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Integration of organic animal production into land use with special reference to swine and poultry

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Abstract

The development in organic livestock production can be attributed to an increased consumer interest in organic products while, at the same time, increased farmers' interest in converting to organic production methods—often stimulated by governmental support or subsidies. It is important that organic production systems can fulfil the expectations of each of these stakeholders if organic livestock production is to increase further. This is of particular importance if organic pig and poultry production (other than egg) is to move from the present niche-production to a significant place in the food market, as in the case of beef and milk.

It can be argued that the limited organic pork and poultry production is related to the fact that it is far more difficult for farmers to change the existing production systems for pig and poultry compared to production systems for cattle and other ruminants in a way that gives a harmonious balance between the different aims of organic farming. Conflicts may occur as to the most appropriate rearing practice in considerating the basic aspects of the innate behaviour of animals on one hand, the risk of pollution from the production on the other and, in addition, the aim of producing in sufficient quantities. These possible conflicts are reflected in the compromises made in national or EU regulations on organic farming.

In the regulations for organic farming, the aspect of allowing a high degree of natural behaviour of the livestock is, among others, translated in the requirement that livestock, in certain periods of their life or of the year, should be allowed to graze or have access to an outdoor area. The most common outdoor systems for pig and poultry used in intensively managed organic production have some significant drawbacks in relation to environmental impact (risk of N-leaching and ammonia volatilisation), animal welfare (nose-ringed sows), high mortality in poultry and workload and management constraints.

From recent experience of such systems, it is argued that there is a need for a radical development of the systems. There is a need for outdoor/free range systems (for the sake of the livestock), which are constructed and managed in such a way that the livestock, at the same time, exert a positive influence on other parts of the farming system. There is evidence that pregnant sows can fulfil their nutritional needs to a large extent by grazing, that co-grazing sows with heifers can diminish the parasite burden of the heifers, and that the pig inclination for rooting can be managed in a way that makes ploughing and other heavy land cultivation more or less superfluous. As regard poultry, there is an indication that quite big flocks can be

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managed efficiently in a way where the flock act as weeders in other crops or fight pests in orchards. These elements need to be further explored as a basis for future system development.

Keywords: Pigs; Poultry; Free range systems; Environmental impact; Grazing

1. Introduction

There has been a tremendous growth in the number of organic farms in Europe over the last 20 years—from approximately 8000 in 1985 to more than 142,000 in 2001 and with a correspondingly increase in organically managed land (Fig. 1). The country with the highest number of farms and greatest number of hectares is Italy. Germany has the largest organic market with a sales value of approximately 2.5 billion Euro. In terms of per capita consumption of organic products, however, Denmark and Switzerland are the clear leaders. Nevertheless, at present only 3% of the European agricultural land is managed organically and the market share is no more than 1–2% (Willer and Richter, 2003), although with large differences among countries as shown in Table 1. It also appears from Table 1 that the market share in USA and Canada is estimated to be approximately 2% and with a similar expected high annual growth as in the European countries.

Livestock often plays an important role—besides supporting income for the farmers—in realizing some of the principle aims in organic farming, i.e., diversified production and supporting biological cycles within the farming system. However, some conflicts may occur as to how and to what degree the different aims can be obtained. In relation to livestock, conflicts may occur as to the most appropriate rearing practice in considerating the basic aspects of their innate behaviour on one hand, the risk of pollution from the production on the other and, in addition, the aim of producing in sufficient quantities. These possible conflicts are reflected in the compromises made in national or EU regulations on organic farming. The regulations, however, often develop after an intensive debate where, sometimes, you may get the impression that livestock production may be

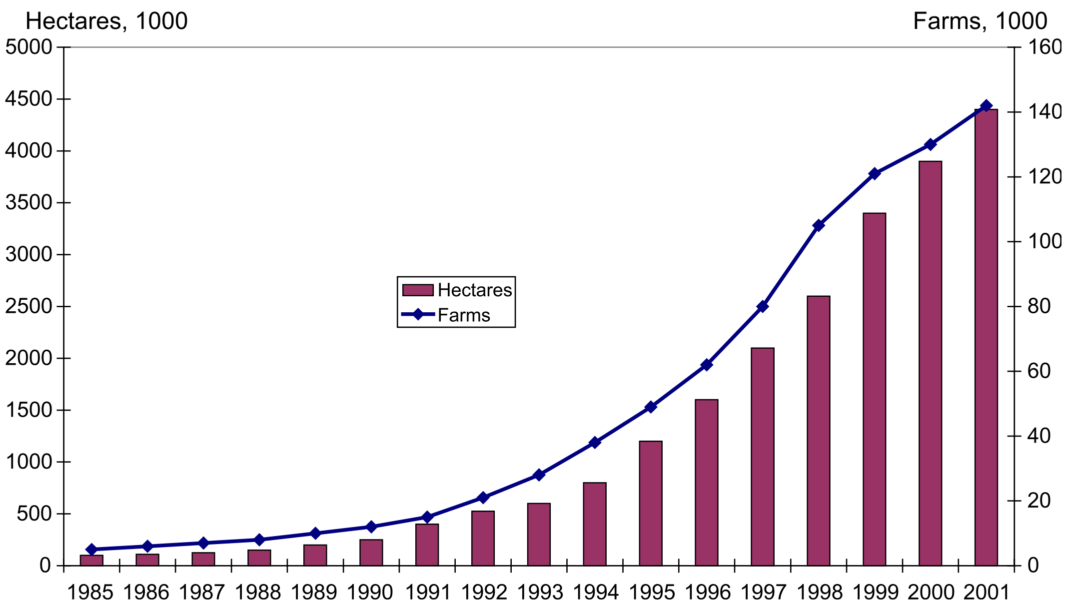

Fig. 1. Development of land under organic management and of organic farms in the European from Union 1985 to 2001 (Source: FiBL).

