



Assessment of welfare in pigs

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ABSTRACT

According to the definition given by Appleby (1996), animal welfare represents the state of well-being brought about by meeting the physical, environmental, nutritional, behavioural and social needs of the animal or groups of animals under the care, supervision or influence of people. Suitable husbandry techniques and disease control (in which man is directly involved) may satisfy an animal's physical, environmental and nutritive needs. However, it cannot be stated that people's supervision or influence always guarantee the satisfaction of behavioural and social needs. Thus, special attention must be paid to these factors in intensive husbandry.

This paper calls attention to the main factors characterizing pig welfare on the basis of productive, physiological, pathological and behavioural indicators; to the behavioural needs, which are characterised by several peculiar traits (it is noteworthy that, since the beginning, all categories of reared pigs have been involved in welfare legislation); to all categories of pigs that often show the effects of negative stimuli on their behaviour (limitations, variations); to the main critical points on the farm likely to cause welfare impairment or stress including buildings, inner facilities, space allowance, microclimate, lighting systems, environmental stressors, feeding management, mutilations, weaning, social factors, and stockmanship; and to environmental stressors including dust, odours (especially ammonia) and noises. This paper takes into account sources, effects and possible solutions for noises; the positive effect of fibrous feeding; environmental enrichment and other possible techniques for improving social status and for preventing/reducing stereotypic behaviour and abnormal reactions (e.g. tail biting).

The scientific/objective evaluation of welfare for intensively reared pigs may be carried out by means of direct observation of the animals themselves (animal-based or encompassing performance or output criteria), as well as through examinations of a structural nature (design or resource-based, or derived from engineering or input criteria). Preference should be given to the former since they are can be better adapted to the different pig categories and management systems. Design criteria, on the other hand, are easier to evaluate and they should integrate animal criteria. Thus, the most correct protocols for on-farm evaluation of pig welfare should involve both animal-based criteria and design criteria. Examples of both criteria are reported herein. In extensive farming which includes (although somewhat improperly) outdoor and organic farming, achieving a good level of welfare is one of the declared objectives. However, there are several causes of welfare impairment that can be successfully overcome only if highly professional workers are employed: unfavourable climate, parasitic diseases, intake of plants containing poisons or anti-nutritional factors, high piglet mortality.

Key words: Pig, Behaviour, Welfare, Design criteria, Animal-based criteria.

RIASSUNTO

VALUTAZIONE DEL BENESSERE NEL SUINO

Secondo la definizione di Appleby del 1996, il benessere animale rappresenta il soddisfacimento dei bisogni fisici, ambientali, nutritivi, comportamentali e sociali dell'animale o di gruppi di animali sotto la cura, la supervisione o l'influenza delle persone. Se il ricorso ad accurate tecnologie di allevamento e il controllo delle patologie (dirette conseguenze del coinvolgimento dell'uomo) possono essere adeguati a soddisfare i bisogni fisici, ambientali e nutritivi degli animali, non è certo che la supervisione o l'influenza delle persone siano adeguate a garantire il soddisfacimento dei bisogni comportamentali e sociali. Nell'allevamento intensivo odierno, quindi, sono soprattutto questi aspetti a richiedere la massima considerazione.

Nel testo viene posta attenzione agli elementi che caratterizzano il benessere (basati su indicatori produttivi, fisiologici, patologici e comportamentali); al fatto che il suino presenti elevate esigenze comportamentali, che si traducono in numerose impronte caratteristiche (emblematico che sia l'unico caso di estensione delle normative di legge sul benessere, fin dall'inizio, a tutte le categorie produttive), e mostri frequentemente effetti negativi sul repertorio comportamentale (limitazioni e variazioni) in tutte le categorie; ai principali punti critici in allevamento (potenzialmente in grado di provocare riduzione del benessere o stress): edifici, strutturazione interna, substrato, superficie unitaria, microclima, illuminazione, stressor ambientali tra cui polveri, odori da gas nocivi (ammoniaca in primis) e rumori (particolarmente sottovalutati), management alimentare, mutilazioni, svezzamento, aspetti sociali, personale. Vengono esaminati, per i rumori, fonti, effetti e possibili soluzioni; per l'alimentazione, gli effetti benefici della fibra; per gli aspetti sociali e per impedire/ridurre le stereotipie e le anomalie reattive (tra cui caudofagia), l'arricchimento ambientale e altri possibili provvedimenti per un adeguato benessere.

La valutazione oggettiva del benessere dei suini in allevamento intensivo può essere condotta sia attraverso riscontri direttamente rilevati sugli animali (animal-based o performance o output criteria), sia attraverso rilievi di natura strutturale (design o engineering o input criteria): la preferenza dovrebbe essere accordata ai primi, in quanto meglio adattabili alle differenti categorie dei suini e al diverso management aziendale, mentre i secondi, più facili da controllare ma meno flessibili, possono efficacemente integrarli. L'indirizzo più valido e convincente, al fine della compilazione di protocolli per la valutazione aziendale del benessere dei suini, dovrebbe quindi essere rappresentato da una proficua integrazione tra animal-based criteria e design criteria. Il lavoro riporta esempi di entrambi.

Nell'allevamento estensivo, in cui vengono ricompresi non del tutto propriamente l'allevamento all'aperto e l'allevamento biologico, l'ottenimento di un buon livello di benessere è tra gli obiettivi dichiarati, ma le cause di riduzione del benessere, a fianco di effetti positivi ottenibili solo con elevata professionalità degli addetti, sono numerose: esposizione a condizioni climatiche sfavorevoli, infezioni parassitarie, ingestione di specie vegetali tossiche o contenenti fattori antinutrizionali in caso di pascolamento, elevata mortalità dei suinetti.

Parole chiave: Suini, Comportamento, Benessere, Criteri strutturali, Valutazioni sugli animali.

Introduction

The concept of welfare includes many factors, and it is difficult, or even inappropriate, to draw a unique definition for it. Among the different definitions of welfare, it seems advisable to report the words of Appleby (1996), since the author stressed the importance of the responsibility of man in animal welfare, described as "the state of well-being brought about by meeting the

physical, environmental, nutritional, behavioural and social needs of the animal or groups of animals under the care, supervision or influence of people".

Welfare is also the fulfilment of needs related to the respect of the "five freedoms" listed in the Brambell Report (1965), reviewed and broadened by the Farm Animal Welfare Council (1993), which are to date the elements of inspiration and the objectives of scientific research on animal welfare.

The functional approach to animal welfare, which states that welfare and distress are antithetic, links the achievement of high productivity standards with the maintenance of the physiological functionality of the animal organism (including the normal behaviour and longevity) and with the absence of diseases, lesions and bad nutrition.

Generally speaking, for intensively reared species, it may be stated that, by means of productivity, physiological, pathological and behavioural indicators, it is possible to get an estimate of the level of animal welfare; nevertheless, it is important to recognize that animal welfare cannot exist without proper hygiene management, limitation and control of sufferings, and prevention of farming-induced diseases. Among the above-mentioned welfare indicators, the importance of behaviour must be stressed, since its variation represents the first adaptive response of the animal to distress.

Legislation on the protection of farmed pigs

Farmed pigs are the object of the most complex and detailed collection of rules existing in the field of farmed animal protection (Figure 1). The recent Italian legisla-

tive decree DL 53/2004 (implementation of Directives 2001/88/EC and 2001/93/EC) has been added to DL 534/1992 (implementation of Directive 91/630/EEC).

