Review of Production, Husbandry and Sustainability of Free-range Pig Production Systems

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ABSTRACT : A review was undertaken to obtain information on the sustainability of pig free-range production systems including the management, performance and health of pigs in the system. Modern outdoor rearing systems requires simple portable and flexible housing with low cost fencing. Local pig breeds and outdoor-adapted breeds for certain environment are generally more suitable for free-range systems. Free-range farms should be located in a low rainfall area and paddocks should be relatively flat, with light topsoil overlying free-draining subsoil with the absence of sharp stones that can cause foot damage. Huts or shelters are crucial for protecting pigs from direct sun burn and heat stress, especially when shade from trees and other facilities is not available. Pigs commonly graze on strip pastures and are rotated between paddocks. The zones of thermal comfort for the sow and piglet differ markedly; between 12-22°C for the sow and 30-37°C for piglets. Offering wallows for free-range pigs meets their behavioural requirements, and also overcomes the effects of high ambient temperatures on feed intake. Pigs can increase their evaporative heat loss via an increase in the proportion of wet skin by using a wallow, or through water drips and spray. Mud from wallows can also coat the skin of pigs, preventing sunburn. Under grazing conditions, it is difficult to control the fibre intake of pigs although a high energy, low fibre diet can be used. In some countries outdoor sows are fitted with nose rings to prevent them from uprooting the grass. This reduces nutrient leaching of the land due to less rooting. In general, free-range pigs have a higher mortality compared to intensively housed pigs. Many factors can contribute to the death of the piglet including crushing, disease, heat stress and poor nutrition. With successful management, free-range pigs can have similar production to door pigs, although the growth rate of the litters is affected by season. Piglets grow quicker indoors during the cold season compared to outdoor systems. Pigs reared outdoors show calmer behaviour. Aggressive interactions during feeding are lower compared to indoor pigs while outdoor sows are more active than indoor sows. Outdoor pigs have a higher parasite burden, which increases the nutrient requirement for maintenance and reduces their feed utilization efficiency. Parasite infections in free-range pigs also risks the image of free-range pork as a clean and safe product. Diseases can be controlled to a certain degree by grazing management. Frequent rotation is required although most farmers are keeping their pigs for a longer period before rotating. The concept of using pasture species to minimise nematode infections in grazing pigs looks promising. Plants that can be grown locally and used as part of the normal feeding regime are most likely to be acceptable to farmers, particularly organic farmers. However, one of the key concerns from the public for free-range pig production system is the impact on the environment. In the past, the pigs were held in the same paddock at a high stocking rate, which resulted in damage to the vegetation, nutrient loading in the soil, nitrate leaching and gas emission. To avoid this, outdoor pigs should be integrated in the cropping pasture system, the stock should be mobile and stocking rate related to the amount of feed given to the animals. ***(Asian-Aust. J. Anim. Sci. 2004. Vol 17, No. 11 : 1615-1634)***

Key Words : Free-range Pig, Sustainability, Production, Management, Husbandry

INTRODUCTION

Recently there has been commercial interest in the pork products originating from natural animal production systems because consumers have become more interested in buying products from animal that are kept in welfare friendly systems. Intensive pig farming is considered to compromise the welfare of the pigs and there is a perception that there is widespread use of synthetic chemicals (e.g. medication and growth promoters) in the feed (Barton-Gade, 2002). The concern for animal welfare, the high capital cost of intensive pig production and the increasing demand for organic pork has put pressure on the pig industry to develop systems which enable the pigs to behave naturally (Petersen et al., 1995; De Jonge et al., 1996). As a result there has been an increasing search for simpler, less capital-intensive systems for the production of pork under ecologically, sustainable non-intensive conditions.

Free-range pig production systems has been included as one of the main targets for the European and North American pork industries (Sather et al., 1997). It is believed that pigs under this system can express their natural behaviour in a free-range environment. Free-range pork has superior taste compared to pork produced in intensive condition and has health benefits for humans due to the increased total n-3 and n-6 polyunsaturated fatty acids (PUFA) of neutral lipids and total n-3 of polar lipids (Simopoulos, 1991; Muriel et al., 2002). These polyunsaturated fatty acids are essential for growth and development in humans (Simopoulos, 1991). With these advantages, the number of pigs kept outdoors has increased

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dramatically in the last 20 years. For example, 25% of the breeding sows are kept outdoors in the UK (Sheppard, 1998). The number of free-range pig farms in France increased from 209 in 1984 to 1608 in 1994. In Australia there is an increasing trend to keep sows outdoor and to grow pigs in straw-based shelters (Henschke, 1999). The use of low cost eco-shelters and electric fencing has resulted in an increase in outdoor pig production (Dagorn et al., 1996) and reduced behavioural disturbances, especially during parturition in sows (Andresen and Redbo, 1999). However, a successful free-range production system requires producers to have suitable pig breeds and sound knowledge of management. As a result, the purpose of this review is to describe the free-range production systems currently been used including the breeds, pig management, performance, disease problems and sustainability of free-range systems.

DESCRIPTION OF PRODUCTION SYSTEMS

From an animal welfare point of view, the free-range system is the preferred option. The system of outdoor rearing was traditionally thought to involve high labour, low cost, and low management. Modern outdoor rearing system requires simple, portable housing, watering systems and feeders. Pigs and huts are moved with a tractor, loader, hydraulic cart, or all-terrain vehicle. Low cost, portable electric fencing works well. Structures are dispersed over several acres, and animals distribute manure naturally. Straw and corn stalks can serve as bedding. However, there are different systems for pigs at different physiological stages. The following outdoor production systems are used in Europe.

Growers

The growers are housed in semi-intensive conditions in large covered yards or pens with straw bedding. The piglets are kept outdoors for less than four weeks. Approximately 50% of outdoor bred piglets are transferred to intensive units for finishing. Growers are finished (slaughtered) at about 22 weeks, when they reach a weight of about 95 kg (Baker, 2002).

Breeders

Once the gilts have been artificially inseminated (AI) in indoor pens, they are moved to outdoors in small groups in mobile arcs with access to mud wallows, essential in the summer to help the sows keep cool. A week before farrowing they are transferred to individual outdoor grassy paddocks with insulated arcs with abundant straw bedding. The whole operation falls within the farm's rotational system. Piglets are weaned at 24 days at which point the sows go back into the shed and the cycle starts again. The sows are re-served, stay indoors for four weeks before going back into the fields. Pasture farrowers typically stock 7 to 15 sows and litters per acre. When a sow has 6 to 8 litters, at around four to five years old, it is sold and slaughtered (Baker, 2002).

In Europe, the system involves outdoor fenced paddocks holding groups of sows. At around 15-25 sows per hectare, the stocking density is equivalent to a minimum of 40 sows, a very much lower density than the 1.5 m^2 per sow in a stall. Accommodation for pregnant sows are made from corrugated-iron 'arcs', each housing 5-6 sows. In this system, the sows forage and root in the grassy enclosure at will (Metcalfe, 2001).

Suckling pigs

The piglets are kept outdoor for less than four weeks before they are weaned and transported to a 'nursery' unit and/or 'finishing' unit (Baker, 2002).

BREEDS FOR FREE-RANGE PIG PRODUCTION

The ideal breeds for a free-range pig system should perform well under a very harsh environment, exhibit resistance to disease and have high feed conversion efficiency, especially for fibrous materials. These criteria make it necessary to breed new pig genotypes more resistant than those currently available for the free-range system, especially because growth-stimulating hormones and antibiotics are banned. The University of Agricultural Science (Godollo, Hungary) developed a new crossbred variety (Hungarian Large White, 75%)×Mangalica (pig with curly bristles, 25%) for these purposes (Hungamang Standard, 1990 cited by Dworschak et al., 1995). Ru and Glatz (2001) also demonstrated that a cross breed of the two commercial pig breeds (Landrace×Large White), could be used for free-range production under southern Australian conditions.

One approach is to cross the current commercial breeds with local breeds which are often resistant to diseases and the harsh environment. McGlone and Hicks (2000) assessed two crossbred genotypes containing 15% Camborough and 25% Meishan, respectively under outdoor conditions. They found that the 25% Meishan had greater reproductive performance and weaned 1.7 more pigs per sow than the Camborough-15.

Local pig breeds or outdoor-adapted breeds for certain environment are often more suitable for free-range systems and are widely available. A typical example is the Iberian pig which is produced in free-range conditions in evergreen-oak forest located in the South West of Europe. The natural diet consists mostly of acorns and grass. The high quality pork obtained from the Iberian pigs is attributed mainly to this feeding regime (Lopez Bote and

Rey, 2001). Mayoral et al. (1999) also reported that the Iberian pig is the only free-range pig breed of importance in the Spanish meat market, with nearly two million animals slaughtered per year (Lopez-Bote, 1998). Profitable Iberian pig production is based on the gourmet quality of the dry-cured meat products (Antequera at al., 1992; Ruiz et al., 1998).