Table 1
Overview world markets for organic food and beverages (forecast) (Source: Compiled by ITC, December 2002)

Markets	Retail sales, 2003 (million US$)	Percent of total food sales (estimates)	Annual growth, 2003–2005 (%)
Germany	2800–3100	1.7–2.2	5–10
U.K.	1500–1750	1.5–2.0	10–15
Italy	1250–1400	1.0–1.5	5–15
France	1200–1300	1.0–1.5	5–10
Switzerland	725–775	3.2–3.7	5–15
Netherlands	425–475	1.0–1.5	5–10
Sweden	350–400	1.5–2.0	10–15
Denmark	325–375	2.2–2.7	0–5
Austria	325–375	2.0–2.5	5–10
Belgium	200–250	1.0–1.5	5–10
Ireland	40–50	<0.5	10–20
Other Europe	750–850	–	–
Total (Europe)	10,000–11,000	–	–
USA	11,000–13,000	2.0–2.5	15–20
Canada	850–1000	1.5–2.0	10–20
Japan	350–450	<0.5	–
Oceania	75–100	<0.5	–
Total	23,000–25,000	–	–

acceptable but not desirable in organic farming, at least for some species. Therefore, in the long term, it is important that production systems are developed so that different sorts of livestock production can contribute directly towards fulfilling the organic ideals on a national scale or at farm level. This point of view has until now been scarcely discussed.

Andresen (2000) puts words to the idea, saying that the view of livestock should be changed from considering them as being passive (receivers) to active components of the sustainable development of production systems. More attention should be focused on the (various) capabilities of the animals and less on the "requirements" of the animals. The challenge is then to supply conditions so that the livestock can optimize the value of their various capabilities rather than to control the animal in the environment. The emphasis on animal performance then shifts from mere feed conversion to functional efficiency in the farming system. This leads to new parameters for evaluation.

Several examples of interaction/synergism can be given. First of all, there is the well-known and accepted role of ruminants in converting fibrous feed to high value nutrients (for example, fibrous feed from the grassland), which is grown, for example, for the purpose of maintaining soil fertility and limiting growth of weeds in organic crop rotations (Younie and Hermansen, 2000), or, for example, the sheep-olive integration (Trujillo, 2000).

This relationship may—as one of several factors—be the reason that organic milk and beef products were in the top five of consumption in 13 and 7, respectively, of 18 European countries in the late 1990s (Michelsen et al., 1999). Organic pork and poultry were not in the top five list in any country but organic egg production was included in 4 of 18 countries. There is no reason to believe that this difference is due to a different consumer preference. It is more likely due to the fact that it is far more difficult for farmers to change the production system for pig and poultry compared to production systems for cows and other ruminants in a way that gives a harmonious balance between the different aims of organic farming.

However, pigs and poultry may also exert an important synergism in supporting the harmonic development of a farm. A main issue in this context may be to find ways for a better integration of pig and poultry production into land use in general. It is anticipated that a further overall increase in organic production in many countries will depend to what extent such a development actually can take place. The aim of this paper is to highlight some of the prospects and constraints for such an integration based on European experience so far.

2. Pig production

2.1. Production systems

Organic production methods must meet the basic standards of the International Federation of Organic Agricultural Movements (IFOAM, 2000). Within the EU, it must also meet the rules laid down in Council Regulation (EC) No. 1804/1999 of 19 July 1999. Some main requirements within the EU relating to pig production are that pigs should have access to grazing for at least some part of the year, though finishers can be housed in barns if they have access to an outdoor run for at least 80% of their lifetime. As regard feed, chemically synthesized or GMO-derived amino acids and vitamins are excluded as well as feed containing

Fig. 2. Nose-ringed sows on pasture.

antibiotics and growth promoters. The weaning age for piglets should be at least 40 days.

In different countries or different certification bodies, stricter rules can be implemented. So, it is possible to have several organic pig production methods due to different practices or different regulations in different countries. The system in Denmark represents some of the major challenges facing the development of organic pig production. Typically, sows are kept in outdoor systems all year round (Fig. 2) and pigs are moved to an indoor pig unit with an outdoor yard when they are weaned at 7 weeks of age. This system was stimulated by a simultaneous development of outdoor systems for conventional sow production as indicated in Table 2. Since 1996, the number of sows housed outdoors has doubled and organic production has increased fourfold. However, as shown in Table 2, stagnation in organic pig production has taken place. The number of finishers at 74,000 is less than 0.3% of the total Danish pork production of approximately 23 million per year. This highlights the underdevelopment of this sector in Denmark.

Because it is part of the organic regulations to have the sows on pasture for at least 150 days during summertime and a number of conventional farmers had positive experiences with keeping their sow herds outdoors all year round, the organic producers choose this system too. In this way, they have only one production system for their sow herd instead of having both a system for summer housing and a system for winter housing (Fig. 3). The layout of the paddocks depends on soil type and the available land to the individual farm. The paddocks are normally moved to a new field every spring, often in a 2-year crop rotation—1 year with barley with an under-sown

Table 2
Scale of outdoor and organic pig production in Denmark, 1996–2002

Year	Outdoor			Organic		
	Number of herds	Breeding animals (n)	%	Number of herds	Sows (n)	Finishers produced (n)
1996	451	19,839	1.9	210	1073	18,000
1997	1059	28,021	2.5	335	1726	20,000
1998	1264	36,735	3.1	448	2966	47,000
1999	1234	39,096	3.3	535	4084	63,000
2000	1171	39,612	3.4	483	3344	64,000
2001	1080	41,209	3.5	400	3939	62,500
2002	961	41,969	3.5	–	4078	74,000

Fig. 3. Outdoor sow herd in wintertime.

grass-ley and 1 year with sows on pasture. The stocking rate is adjusted to an excretion of 140 kg N in pigs manure per hectare and year (often practised as 280 kg N/ha every second year).