Since the European Food Safety Authority (EFSA, 2005) recently published an opinion about "The welfare of weaners and rearing pigs: effects of different space allowances and floor types," future developments of EC rules on pig protection can be expected.

As a rule it can be stated that the pig is the only species which is controlled throughout its production cycle, taking into account all categories and every rearing phase, by detailed national and European legislation.

Behaviour as an indicator of pig welfare

The behaviour of pigs

As for other intensively kept species, it is often difficult to distinguish the pig's adaptive behaviours caused by intensive rearing conditions from its inner species-linked behaviour; the latter is indeed also influenced by rearing conditions and management. Learned behaviours should be considered as positive, since they make animal management easier and limit the possible damage caused by anxiety and fear.

Furthermore, the behaviour of domestic

Figure 1. EC legislation and Italian related laws about pig protection and welfare.

- Legislative Decree no. 534, 30/12/1992: implementation of Directive 91/630/EEC, establishing minimal rules for pig protection.
- Council Directive 2001/88/EC (23/10/2001) establishing minimal rules for pig protection (amending Directive 91/630/EEC).
- Commission Directive 2001/93/EC (09/11/2001) establishing minimal rules for pig protection (amending Directive 91/630/EEC).
- Legislative Decree no. 53, 20/02/2004: implementation of Directive 2001/93/EC, establishing minimal rules for pig protection.

pigs is influenced by bio-rhythms which affect the sleeping/waking sequence and other important moments of its life: e.g., time of farrowing which, similarly to man and horse, mainly occurs during the night, when the maximum peacefulness is achieved (Friend *et al.*, 1962).

The social behaviours, including sexual and maternal behaviours, are the most important fields of study for pig welfare evaluation, since pigs often express within this framework the abnormal behaviours indicating a state of distress.

Pigs are social animals and their whole way of living is strongly affected by hierarchy from their birth; the assessment of the "teat order" quickly after birth is a significant example. The hierarchy is mainly based upon weight and age. A dominant animal can control up to 20-30 fellows (Fraser and Broom, 1997), and all the members of a group can recognize each other and identify an outsider. Olfactory and, secondarily, visual stimuli are responsible for recognizing mechanisms (Ewbank and Meese, 1974; Meese *et al.*, 1975). Present knowledge of sound communication indicates that it involves mainly alarm signals, courtship (mating song), piglets' calls to the sow and the dialogue between the sow and her litter during suckling (Jensen and Algers, 1982; Algers, 1984).

Agonistic behaviours mainly involve pressing, levering and attacks with or without bites.

Maternal behaviour may already be detectable before farrowing as a variation of social and feeding behaviour: the sow tries to withdraw, to build a nest and reduces food intake. Immediately after farrowing the sow eats the placenta and licks the piglets. Many of these actions cannot be performed by sows kept in individual farrowing cages, inside of which animals cannot turn over. In these conditions sows, especially gilts, may

show indifference towards piglets' calls, and the propensity to cannibalism is more frequent. The aggressive behaviour towards her litter of a sow kept in a restricted space is the most dramatic example of the links existing between stress and behaviour in swine (Jarvis *et al.*, 2004): such behaviours to a different extent depending on *noxae* and category, often result in a worsening of productive and reproductive parameters (Figure 2).

Also, alterations with respect to feeding behaviour are of importance for welfare evaluation; generally speaking, they include aggressive behaviours when group-housed pigs are kept under critical conditions (such as insufficient food supply or limited feeding space), and oral stereotypic behaviours (e.g. chewing) in individually housed sows which cannot satisfy their oral need (Brouns and Edwards, 1994; Turner *et al.*, 2002). This behaviour, as well as the majority of other stereotypes, can be reduced by supplying rooting materials, as described below (Tuytens, 2005).

Behavioural syndromes

Whatever the source of stress, the appearance of behavioural syndromes clearly indicates an unsatisfactory degree of animal welfare. As reported above, stereotypes have a great importance in pigs since their frequency is high. They are recognizable as repeated movements which seem to have no aim. Stereotypes generally appear in conditions such as lack of motivation, restriction and fighting; they may be seen as compensatory reactions to a lack of stimuli, as defence mechanisms by which the pig ceases its higher nervous functions, and as cathartic reactions to emotional tension or frustration.

Together with abnormal postures (the best known is the dog-sitting posture), stereotypes are included among somatic ab-

Figure 2. Main abnormal behaviours of pigs.

- Stereotypic behaviours (bar biting, vacuum chewing, continuous getting up and lying down movements, continuous scratching against the structures, floor scraping, rooting in the empty feeder, head shaking, drinker playing, polydipsia)
Main causes:
 - lack of stimuli
 - scarce food availability
 - food characteristics (fibre, energy, feeding system, particle size)
 - lack of enrichment materials

- Dog-sitting posture
Cause:
 - lack of stimuli

- Piglet crushing (sow; in farrowing cage it is considered a "technological incident")
Causes:
 - farrowing cage design
 - piglet's hypothermia
 - genetics

- Piglet savaging (sow)
Main causes:
 - milk production decrease
 - very precocious oestrus after farrowing
 - genetics

- Aggressiveness (group housed growing-fattening pigs/pregnant sows)
Causes:
 - lack of space
 - lack of feed
 - lack of enrichment materials

- Tail biting, ear biting and cannibalism (growing-fattening phase)
Causes:
 - multifactorial

- Dirtying out of the proper areas (growing-fattening phase)
Causes:
 - lack of space
 - pen design

normalities. Many of these are represented by abnormal feeding behaviours (vacuum chewing, bar biting, drinker playing, polydipsia, etc...), often linked to frustration of oral and feed-related needs.

Normal activities with abnormal intensity or lacking a biological aim are classified as reactive abnormalities. Examples of these are both excessive aggressiveness, which may lead to cannibalism, and apathy.

Critical points of intensive pig farming

To evaluate the level of animal welfare, the identification of the main critical points is of great importance. The latter are represented by structural elements and management system. Farmed pigs are usually managed at a high animal density in confined spaces; such situations hold a special importance in the investigation of abnormal behaviours. Structural elements can influence the indoor microclimate allowing the animals to be more or less comfortable. Management is responsible for social changes in the herd (e.g. the frequency of group-mixing, which causes hierarchy impairment and social discomfort). Among managerial factors, the qualitative level of the stockmen is also very effective as respects pig welfare, and includes both inner (aptitude) and acquired (courses attendance) traits. Public institutions (regions, countries) promote suitable courses, but the farm owner/manager is responsible for staff training.

Stressors, or factors which can cause stress, include all the variations of microclimate traits outside of the optimal ranges. Dust, odours and noises are without any doubt environmental stressors for intensively farmed pigs since they “are clearly irritating environmental agents whose complete absence, although impossible, would be preferable” (Scipioni, 2005).

Among the above-cited stressors, noise

is now receiving particular attention since its recent and innovative inclusion within the rules on pig protection. The DL 53/2004 states that continuous noises of 85 dB, as well as constant and sudden noises, must be avoided. Eighty-five dB is the intensity scheduled for “high traffic” (Ministry of Health, note 2005/3/2), and is the maximum intensity allowed for men working 8 hrs without protection (DL 494/96). Noises may come from different places and from different sources (Table 1). It is obvious to state that sudden noises must be avoided, including the acute vocalizations from frightened pigs; but it must be stressed that the sources of continuous noises, which cause continuous bother, must also be controlled (e.g. ventilation systems). As potential environmental stressors for animals (Otten *et al.*, 2004), noises are responsible for a wide range of productive and reproductive alterations in pigs. As shown in Table 2, the answer to excessive sound stimuli is often represented by an “alarm reaction” which produces higher heart frequency and blood glucocorticoids. Piglets exposed to 90 dB noises for an extended period showed muscle degeneration due to stress and exposure to strong and sudden noises (explosions) for a long time caused infertility and abortions in sows. In any case, sound intensity of 80 dB seems to be tolerated by sows without negative consequences (Bernier and Dietel, 1992).