MANAGING FREE-RANGE PIGS

Housing

The selection of a site for housing free-range pigs requires consideration of the welfare of pigs and the impact on the environment and the local community. Sites exposed to wet and windy conditions greatly increases the potential for poor welfare in outdoor systems (Thornton, 1990; Anon, 1996). Recommendations from the UK indicate that farms should be located in a low rainfall area and paddocks should be relatively flat, with a light topsoil overlying a free-draining subsoil with the absence of sharp stones that can cause foot damage (Thornton, 1990). However, McGlone (J. McGlone pers. com.) suggested that light soil is not required if the land is flat. In Australia, it is recommended that outdoor production should be confined to regions where temperature rarely exceeds 30°C, low rainfall, gently sloping land to reduce the risks of flooding and movement of straw, and a variety of soil types (Barnett et al., 2001). However, these recommendations can be changed if a proper management system is in place. A typical example is for free-range pigs which performed very well in a hot dry summer in South Australia (>35°C) where wallows and a fogger system was supplied. After two years study on the physical and chemical impact on the soil from outdoor pig production on different Swiss farms, Zihlmann et al. (1997) gave the following recommendations for an environmentally-friendly outdoor pig production: 1) heavy soil, low rainfall and good grass cover, 2) an area of at least 0.015-0.02 ha per fattening pig and 0.03-0.05 ha per sow for a rotation area of four-months in the plot, 3) the location of the huts should be changed from time to time, 4) feeding places should be provided with a hard surface, and 5) the copper and zinc content of the feed should not exceed animal requirements.

House design should be flexible, depending on the environment conditions. In Australia, cheap mobile eco-shelters have become very popular for outdoor pigs. Some farmers are using straw huts which reduce the housing and bedding cost for grazing pigs although the performance under this system has not been assessed. It is clear that hut design for outdoor pig can affect pig production. McGlone and Hicks (2000) found that litters farrowing in the English-style huts weaned 1.5 more ($p<0.05$) piglets per sow than did litters in the American-style huts. English huts with four straight-sided walls were bigger than American huts (4.28 vs. 3.32 m^2) and bedded with wheat straw.

Stocking rate

A survey conducted in UK for a total of 30,423 breeding sows showed that average stocking rates in sow, dry sow and farrowing paddocks were 33.1, 26.9 and 19.3 pigs/hectare respectively and average hut lying areas (m^2/pig) were 1.2, 1.6 and 3.9. The average pre-weaning mortality was 12.1% for all hut types and a crushing was involved in 98% of piglet death. Average weaning age and weight were 24.5 days and 7.1 kg, respectively (Abbott et al., 1996).

Water and feed allowance

While water should always be available for free-range pigs, the feed allowance is variable, depending on the quantity and quality of forage in the paddock available for the pigs. Pigs commonly graze on strip pastures and rotated between paddocks. Also outdoor pigs can be fed *ad libitum* on a conventional grower feed until the animals reach a weight of 60 kg and thereafter provided a restricted diet of 2.8 kg per pig per day (Hogberg et al., 2001). The details on nutrient requirements of free-range pigs and the nutritive value of forage for pigs will be reviewed in another paper.

Heat release

Free-range pigs are exposed to the impact of a number of environmental factors. Among these, temperature is one of the key factors determining the success of free-range production systems. When the temperature is below the lower critical temperature (LCT), pigs must increase heat production through shivering and other metabolic processes to maintain body temperature. On the other hand, when the temperature is higher than its evaporative critical temperature (ECT), the evaporative heat loss of pigs begins to increase, particularly from the lungs, through increased respiration. The zones of thermal comfort (temperature between LCT and ECT) for the lactating sow and piglet differ markedly; between 12-22°C for the sow and 30-37°C for piglets (Black et al., 1993). Capstick and Wood (1922) and Heitman and Hughes (1949) reported that the critical temperature for optimum performance of pigs weighing more than 75.34 kg is between 15.5 and 21.1°C.

Pigs are not able to sweat and are more sensitive to hot than cold conditions (Ingram, 1965). Most researches have focused on the effect of high temperature and have clearly demonstrated that ambient temperatures above the ECT of lactating sows leads to a reduction in food intake, milk yield, reproductive performance and growth rate of piglets. Black et al. (1993), reviewed a number of studies and found that for each 1°C increase in ambient temperature above 16°C, daily voluntary energy and food intake of lactating sows decreased by 2.4 MJ DE and 0.17 kg, respectively. However, the relationship between ambient temperature and food intake is unlikely to be linear over the range of temperature and the decrease in intake may depend on the extent to which ambient temperature exceeds the animal's ECT (Giles and Black, 1991). Mullan et al. (1992) also reported that feed intake was depressed by approximately 25% and milk yield by 15% for sows housed at 30°C compared with those housed at 20°C and the high ambient temperature had a direct effect on milk yield. The reduction in food intake of the lactating sows is associated with an increase in deep body temperature as is also observed in growing pigs. The direct effect of high temperatures on milk yield may result from a redirection of blood flow to skin and away from other tissues, including the mammary gland. Oxygen uptake of lactating sows decreased from 523 to 411 ml/min when ambient temperature was increased from 18 to 28°C. This decline of 20% in heat production was associated with a 25% decline in milk yield and 40% reduction in food intake (Black et al., 1993).

The effect of high ambient temperatures on voluntary food intake also has important consequences for reproductive performance. Primiparous sows lactating during summer have a greater interval between weaning and mating than do those during winter, but season does not appear to have the same effect with multiparous sows (Clark et al., 1986), probably because the young animal mobilises a greater proportion of its more limited body reserves if voluntary feed intake is low during lactation. There is conflicting evidence on the mechanism by which the season influences reproductive performance. Evidence from primiparous sows suggests that the high ambient temperatures during lactation cause a decrease in luteinizing hormone (LH) pulse frequency and that this is responsible for the delay in rebreeding after weaning (Barb et al., 1991). However, there is also evidence that low nutrient intakes in primiparous sows, housed under standard conditions during lactation cause an increase in the weaning to mating interval and this is due partially to a disruption of the normal secretory pattern of LH (Mullan et al., 1991). Feed intake (Barb et al., 1991) was reduced from 6.1 to 2.9 kg/day due to the effect of high ambient temperatures.

The reduction in growth rate of piglets that are suckling sows maintained at high temperatures has been assumed to reflect a reduction in milk yield. For example, Schoenherr et al. (1989b) and Vidal et al. (1991) recorded decreases in milk yield of 10 and 35% and an associated decline in piglet growth rate when ambient temperature was increased by 8°C and 10°C, respectively.

Milk yield of sows exposed to high temperatures can be improved by reducing normal heat production or increasing heat loss to the environment. Pigs can adjust their behaviour to adapt to the harsh environment. For example, on hot days pigs cool themselves by going into a wallow or under water sprinklers (Heitman et al., 1962), or seek protection from the sun in the shade (Heitman et al., 1962; Blackshaw and Blackshaw, 1994) when such facilities are available. Pigs can also increase their heat loss by moving away from hot places to a cooler floor or a place with higher air velocity, changing their lying posture from belly to side, or by avoiding body contact with other pigs (Geers et al., 1986). On hot days pigs attempt to lie in a damp place or wallow, or even bathe in a standing position, as they do in natural conditions (van Putten, 1978). By rolling from side to side in the wallow or damp place (van Putten, 1978), the moist upper side of their bodies will be cooled by evaporative heat loss (Ingram, 1965). However, wallowing is not only performed on hot days but also on cooler days, suggesting that wallowing also plays a role in skin and hair care (van

Table 1. Ambient temperature in relation to evaporative critical temperature (ECT) for the sow and its effect on the predicted[1] performance of a sow and litter during a 28 day lactation (post-partum body weight of 150 kg, fed a diet containing 13.5 MJ DE and 164 g crude protein per kg dry matter, litter size of 9, no creep feed provided) (Black et al., 1993)

Items	Treatment			
	Thermal comfort (dry)		Proportion of wet skin	
	Sow[2]	Piglet[3]	15-30[4]	100[5]
Temperature (°C)				
Ambient	20	33	33	33
ECT	22	26	25	21
Sow				
Feed intake[6] (kg/day)	5.26	2.61	4.31	5.26
Digestible energy (DE) intake (MJ/day)	71	35	58	71
Weight change (kg)	+1.8	-29.1	-9.6	+1.4
Weaning to mating interval (days)	5.0	19.1	9.6	5.0
Latent heat loss of evaporation from skin (MJ/day)	10.9	10.5	16.0	25.9
Piglet				
Average daily gain (g)	152	168	193	194
Mean weight at weaning (kg)	5.64	6.08	6.79	6.80

[1] Predicted by Auspig model (Black et al., 1986). [2] Zone of thermal comfort for sows.
[3] Zone of thermal comfort for piglets. [4] Simulating the effect of drip cooling by increasing the proportion of wet skin for the sows from 15 to 30%.
[5] Simulating the situation where the proportion of wet skin for the sow is up to 100%. [6] Does not include feed wastage.

Table 2. Effectiveness of a wallow and water spray on the growth of swine (Culver et al., 1960)

Variable	Treatment		
	I-Control	II-Wallow	III-Spray
Number of pigs	12	12	12
Initial weight, kg	38.58	38.58	38.58
Final weight, kg	92.60	96.68	98.50
Total gain, kg	54.01	58.10	59.91
Avg. daily gain, kg	0.86	0.93*	0.95**
Avg. daily feed, kg	3.09	3.27	3.41
Feed per kg. gain, kg	1.63	1.60	1.63

* $p<0.05$, ** $p<0.01$.

Putten, 1978). Free range pigs are exposed to variable environmental conditions where the temperature fluctuates seasonally and daily resulting in variable feed intake, milk yield and growth rate of pigs. Based on these facts, a number of strategies have been examined to reduce heat production and/or increasing heat loss, including offering cooling systems and feeding appropriate diets.