The production system may be different in other countries. In some countries, the sows are mainly kept on pasture in the summer period. On the other hand, in Sweden, it is also mandatory to keep finishers on grass in the period May–September in organic systems. Several challenges exist in the management of sows and finishers, which will be elaborated on later.

2.2. Sow production

Only limited data on the overall productivity of outdoor organic sows are available. Investigations over a 4-year period from four organic herds gave production results on a per-litter basis, which in the last part of the investigation period was almost comparable to the 25% best results from Danish indoor herds, i.e., for organic and conventional herds, respectively (Lauritsen et al., 2000; Larsen, 2001):

- born alive/litter: 11.8 versus 12.1
- weaned/litter 9.8 versus 10.8

The number of litter per sow was lowest in the organic system, partly because of a longer weaning period (7–8 weeks compared to 4–5 weeks) and partly because of poorer reproduction results. Larsen and Jørgensen (2002) found in non-organic, outdoor herds that the reproduction results were comparable to results from indoor systems indicating that poor production results are not related to the fact that sows are kept outside per se. A possible explanation for the poorer reproductive performance observed in organic herds may be related to the longer lactation period in which some sows come in heat followed by an irregularity after weaning.

It has been speculated that the longer lactation period may compromise the welfare of the sow because of weight loss and a growing conflict between the willingness of the sow to suckle and the piglets' demand for food. However, in a study comparing a weaning age of 5 and 7 weeks, Andersen et al. (2000a,b) found no differences in weight loss (−4 versus −3 kg), restlessness, or aggression towards the piglets related to weaning age. The authors concluded that, overall, there was no indication that sows suffered more by 7 weeks of lactation than by 5 weeks of lactation, but the piglets seemed to profit by a suckling period of 7 weeks compared to weaning after 5 weeks. It was specified that the lack of effect of weaning age on restlessness and piglet-directed aggression in the present study might be due to the outside housing in a paddock, which allowed the sows to avoid the piglets by merely walking away. Also the piglets had access to more natural substrates for exploration, which might be an explanation for the stable level of restlessness and aggression towards the piglets between sows in the two treatments.

2.3. Sows on grass

One of the major concerns in keeping sows on grass in intensively management production has been the potential environmental impact due to high excretions of plant nutrients, especially N and P in the manure.

To a great extent, the environmental impact of outdoor pig production is related to the amount of nutrients in the supplementary feed for the pigs and the stocking density. Recent investigations have shown a surplus of 330–650 kg N/ha of land used for grazing sows on organic farms (Larsen et al., 2000). Although this level is lower than that found on average in conventional outdoor sow herds, the present nutrient surplus definitely represents an environmental risk, as it has proved difficult to obtain optimal efficiency of the nutrients deposited during grazing (Zihlmann et al., 1997; Williams et al., 2000; Eriksen and Kristensen, 2001). The adverse consequence of this is considerable losses from grazed pastures and undesirably low nutrient availability in the rest of the crop rotation. Nitrogen losses due to outdoor pigs are related to nitrate leaching (Eriksen, 2001), ammonium volatilization (Sommer et al., 2001) and denitrification (Petersen et al., 2001). In previous investigations in sow paddocks (Eriksen et al., 2002), the N-input in feed to the paddock could be accounted for in piglets (44%), as ammonia volatilisation (13%), as denitrification (8%), or as nitrate leaching (16–35%).

Another concern for outdoor production is the maintenance of the grass sward. A well-maintained grass-sward serves several important purposes. The uptake of nitrogen and water by the grass decreases the risk of nitrogen leaching (Watson and Edwards, 1997). In paddocks for lactating sows, a high level of grass cover is one of the factors which seem to decrease piglet mortality (Kongsted and Larsen, 1999), probably related to the ability of the sow to keep the hut dry and clean. In addition, for pregnant sows, grass can constitute a significant part of their daily energy requirement (Sehested et al., 2000; Rivera Ferre et al., 2000).

In Denmark, the sows kept outdoors are ringed to prevent them from rooting and damaging the sward. The UK Soil Association prohibits ringing of sows, and from September 2001, ringing is prohibited in The Netherlands, too (Mul and Spoolder, 2000). However, even though the sows are ringed, a clear seasonal pattern of grass cover/grass height has been found under Danish conditions (Larsen and Kongsted, 2000). Where ringed sows were grazing, the level of grass cover was low (20–30%) in the beginning of the year and reached a higher level (60–80%) during the summer period. A similar pattern was found in Scotland (Watson and Edwards, 1997). A French investigation (Ogel, 1997) concluded that three factors were essential to maintain grass cover. These factors were the area available (the stocking rate), the ringing of sows and the use of supplementary paddocks. In another experiment (Watson and Edwards, 1997), it was shown that unringed sows reduced the vegetation cover to 10% within a month.

However, the placing of a ring in the snout of sows prevents the sows from rooting, which is one of the sows' basic behaviours, by creating pain for the animal. This is in disagreement with organic ideals for animal husbandry and should be avoided, if possible. Outdoor domestic pigs in semi-natural environments spend about half their active time exploring (Blasetti et al., 1988; Tober, 1996) and 40% of their exploration consist of rooting (Stolba and Wood-Gush, 1984). By rooting, the pigs search for, locate and harvest food. Studnitz et al. (2003) demonstrated that rooting is the preferred explorative behaviour of pigs and rooting behaviour is considered to be a behavioural need of pigs (Horrel et al., 2001), which according to the organic ideals must be taken into consideration. So, there is a definite need for reconsidering the practice of ringing of sows.