A partial innovation of the recent legislation is also represented by the needs for intensity and duration of lighting. The rule requires a minimum of 8 hrs of light per day of at least 40 lux intensity, thus recognizing the pig as a mainly diurnal species. This rule is designed to curb the practice of keeping pigs in dim light as is done by some farmers in order to reduce fights and competition. This practice has been shown to be negative for pig welfare and lacks any docu-

Table 1. Sound intensity according to site and source.

	Range of sound intensity (dB)	Authors
Interested sites and phases:		
Farm (growing-fattening phase)	95-110	Owen, 1992
	69-78	Otten <i>et al.</i> , 2004
Farm (mounting room)	69-82	Algers <i>et al.</i> , 1978
Transport	91	Talling <i>et al.</i> , 1998
	88-96	Otten <i>et al.</i> , 2004
Waiting room at slaughtering plant	89-97	Talling <i>et al.</i> , 1998
	96	Lippmann <i>et al.</i> , 1999
Slaughtering plant	76-86	Talling <i>et al.</i> , 1998
	85-97	Otten <i>et al.</i> , 2004
Noise source:		
Fan	36-84	Algers <i>et al.</i> , 1978
	73	Talling <i>et al.</i> , 1998
Food mixer	72-74	Algers <i>et al.</i> , 1978
Food supplying	71-83	Algers <i>et al.</i> , 1978
Driver voices at slaughtering plant	107	Spensley <i>et al.</i> , 1994
Animals		
· normal activity	49-64	Algers <i>et al.</i> , 1978
· during food supplying:		
- automatic	70-77	Algers <i>et al.</i> , 1978
- manual	81-95	Algers <i>et al.</i> , 1978

mented effectiveness (Christison, 1996). Increasing the duration of the photophase improves the piglets' feed intake (Bruininx *et al.*, 2002) and, if an appropriate scotophase (minimum 8 hrs) is applied, it also reduces some abnormal behaviours of heavy pigs (Martelli *et al.*, 2005; Table 3). Also a light intensity higher than 20 lux has been shown to reduce abnormal behaviours (Mattiello *et al.*, 2004; experimental data obtained

by Martelli). Although pigs dislike light of high intensity (Taylor *et al.*, 2006), it can be stated that the majority of the studies agree on the effectiveness of keeping pigs in well-lighted places.

With respect to housing (primarily space allowance and floor type), the law takes into account growing pigs and boars, as well as sows and gilts. With respect to boars, according to the DL 534, full floor is manda-

Table 2. Effects caused by noises.

Piglets	90 dB for 10 d	muscle degeneration	Bond <i>et al.</i> , 1963
Piglets	85 to 95 dB	increase of heart rate (148 vs 133 beats/min)	Spensley <i>et al.</i> , 1994
Growing pigs	120 to 135 dB for 12 sec	increase of heart rate	Bond <i>et al.</i> , 1963
Growing pigs	120 dB (short exposition)	increase of plasma glucocorticoids	Kemper, 1976
Growing pigs	108 dB for 72 h	increase of plasma catecholamines; progressive decrease of plasma glucocorticoids	Kemper <i>et al.</i> , 1976
Growing pigs	80 to 85 dB fast music	lower performances vs control and slow music	Ekachat and Vajrabukka, 1994
Farrowing sows	80 dB for 3 min	tolerated	Berner and Dietel, 1992
Farrowing sows	95 dB	anxiety; increase of heart rate until 130-175 beats/min	Berner and Dietel, 1992
Sows	92 to 102 dB 7 explosions/d	infertility, abortions; decrease of piglets' growth rate (+30 d)	YongJun <i>et al.</i> , 1999

Table 3. The effects of the duration of the artificial photoperiod on the behaviour of heavy pigs (Martelli *et al.*, 2005).

		14L:10D (h/d) 70 lux	8L:16D (h/d) 70 lux	Significance level
Pigs	n	28	28	-
Initial body weight	kg	111.2	113.9	ns
Final body weight	"	163.1	157.5	P<0.1
Pigs' behaviour (percent of total surveys):				
Standing inactive		0.13	1.08	P<0.01
Sitting inactive (dog-sitting posture)		1.85	3.22	P<0.001
Lateral recumbency		69.56	67.77	ns
Sternal recumbency		15.38	13.00	P<0.01
Eating		3.69	3.32	ns
Drinking		0.19	0.09	ns
Bar biting or other		0.08	0.14	ns
Pawing at the floor		0.03	0.13	ns
Over sniffing/exploring the floor		7.55	10.00	P<0.001

L: light; D: darkness.

ns: not significant.

tory. On the other hand, full slatted floor is not allowed for gilts. In any case, the previous DL 534 had already nullified one of the main reasons for the use of this kind of floor, by recommending higher space allowances (Table 4).

Despite of recent recommendations of the EFSA Scientific Panel on Animal Health and Welfare (2005) on the suitability of a floor space allowance giving all pigs the possibility of lying down at the same time, present legislation makes no additional provision regarding space for pigs weighing more than 110 kg, such as Italian heavy pigs of 160 kg and more at slaughtering. The comparison between the allowance of 1 vs 1.3 m²/pig up to 160 kg live weight showed an increase in time devoted to resting (Martelli *et al.*, 2003; Table 5).

A strong link exists between feed management and abnormal behaviours. Among these the most common are linked to the lack of satisfaction of the oral and ingestive behaviours caused by the limited amount of feed allowed to some categories. Pregnant sows are the most significant example (Table 6) since their level of feed allowance must be restrained in order to avoid low performance in the subsequent lactation. The provision of manipulable materials (straw) and fibrous feeds, which can increase the sense of satiety without raising the energy content of the diet, are managerial and nutritional strategies able to significantly reduce the most common stereotypes, such as bar biting and vacuum chewing, occurring before and after feeding (Fraser, 1975; Robert *et al.*, 1993, 1997; Brouns *et al.* 1994; Spoolder *et al.*, 1995).

Furthermore, it is advisable to control access to feed in group-housed pregnant sows, to allow all animals to satisfy their nutritive needs. For this purpose division bars (e.g. partial barriers) can be placed in collective feeders or individual stalls to facili-

Table 4. Rules about the minimal available surface without distinction between growing pigs and sows (DL 534) and following integrations for sows and gilts (DL 53).

DL 534 (1992):	
average weight	m ² /head
≤10 kg	0.15
10 – 20 kg	0.20
20 – 30 kg	0.30
30 – 50 kg	0.40
50 – 85 kg	0.55
85 – 110 kg	0.65
>110 kg	1.00
barrows	6

DL 53 (2004):
gilts after insemination and sows are excluded from the minimal surfaces;
the surface must be 1.64 and 2.25 m²/head, respectively (+10% for groups <6 animals and -10% for groups of 40 animals and more); of these, at least 0.95 and 1.3 m² must be on full floor.

tate sow's approach and withdrawal and to reduce the competition for feed (Petherick *et al.*, 1987). In some cases an adequate period of training is necessary for animals to learn the use of electronic devices (Thomas and Signoret, 1989). Similar advice may be given for growing pigs which require a suitable feeder-space depending on body size allowing the contemporary access to food for all the members of a group.