Wallow

Offering wallows for free-range pigs will not only meet their behaviour requirements, but also overcome the effect of high ambient temperatures on feed intake. Pigs can increase the evaporative heat loss via an increase in the proportion of wet skin. Mud from wallow can also coat the skin of pigs, preventing sunburn. Black et al. (1993) used an Auspig model to predict the effect of wet skin on feed intake of sows and found that an increase in the proportion of wet skin improved feed intake and shortened weaning to mating interval of sows (Table 1).

Using a wallow to improve outdoor pig performance is not new. Early research showed that the rise in respiration rate and rectal temperature was reduced in swine with access to the wallow. At temperatures over 26.7°C, the use of a wallow increased appetite, rate of gain, and efficiency of feed utilisation (Jackson, 1938; Culver et al., 1960). Pigs being fattened on pasture in Louisiana with the use of a wallow, increased daily gain nearly 181.6 g per pig during a 73-day period (Bray and Singletary, 1948). However, pigs use the wallow for lying and oral behaviour within the temperature range (-4 to 24°C), but the duration of these behavioural patterns increased when the temperature exceeded 15°C (Olsen et al., 2001). However, the effectiveness of wallow in a southern Australian summer is questionable when the temperature is over 38°C. Under this environment, the establishment of wallow in the shaded area may be beneficial (Ru and Glatz, 2001). An early study by Garrett et al. (1960) clearly demonstrated consistent and significant increases in average daily gain and daily feed intake for pigs provided with shaded wallows. Rectal temperatures and respiration rates were higher for pigs with the unshaded wallow. Garrett et al. (1960) also found that wallow temperature during the hottest part of the day was 12.2°C lower in a shaded wallow. Comparatively little use was made of an unshaded wallow after the water temperature reached 35°C.

Sprinklers

Wet skin can release the heat stress of grazing pigs. A number of methods can be used to achieve this objective such as a wallow, water drips and spray. However, water sprays seems to be more effective than wallows (Culver et al., 1960, Table 2). McCormick et al. (1956) found that sprinklers increased daily gain from 45-144 g/pig. However, sprays are not effective in cool, rainy weather. Wallace et al. (1957) found that under Florida's hot dry conditions the use of a mist-type spray significantly increased rate of gain, especially when temperatures were above 32.2°C. Ru and Glatz (2001) found that foggers were successful in reducing heat stress of grazing pigs, especially when they were set up in the shaded areas. McGlone et al. (1988) reported that at ambient temperatures above 29°C, drip cooling decreased the weight loss of sows from 27 to 9 kg and improved litter weight gain from 1.47 to 1.85 kg/day during a 28 day lactation. Similarly, Maxwell et al. (1990) recorded a reduction in respiration rate and an estimated increase in milk yield of approximately 1 l/day for sows that were drip cooled when ambient temperature exceeded 26°C. However, pigs often root under the sprinklers especially when soil moisture is elevated.

Housing/huts

Huts or shelters are crucial for preventing pigs from direct sun burn and heat stress in pigs, especially when shade from trees and other facilities is not available. McGlone (1987) also reported that for farrowing sows, the huts in paddocks might have some merits during very warm summer weather in temperate climates or in a tropical environment. However, the effectiveness of housing facilities on heat release, largely depends on the ground vegetation, ground moisture and the materials used for the housing facilities because these affect ground temperature beneath the shade and thus affect the animal heat load. In addition, a shade area may be designed in a way that permits maximum heat loss from the animal. Roof treatments which are satisfactory, include straw, wood, galvanised steel, aluminium or laminated polyethylene plastic. White-painted aluminium sheets were 9.4°C cooler than unpainted aluminium in the direct sun, while white painted galvanised iron was 10°C cooler than unpainted sheets (Andrews et al., 1960).

Feeding appropriate diets

The depression in feed intake and growth rate observed in heat stressed animals can be partially alleviated by

Table 3. Least squares means and standard errors for production performance of Newsham sows and piglets housed indoors *vs* outdoors over two parities from January to September 1999 (Johnson et al., 2001)

Production measures	Indoor	Outdoor	P-value[a]
Number of sows and litters	147	140	
Pigs born (No./litter)	10.8±0.10	10.5±0.11	0.15
Pigs born alive (No./litter)	9.4±0.49	9.4±0.44	0.95
Still-births	0.9±0.10	0.7±0.11	0.15
Mummies (No./litter)	0.0048±0	0.0039±0	0.73
Days of lactation	23.8±0.47	22.2±0.48	0.10
Piglets weaned (No./litter)	8.4±0.41	7.6±0.37	0.33
Mortality (%)	11.0±1.61	11.8±1.74	0.76
Litter birth wt (kg/litter)	19.7±1.35	21.1±1.48	0.22
Piglet birth wt (kg/pig)	1.9±0.14	2.1±0.15	0.29
Litter wean wt (kg/litter)	58.4±2.96	53.3±3.24	0.08
Sow start wt (kg)	216.4±6.47	227.3±6.79	0.08
Sow end wt (kg)	190.6±3.59	186.1±3.91	0.15

[a] P-value comparing indoor- and outdoor-reared piglets.
[b] Weight of sow on the day she entered the farrowing facilities and on the day she returned to breeding after piglets were weaned.

altering the heat increment of the diet by lowering the dietary protein level and reducing those levels of essential amino acids which are excess to the animal's minimum requirement (Waldroup et al., 1976). In a comprehensive experiment, Schoenherr et al. (1989 a,b) housed lactating sows at either 20 or 32°C and fed basal, high-fibre or high-fat diets. In the hot environment, increasing the energy density of the diet improved milk yield at all stages of lactation. Conversely, the addition of fibre in a hot environment depressed milk yield, and hence the weight of piglets at weaning compared to either the basal or high fat diets. Heat production associated with the microbial fermentation of dietary fibre in the hindgut account largely for the poorer performance of sows fed high fibre diets in hot environments. However, under grazing conditions, it is difficult to control the fibre intake of pigs although a high energy, low fibre diet can be used for free-range pigs.

Nose rings

In some countries outdoor sows are fitted with nose rings to prevent them from uprooting the grass. Nose rings can effectively prevent the sows from rooting by causing pain in the nose. This reduces nutrient leaching of the land. From the animal welfare point of view, nose rings under free-range condition allows the pigs to perform most of their natural behaviour patterns, but prevents them from engaging in rooting behaviour, an important behaviour activity under taken by pigs to gain information about their surroundings (Studnitz and Jensen, 2002). Studies conducted in semi-natural conditions showed that sows spend 40-60% of their active time seeking food and exploring (Blasetti et al., 1988; Edwards et al., 1993), and rooting behaviour constitutes 10-20% of their active time (Stolba and Wood-Gush, 1984; Horrell and A'Ness, 1996; Berger et al., 1998). Nose rings may also restrict the foraging capability of pigs, especially when the sward is short. No information is available on the effect of nose rings on forage intake and grazing behaviour of free-range pigs.

Mortality

Generally, free-range pigs have a higher mortality compared to intensively housed pigs. Many factors can contribute to the death of the piglet including crushing, disease, heat stress and poor nutrition. Leite, et al. (2001) determined the causes of pre-weaning mortality in 106 piglets reared in outdoor system from October 1996 to October 1999. He found that crushing was the main cause of the piglet mortality (76.42%), followed by injury (13.21%) and other causes (5.66%) such as diarrhoea and infections. Mortality due to crushing was more frequent in the first 24 h after farrowing (37.74%). The mortality in piglets born in winter with a birth weight of 1.5 kg was 33.96%, and 37.74 and 24.53% in litters from sows in third and fourth parity respectively. However, Johnson et al. (2001) found that production and mortality of sows and piglets were not affected by the production systems (indoor or outdoor). Johnson (2001) reports that in these experiments, gilts had a high health status (negative for pseudorabies, brucellosis, porcine respiratory and reproductive virus, syndrome and mycoplasmal), and a dewormer was included in the diet. After surveying 54 outdoor systems, Kongsted and Larsen (1999) found the average mortality rate (18.3%) for free-range pigs was similar to that found in indoor pigs (18.7%). Breed did not affect mortality rates and mortality was not correlated with temperatures nor with level of dry bedding. Mortality rate was lower when sows were moved to farrowing paddocks 10 days before farrowing compared with sows moved 0-6 days before. The mortality rates tended to be lower with increased grass cover and to be elevated when rainfall was higher.

PERFORMANCE OF FREE-RANGE PIGS

The production performance of free-range pigs is strongly influenced by season, nutrition and management. The performance of growers and sows has been assessed by many researchers under different environmental conditions.

Sows

Outdoor production systems for sows is common in a number of European countries. The numbers of sows housed outdoors has increased dramatically in EU in recent years, with 20% of the breeding herds in UK housed outdoors. The characteristics of the outdoor production systems include; 1) all sows are outdoors and loose during

Table 4. Least square means and standard errors for sow and piglet performance by season (Stansbury et al., 1987)

Production variable	Season				SE[a]	P-value
	Spring	Summer	Autumn	Winter		
Number of litters	83	95	75	88		
Litter weaning weight (kg)	59.03	56.84	56.67	58.18	1.16	0.44
Weaning number	8.7	8.6	8.6	8.5	0.13	0.48
Pig weaning weight (kg)	6.80	6.60	6.64	6.92	0.11	0.11
Mortality (%)	11.60	12.72	13.22	13.94	1.18	0.83
Splay-legged/litter	0.32^{cd}	0.17^{c}	0.44^{d}	0.45^{d}	0.08	0.04
Sow feed intake (kg/day)	6.05^{c}	6.56^{d}	6.48^{d}	6.50^{d}	0.13	0.02
Sow weight loss (kg/lactation)[b]	23.05	19.98	21.36	18.15	1.55	0.15
Weaning to oestrus (day)	4.9	5.6	6.1	4.8	0.44	0.13

[a] Pooled standard error of the mean. n=85.
[b] Weight change from entering farrowing barn (pre-farrowing) to end of 28 day lactation.
[c, d] Means in the same row without a common superscript differ ($p<0.05$).