Some results suggest that it might be possible to reduce rooting behaviour by providing the sows with a fibre-rich diet (Brouns et al., 1994; Martin and Edwards, 1994; Braund et al., 1998) and by a lower stocking rate (Andresen, 2000). However, further research is needed to identify management initiatives, which allow for maintaining grass as a source of feed for the sows and thereby obtain satiety and at the same time make it possible for the sows to follow their inclination to root. It seems most promising that research activities focus on pregnant sows because they are fed restricted amounts of concentrates but at the same time have the highest potential to utilise grass as a very significant part of their energy and protein requirements.

In a Danish investigation (Eriksen, personal communication), the effect of ringing and short-term stocking density for pregnant and lactating sows on vegetation cover and risk for leaching of N is being studied. The overall stocking rate evaluated on the basis of expected excretion of N from the sows (equivalent to an expected load of 280 kg N/ha) and calculated on a yearly basis was similar in all treatments. Sows were given either an approximately 360 or 180 m^2 per sow across a 20- or 10-week summer period. The preliminary results showed that the ring did not affect grazing behaviour, but to some extent prevented rooting/damaging the grass cover in the paddocks with pregnant sows. In the nursing pens, ringing had no significant effect if each sow was given an area of 360 m^2. At 180 m^2 per sow (only unringed), the vegetation cover was much lover.

However, the relationship between ringing and content of highly soluble N in the soil was not that simple. In fact, no clear effect of ringing was found at the paddock level. On a sample plot level, a negative correlation between vegetation cover and content of highly soluble N in the soil was found in the paddocks for pregnant sows but not for lactation sows.

These results indicate that ringing probably should be considered more as a way of maintaining grass sward without necessarily affecting leaching and, in consequence, be evaluated as a relevant option in this context.

2.4. Rearing of growing pigs in pig houses with access to outdoor areas

A comprehensive work programme has been carried out in relation to organic production of slaughter pigs. Regarding the construction of pig houses with access to outdoor runs, Møller (2000), Olsen (2001) and Olsen et al. (2001) investigated the influence of the type of indoor floor (deep-bedded and partly slatted floors), the size of outdoor run and a partial cover of the outdoor run on production and behaviour. In all cases, the stables were naturally ventilated and the floors of outdoor runs were solid (concrete). Overall, very good production results were obtained in these systems, >900 g daily weight gain, low feed consumption and a lean content of approximately 60%. Aggression levels among pigs were low and the indoor climate was good with a low concentration of ammonia, carbon dioxide, and dust. This was partly a result of the fact that most of the manure (>80%) was placed on the outdoor run. This resulted in a low straw consumption compared to other systems based on deep litter.

In relation to the planned treatments, differences were small. This type of stabling and, particularly, the type described in detail by Olsen (2001) can doubtless function very well, but they are expensive to establish.

Several investigations have focussed on the use of roughage for finishers. The overall idea was to explore the beneficial effect, if any, in relation to feeding. For instance, Danielsen et al. (2000) investigated the effect of restricting concentrate on the ad libitum intake of clover grass and clover grass silage, in two experiments, as well as on production results and sensory meat quality. Restricting concentrate to 70% of ad lib intake on a daily basis resulted in a lower daily gain (12–16%), a lower feed consumption per kilogram of gain (10%), an increased lean content (1–2%), and a reduced tenderness of the meat. Roughage intake was increased by 20–30% but, nevertheless, only amounting to 5–6% of total energy intake.

In the experiments mentioned above, no reference was made to non-organic production. However, Hansen et al. (2001) focused on almost all aspects of meat and sensory quality. Treatments included non-organic production in the same environment as the organic production except that no access was given to either outdoor run or roughage. In three other treatments, organic concentrates were given without access to roughage or with access to two different types of roughage and, at the same time, a reduced level of concentrates. The main results are given in Table 3.

The organic production (although without access to roughage) resulted in a slightly lower daily gain and a slightly higher content of polyunsaturated FA in the fat, whereas no differences were observed in lean content, tenderness, and vitamin E content in the muscles. Restricting concentrates gave the same

Table 3
Production results and carcass characteristics in growers fed organic or conventional concentrates ad libitum, or restricted amounts of organic concentrates together with silage ad libitum (after Hansen et al., 2001)

Concentrates	Conventional (ad lib)	Organic (ad lib)	Organic (70% of ad lib)
Silage:	No	No	Yes
Outdoor area:	No	Yes	Yes
Daily gain (g)	999	935	728
Feed conversion (SFU[a]/kg gain)	2.99	3.09	2.96
MJ/kg gain	23.1	23.9	22.8
Lean content (%)	60.6	60.4	61.6
In muscles			
Intramuscular fat (%)	1.6	1.5	1.2
Vitamin E	3.13	3.15	2.81
Tenderness	8.7	8.6	7.5
In fat			
Saturated FA (%)	41	40	39
Monosaturated FA (%)	45	43	42
Polyunsaturated FA (%)	14	15	18
Iodine value	68.3	72.2	74.6

[a] Scandinavian Feed Units for pigs.

results as in the investigation of Danielsen et al. (2000) in relation to lean content and tenderness, i.e., higher lean content and a reduced tenderness. In addition, a marked reduction in intramuscular fat and vitamin E content in muscles and a higher content of polyunsaturated FA in fat were observed. Also (data not shown), organic feeding and access to outdoor run led to a higher proportion of ham muscles in the carcass. These results are much in line with the results of Millet et al. (in press) who found that organic housing leads to higher muscle and back fat thickness.