With respect to lactating sows, the availability of liquid feed throughout the day, which results in a higher dry matter intake, can improve the sows' welfare as demonstrated by Scipioni *et al.* (2001 and 2005), who pointed out a reduction of vocalizations

Table 5. The effects of two floor space allowances on the behaviour of heavy pigs (115 to 160 kg LW) kept on slatted floor (Martelli *et al.*, 2003, mod.).

Floor space allowance		1 m ² /head	1.3 m ² /head	Significance level
Pigs	n	20	20	-
Final body weight	kg	159.3	162.7	ns
Pigs' behaviours (%):				
Standing		11.89	8.53	P<0.01
Sitting		2.22	2.26	ns
Lateral recumbency		73.86	77.71	P<0.04
Sternal recumbency		10.10	9.65	ns
Resting (lateral + sternal recumbencies)		83.96	87.36	P<0.01
Other behaviours		1.93	1.86	ns

ns: not significant.

Table 6. Effects of dietary fibre on pregnant sow behaviour (Robert *et al.*, 1993).

		Crude fibre 2.2%	Crude fibre 10.5%
Chain biting*	n	42.8	22.7
Chain biting*	min	93.3	39.8
Position changing	n	12.5	10.3

*= statistically significant difference among groups.

and stereotypes by means of videotaped and directly observed behaviours (Table 7).

Since animal welfare cannot exist without a good health status, feeding management must avoid all possible sources of organ damage, such as providing feeds without proper physical form (e.g. meals with a particle size that is too small), which can cause lesions of gastric mucosa (Potkins *et al.*, 1989).

In addition to feeding, drinking behaviour also plays a major role in swine welfare. According to current legislation all pigs over two weeks of age must have permanent access to a sufficient amount of fresh water.

Due to its wide array of metabolic functions, water should always be available *ad libitum* to dry-fed pigs. Special attention should be paid to the drinkers' efficiency, number and positioning, as well as to the physico-chemical properties of water (such as temperature, taste, flavour and Total Dissolved Solids – TDS). Although pigs seem to be fairly adaptable animals to low-quality drinking water (Sørensen *et al.*, 1994), unpalatable water can cause relative water deficiencies that can lead to various degrees of welfare impairment.

As a rule, recommended nipple water flow rates vary from 500 ml/min for starters

Table 7. Behavioural patterns (percentage of total observed behaviours) of sows either receiving *ad libitum* liquid feeding or dry feed twice a day (Scipioni *et al.*, 2005).

Behaviours	Feed frequency/feed type		Significance level
	<i>Ad libitum</i> /liquid	Twice a day/dry	
Standing	11.48	5.87	P<0.001
Sitting inactive	2.38	3.78	P<0.01
Sternal recumbency	12.07	12.04	ns
Lateral recumbency	46.17	54.03	P<0.01
Standing up	1.40	1.80	ns
Lying down	0.99	1.18	ns
Nursing	14.40	14.80	ns
Using the feeder	6.65	1.90	P<0.001
Drinking	0.12	0.16	ns
Bar biting	0	0.16	P<0.01
Others	4.34	4.28	ns

ns: not significant.

to 1000 ml/min and more for finisher pigs. Pigs usually adapt to a slow flow rate by increasing drinking time; on the other hand when the flow rate of drinkers is higher than the recommended level, pigs increase water spillage (Li *et al.*, 2005). With respect to the number of drinkers, providing one drinker per 20 animals (growers), kept in environmental controlled rooms, does not affect the diurnal spread of drinking or social behaviours and production parameters even when pigs are raised in large groups (60 pigs) (Turner *et al.*, 2000).

Finally, special attention should be given to fulfilling the need related to exploration. Along these lines current legislation states that pigs must have permanent access to a sufficient quantity of material to enable proper activities of investigation and manipulation. Comparing 74 enrichment objects, Van der Weerd *et al.* (2003) concluded that pigs prefer ingestible and destructible items (Table 8). More recently, Bracke *et al.*

(2006) concluded that straw and compound materials were the best enrichment elements, followed by rubber, wood, rope and roughage.

With the exception of not-rootable objects (e.g. chains), the practice of enriching the environment of pigs with manipulable materials is still fairly uncommon and this fact is mainly tied to problems arising from the negative impact that such materials may have on manure-removal systems.

Objective evaluation of pig welfare

The World Organisation for Animal Health (OIE, 2005) recently stated that a strong relationship exists between animal health and welfare, and consequently improving welfare often leads to better performance and safety of animal products. Man uses animals for profit, scientific aims and pleasure, thus improving his own welfare. In exchange, man must assure, from

Table 8. The top 10 most popular objects for grower pigs ranked according to object interaction and characteristics (Van de Weerd *et al.*, 2003, mod.).

Objects	Ingestible	Destructible	Contained	Not particulate	Not rootable	Object interaction(s)
Lavender straw with whole peanuts in box	1	1	1	0	0	9.3
Carrots hanging on string	1	1	0	1	1	6.4
Coconut halves hanging	1	1	0	1	1	6.0
Straw (long) in box	1	1	1	0	0	5.8
Swedes in box	1	1	1	1	0	5.8
Mushroom compost in box	1	1	1	0	0	5.4
Compost in box	1	1	1	0	0	5.1
Straw (chopped) in box	1	1	1	0	0	4.8
Sisal rope (hanging)	0	1	0	1	0	4.6
Paper (shredded) in box	1	1	1	0	0	4.5

an ethical point of view, the best available level of welfare to animals.

The scientific evaluation of animal welfare is a fast-progressing science, based on different indicators (pathological, emotional, physiological, behavioural, as well as immunological parameters) which should be considered in an integrated system. To assess the level of animal welfare, data obtained directly on animals (animal-based or encompassing performance or output criteria) should be preferred to structural ones (design or resource-based or derived from engineering or input criteria). Design criteria are frequently included in protocols for the certification of quality products (Main *et al.*, 2001) and they are easier to control. In any case, design criteria may be not flexible, and thus poorly adaptable to different farming conditions (e.g. local traditions), both for categories of animals and management (Regula *et al.*, 2004).

Welfare is multidimensional and so its assessment corresponds to a multicriteria

evaluation approach. From a general standpoint, the main animal-based criteria for pig welfare evaluation (Figure 3) are the following: recording of clear status of disease and performance impairment, specific clinical remarks (evaluation of faecal firmness, of respiratory frequency and depth, of nutritional status, of the efficiency of locomotor apparatus); monitoring of specific parts of the animal organism, to obtain knowledge of distress magnitude and origin; monitoring of peculiar behaviours; monitoring of haematological, haematochemical and hormonal parameters. Due to their cost, blood analyses cannot currently be regarded as routine surveys.

Among animal criteria, some body regions are very important to examine, since they may be possibly affected by injuries and proliferative processes caused by fighting or poor environmental conditions: ears, snout, shoulders, flanks, legs distal joints, toes, perineum and tail (Boyle *et al.*, 2000; Anil *et al.*, 2005; Cagienard *et al.*, 2005; Scott *et*

Figure 3. Main Animal Criteria and Design Criteria for the evaluation of pig welfare.

<p><i>Animal Criteria</i></p> <ul style="list-style-type: none"> • Health status • Productive performances • Haematological, haematochemical and hormonal traits • Behavioural traits • Body damage scores • Foot damage scores • Cleanliness scores • Anatomic-pathological findings <p><i>Design Criteria</i></p> <ul style="list-style-type: none"> • Possibility of social contacts (group farming) • Cleanliness and hygiene of the environment • Space availability • Water availability • Feeding (including elements affecting competition for food) • Presence of rooting material/other enrichment elements • Social stability of the group • Air quality • Functional subdivision of the areas (defecation, resting) • Thermal comfort • Resting area comfort • Noises • Lighting (duration and intensity)
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al., 2006). The wideness and severity of the lesions may also be evaluated (“body damage score”).