Table 5. Least square means and standard errors for sow and piglet performance in different farrowing house temperatures (Stansbury et al., 1987)

Production variable	Temperature (°C)			SE[a]	P-value
	18	25	30		
Number of litters	29	29	30		
Litter weaning weight (kg)	63.23^{c}	61.13^{c}	52.38^{d}	2.47	0.01
Weaning number	8.1	8.9	8.3	0.27	0.13
Pig weaning weight (kg)	7.82^{c}	6.87^{d}	6.40^{d}	0.20	0.001
Mortality (%)	20.35^{c}	11.97^{d}	18.79^{c}	2.29	0.04
Creep feed intake (kg/lactation)	3.13	3.04	2.61	0.74	0.88
Sow feed intake (kg/day)	6.46^{c}	6.13^{c}	4.20^{d}	0.19	0.001
Sow weight loss (kg/lactation)[b]	3.14^{c}	7.86^{c}	24.21^{d}	2.25	0.001
Weaning to oestrus (day)	7.3^{c}	4.4^{d}	5.3^{d}	0.62	0.01

[a] Pooled standard error of the mean. n=85.
[b] Weight change from entering farrowing barn (pre-farrowing) to end of 28 day lactation.
[c, d] Means in the same row without a common superscript differ ($p<0.05$).

lactation, 2) the facilities for serving are either outdoors or indoors and the servings are based on uncontrolled natural services, controlled services, artificial inseminations, or a combination of these practices. All dry sows are loose-housed and in groups. The sows in outdoor systems are housed under different conditions in their complete reproduction cycle or at least in significant parts of it, compared to indoor sows. This means that outdoor housed sows are exposed to changes in the length of daylight (Perera and Hacker, 1984; Prunier et al., 1994), and variation in temperatures (Stansbury et al., 1987; Prunier et al., 1994). Thus it is difficult to compare the performance of outdoor sows between experiments and often the research outcomes are contradictory. For example, a recent study by Johnson et al. (2001) showed no difference in the performance of Newsham sows and their piglets housed indoors and outdoors (Table 3). Larsen and Jorgensen (2002) analysed sow records from three Danish and one Scottish outdoor herd and found that the average level of the reproduction cycle was 149.9 days between farrowings, 28.0 days from farrowing to weaning, 5.6 days from weaning to first recorded service and 116.2 days from first recorded service to farrowing. These are similar to performance observed in the indoor system. However, Oldigs et al. (1995 cited by Wulbers-Mindermann et al., 2002) reported that outdoor sows lost more backfat and weight during lactation.

The sow's performance is affected by season, reflecting the influence of temperature. An evaluation of 341 farrowing records, collected over a 2-year period by Stansbury et al. (1987) showed that the number of splay-legged pigs and daily sow feed intake were directly affected by season (Table 4). Litters contained fewer splay-legged pigs per litter during the summer than during autumn or winter. Daily intake of sows was lower in the spring than in any other season. Total litter weaning weights were lighter in 30°C than in 18 or 25°C environments. Average individual pig weaning weight was higher in the 18°C environment than in the 25 or 30°C environments. Litter mortality was 8% and 7% lower in the 25°C than in the 18 or 30°C environments, respectively. High temperature (30°C) reduced daily sow feed intake and increased the body weight loss of sows. Sows in the 18°C environment took 2-3 days longer to come into oestrus after weaning than those in the warmer environment (Table 5).

Growing pigs

Many factors influence the performance of growing pigs

Table 6. The effect of housing within season on production performance adjusted to an off-farm (finishing) weight of 105 kg (Sather et al., 1997)

Trait	Season								Contrast			
	Summer				Winter				Main effect			
	Confined		Free-range		Confined		Free-range		Season	Housing	Summer	Winter
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	P>F	P>F	P>T	P>T
Weight on test[z]	25.0	0.55	25.7	0.54	25.8	0.56	26.3	0.56	0.1659	0.2896	0.3648	0.5511
Weight on test[z]	102	2.4	112	2.3	102	2.4	106	2.4	0.2637	0.0062	0.0055	0.2608
Age to market	168	1.2	185	1.2	159	1.2	175	1.2	0.0001	0.0001	0.0001	0.0001
Average daily gain	897	6.7	750	6.8	935	6.9	786	6.8	0.0001	0.0001	0.0001	0.0001
Feed conversion	2.81	0.069	2.76	0.076	2.86	0.069	3.18	0.066	0.0501	0.0922	0.8766	0.0132
Daily food intake	2.49	0.047	2.17	0.052	2.65	0.047	2.52	0.045	0.0037	0.0010	0.0038	0.0906
Total food consumption	226	5.3	229	5.3	222	5.8	252	5.1	0.1335	0.0185	0.6775	0.0150
Number of pigs	35	35	36	36	34	34	34	34				
Number of pens	3	3	3	3	3	3	3	3				

[z] Unadjusted for off-farm weight.

in the outdoor environment. These include environmental conditions, quality of supplementary feed and forages, disease control and the nursing capability and parity of sows. With successful management, free-range pigs can have higher growth rate and a heavier carcass (91.2 vs. 81.3 kg) than indoor pigs (Gentry et al., 2002a,b). Research conducted by Wulbers-Mindermann et al. (2002) demonstrated that outdoor piglets grew faster with reduced litter variation in piglet weight at weaning than indoor piglets, although they had no access to piglet creep feed given to indoor litters. The authors believed that this result may be due to the greater willingness by the sow to nurse her litter because outdoor environment promotes the sow to invest more of her body energy into the rearing of her offspring, although no evidence shows that outdoor sows have a higher nursing frequency or a higher total milk yield. Wulbers-Mindermann et al. (2002) also suggested that the stronger immune system and the lower pressure of infection resulting from less animals per unit promoted growth of the outdoor pigs compared to indoor pigs. There was no evidence that increasing exercise by providing a greater improvements pig performance (Gentry et al., 2002c). However, some researches have shown that free-range pigs took more days to reach target weight. For example, pigs reared from 25 to 105 kg required 16±1.2 (SEM) more days to reach market weight compared with confined pigs and the daily gain was lower than the confined pigs (916±27 vs. 1,089±27 g/day) (Sather et al., 1997). A similar result was reported by Sans et al. (1996). Daily gain from 40 to 140 kg body weight was low (384 g/day) for Gascony pigs reared in an outdoor system. However, it seems that piglet mortality is higher among outdoor herds than indoor herds, especially during the colder season with huts having no insulation. Large variations in management practices exist between herds, and therefore piglet mortality will vary. The survival of the piglet is more dependent on environmental factors (Wulbers-Mindermann et al., 2002) although the sow's maternal behaviour is also associated with the mortality of piglets (Vieuille et al., 2003). However, management strategies for reducing piglet mortality are still not adequately developed for free-range pigs compared to indoor housing systems.

The growth rate of the litters is also affected by season. Piglets grow quicker indoors during the cold season compared to outdoor systems (McGlone et al., 1988; Azain et al., 1996). The seasonal effect is more apparent in free-range system. The above authors found that during the cold season, outdoor sows were probably less active grazing and rooting on frozen ground due to the lower air temperatures, and shorter day length. Therefore sows might have spent more time inside the hut, conserving energy and nursing piglets. Wulbers-Mindermann et al. (2002) also reported that the multiparous outdoor sows have faster growing litters than primparous sows. This is due to the maternal experience in combination with an outdoor environment supplying the sows with good conditions to perform their maternal behaviour in such a way that it supports the piglet growth rate. Sather et al. (1997) compared the performance of growing pigs housed in confined or free-range systems during different seasons. While housing did not affect feed requirements during the summer, food consumption increased by 13.7% for free-range pigs during winter. Pigs in the confined environment consumed more feed than free-range-reared fed pigs in both winter and summer. During summer, free-range pigs were more feed efficient than confined pigs. Rearing pigs in free-range lots from 25 to 100 kg resulted in a reduction in growth rate and an increase in slaughter age, with a modest increase in feed conversion and in total feed consumption during the winter months compared with the intensive housing system (Table 6). However, Costa et al. (1995) reported that the rate of return on the total capital invested in the outdoor systems was close to 24%, 5-8% higher than the two traditional systems with fully or partially slatted flooring.

Table 7. Least squares means and standard errors for behaviour performed by Parity-2 Newsham piglets indoors *vs* outdoors from January to March 1999 (Johnson et al., 2001)

Behavioural measures	Environment		SE	P-value[a]
	Indoor	Outdoor		
Number of sows	20	20		
Standing (%)	15.7	22.1	2.38	0.23
Lying (%)	72.2	68.1	3.11	0.19
Sitting (%)	3.3	3.4	0.64	0.94
Walking (%)	5.2	10.1	1.72	0.02
Nursing (%)	20.3	27.5	2.02	0.03
Playing (%)	1.7	5.0	1.26	0.046
Out of sight (%)	0.21	0.74	0.26	0.08
Contact with sow (%)	38.8	39.2	2.78	0.94
No contact with sow (%)	61.0	60.0	2.86	0.84

[a] P-value for comparison of indoor- and outdoor-housed lactating sows. P-values are based on analysis of transformed data.