In the Danish experiments mentioned above, soybean meal was the primary source of protein. It appears that even in this situation, organic feeding, and especially if fed restrictively, resulted in an increased content of polyunsaturated FA.

At present and, perhaps also in the future, alternative protein sources will be used because of the ban on GMO-products and products resulting from fat extraction with chemical solvents. Therefore, probably more fat-rich sources will have to be considered. The above-presented results indicate that it will be important in this situation to consider harmful effects on the 'fat-quality' of the pork.

2.5. Growing pigs at pasture

The rearing of organic growing pigs in barns with an outdoor run, which is the common practise in several European countries, is heavily constrained by the fact that building costs are considerable higher than for conventional production systems due to higher requirements for area etc. At the same time, it may be questioned if pigs reared under such conditions comply with the consumer's expectations of organic farming. This calls for a reconsideration of the appropriateness of the system.

Several investigations indicate that growth rate obtained in outdoor systems can be comparable to the growth rate in indoor production (Lee et al., 1995, Andresen et al., 2001 Gustafson and Stern, 2003). However, variable feed conversion rates have been obtained. In the summer, a feed conversion comparable to indoor conditions has been obtained in some investigations (Sather et al., 1997), whereas in other periods of the year or in other investigations, a higher feed consumption per kilogram of gain have been reported (Stern and Andresen, 2003; Sather et al., 1997).

Although the growing pig can consume grass and other herbage up to 20% of daily dry matter intake (Carlson et al., 1999), the overall contribution to the energy supply of the pig when fed ad libitum with concentrate mixtures is normally much lower, ranging from 2% to 8%. This means that most feeds given to the pigs at pasture need to be concentrates with a consequent high risk of environmental impact unless measures are taken to counteract this.

At the moment, we are investigating strategies combining grazing and rearing in barns so as to reduce the risk of environmental impact and at the same time allow growing pigs to have plenty of space when they are young and most active. Five strategies are being investigated:

(1) Piglets are moved indoor at weaning and fed ad libitum until slaughter
(2) Piglets stay on pasture and are fed restrictively (70% of expected ad libitum intake) with concentrates until 40 kg live weight, followed by ad libitum feeding in a barn pen
(3) Piglets stay on pasture and are fed restrictively with concentrates until 80 kg live weight, followed by ad libitum feeding in a barn pen

(4) Piglets stay on pasture until slaughtering and are fed restrictively in the whole period
(5) As treatment 4, but the growers are fed ad libitum until slaughtering

The preliminary results show a normal growth rate (≈750 g daily gain) and no marked differences between the pigs fed ad libitum outdoor or ad libitum indoor. However, the feed intake per kilogram of gain outdoor was increased by 13% when fed ad libitum. On the other hand, outdoor kept pigs, which were restricted in energy intake (strategy 4), had the same feed conversion rate as the indoor treatment (1) and, in addition, a significantly higher lean content (approximately 4 units), but growth rate was, of course, reduced (16%). A very interesting finding was in the strategy with restricted intake in outdoor kept pigs until 80 kg live weight followed by ad libitum indoor (strategy 3). The strategy resulted in a feed conversion rate comparable to indoor feeding and the overall daily gain was only reduced by 10–15% compared to ad libitum feed indoor.

These results indicate that options are available in order to get very good production results from outdoor kept finishers.

With the stocking rate applied (100 m^2 per outdoor pig kept from 20 to 100 kg live-weight), however, all vegetation was destroyed. Complementary measurements on risk for N-leaching will elucidate the environmental risks in the systems but these data are yet not available. However, a choice has to be made, i.e., using a considerably lower stocking rate than used in this experiment to keep good vegetation cover or to accept the rooting and try to take advantage of it.

3. Future systems based on integration in land use

Several systems for a better integration of pig production in land use should be considered.

As regard pregnant sows, which can be handled in relatively large flocks, one way could be to base feed intake on forage. There is no doubt that forage can constitute a very large part of the nutrient requirement for pregnant sows. In addition, it has been shown that co-grazing sows and heifers reduce the parasite burden of the heifers and result in an overall better sward quality compared to grazing separately (Roepstorff et al., 2000; Sehested et al., 2004). The live weight gain and the estimated grass intake for heifers and pregnant sows grazing together or separately are shown in Table 4. Fig. 4 shows the larvae infection in the grass sward. It appears that both sows and heifers had a higher daily gain when grazed in the mixed systems although only the different growth rate for heifers was significant in each experiment. It can also be observed that the sow grass-intake corresponded to half of the energy requirement. The peak of larvae infection for heifers per kilogram of grass DM was in the mixed system and was only half of the infection in the separately grazed systems. Serum pepsinogen levels in blood samples of the heifers confirmed the lower infection rate in the mixed grazing systems. No difference in parasite burden as regard the sows was observed.

These results were based on sows equipped with a nose ring, but since this strategy seems suitable in combination with a low stocking rate as regard pigs, one may expect a lower overall rooting and, consequently, that similar results can be obtained with unringed sows.

