24 hours as in simultaneous feeding systems. Such a schedule may also promote resting and help subordinates to avoid encountering dominants. Finally, a stable feeding order may allow stockpeople to detect health problems or even oestrus because of deviations from the usual order. This would be an additional aide to the daily list of sows with uneaten feed (Bressers *et al* 1993). However, feeding order has been found to be less stable in dynamic groups.

Composing large groups have been proposed as a management option in competitive systems since research on immature pigs (Turner & Edwards 2004) and commercial experience on sows fed with protected ESF (Edwards *et al* 1993) indicates that aggression is minimized. However, some aspects should be carefully considered before adoption as a standard practice in FITMIX. Firstly, this option would involve the use of dynamic groups in most of the cases. As a consequence, establishment of a feeding order may be hindered. Repercussions of the lack of feeding order in an unprotected system such as FITMIX should be carefully assessed. Secondly, increases in group size may involve a constraint on feeding behaviour that should be gradually assessed, especially when estimating feeder capacity.

FITMIX was not working at capacity at all with a group of 20 animals. Sows used the feeder 20 minutes a day on average. That means that theoretically 72 sows could be fed from a single feeder. However this would force some of the sows to feed at night. Yet it may not have adverse effects on performance, circadian rhythm would be altered as they would never chose to eat at night in nature (Walker 1991). In any case, extrapolation is not admissible as feeding and social behaviours are sensible to group size. In *ad libitum* pigs, number of daily visits and daily feeder occupation is often reduced as group size is increased (Nielsen *et al* 1995a; Hyun & Ellis 2001, 2002). Increasing group size but maintaining feeder allocation in order to decrease competitiveness may be another option to consider. In conclusion, progressive increases in group size should be tried in order to assess both beneficial and adverse effects on welfare. The optimal group size on a welfare basis may be smaller that the theoretical capacity of the feeder.

CHAPTER 7

Conclusions

The results obtained in this thesis allow us to conclude that in our experimental conditions:

Chapter 3: "Evaluation of welfare and productivity in pregnant sows kept in stalls or in two different group housing systems"

1. Both trickle feeding and Fitmix diminished the level of oronasofacial stereotypies compared to stalls, especially the level of long-established sham-chewing.
2. Fitmix also diminished the level of environment-directed stereotypies and increased resting behaviour in comparison to the other systems, suggesting that sows found this system less restrictive and more comfortable.
3. Compared to sows, gilts performed stereotypies less frequently and rested for longer in all the systems, suggesting that level of stereotypies and general activity increases with confinement time, as all sows had previously been in stalls.
4. No differences were found among systems in the levels of acute phase proteins, suggesting similar levels of tissue damage.
5. No differences in body condition or reproductive performance were found among systems, suggesting that well-managed group housing systems can produce at the same level as stalls.

Chapter 4: "Aggressive behaviour in two different group housing systems for pregnant sows"

6. Sequential feeding made Fitmix a more competitive feeding system, as sows showed higher frequency of aggressions, mainly around the feeder, with a higher proportion of physical contact and resolution than trickle feeding. However, simultaneous feeding in trickle feeding increased aggressions around the drinker.
7. Older sows initiated more aggressions than gilts in both group housing systems. Older sows also received more aggressions than gilts in Fitmix, since the establishment of a feeding order made sows of similar fighting ability try to gain

access to the feeder at the same time. However, gilts received more aggressions than they initiated in both systems.

8. Dominance rank’s correlations with liveweight and parity were stronger in Fitmix than in trickle feeding since these variables favour individuals in competition. No correlations were found between dominance rank and performance measures in any system.

Chapter 5: "Feeding behaviour patterns in group-housed pregnant sows fed with an unprotected electronic sow feeder (Fitmix)”

9. Fitmix presented more adaptation problems, which were related to social factors rather than impaired cognitive abilities.

10. Sows fed with Fitmix split their ration in several visits to the feeder owning to lack of protection while feeding, contrarily to what has been reported in protected ESF.

11. Fitmix may be more efficient than protected ESF since it may reduce non-feeding occupation of the feeder. However, efficiency optimization seemed to take several weeks. Efficiency may be enhanced by increasing the number of sows per feeder over 20, although every increase should be carefully assessed.