Welfare and behaviour of free-range pigs

Pigs were known as lazy animals because of their habit of lying motionless for long periods in shaded areas and as unclean animals because of their preference for mud wallows in warm weather. It is now recognised that the pig uses this behaviour to instinctively protect itself against hyperthermia, sunburn and possible heat shock by the use of shade and evaporative cooling (Culver et al., 1960). This is particularly important for pigs foraging outdoors.

Behaviour of outdoor pigs vs. indoor pigs:

Pigs reared outdoors have shown calmer behaviour (Warriss et al., 1983). Their calmness and increased exercise behaviour make free-range pigs less susceptible to stress. Aggressive interaction frequencies during feeding were found to be lower compared to earlier indoor studies (Jensen and Wood-Gush, 1984). The lower A/R-ratio (the total number of observed "attacks" divided by the total number of observed "retreats") of 0.13±0.10, compared to 0.4, 3.6 and 8.2 in the 3 indoor systems, indicates a low aggression level and a stable social system in the free-ranging group (Jensen and Wood-Gush, 1984). Wood-Gush and Stolba (1982) observed the behaviour of pigs in a park, consisting of an enclosure of 1.3 ha containing a small pine copse, gorse bushes, a stream and a swampy wallow. Pigs made a large number of communal nests for sleeping. They were some distance from the feeding site, were protected against the prevailing winds and had a wide view that allowed the pigs to see anything approaching the nest from most directions. Before retiring to the nest, the animals tended to bring nesting material for the walls and to rearrange the nest. This was not a coordinated activity but most pigs performed it. Some individuals carried more nesting material than others. On leaving the communal nest in the morning, the animals walked at least 5 metres before urinating and defaecating, the latter mainly on paths between bushes. In autumn, 51% of the day was devoted to rooting. Much behaviour took place in the border of the wood and the open vegetational zone. Here trees were used for marking, in which the facial area is rubbed, sometimes in one direction only. Special relationships were found, e.g. a pair of sows might join together several days after farrowing and forage and sleep together. However, no cross-suckling has been seen in the litters of such animals. Members of a litter of the same sex tend to stay together and to pay attention to one another's exploratory behaviour. Aggressive play appears to be more common amongst the young males. Both sexes showd manipulative play. Farrowing nests were constructed by the sows, usually some distance from the communal nest, and the site chosen was usually under a branch or fallen tree. After farrowing, the nest was protected for about five days. From about that time, the sow tended to leave her litter for varying periods and piglets began to explore their environment. Guy et al. (2002) reported that pigs in outdoor paddocks spent the majority of time inside the shelter hut. When not in the hut, rooting and chewing at the floor and surroundings, and moving around the paddock accounted for a large part of their activity

Webster and Dawkins (2000) determined the effect of outdoor and indoor lactation on the development of pig behaviour at weaning. On day 1, 8, 15 and 57 post-weaning it was found that from weaning to day one post weaning, outdoor bred pigs feed more than indoor pigs. From days 8-57 post weaning, outdoor pigs rooted more than indoor pigs (22.5 vs. 24.7 observations/pen/day). These findings suggest that the lactation environment has a significant effect on the behaviour of pigs in their subsequent growing environment. Johnson et al. (2001) found that outdoor piglets spent more time engaged in play activity than indoor-reared piglets (Table 7). Webster (1997) also reported that outdoor born piglets at day 15 spent less time in contact with the sow and more time directing their rooting toward the soil, plants, and straw available in the pasture compared with indoor born piglets.

Pigs reared in a poor environment (intensive, in a farrowing crate) behave more aggressively. The subordinates of these pigs also develop chronic social stress indicated by the delayed onset of puberty, reduced daily gain and elevated basal cortisol levels. The deterioration in social skills lead to increased social stress and a failure to cope with stressors in general (de Jonge et al., 1996). However, Warriss et al. (1983) reported that the rearing environment of pigs (confined vs. free-range) had no effect on indicators of stress (blood cortisol levels and adrenal gland ascorbic acid levels). Their research also demonstrated that confinement-reared pigs were more difficult to load into trucks than free-range pigs, which was supported by Barton-Gade and Blaabjerg (1989)'s findings. Grandin (1989) also believed that environmental enrichment (access to toys, outdoor rearing) reduced

Table 8. Least squares means and standard errors for behaviours performed by Parity-2 Newsham sows indoor vs. outdoor from January to March 1999 (Johnsen et al., 2001)

Behavioural measures	Environment		SE	P-value[a]
	Indoor	Outdoor		
Number of sows	20	20		
Active (%)	9.1	27.9	2.76	<0.001
Lying (%)	90.9	72.1	2.76	<0.001
Sitting (%)	3.2	1.9	0.66	0.34
Drinking (%)	4.4	1.4	0.60	0.004
Feeding (%)	1.4	3.0	0.92	0.09
Nursing interval (min)	40.1	42.2	2.47	0.30

[a] P-value for comparison of indoor- and outdoor-housed lactating sows. P-values are based on analysis of transformed data.

Table 9. Frequency of behaviour in relation to feed level corresponding to 80 or 100% of indoor recommendations (Stern and Andresen, 2003)

Behaviour	Feed level		Level of significance
	100%	80%	
Rooting	5.8	8.5	**
Grazing	30.0	33.6	NS
Other activities	9.7	7.1	*
Passive (outside the hut)	12.1	12.1	NS
In hut	42.4	38.7	NS

Least square means and level of significance.
*p<0.05. **p<0.01, NS. p>0.05.

excitability in pigs, which in turn allowed easier handling and less stress prior to slaughter.

Outdoor pigs are often supplied with bedding materials such as straw which encourages pigs to spend more time on rooting and foraging and less time on tail-biting and other stereotypic behaviours. Interaction between genotype and housing system did not occur to any major degree (Guy et al., 2002). Olsen (2001) examined the effect of roughage (including straw) and access to shelter in pens with outdoor runs on oral activity towards penmates and other environmental stimuli. He found that access to a combination of roughage and shelter reduced penmate-directed oral activities. However, access to roughage in particular reduced redirected oral activities and skin lesions.

The behaviour of outdoor sows

After sunset, outdoor sows reduce their activities and remain lying during the night. In hot seasons, sows have a reduced intake, but the intake can be increased in cooler seasons (Quiniou et al., 2000). Santos Ricalde and Lean (2002), however, suggested that an increase in grazing behaviour can occur during the night. Generally outdoor sows are more active than indoor sows (Johnson et al., 2001, Table 8). During the first few days after parturition the outdoor sows often leave the hut mainly for defecating and urinating, eating and drinking. Csermely (1994) reported that during the first 2 days after farrowing, the feral sow spent 76% of her time lying in her nest, but from day 3 until weaning decreased her lying time to 42% and moved a greater distance (>10) away from the nest. Jensen (1994) noticed that sow behaviour significantly changed during the first 4 weeks of nursing. Foraging and locomotion increased whereas lying, nursing, and contact with piglets decreased. Sows soon find the older piglets increasingly stressful to manage and in a natural setting choose to spend more time away from the litter.

Petersen et al. (1990) studied the behaviour of sows and piglets during farrowing under free-range conditions. It was concluded that pigs, in spite of domestication, are behaviourally well adapted to cope with the problems associated with farrowing under free-range conditions. The general behaviour and also the birth data of the piglets in their study were not so different from what has been found in indoor housing systems (English and Smith, 1975). The females showed behaviour which may promote social bonding. The observation that pigs sniff at the young of the females is similar to observations in wild boar (Gundlach, 1968 cited by Petersen et al., 1990), in intensive housing systems (Jones, 1966) and in free-range domestic sows (Jensen, 1986).

Dailey and McGlone (1997a) monitored pigs continuously for 24 h. Every 5 min an observor (working in 2 h shifts) recorded pig behaviour. Outdoor sows spent more time being active (53.67 vs. 26.10 min/2h) and a greater frequency of standing (0.9 vs. 0.49). Similar results for gilts were reported by Dailey and McGlone (1997b). It is likely that foraging opportunities for outdoor sows may have increased due to the availability of earthworms and insects in the pasture. Over 24 h, outdoor sows had two periods of active behaviours: 1) in the early morning and 2) towards evening. Outdoor sows showed a decreased frequency of activity in the afternoon. Indoor sows maintained a relatively constant level of activity from feeding until mid-afternoon. However, no differences (p>0.10) were found between treatments (on pasture, soil and gestation crates) for sitting, rooting, total oral/nasal/facial or oral/nasal/facial feeding and drinking.