The strong correlation between floor type and foot health led to the “foot damage scores”, which take into account white line lesions, toe erosions, sole erosions and heel erosions (Smith and Morgan, 1997).

A further evaluation may be carried out for cleanliness of intensively kept pigs, measuring the proportion of clean skin on the whole body surface (Scott *et al.*, 2006).

As respects the recording of behaviour patterns as an indicator of welfare problems, we can confirm that which has already been described regarding behavioural syn-

dromes. It is important to emphasize that it is impossible to note an abnormal behaviour if the normal behaviour of the species and, within species, of the category under observation, is unknown. In this framework, boars and heavy pigs are the categories with the most limited amount of information.

Similar to the remarks of Fraser and Broom (1997), data obtained by Sardi and Martelli from various experiments (Table 9) show that the heavy pigs spend the largest part of the day, more than 19 hours, resting (in sternal and lateral recumbency), and their activity is mainly devoted to exploration (principally floor exploration), probably because of oral dissatisfaction due to re-

Table 9. Activities of heavy pigs throughout 24 hours*.

Activity	Day (06:00-18:00)	Night (18:00-06:00)
Lateral recumbency	5h 33'	11h 6'
Sternal recumbency	2h 53'	37'
Eating	46'	0'
Sitting	30'	4'
Standing inactive	19'	3'
Drinking	4'	<1'
Walking	7'	2'
Rooting the floor	1h 40'	6'
Other**	7'	<1'

*Data obtained by Sardi and Martelli from various experiments (remarks on 200 pigs -100 to 160 kg LW- kept in small groups on fully slatted floor).

**Structures biting, fighting, changing position.

stricted feeding and/or to the lack of rooting materials in animals kept on slatted floors.

In blood, morphological alterations as neutrophils/lymphocytes ratio, caused by acute stress and tied to the cortisol level, may be observed (Mc Glone *et al.*, 1993; Stull *et al.*, 1999), as well as some modifications of acute phase proteins generally occurring under diseased (inflammatory processes) conditions (Petersen *et al.*, 2002; Murata *et al.*, 2004). With respect to blood cortisol, non-harmful estimations, such as saliva and faecal metabolites, should be preferred because they avoid sampling-related stress (Anil *et al.*, 2005).

Within the framework of animal-based criteria, anatomic and pathological observations at slaughtering may be carried out to investigate the frequency and severity of hyperparakeratosis and gastric ulcers (Potkins *et al.*, 1989), osteochondrosis of the limbs (Slevin *et al.*, 2001), and lung and pericardium inflammatory processes (Scott *et al.*, 2006). It seems right to note that some anatomic and pathological investigations may be considered as routine surveys at the slaugh-

ter house, whilst other *post-mortem* remarks, such as the observation of the gastric mucosa, which entails the opening of abdominal viscera with a negative impact on slaughtering hygiene, are more difficult to achieve.

The design criteria include the structural, environmental and managerial elements, directly controlled by man, that can affect animal welfare through the reaction of single individuals.

A peculiar relevance for pig welfare is attributed nowadays to the following structural and managerial elements: space allowance, subdivision in functional areas, floor type, food accessibility, water availability, availability of rooting material, cleanliness, anti-crushing equipment for piglets, efficiency of the equipment to control temperature and ventilation systems, possibility of social contacts, and management that encourages a stable hierarchy (Bracke *et al.*, 2002a, 2002b; Knierim *et al.*, 2003).

The "IPPC directive" (96/61) on environmental pollution prevention and control has recently become operative. With respect to the sustainability of pig farming, it seems

right to hope that building criteria limiting the environmental impact of slurry and ammonia output, with consequent improvement of the microclimate traits of piggeries, are applied.

Thus, profitable integration of animal-based and design criteria seems to be the most effective line for devising protocols for the on-farm evaluation of pig welfare (Figure 4).

Outdoor, organic and extensive pig farming

In recent years interest in “alternative” pig farming systems (“animal-friendly,” “low-input,” etc..) has grown, thanks to increasing interest in more natural management systems, resulting in lower impact on the environment and lower costs of investment.

The extensive farming, which may be organic or not, involves a maximum of ABU/hectare/year equivalent to the output of 170 kg of nitrogen/hectare/year. For pigs, this is equal to 8.4 sows or 12.6 heavy pigs or 84.3 piglets (Emilia Romagna Regional Council, 2003). Outdoor farming is not properly considered an extensive rearing system since it just involves the use of simple structures for shelter in wide open spaces. Organic farm-

ing also involves open spaces, and the well known limitations on feeding and therapeutic treatments.

For the study of animal welfare in these types of farming, beside the observation of the normal biological functions of the pigs (functional approach), the natural approach is useful as it takes into account the possibility of expression of the natural/instinctive behaviour of the species. In natural-like conditions pigs, and especially sows, express a series of instinctive and species-typical behaviours not allowed in indoor rearing, leading to a higher level of animal welfare. These include looking for materials for nest building, rooting, wallowing, resting out of the shelters, walking, etc...

Some typically farming-induced diseases, such as respiratory and gastro-enteric syndromes, show lower incidence (FAWC, 1996; Hansson *et al.*, 2000; Guy *et al.*, 2002; EFSA, 2007).

Some microclimate components, such as noises, odours, harmful gases, artificial light control, dust, improper ventilation or humidity, which in intensive farming cause irritation or diseases, are normally absent.

Nevertheless, outdoor farming entails a series of new problems, and after such a

Figure 4. Proposal of elements suitable to be included in protocols for an integrated evaluation of pig welfare.

- Check for respect of “Five Freedoms”*
- Check of health status
- Check of productive and reproductive efficiency
- Occurrence of abnormal behaviours
- Body and Foot Damage Scores
- Evaluation of structural traits** and of micro-climate traits (see design criteria)
- Evaluation of workers’ level of training
- Possible non-invasive evaluation of cortisol level
- Possible anatomo-pathological remarks, easily feasible at slaughtering

*Including the possibility of expressing the specific behaviours of every productive category.

**The evaluation includes the system for slurries removal according to IPPC Directive.

Table 10. Productive data from an outdoor sow farm, divided for monitored year and season (Volpelli, 2001).

	Farrowings no.	Newborn piglets/litter no.	Mortality %	Weaned piglets /litter no.	Farrowing interval days
1 st year	214	10.0 ^{ab}	23.0 ^b	7.5	163
2 nd year	179	10.4 ^a	29.5 ^a	7.4	164
3 rd year	102	9.4 ^{bc}	18.3 ^{bc}	7.6	171
4 th year	56	8.8 ^c	15.1 ^c	7.6	161
Winter	329	9.8	25.7 ^a	7.3	161
Summer	222	10.0	20.1 ^b	7.8	170

On the same column: a, b, c = $P < 0.05$.

long period of indoor farming both animals and man may not cope well with them (Algers, 1994).

First of all, there is exposure to extreme climatic conditions (cold and heat), which is only partially lessened by means of shelters and various measures (Millet *et al.*, 2005). Pigs have great difficulty adapting to both low and high temperatures, especially modern and genetically improved genotypes, which in the majority of cases have white bristles and pink skin, and are therefore very sensitive to direct exposure to the sun.