Another strategy for pregnant sows and also growers could be to take advantage of their rooting inclination in land cultivation. Stern and Andresen (2003) found in experiments with growing pigs at pasture that grazing and rooting were most frequent on newly allotted areas (3–6 m^2 per pig daily) compared with transfer and dwelling areas. Also, defaecation and urination were most frequent in newly allotted areas. At a reduced level of supplementary feed, a higher frequency of rooting appeared. These results suggest that it is possible, through management measures like allocation of new land, feeding strategy, and move-

Table 4
Growth and estimated grass intake for grazing heifers and pregnant sows grazing separately or mixed (average of two experiments; after Sehested et al., 2004)

Grazing system	Separately	Mixed
Heifers (per heifer and day)		
Live weight gain (g)	866	1063
Grass intake (NE, MJ)	41.1	52.5
Sows (per sow and day)		
Daily live weight gain (g)	512	557
Supplementary concentrates (NE, MJ)	11.0	11.0
Grass intake (NE, MJ)	10.3	10.8

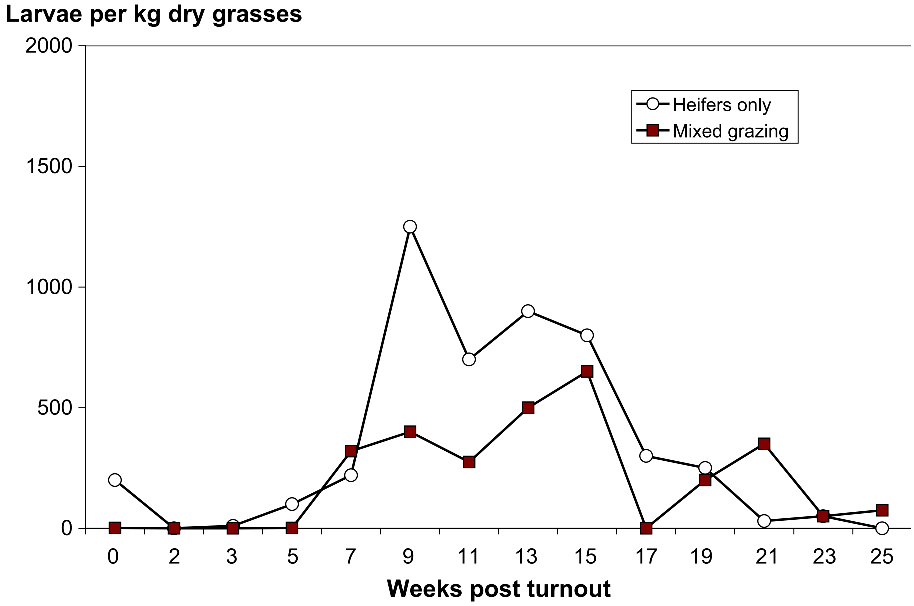

Fig. 4. Numbers of infective *Ostertagia ostertagi* larvae per kilogram of dry grass on two pastures grazed by heifers only or by a mixed herd of pregnant sows and heifers (after Roepstorff et al., 2000).

ment of housing and feeding facilities, to have a stratified land cultivation and nutrient load on the land. In fact, Andresen et al. (2001) demonstrated that the rooting could replace mechanical treatment and even result in a higher crop yield of the following crop.

Andersen et al. (2000a,b) and Jensen et al. (2002) have proposed a system handling both sows and finishers in small decentralized units. Each unit consists of a climate tent placed upon an area protected against leaching. A layer of mussel shells is put on a bio-membrane and covered with a layer of straw, upon which the climate tent is constructed. The idea is that four to six sows are farrowing in the unit. At weaning, the sows are moved to another tent and the finishers stay in the unit. In periods where there is a crop to be grazed or a need for a controlled tillage of the soil, the pigs—whether sows or finishers—are allowed access to the field. This way, a considerable part of the manure produced can be collected and used elsewhere in the farming system and the risks of excessive leaching of nutrients can be diminished.

This system is at present being tested and further developed. Growth and nutrient management is functioning very well. However, there is still some way to go in order to get farrowing to function well and to have an acceptable workload in the system.

4. Poultry

4.1. Production systems

The implementation of the organic ideals in the EU-regulation for poultry production includes a maximum flock size for layers of 3000 and for chickens of 4800. These flock sizes are well below flock sizes normally seen in conventional free-range poultry production but still much higher than what can be considered as “natural” flock sizes. The birds shall be kept under free-range conditions, i.e., having access to a hen yard corresponding to at least 4 m^2 per laying hen. Also, coccidiostats cannot be included in the feed, no beak trimming is allowed and ages at slaughter for chickens should be at least 81 days to counteract a too high growth rate.

The organic egg production, where the hens are kept in relatively large flocks and have access to an outdoor area, can be carried out quite efficiently in terms of egg production and feed conversion compared to conventional egg production in cages, although the feed consumption often is considerable higher (Kristensen, 1998). In Denmark, the share of organic egg-production amounts to approximately 13%.

Table 5
Average productivity and prices in the period 1995–2002, per hen housed at insertion (Danish Poultry Council, 2003)

	White layers in cages (21–76 weeks)	Organic brown layers (21–68 weeks)
Feed (g)/day	112	131
Laying (%)	86.8	73.5
Mortality (%)	4.9	14.8
FCR[a] (kg feed/kg eggs)	2.07	2.81
Egg prices (DKK/kg)	5.89	14.21
Price relation (egg/feed)	4.17	6.39

[a] Feed conversion rate.

In Table 5 the average productivity and price relations during the last 8 years are given for the flocks participating in the voluntary recording scheme organized by the Danish Poultry Council. It appears that the laying percent is lower in organic production compared to the cages system when calculated per hen inserted. This is partly due to a considerable higher mortality in organic systems. During the period, it has been possible to obtain more than double the selling price for the eggs, which in turn resulted in an improved egg/feed price relation.

The production results given above are valid, at least where the high yielding commercial lines or crosses are used. However, the high yielding hen, through many generations, has been selected for high performance on the base of her production capacity measured in individual cages. Thus, little attention has been paid to her genetically based ability to behave well in a larger flock of hens. The result of such breeding policy is a high yielding hen, but it seems that she has lost some of her ability to have social relations with many hens in large flocks (Sørensen and Kjær, 2000). Table 6 shows the results from an experiment in which different genotypes kept under organic conditions were compared. There is obviously a considerable difference in laying capacity among the four lines with ISA-Brown having the highest laying capacity. Regarding mortality, the lines were ranked in almost the opposite way. In particular, the cannibalism of the ISA-Brown was to such a level that it was above 10% in six of the eight replicates within a period of 6 months from 18 to 43 weeks of age. Hardly any cannibalism was seen for the other breeds. The higher mortality of New Hampshire was partly due to a mild outbreak of coccidiosis, which mainly hit the New Hampshires.