Feeding level and behaviour of outdoor pigs

The activities of pigs, especially those associated with foraging behaviour are affected by feeding levels. For example, Santos Ricalde and Lean (2002) reported that the time spent grazing, grazing activities and distance walked was significantly reduced with increasing energy intake. Extremely high temperature had a greater effect on grazing behaviour and body temperature than energy intake in pregnant sows kept outdoors under tropical conditions. Stern and Andresen (2003) studied the foraging behaviour and daily weight gain of outdoor growing pigs given 100 or 80% of the indoor recommended feed allowance. While the mean daily weight gain was higher for the high feeding level, pigs on the high feeding treatment spent most of their time on rooting (Table 9). It was surprising that time spent

Table 10. Proportion of recordings of behavioural elements in relation to stocking rate (Andresen and Redbo, 1999)

Behaviour	Stocking rate			
	5 pigs/ 50 m^2	5 pigs/ 100 m^2	P value	Significance
Powerful rooting	0.089	0.062	0.079	tendency
Light rooting	0.076	0.050	0.072	tendency
Eating	0.392	0.569	0.009	**
Nosing	0.036	0.022	0.005	**
Other activities	0.139	0.096	0.026	*
Inactive	0.265	0.199	0.096	tendency
Rooting [1]	0.165	0.111	0.067	tendency

** $p<0.01$. * $p<0.05$, tendency: $p<0.10$.

[1] Rooting=powerful rooting+light rooting.

on foraging was not affected by feeding level. However, a study with twenty-four primiparous sows showed that time spent grazing, grazing activity and distances walked was significantly reduced with increasing dietary energy intake from 19 to 33 MJ DE/day. Rectal temperature increased significantly as energy intake increased. Increases in feed intake during pregnancy reduced grazing behaviour during daytime and increased the rectal temperature (Santos Ricalde and Lean, 2002). Studies under indoor conditions suggest that feed with inadequate crude protein content can induce rooting behaviour (Jensen et al., 1993) and pigs may select a diet suitable for their needs if given the choice (Kyriazakis and Emmans, 1991). However, the extremely high ambient temperature had a greater effect on grazing behaviour and body temperature than energy intake in pregnant sows kept outdoors under tropical conditions

Temperature and behaviour of outdoor pigs

As mentioned in the previous section, pigs are very sensitive to the ambient temperature. High temperature has a strong effect on pig behaviour, especially the activities associated with the wallow. It was observed that rooting and making bubbles in wallow water increased as temperature rose. The duration of behavioural activities towards the wallow water increased when the ambient temperature exceeded 15°C. Olsen et al. (2001) suggested that at this temperature the behaviour gradually changes towards temperature regulatory associated behaviour. However, other researchers found that in outdoor kept pigs, wallows are used regularly when temperature exceed 18-19°C (Stolba and Wood-Gush, 1989; Andresen and Redbo, 1999). Pigs also lay in the wallow, even at temperatures below 0°C-but not for very long, suggesting that wallowing may play a role in care of pigs' skin and hair (van Putten, 1978). Also the duration of rubbing the trunk and the hindquarters increased with increasing temperatures. This might indicate that these behavioural comfort activities are related to the temperature regulatory behaviours (Sambraus, 1981 cited by Olsen et al., 2001).

There were no relationships between temperature and rooting behaviour in outdoor growing pigs (Andresen and Redbo, 1999). Above 5°C, the ambient temperature has little effect on the shelter-seeking behaviour of the pigs and radiant temperature appears to have no effect. Rain increased the time spent on chewing, sucking or making rooting movements towards penmates in the indoor part of the pen, and biting or rooting towards pen hardware in the outdoor run. Rain increases oral activities towards penmates regardless of housing system. Rain also encourages tail-biting which is undesirable from both an economic and welfare point of view. However, further studies are required to determine if oral activities directed towards penmates are affected by rain. Buckner et al. (1998) also found that on rainy days, the pigs spent less time outside their huts. Air movement appeared to affect the pigs' choice of habitat to the greatest degree, with pigs usually choosing to avoid the windiest parts of their paddocks. Although the growing pigs sought shelters more often when the temperature fell below 5°C. This was well below their lower critical temperature of about 20°C; thus most of the time the pigs spent outside involved additional heat loss.

Lying in deep straw with body contact was negatively correlated with temperature. Keeping pigs in straw is an effective way to stay warm (Geers et al., 1986). The duration of lying in deep-straw without body contact, and lying in all the other areas were positively correlated with temperature. These findings may suggest that lying with body contact in deep-straw is a significant way of staying warm, whereas lying in other areas of the pen and the outdoor run are ways to increase heat-loss from the body.

Stocking rate and behaviour of outdoor pigs

The behaviour of free-range pigs is associated with the area of the paddock, herbage availability and stocking rate. The frequency of eating was 18% higher on a low stocking rate compared to a high stocking rate, whereas rooting (powerful and light rooting) and passive behaviour tended to be higher on the higher stocking rate (Andresen and Redbo, 1999, Table 10). It seems grazing was preferred to rooting, when herbage still was available. The tendency for a higher incidence of rooting on the smaller plots might thus be a substitute for above-ground foraging (Andresen and Redbo, 1999).

Urinating behaviour of grazing pigs

It seems that pigs prefer to dung in light and draughty areas (Randall et al., 1983) and away from their sleeping area (Stolba and Wood-Gush, 1989). Pigs also dung in the wallow because they prefer to excrete in wet areas (Fritschen, 1975). In sows, Sambraus (1981 cited by Olsen et al., 2001) found that defecation and urination was done before wallowing, but he found only a few cases of

Table 11. Helminths found in pigs in relation to type of management (Nansen and Roepstorff, 1999)

Helminth	Wild boar	Domestic pig		
		Outdoor	Indoor (extensive)	Indoor (intensive)
Ascaris	+	+	+	+
Oesophagostomum	+	+	+	(+)
Trichuris	+	+	+	(+)
Strongyloides	+	+	+	
Hyostrongylus	+	+	(+)	
Metastrongylus	+	+		
Stephanurus	+	(+)	(+)	
Ascarops	+	(+)		
Physocephalus	+	(+)		
Macracanthorhynchus	+	(+)		
Trichinella	+	(+)	(+)	
Taenia	+	(+)		
Schistosoma	+	(+)		
Fasciola	+	(+)		
Dicrocoelium	+	(+)		

defecating and urinating in the wallow. Hacker et al. (1994) stated that pigs drink, urinate and defecate in a close sequence. Olsen et al. (2001) observed that pigs placed more than 75% of the dung in the outdoor runs and about 50% in the wallow. The pigs excreted away from the roughage and their lying area and shade. Stern and Andresen (2003) found that defecation and urination were most frequent in newly allotted areas, followed by the dwelling area. This suggests that successive allocation of new land gives rise to a distinct foraging area, which also is frequently used for excretory behavior. Olsen et al. (2001) suggested pigs do not prefer to dung in busy areas because of the so-called 'unstable posture' during excretion as proposed by Randall et al. (1983) and Aarnik et al. (1997).

Teeth clipping and behaviour

Delbor et al. (2000) studied the effect of teeth clipping and iron injections on skin lesions and growth of piglets born in the outdoor system. Leaving the teeth intact increased piglet growth rate between birth and weaning (+0.016 kg/day; $p<0.05$) and there was no significant difference from weaning to 63 days. Leaving the teeth intact was associated with an increase in the severity of skin lesions at days of age, but it disappeared at weaning. It is concluded that the procedures commonly used in outdoor systems, teeth clipping and iron injection, do not improve piglet performance. However, teeth clipping may have an effect on behaviour and forage intake of free-range pigs.

DISEASE CONTROL

A number of researchers have reported that pigs in outdoor units have better health than indoor herds, especially fewer respiratory problems and a lower incidence of enteric disease (Thornton, 1990; Tubbs et al., 1993). On the other hand, deaths from swine urogenital disease (32.4%), heart failure (21.8%) and locomotor problems (33.1%) have been reported to be higher in outdoor production (Karg and Bilkei, 2002). Nansen and Roepstorff (1999) summarized the helminthes found in indoor and outdoor pigs (Table 11). It is obvious that outdoor pigs have a higher parasite burden, which increases the nutrient requirement for maintenance and reduces feed utilization efficiency of the free-range pigs. The high numbers of parasite in free-range pigs may also risk the image of free-range pork as a clean and safe product. Rodriguez-Vivas, et al. (2001) also reported that *Isospora* were prevalent in 94 and 41% of the sows in the outdoor and indoor systems, respectively. Sows in the outdoor system have a higher excretion of *oocysts* from *Isospora* than sows kept indoors. Leite et al. (2000) measured that the incidence of internal parasites in outdoor pig production, after use of some husbandry practices without anthelmintic administration. Over two experimental years, 83% and 78% of the faecal samples were positive for eggs of *Strongyloidida*e and *coccidia oocysts*, respectively. Ectoparasites or erysipelas were not found in the adults and no endoparasites were found in the piglets. The helminth infections will be more prevalent for pigs under organic production systems which rely heavily on grazing without using antibiotics and other chemicals. In a short to medium term perspective, integrated control may combine grazing management with biological control using nematophagous micro-fungi, selected crops like tanniferous plants and limited use of antiparasiticides (Table 11).