12. Feeding order was established quickly and maintained over several weeks in stable groups of sows fed with Fitmix. Feeding order was highly correlated to rank order.

CHAPTER 8

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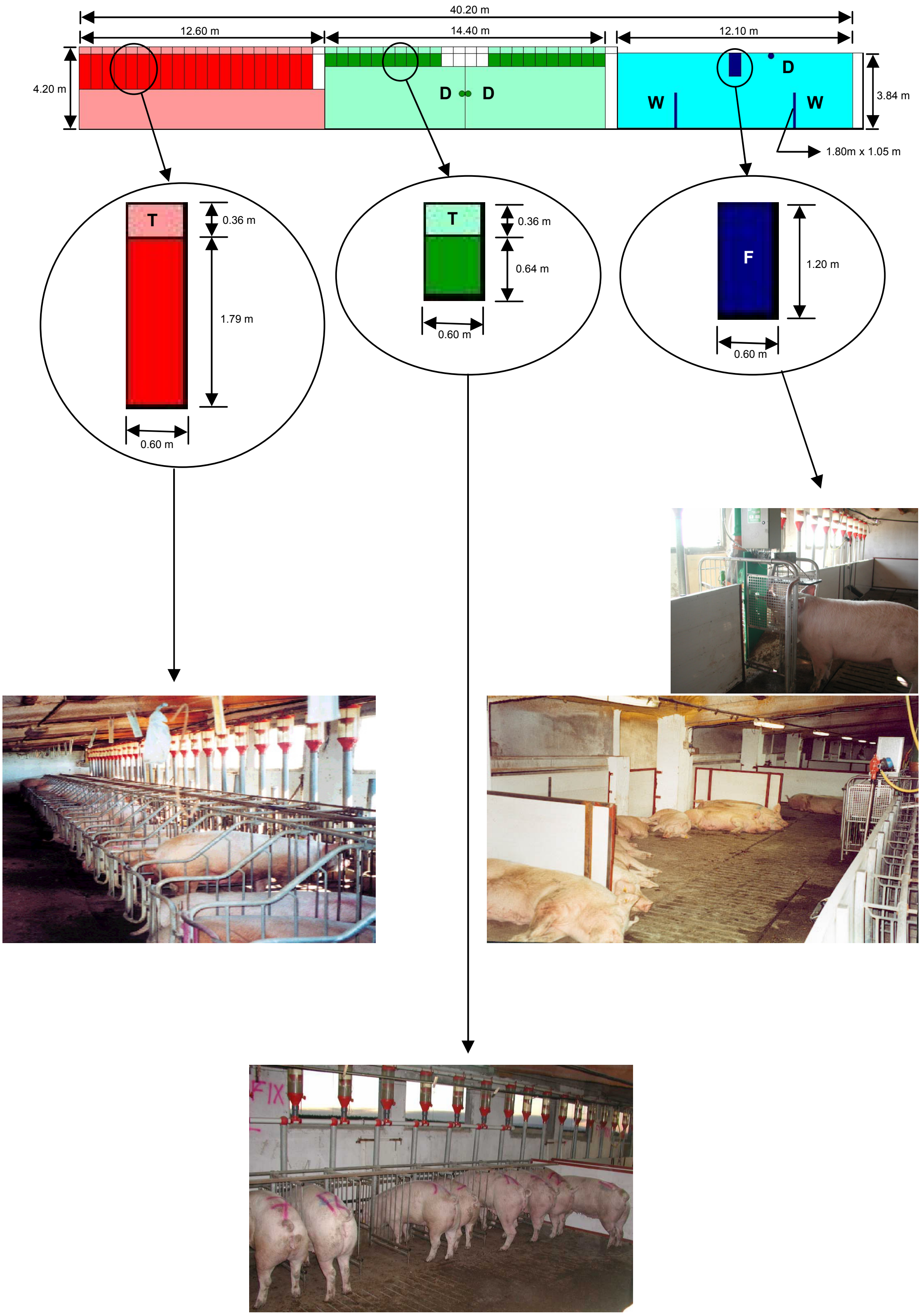
ANNEX



Map of the experimental facilities. From left to right: STALL (red), TRICK (green) and FITMIX (blue). T = trough, F = feeder, D = drinker, W = protecting walls.