Climate is actually the main factor responsible for the high incidence of newborn mortality and for the low indexes of fertility which are often reported for outdoor farming (Le Denmat *et al.*, 1995; Guégen *et al.*, 2000; Waller and Bilkei, 2002; Akos and Bilkei, 2004). Furthermore, the reports from researchers in Italy and other countries emphasize the great variability as respects the productivity of outdoor farms, since it is greatly affected, more so than for indoor farms, by the stockman's ability and experience. Above all, it is strongly affected by the environment and climate (Mortensen *et al.*, 1994; Berger *et al.*, 1997; Bertacchini, 1997; Carazzolo *et al.*, 1999; Volpelli, 2001; Honeyman, 2005) (Table 10).

Besides this, and without contradicting that which has been reported above about the lower incidence of some diseases, outdoor farming may facilitate the outbreak of other pathologies: first of all, parasitic diseases, from the forms affecting the skin to the wide series of worm diseases (Nansen and Roepstorff, 1999; Damm *et al.*, 2003; Kouba, 2003; Millet *et al.*, 2005); limps and arthritis, due to walking on rough grounds and to prolonged contact with damp ground (Hansson *et al.*, 2000); poisoning from vegetal sources (Martelli, 2002); predation (from mice, foxes, etc.).

It must be stressed that a portion of these problems is typical of these farming systems, and consequently unavoidable, but another portion of problems may be significantly lessened by proper management (Millet *et al.*, 2005), which should include specific training, choice of suitable genetic types, choice of proper grounds (type and position) and of proper equipment.

Conclusions

Intensive pig farming is a quite complex system including distinct forms, which deeply vary depending on animal category.

ries, and characterized by different needs and types of management. The current legislation which guarantees swine protection indicates specific environmental and managerial attributes which vary according to animal age and productive destination.

In farming practice, only sows and boars (especially the former) undergo routine individual estimations of productivity (e.g. calculation of yearly output of piglets) which may be related to the level of individual welfare. Regarding the relationship between productivity and welfare, it is important to bear in mind that, if it is true that when we observe a decrease in performance a subsequent state of discomfort is generally present, it is equally true that a high level of productivity is not necessarily accompanied by a satisfactory level of welfare. Thus, the drawing of an opinion about the welfare of sows should include, together with the productivity indexes, other observations, mainly ethological in nature, since sows are, among the different categories of pigs, those which more frequently demonstrate behavioural syndromes.

After the post-weaning phase, the estimation of productivity in growing-fattening pigs is merely collective, and it is well

known that differences in weight gain, even strong in value, may occur in a lot of pigs. Such differences may not be easily perceived, since the total sum, e.g. weight of the lot, can hide the individual effects. Among other elements, falling within the set of the widely recognized and accepted design and animal criteria, special attention should be paid to monitoring the health status of growing-finishing pigs. This goal can be easily achieved by checking the frequency and the type of therapeutic interventions as well as by recording at slaughtering the prevalence of specific lesions, such as skin, foot, thoracic viscera and liver lesions, which can be detected as routine along the slaughtering chain.

Also, with respect to the evaluation of the welfare level of outdoor/extensively raised pigs, special attention should be paid to their health status with particular regard to "outdoor-related" pathologies such as worm infections, predation and sunburn.

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REFERENCES

- Akos, K., Bilkei, G., 2004. Comparison of the reproductive performance of sows kept outdoors in Croatia with that of sows kept indoors. *Livest. Prod. Sci.* 85:293-298.
- Algers, B., 1984. Acoustic communication during suckling in the pig. Influence of continuous noise. pp 105-107 in: G. van Putten and K. Zeeb (eds.) *Proc. Int. Congr. on Applied Ethology in Farm Animals*, Kiel, Germany.
- Algers, B., 1994. Health, behaviour and welfare of outdoor pigs. *Pig News Inf.* 15:113N-115N.
- Algers, B., Ekesbo, I., Stromberg, S., 1978. Noise measurements in farm animal environments. *Acta Vet. Scand.* 68 (suppl.):1-19.
- Anil, L., Anil, S.S., Deen, J., Baidoo, S.K., Wheaton, J.E., 2005. Evaluation of well-being, productivity, and longevity of pregnant sows housed in groups in pens with an electronic sow feeder or separately in gestation stalls. *Am. J. Vet. Res.* 66: 1630-1638.
- Appleby, M.C., 1996. Can we extrapolate from intensive to extensive conditions? *Appl. Anim. Behav. Sci.* 49: 23-28.
- Berger, F., Dagorn, J., Le Denmat, M., Quillien, J.P.

- Vaudelet, J.C., Signoret, J.P., 1997. Perinatal losses in outdoor pig breeding. A survey of factors influencing piglet mortality. *Ann. Zootech.* 46:321-329.
- Berner, H., Dietel, M., 1992. Effect of noise on the course of farrowing. *Tierärztliche Umschau* 47:549-556.
- Bertacchini, F., 1997. Suini all'aperto. L'esperienza inglese e francese. *Professione Allevatore* 9:79-82.
- Bond, J., Winchester, C.F., Campbell, L.E., Webb, J.C., 1963. Effects of loud sounds on the physiology and behaviour of swine. US Dept. Agric., USDA-ARS Tech. Bull. N. 1280.
- Boyle, L.A., Leonard, F.C., Lynch, P.B., Brophy, P., 2000. Influence of housing system during gestation on behaviour and welfare of gilts in farrowing crates. *Anim. Sci.* 71:561-570.
- Bracke, M.B.M., Spruijt, B.M., Metz, J.H.M., Schouten, W.G.P., 2002a. Decision support system for overall welfare assessment in pregnant sows. A: model structure and weighting procedure. *J. Anim. Sci.* 80:1819-1834.
- Bracke, M.B.M., Spruijt, B.M., Metz, J.H.M., Schouten, W.G.P., 2002b. Decision support system for overall welfare assessment in pregnant sows. B: validation by experts opinion. *J. Anim. Sci.* 80:1835-1845.
- Bracke, M.B.M., Zonderland, J., Lenskens, P., Schouten, W.G.P., Vermeer, H., Spoolder, H.A.M., Hendriks, H.J.M., Hopster, H., 2006. Formalised review of environmental enrichment for pigs in relation to political decision making. *Appl. Anim. Behav. Sci.* 98: 165-182.
- Brambell, F.W.R., 1965. Report of the Technical Committee to Enquire into the Welfare of Animals Kept under Intensive Livestock Husbandry Systems. Her Majesty's Stationery Office, London, UK, Cmnd. 2836.
- Brouns, F., Edwards, S.A., 1994. Social rank and feeding behaviour of group-housed sows fed competitively or *ad libitum*. *Appl. Anim. Behav. Sci.* 39: 225-235.
- Brouns, F., Edwards, S.A., English, P.R., 1994. Effects of dietary fibre and feeding system on activity and oral behaviour of group-housed gilts. *Appl. Anim. Behav. Sci.* 39:215-223.
- Bruininx, E.M.A.M., Heetkamp, M.J.W., Van den Bogaart, D., Van der Peet-Schwing, C.M.C., Beynen, A.C., Everts, H., Den Hartog, L.A., Schrama, J.W., 2002. A prolonged photoperiod improves feed intake and energy metabolism of weanling pigs. *J. Anim. Sci.* 80:1736-1745.
- Cagienard, A., Regula, G., Danuser, J., 2005. The impact of different housing systems on health and welfare of grower and finisher pigs in Switzerland. *Prev. Vet. Med.* 68:49-61.
- Carazzolo, A., Chiericato, G.M., Rongaudio, R., 1999. Preliminary observations on outdoor sow breeding. pp 567-569 in F. Angeli (ed.) *Proc. 13th Nat. Congr. ASPA, Piacenza, Italy.*
- Christison, G.I., 1996. Dim light does not reduce fighting or wounding of newly mixed pigs at weaning. *Can. J. Anim. Sci.* 76:141-143.
- Damm, B.I., Pedersen, L.J., Jessen, L.B., Thamsborg, S.M., Mejer, H., Ersbøll, A.K., 2003. The gradual weaning process in outdoor sows and piglets in relation to nematode infections. *Appl. Anim. Behav. Sci.* 82:101-120.
- Ekachat, K., Vajrabukka, C., 1994. Effect of music rhythm on growth performance of growing pigs. *Kasetsart J. Nat. Sci.* 28:640-643.
- Emilia Romagna (Italy) Regional Council, 2003. Resolution of 5 May 2003 concerning the rules for the application of the Council Regulation (EEC) No. 2092/91 and of the Council Regulation (EEC) No. 1804/99, exclusively for the parts concerning the methods of organic production and transformation of agricultural products in animal rearing. No. 2003/794. In: B.U. No. 98 of 09.07.2003.
- European Food Safety Authority, 2005. Opinion of the Scientific Panel on Animal Health and Welfare on a request from the Commission related to welfare of weaners and rearing pigs: effects of different space allowances and floor types. *The EFSA Journal* 268: 1-19. In: http://www.efsa.europa.eu/en/science/ahaw/ahaw_opinions/1203.html
- European Food Safety Authority, 2007. Factors affecting pig welfare. pp 23-55 in: *Scientific report*