The number of parasites in the paddock varied with the season, which mainly reflects the sensitivity of parasites to temperature. Many eggs deposited during summer may die rapidly due to high temperatures and dessication. Some eggs deposited in cold months by foraging pigs cannot survive through lower temperatures, more moisture, and greater sequestration of eggs in the soil by rain and earthworms. For example, Larsen and Roepstorff (1999) found that *A. suum* and *T. suis* eggs, which are very resistant to environmental factors, may be subjected to a high mortality when eggs in faeces are exposed to desiccation and fluctuating temperatures during a dry summer (Larsen and Roepstorff, 1999). *Oesophagostomum* eggs deposited on a pasture in the winter will die (Larsen, 1996) although some infective larvae do survive outdoors during winter in temperate regions (Haupt, 1969 cited by Roepstorff and Murrell, 1997b). Roepstorff and Murrell (1997b) reported that both *O. dentatum* and *H. rubidus* were very sensitive to environmental factors and significant transmission occurred only under the most favorable conditions. Transmission was severely reduced during low temperatures in winter. Mejer et al. (2000) and Thomsen et al. (2001) found that *O.*

dentatum became completely eradicated from heavily contaminated pastures, but Petkevicius et al. (1996) showed a significant winter infection of *O. dentatum* larvae. This suggests that larval survival depends upon weather conditions in combination with the relevant physical/biological factors in the pig facility (Roepstorff et al., 2001). For example, continuous grazing actually reduced transmission of *O. dentatum* and *H. rubidus* because of the reduction in vegetation although this grazing system has adverse environmental effects (Smith, 1979; Mejer et al., 1998). Roepstorff and Murrell (1997a) revealed that *A. suum* and *T. suis* eggs are much more resistant to environmental factors than free-living infective larvae of pig parasites such as *Oesophagostomum* dentatum and *Hyostrongylus rubidus*. Control of these parasites in outdoor pigs will present more difficult challenges than for parasites transmitted by free-living larvae.

Grazing management

Diseases can be controlled to a certain degree by grazing management. Provision of clean (ungrazed) pasture and cleaning of any permanent facilities for each batch or production year are necessities but may not exclude the build up of infections. The time needed for resting pastures between batches to prevent transmission is also debatable. Thus frequent rotation is required although most farmers are keeping their pigs for a long period on a plot before rotating. Roepstorff et al. (2001) suggested that yearly rotation might not be sufficient in the control of parasites with long-lived eggs, such as *A. suum*, and that a pasture rotation scheme must include all areas, including housing where incidency of parasites is greater than other areas. Nansen and Roepstorff (1999) suggested that the controlling strategies for outdoor pigs against helminth infections should include pasture rotation, mixed or alternative grazing with other animal species, and the integrated use of anthelmintics. It is clear that the anthemintic treatment alone cannot completely control the helminthes since the animals will inevitably be infected on the contaminated pastures. The above studies indicate a need for a long-term research on transmission patterns of resistant, long-lived, but slowly developing eggs, like those of *A. suum*. Roepstorff et al. (2001) pointed out that multi-year rotation strategies should be adopted because the eggs survive in considerable numbers from year-to-year. However, no such strategies have been tested in practice and further research on practical pasture management in the control of pig helminths in extensive outdoor systems is required.

Stocking rate

Stocking rate is considered to be an important factor in grazing management (Bransby, 1993; Thamsborg et al., 1999). The development of more intensive systems for animal production on pasture tends to raise the stocking rate. However, there are no recommendations for an optimum stocking rate for free-range or organic pig production systems. Generally a lower stocking rate is maintained on organic farms as a proportion of the grazing area has to be used for nitrogen-fixing plants, particularly clover, when commercial fertilizer is not used.

Animals stocked at higher densities risk obtaining higher levels of gastrointestinal parasites. This has been shown in studies of sheep (Downey and Conway, 1968; Thamsborg et al., 1996) and cattle (Ciordia et al., 1971; Hansen et al., 1981; Nansen et al., 1988), but few studies have investigated the effect of stocking rate on helminth infections of free-range pigs in out-door areas. It is clear that the behaviour of pigs on pasture is different from ruminants because pigs often display rooting behaviour (Graves, 1984) and forage the dung patches. These behaviours may result in a higher risk of disease infection, with the magnitude being associated with stocking rate. Pigs stocked at high densities can rapidly turn the pasture into a mudded area (Roepstorff and Murrell, 1997a), which in combination with hot and dry weather may impede the development and survival of parasitic eggs and larvae (Larsen, 1996; Kraglund, 1999; Larsen and Roepstorff, 1999). In the first year of a two-year study using stocking rates of 17, 42 and 100 weaner pigs per ha, Mejer et al. (1998) found significantly higher faecal egg counts with higher *O. dentatum* worm burdens at the higher stocking rate. However, stocking rate did not correlate with *A. suum* and *T. suis* infection levels. In another study on the dynamics of parasites of free-range pigs at different stocking rates, Thomsen et al. (2001) revealed that the percentage of grass cover was reduced considerably at the high stocking rate (576 m^2/pig) in comparison to the other stocking rates (100 and 240 m^2/pig). The *O. dentatum* faecal egg counts and worm burdens were significantly higher in pigs at the highest stocking rate, but *O. dentatum* did not survive the winter. However, the transmission of *T. suis* was not influenced by stocking rate, but *T. suis* and *A. suum* eggs are still expected to constitute a high risk of infection on intensively used pastures where eggs may survive for years. It was also found that the effect of stocking rate on faecal egg counts and worm burdens was not linear because the infection levels at the low stocking rate were not lower than they were at the medium stocking rates. Thomsen et al. (2001) also pointed out that at high stocking rates, much of the grass disappeared leaving large areas with very short grass or bare soil. In combination with hot and dry weather, this may have provided poor conditions for the development of parasitic eggs and larvae. This further indicates the complexity of parasite transmission for free-range pigs.

Nose rings

To avoid the damage to the grassland, it is common to apply a nose-ring to sows in outdoor herds, thereby reducing their rooting behaviour. This strategy will also assist in the parasite control for free-range pigs as both *Oesophagostomum* larvae (Larsen, 1996) and *Ascaris* and *Trichuris* eggs (Larsen and Roepstorff, 1999) survive well in soil. Roepstorff et al. (1992 cited by Thamsborg et al., 1999) suggested nose-rings could be a contributory factor to the very low infection levels found in several Danish outdoor sow herds not using anthelmintics. However, a recent trial failed to show any significant effect of nose-rings on helminth transmission (Mejer et al., 1998). A study of mixed (and alternate) grazing with nose-ringed sows and heifers, showed promising results in controlling *Ostertagia* infections in the cattle whereas little effect on the nematode infections of sows were noted (A. Roepstorff and J. Monrad, unpublished data). The lush grass surrounding the faecal pats typical of cattle grazing was absent due to the sows grazing and spreading and eating the cattle faeces. In warm moist environments, however, it cannot be excluded that the spreading of faeces may lead to a higher herbage infection.

Plant materials

The concept of using pasture species to minimise nematode infections in grazing pigs looks promising and the possibilities seem far from exhausted. Plants that can be grown locally and used as part of the normal feeding regime are most likely to be acceptable to farmers, particularly organic farmers. The plants can possibly be used in the supplementary diet or they can be grown in a mixture with grass and legume pastures in the grazing paddocks. In line with this, research into the usage of locally available herbs is required to assess their efficacy for controlling diseases. While these herbs used traditionally for therapy are unlikely to have serious side effects, caution needs to be applied in substituting existing well defined chemical anthelmintics with lesser known herbs (Dano and Bogh, 1999).

Dietary manipulation and feeding fungi

Several components in the diet may affect nematode infections but relatively few studies have been carried out in monogastric animals. In pigs, high levels of insoluble dietary fibres have resulted in higher establishment rates and better fecundity of *O. dentatum* compared to diets with similar protein and energy levels but rich in digestible carbohydrates and proteins (Petkevicius et al., 1999). However, *A. suum* infections were not affected. These findings may have important implications for the epidemiology of *Oesophagostomum spp.* in sows under free-range or organic farming conditions. In these production systems, pigs are usually permanently exposed to infection, and roughage, where primarily fresh grass or whole grain silage is fed *ad libitum*. Interestingly, feed structure also affects bacterial infections as commercial pelleted feed increases the prevalence of salmonella compared to homegrown feed.

In pigs, one field trial has shown significant reductions in acquired *Oesophagostomum spp.* and *H. rubidus* infections by adding fungus *D. flagrans* to the feed (Nansen et al., 1996). The effect of *D. flagrans* in faecal cultures from pigs does not seem to be affected by different levels of insoluble dietary fibre in the feed (Petkevicius et al., 1998).

SUSTAINABILITY OF FREE-RANGE PIG PRODUCTION SYSTEMS

It has been recognised that free-range pigs are a resource in the animal and the cropping system. The grazing and rooting of pigs reduce external inputs for soil tillage and weed control in the cropping system. However, one of the key public concerns for free-range pig production systems is the impact on the environment. In the past, the pigs were held in the same paddock for a long period at a high stocking rate, which resulted in an apparent damage to the vegetation, a great nutrient load in the soil, nitrate leaching and gas emission (Worthington and Danks, 1992). Rachuonyo et al. (2002) found that a higher stocking rate (35 gilts/ha) decreased the percentage of ground cover compared to lower stocking rate (17.5 gilts/ha) when grazing was initiated in March/April. The ground cover recovered rapidly after pigs were removed. However, pastures (mainly *Bothriochloa ischaemum*) stocked at the higher rate had lower ($p<0.001$) forage mass. To avoid this, outdoor pigs should be integrated in the cropping pasture system, the stock should be mobile and stocking rate related to the amount of feed given to the animals. Considerable research has been carried out to assess the distribution, losses and uptake of nutrient by crops in free-range pig production systems.