In free-range systems with large flocks, including organic farming systems, too many cases have been observed in which hens have started to perform feather pecking that ended with an unacceptable high rate of cannibalism. As indicated above and confirmed in more detailed investigations, the total mortality is often reported to be at least 20% during a year (Kristensen, 1998). This figure covers not only cannibalism, but also deaths caused by predators and by inappropriate behaviour of the birds, which sometimes suffocate because they tend to bunch together. This high mortality rate is a major problem, particularly from an animal welfare point of view and in the eyes of the consumers. There is a need to develop improved lines that are still high yielding, but with less risk of performing unacceptable feather pecking. Small selection experiments have shown that these behavioural traits have a genetic basis (Boelling et al., 2003) and ought to be incorporated into a breeding program for lines used in organic farming in order to make production in the farming system economically sound and acceptable from a welfare point of view.

Table 6
Results of laying traits and mortality for various breeds (after Sørensen and Kjær, 2000)

Breed genotypes	New Hampshire (NH)	White leghorn (WL)	WL×NH	ISA-Brown	P
Rate of lay (%)	63.2^{c}	72.4^{b}	69.2^{b}	84.6^{a}	0.0001
Number of eggs, hen placed 18–43 weeks	88.8^{c}	103.4^{b}	$105.5^{b,c}$	127.2^{a}	0.0001
Age at first egg (weeks)	22.2^{a}	22.9^{a}	21.4^{b}	19.8^{c}	0.0001
Egg weight (g)	54.7^{c}	58.3^{ab}	57.0^{b}	59.3^{a}	0.0001
Total mortality (%)	13.8^{a}	6.7^{b}	3.9^{b}	19.9^{a}	0.0199
Mortality—cannibalism, 18–43 weeks (%)	1.4^{b}	0.0^{b}	1.1^{b}	16.0^{c}	0.0001

a–c: Estimates in a row with no common superscript differ significantly (P<0.05).

4.2. Management of traditional hens yard

It has been shown that there was a negative correlation between the birds' use of the outdoor area and the feather pecking, as well as between "the quality" of the outdoor area and the feather pecking (Bestman and Wagenaar, 2003). This is an important issue since often only a small percentage of birds actually use the outdoor area, if no specific measures are taken.

Hirt et al. (2000) showed that the percentage of the hens of a flock in the free range area decreased with increasing flock size and that the use of the outdoor area often was restricted to the area closest to the house. Besides affecting feather pecking, this also has implications for the health of the birds and the environment. The manure load just outside the house increases risks for leaching of N and also risks for the spread of infectious diseases among the birds. So, there seems to be a need to develop new strategies for the use of the outdoor areas by birds.

Several management options have been investigated. Inclusions of cockerels in the flocks have been demonstrated to result in less frequent aggressive behaviour among females (Odén et al., 1999), as well as an increased use of the outdoor area and reduced feather pecking (Bestman and Wagenaar, 2003). Our own observations support the idea that the establishment of shelters in the yard, whether natural like trees and bushes, or artificial, actually do stimulate the hens to use the outdoor area better. Nevertheless, it is difficult to manage large flocks in a traditional hen yard without considerable risk of poor welfare or too high an environmental load.

4.3. Beyond hen yards

Probably more radically different concepts for the organic poultry production need to be considered. Elements to be considered include:

- The ability of the poultry to find a significant part of their feed in the outdoor area
- The impact of the poultry on the ground and/or the vegetation
- The impact of the poultry on the presence of pests of importance for crops

As regard layers and broilers, the high nutritional requirements necessary to maintain a high production level seem to be a major constraint. It has been estimated that relatively high yielding layers can consume 1/3 of the feed and N-requirement through forage, worms and insects (Hughes and Dun, 1983). However, for the producer it seems very risky to rely on such a strategy given our present knowledge and being aware of the fact that nutritional stress in high yielding genotypes may have implications for welfare and production. There is clearly a need to expand our knowledge in this area, including knowledge of relevant crops or roots to be grown to support such a strategy.

Although doubtful from a nutritional point of view, it is clear that even layers and broilers do have an impact on the ground vegetation in the outdoor area. In relatively small-scale organic egg productions (flocks of 1000 hens), this has been taken advantage of in combined egg and orchard production. The hens remove the weeds and grass and thereby diminish the need for mechanical weeding in orchards.

More important in such combined production systems is probably the impact of the poultry in fighting pests (insects) in orchards. In organic production in Denmark, nearly no pesticides are allowed. The need for alternative pest control is therefore large. Apple sawfly (*Hoplocampa testusinea*) and pear midge (*Contarinia pyrivora*) cause large crop losses in apples and pears, respectively. Both insects infest fruitlets and cause these to drop prematurely; after which the pests pupate in the topsoil.

Pedersen et al. (2002) investigated under experimental conditions the influence of releasing broilers in the orchard to reduce the population of these insects. Preliminary results (Fig. 5) showed that a significantly reduced catch of sawflies was found on sticky traps in chicken runs. The number of sawflies caught was reduced by 50–75%. It is unknown whether this pattern is caused by a direct effect of broilers predating the pupae and hatching sawflies, or if sawflies prefer to be in the chicken-free areas.