- on animal health and welfare in fattening pigs in relation to housing and husbandry. Annex to the EFSA Journal, 564:1-14. In: http://www.efsa.europa.eu/EFSA/Scientific_Opinion/ahaw_report_pig_welfare_fattening_en,1.pdf
- Ewbank, R., Meese, G.B., 1974. Individual recognition and the dominance hierarchy in the domesticated pig. The role of sight. *Anim. Behav.* 22:473-480.
- Farm Animal Welfare Council, 1993. Second report on priorities for research and development in farm animal welfare. MAFF Publ., Tolworth, UK, PB 1310: 3-4.
- Farm Animal Welfare Council, 1996. Report on the welfare of pigs kept outdoors. Home page address: <http://www.fawc.org.uk/reports/pigs/fawcptoc.htm>
- Fraser, D., 1975. The effect of straw on the behaviour of sows in tether stalls. *Anim. Prod.* 21:59-68.
- Fraser, A.F., Broom, D.M., 1997. Farm animal behaviour and welfare. CABI Publishing, CAB International, Wallingford, UK.
- Friend, D.W., Cunningham, H.M., Nicholson, J.W.G., 1962. The duration of farrowing in relation to the reproductive performance of Yorkshire sows. *Can. J. Comp. Med. Vet. Sci.* 16:127-130.
- Guégen, R., Quillien, J.P., Meunier-Salaún, M.C., Salaún, C., Callarec, J., 2000. Incidence du système de logement et de la saison sur la survie néonatale des porcelets. *Journ. Rech. Porcine en France*, 32:123-128.
- Guy, J.H., Rowlinson, P., Chadwick, J.R., Ellis, M., 2002. Health conditions of two genotypes of growing-finishing pig in three different housing systems: implications for welfare. *Livest. Prod. Sci.* 75:233-243.
- Hansson, I., Hamilton, C., Ekman, T., Forslund, K., 2000. Carcass quality in certified organic production compared with conventional livestock production. *J. Vet. Med.* 47:111-120.
- Honeyman, M.S., 2005. Extensive bedded indoor and outdoor pig production systems in USA: current trends and effects on animal care and product quality. *Livest. Prod. Sci.* 94:15-24.
- Jarvis, S., Reed B.T., Lawrence, A.B., Calvert, S.K., Stevenson, J., 2004. Peri-natal environmental effects on maternal behaviour, pituitary and adrenal activation, and the progress of parturition in the primiparous sow. *Anim. Welfare* 13: 171-181.
- Jensen, P., Algers, B., 1982. An ethogram of piglet vocalizations during suckling. *Appl. Anim. Ethol.* 11:237-248.
- Kemper, A., 1976. Der verlauf der plasmakonzentrationen an katecholaminen und kortikosteroiden sowie des plasmabundenen jods (PBJ) bei schweinen unter einwirkung von geräuschen bei verschiedenen haltungsformen. *Arch. Exp. Vet. Med.* 30:309-315.
- Kemper, A., Wildenhahn, V., Lyhs, L., 1976. Die einwirkung lang anhaltender geräusche auf die plasmakonzentration an katecholaminen, glukokortikosteroiden und PBJ bei schweinen. *Arch. Exp. Vet. Med.* 30:619-625.
- Knierim, U., Hesse, D., Von Borrel, E., Herrmann, H.J., Muller, C., Rauch, H.W., Sachser, N., Zerbe, F., 2003. Voluntary animal welfare assessment of mass-produced farm animal housing equipment using a standardised procedure. *Anim. Welfare* 12:75-84.
- Kouba, M., 2003. Quality of organic animal products. *Livest. Prod. Sci.* 80:33-40.
- Le Denmat, M., Dagorn, A., Aumaitre, A., Vaudelet, J.C., 1995. Outdoor pig breeding in France. *Pig News Inf.* 16:13N-16N.
- Li, Y.Z., Chénard, L., Lemay, S.P., Gonyou, H.W. 2005. Water intake and wastage at nipple drinkers by growing finishing pigs. *J. Anim. Sci.* 83: 1413-1422.
- Lippmann, J., Schaffer, D., Laube, R.B., 1999. Noise at slaughter plants – Behavioural adaptation of slaughter pigs to different noise situations. *KTBL Schrift* 382: 181-188.
- Main, D.C., Webster, A.J.F., Green, L.E., 2001. Animal Welfare Assessment in farm assurance schemes. *Acta Agr. Scand.* 51(suppl.30): 108-113.
- Martelli, G., 2002. Intossicazioni alimentari del suino da composti inorganici ed organici. pp 67-85 in: Proc. 28th Ann. Meet. SIPAS, Round table on Feed poisoning of pigs, Piacenza, Italy.
- Martelli, G., Scipioni, R., Parisini, P., Badiani, A., Sardi, L., 2003. The effects of two floor space al-