Nutrient distribution in paddocks

The distribution losses and utilization of nutrients in the paddock in succeeding rotated crops were investigated after grazing by pigs (Williams et al., 2000; Eriksen, 2001; Eriksen and Kristensen, 2001). A significant correlation between soil inorganic N and the distance to feeding sites was found after the paddocks had been used by lactating sows for 6 months. Near to feeders, inorganic N levels became extremely high whereas 30-40 m from feeders some patches had N levels in the topsoil corresponding to the levels in the reference area without sows. In the following spring, only a minor level of inorganic N was still present in the top 40 cm of soil. Similarly, extractable P and exchangeable K in topsoil were affected by distance to feeders with the highest values close to the feeder. The nutrient load was high in the soil close to the hut. Although huge variations in dry matter production and nutrient content occurred in the succeeding potato crop, these were related to the distribution of nutrients (N, P, K) in the previous year, which explained 17% of the total variation in dry matter production. This suggests that a uniform distribution of nutrients should be obtained by manipulating the excretory behaviour of the sows and adjusting stocking densities to locally acceptable nutrient surpluses for an increased nutrient efficiency in outdoor pig production (Eriksen and Kristensen, 2001). However, Rachuonyo et al. (2002) did not find any differences in soil nitrate content (15 cm deep, after 306 d trial) between the following locations: near the point or radial (centre point of experimental area), the middle region of each treatment (containing a hut and a wallow area) or the outer section where gilts were fed each day. Worthington and Danks (1992) estimated annual feed N inputs at 625 kg N/ha for systems stocked at 14 sows/ha. Nitrogen output in pig meat was at 119 kg N/ha, leaving a surplus of 506 kg N/ha. This large surplus will be returned to the soil via dung and urine excretion, as ammonium-N and organically bound N. Some of the ammonium N will be lost to the atmosphere by volatilisation, with the remainder converted by nitrifying bacteria to nitrate-N. The organic N will mineralise gradually over time to produce ammonium-N which will be converted to nitrate-N and contribute to the soil mineral nitrogen pool. The nitrate-N will be available for plant uptake, but will also be susceptible to loss from the soil either by leaching or by conversion to di-nitrogen (N_2) and nitrous oxide (N_2O) gas during denitrification.

Denitrification and nitrogen leaching

The spatial distribution of denitrification activity in a 5× 5 m grid in a grazed paddock compared to an ungrazed paddock was assessed by Petersen et al. (2001) immediately after the sows (32 sows/ha for 6 month) were removed in October 1997, and again the following March. Denitrification rates averaged 0.01 kg N/ha per day in the control paddock, and 0.5 kg N/ha per day for the grazed paddock in October, while the corresponding figures in March were 0.01 and 0.1 kg N/ha per day. The highest denitrification rates were observed around the feeder, and this is also the case for concentration of dissolved organic C and inorganic N in the soil. A similar result was reported by Eriksen (2001), who found that the inorganic nitrogen concentration in soil was uneven after sow grazing, with the highest values found near the feeding area. Ten metres from the feeding area, leaching losses were 500 ka of N/ha and 330 kg of N/ha for 16 m over 18 months. The nitrate leaching was determined by using the suction cup technique. Petersen et al. (2001) also stated that both climate and management (position of huts and feeder) appeared to influence denitrification, which was estimated to be 69 kg N/ha per year, or 11% of the N surplus of this production system.

Williams et al. (2000) examined the nitrogen losses from outdoor pig farming systems in the UK. Three types of management system were included in this study, current commercial practice (CCP)-25 dry sows/ha on arable stubble; improved management practice (IMP) (18 dry sows/ha) on stubble undersown with grass and best management practice (BMP) (12 dry sows/ha) on established grass. In the first winter, mean nitrate-N concentrations in drainage water from the CCP, IMP, BMP and arable paddocks were 28, 25, 8 and 10 mg NO_3/L, respectively. On the BMP system, leaching losses were limited by the grass cover, but this was destroyed by the pigs before the start of the second drainage season. In the second winter, mean concentrations increased to 111, 106 and 105 mg NO_3-N/L from CCP, IMP and BMP systems, compared to only 32 mg NO_3-N/L on the arable paddock. Ammonia losses from outdoor dry sows were in the region of 11 g NH_3-N/sow/day. Urine patches were the major source of nitrous oxide emission, with N_2O-N losses estimated at less than 1% of the total N excreted. Nitrogen inputs to all the outdoor pig systems greatly exceeded N taking off by crop plus N losses, with estimated N surpluses on the CCP, IMP and BMP systems after two years of stocking at 576, 398 and 264 kg N/ha, respectively, compared with 27 kg N/ha on the arable control. These large N surpluses are likely to exacerbate nitrate leaching losses in the following seasons and make a contribution to the nitrogen requirement of future crops. It seems that maintaining a vegetative cover during the stocking period will limit nitrate leaching losses from outdoor pig farming. Rhizominous grasses such as creeping red fescue (*Festcua rubra*) and smooth stalked meadow grass (*Poa pratensis*) may be more resistant to trampling and rooting habits of the pigs than the ryegrass (Williams et al., 2000). Changes in management practice, such as moving pigs to a new paddock on an annual basis may also be necessary to minimise nitrate leaching losses by maintaining a grass cover.

Ammonia emission

Ammonia losses from outdoor pigs (11 g NH_3-N/dry sow/day) measured by Williams et al. (2000) were similar to those measured for grazing dairy and beef cattles (17 and 5 g NH_3-N/animal/day). The nitrous oxide emissions measured from pig paddock were similar to annual losses of 0.5 kg N_2O-N/ha measured by Carran et al. (1995) from low fertility pasture soils grazed by dairy cattle, indicating increasing production of outdoor pigs would probably have little impact on total nitrous oxide emissions from agriculture.

CONCLUSION

Due to public concerns on welfare of intensively housed pigs and the increasing demand for free-range or organic products, more pigs will be reared under free-range systems where pigs can express their natural behaviours. The free-range pig production system has been successful for many farms under different environments although some farms have failed to be sustainable. Most farms are keeping their pigs in the same location for many years before rotating, frequently with a high stocking rate and a high output per unit of land area. This practice has resulted in a degradation of vegetation and the build up of nutrients, which is a cause for great concern to the public. Current research by Ru et al. (2001) has shown that free-range pigs can be incorporated into a crop-pasture rotation system where pigs can play a role that sheep currently play in this system. This system requires a low stocking rate and frequent rotation. It was demonstrated that free-range pigs had had a similar effect on soil fertility and weed population although pigs consumed less pasture than sheep. However, the sustainability of this system requires further assessment, especially the optimum stocking rate and the most suitable pastures for this system under different soil types.

High mortality of free-range piglets is also noticed by many farmers and researchers. Many factors contribute to the high mortality. These include high disease infections, variable environmental conditions and the behaviour of sows. It is clear that free-range sows have a better nursing capability and most of the deaths of piglets is caused by crushing. Disease control is a major task for free-range pigs although some researchers have shown that free-range pigs are healthier than indoor pigs. The studies on the dynamics of parasites in free-range system clearly showed that the prevalence of parasite infections is influenced by season (temperature), stocking rate and grazing management. Under current production systems, except for organic farms, regular use of anthelmintics alone is the most common control method, unfortunately sometimes the only control intervention. It is apparent that an integrated parasite control system is more efficient under practical farming conditions. These include, 1) the purchasing of pigs from intensive indoor herds to limit the risk of introducing parasites, 2) frequent rotation (cropping) to prevent the build up of parasite, 3) mixing grazing with other livestock species such as cattle, 4) dietary manipulation, 5) the use of micro-fungi as biological control agents and incorporation in the pasture, plant species which have an effect on nematode infections, and 6) use of nose rings to prevent pigs from ingesting soils which often have a high parasite load. Future research in this area should include the identification of 'new' parasitic problems in free-range pigs and assessment of risk factors and their impact on health and production in organic farming. Acceptance of a certain degree of production loss without compromising welfare could be an option. An important issue is the risk assessment of parasitic zones in large outdoor pig rearing units.

It is well understood that pigs are sensitive to environmental conditions especially temperature. When the temperature is below the lower critical temperature, pigs must increase heat production through shivering and other metabolic processes to maintain body temperature. On the other hand, when the temperature is higher than its evaporative critical temperature, the evaporative heat loss of pigs begins to increase, particularly from the lungs, through increased respiration. Because pigs are not able to sweat, they are more sensitive to hot than cold conditions. Pigs exposed to temperatures above the evaporative critical temperature have a low feed intake, milk yield and poor reproductive performance and growth rate. Water drippers, sprays and wallows are effective in reducing the impact of ambient temperature and improve the production of free-range pigs. However, foraging pigs can also damage soils around these facilities and dung in the water, with a build up of parasite load. Currently a natural product (betain) has been approved to be effective in heat release and is available commercially. The use of this product or similar products in free-range pigs need to be assessed.

Drinking water should be always available for free-range pigs. This is particularly important for pigs in a hot environment. However, most pig producers ignore the quality of water. Under free-range system, water troughs are often accessible to wild birds and contaminated with dust, resulting in a high potential for disease transmission. This high temperature may cause a low water intake as found in intensively housed pigs by Cargill (2002). Thus the strategies for cooling water in summer should be developed for free-range pig production systems.

One of the major concerns for the community on free-range pigs is the emission of ammonia. Currently most research has been undertaken to assess the ammonia level in sheds where pigs are housed intensively. Little data is available on the ammonia released from free-range pigs. While it is clear that the total ammonia released to the air is dependent on the number of pigs in the paddock, the data on ammonia emission will assist farmers to establish the optimum stocking rate from an air quality point of view for the community. More research is needed in this area.

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