- lowances on meat quality and behaviour of heavy pigs. Proc. 54th Ann. Meet. EAAAP, Roma, Italy, Wageningen Pers, Book of Abstracts no. 9: 178 (Poster CMNSI.27).
- Martelli, G., Scipioni, R., Scalabrin, M., Sardi, L., 2005. Effects of the length of the artificial photoperiod on growing parameters and behaviour of heavy pigs. *Vet. Res. Comm.* 29:367-369.
- Mattiello, S., Heinzl, E., Abruzzese, C., Carezzi, C., 2004. Effetto dell'intensità di illuminazione sul benessere del suino pesante in due differenti sistemi stabulativi. *Riv. Suinicolt.* 45(10):143-149.
- McGlone, J.J., Nicholson, R.I., Hellman, J.M., Herzog, D.N., 1993. The development of pain in young pigs associated with castration and attempts to prevent castration-induced behavioural changes. *J. Anim. Sci.* 71:1441-1446.
- Meese, G.B., Conner, D.J., Baldwin, B.A., 1975. Ability of the pig to distinguish between conspecific urine samples using olfaction. *Physiol. Behav.* 15:121-125.
- Millet, S., Moons, C.P.H., Van Oeckel, M.J., Janssens, G.P.J., 2005. Welfare, performance and meat quality of fattening pigs in alternative housing and management systems: a review. *J. Sci. Food Agric.* 85:709-719.
- Mortensen, B., Ruby, V., Pedersen, B.K., Smidth, J., Larsen, V.A., 1994. Outdoor pig production in Denmark. *Pig News Inf.* 15:117N-120N.
- Murata, H., Shimada, N., Yoshioka, M., 2004. Current research on acute phase protein in veterinary diagnosis: an overview. *Vet. J.* 168:28-40.
- Nansen, P., Roepstorff, A., 1999. Parasitic helminths of the pig: factors influencing transmission and infection levels. *Int. J. Parasitol.* 29:877-891.
- OIE - World Organisation for Animal Health, 2005. Terrestrial Animal Health Code 2005. Appendix 3.7.1. Introduction to guidelines for animal welfare. Home page address: <http://www.oie.int/>
- Otten, W., Kanitz, E., Puppe, B., Tuchsherer M., Brüssow, K.P., Nürnberg, G., Stabenow, B., 2004. Acute and long term effects of chronic intermittent noise stress on hypothalamic-pituitary-adrenocortical and sympatho-adrenomedullary axis in pigs. *Anim. Sci.* 78:271-283.
- Owen, G., 1992. Dangerous bacon. *Occup. Health Rev.* 38: 32 (abstr.).
- Petersen, H.H., Dideriksen, D., Christiansen, B.M., Nielsen, J.P., 2002. Serum haptoglobin concentration as a marker of clinical signs in finishing pigs. *Vet. Rec.* 151:85-89.
- Petherick, J.C., Bodero, D.A., Blackshaw, J.K., 1987. The use of partial barriers along the feed trough in a group housing system for non-lactating sows. *Farm Build. Eng.* 4:32-36.
- Potkins, Z.V., Lawrence, T.L.J., Thomlinson, J.R., 1989. Oesophagogastric parakeratosis in the growing pig: effect of the physical form of barley-based diets and added fibre. *Res. Vet. Sci.* 47:60-67.
- Regula, G., Danuser, J., Spycher, B., Wechsler, B., 2004. Health and welfare of dairy cows in different husbandry systems in Switzerland. *Prev. Vet. Med.* 66:247-264.
- Robert, S., Matte, J.J., Farmer, C., Givand, C.L., Martineau, G.P., 1993. High-fibre diets for sows: effects on stereotypes and adjunctive drinking. *Appl. Anim. Behav. Sci.* 37:297-309.
- Robert, S., Rushen, J., Farmer, C., 1997. Both energy content and bulk of food affect stereotypic behaviour, heart rate and feeding motivation of female pigs. *Appl. Anim. Behav. Sci.* 54:161-171.
- Scipioni, R., 2005. Stressor ambientali e benessere animale. In: L. Alborali and M. De Cillà (eds.) Proc. 28th Course on Swine Pathology and Production. Fondaz. Iniziative Zooprof. Zoot. Publ., Brescia, Italy, 60:25-41.
- Scipioni, R., Martelli, G., Paganelli, R., Sardi, L., 2005. The behaviour of the lactating sow as affected by two different feeding techniques. *Vet. Res. Comm.* 29: 383-385.
- Scipioni, R., Martelli, G., Sardi, L., Parisini, P., 2001. Behaviour of lactating sows and litters in relation to the feeding system of the sows. pp 323-325 in Proc. 14th Nat. Congr. ASPA, Firenze, Italy.
- Scott, K., Chennels, D.J., Campbell, F.M., Hunt, B., Armstrong, D., Taylor, L., Gill, B.P., Edwards, S.A., 2006. The welfare of finishing pigs in two contrasting housing systems: fully slatted versus straw-bedded accommodation. *Livest. Sci.* 103: 104-115.

- Slevin, J., Wiseman, J., Parry, M., Walker, R.M., 2001. Effect of protein nutrition on bone strength and incidence of osteochondrosis. Page 11 in Proc. Ann. Meet. Brit. Soc. Anim. Sci., York, UK.
- Smith, B., Morgan, M., 1997. The role played by the floor surface in the development of claw lesions in the pig. Project report, SAC Veterinary Science Division. Scottish Agricultural College ed., Aberdeen, UK.
- Sørensen, M.T., Jensen, B.B., Poulsen, I.D., 1994. Nitrate and pig manure in drinking water to early weaned piglets and growing pigs. *Livest. Prod. Sci.* 39: 223-227.
- Spensley, J.C., Lines, J.A., Hartung, J., Waran, N.K., 1994. The effect of noise on individual piglets. *Appl. Anim. Behav. Sci.* 41:278 (abstr.).
- Spoolder, H.A.M., Burbidge, J.A., Edwards, S.A., Simmins, P.H., Lawrence, A.B., 1995. Provision of straw as a foraging substrate reduces the development of excessive chain and bar manipulation in food restricted sows. *Appl. Anim. Behav. Sci.* 43:249-262.
- Stull, C.L., Kachulis, C.J., Farley, J.L., Koenig, G.J., 1999. The effect of age and teat order on alpha1-glycoprotein, neutrophil-to-lymphocyte ratio, cortisol, and average daily gain in commercial growing pigs. *J. Anim. Sci.* 77:70-74.
- Talling, J.C., Lines, J.A., Wathes, C.M., Waran, N.K., 1998. The acoustic environment of the domestic pig. *J. Agr. Eng. Res.* 71: 1-12.
- Taylor, N., Prescott, N., Perry, G., Potter, M., Le Sueur, C., Wathes, C., 2006. Preference of growing pigs for illuminance. *Appl. Anim. Behav. Sci.* 96:19-31.
- Thomas, C., Signoret, J.P., 1989. Apprentissage de l'utilisation d'un système de libre service alimentaire par un groupe de truies gestantes: rôle des facteurs individuels et sociaux. *Journ. Rech. Porcine en France* 21: 297-300.
- Turner, S.P., Dahlgren, M., Arey, D.S., Edwards, S.A., 2002. Effect of social group size and initial live weight on feeder space requirement of growing given food ad libitum. *Anim. Sci.* 75: 75-83.
- Turner, S.P., Sinclair, A.G., Edwards, S.A., 2000. The interaction of liveweight and the degree of competition on drinking behaviour in growing pigs at different group sizes. *Appl. Anim. Behav. Sci.* 67: 321-334.
- Tuytens, F.A.M., 2005. The importance of straw for pigs and cattle welfare. *Appl. Anim. Behav. Sci.* 92: 261-282.
- Van de Weerd, H.A., Docking, C.M., Day, J.E.L., Breuer, K., Edwards, S.A. 2003. Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. *Appl. Anim. Behav. Sci.* 99: 230-247.
- Volpelli, L.A., 2001. Esperienze di allevamento di scrofe all'aperto. pp 147-161 (vol. I) in Proc. 26th Int. Symp. of Animal Production, Portonovo (AN), Italy.
- Waller, C.M., Bilkei, G., 2002. Effect of mating frequency on sow reproductive performance under field conditions and natural mating in large outdoor production units. *Reprod. Dom. Anim.* 37:116-118.
- YongJun, K., MoonHee, J., JeongGon, C., MyoungSoon, K., 1999. Investigation of the causes of abortion and infertility in the swine after consecutive detonation into base rock and use of heavy equipment. *Korean J. Vet. Clin. Med.* 16:381-388.