The reduced catch of apple sawflies, however, had no significant effect on the yield or the fruit quality. The total numbers of flower dusters and, thereby, the potential fruit crops are, however, not known. As regard pear midge, no effect on infected fruitlets was observed. Nevertheless, the results indicate that an

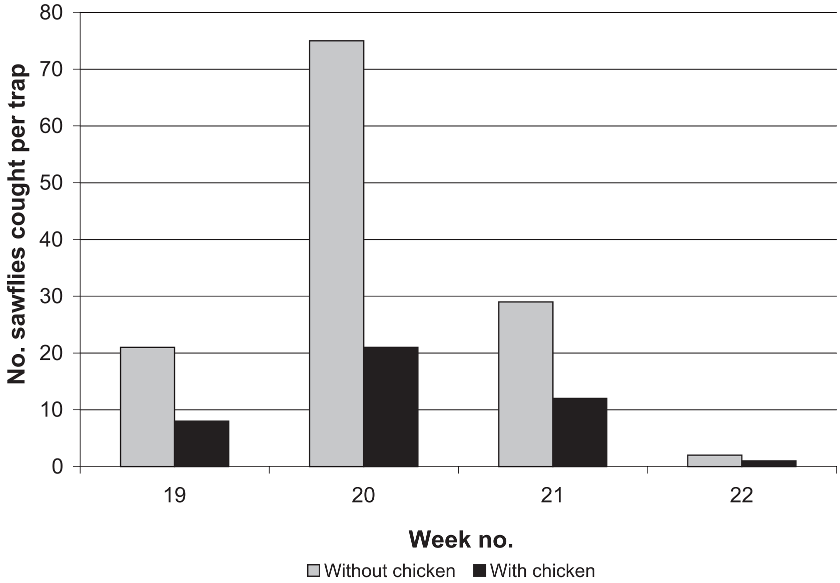

Fig. 5. Catch of apple-sawflies in an apple orchard with or without foraging chickens (Pedersen et al., 2002).

effect can be obtained and may be improved with more detailed knowledge of hen behaviour and the biology of the pests.

In the investigation, two types of broilers were used—a specialised hybrid (I 657) and a pure breed (Labress). The daily gain was 29 and 24 g, respectively, and for the hybrid close to the recommended limit of 30 g for organic production. Overall, the welfare and the health of the broilers seemed to be excellent. Welfare assessment of 80 birds showed no problems with the plumage condition and foot health, and no broilers had skin lesions.

Also, Clark and Gage (1996) evaluated the effect of free range chickens and geese on insect pests and weed in a non-chemical apple orchard with intercropped potatoes. It was found that some insect pests were less abundant on apple trees when chickens were present. However, chickens did not affect weed abundance and crop productivity. The authors suggest that a higher chicken density and the use of lures to draw, in this case, the Japanese beetle within range of the chickens could be used to control this pest without pesticides. The authors also suggest other options, which include the use of movable floorless chicken cages to remove or reduce apple drops on the orchard floor.

The geese, however, were effective weeders resulting in increased potato plant yield. In addition, apple fruit damage was reduced, possibly because of removal of the vegetation. It is concluded from the study that domestic geese can be managed as biological weed control agents, though on-farm evaluations are needed to address the social and economic aspects of weeder geese use.

As part of a participatory research programme, we are making observations in an orchard system, where several types of poultry are used in a synergistic manner. The obtained growth rate, feed intake and nutrient excretion are shown in Table 7.

Table 7
Production results of poultry from a combined production of poultry and fruit

	Broilers (I 657)	Broilers (LaBresse)	Ducks	Geese
Age at slaughter (days)	100	130	100	150
Mortality (%)	5	3	9	9
Final weight (kg)	2.8	2.8	4.9	7.4
Average daily gain (g)	28	22	49	49
Feed consumption (kg/kg LW)	3.3	4.5	6.3	4.1[a]
Average N-surplus/bird/day (g)	1.7	1.6	5.5	1.4
Average P-surplus/bird/day (g)	0.5	0.4	1.5	0.4

[a] Only supplementary feed; geese consume large amounts of green fodder, for which reason consumption of grain and concentrates vary depending on the quality and amount of available green fodder.

We can estimate an N-excretion (supplementary feed−carcass growth) on 1.7 g/chicken/day in average for the growing period of 100 days (Table 7). From pest-fighting's point of view, a high stocking density could be relevant. The present Danish regulations give a maximum of 1250 chickens to be reared on a hectare. This yields an N-supply of approximately 200 kg/N/ha over a period of 100 days, which is more than optimal for many orchard crops. So, this aspect needs to be taken into account.

We found that the combination of chickens and geese seems especially promising. The well-known ability of geese to weed and graze is taken advantage of. In the majority of the growth period, the geese are almost entirely foraging. In this period, only a small amount of net-nutrient deposition on the ground takes place. In other periods, defined by the expected time of the life-cycle where harmful insects are present on the ground, the chickens are used in the orchard. By using this combination, no major overloading with nutrients takes place.

There is a need for a more comprehensive understanding of possible synergy between the birds and "a crop", taking into account a wider range of crops.

5. Conclusion

The most common outdoor systems for pigs and poultry used in intensively managed organic production have some important drawbacks in relation to environmental impact (risk of N leaching and ammonia volatilisation), animal welfare (nose-ringed sows), high mortality in poultry and work load and management. There is a need for a radical development of the systems. There is a need to search for outdoor/free range systems (for the sake of the livestock) which are constructed and managed in such a way whereby the livestock time exerts a positive influence on other parts of the farming systems. The major elements to be considered are the ability of pig and poultry to forage and hereby fulfil their nutritional needs, the ability of the pigs to contribute to land cultivation, the ability of poultry to contribute to reducing pests in orchards, and the importance of diversified livestock rearing in order to reduce parasite burden. These elements need to be further explored as a basis for future system development.

References

Andersen, B.A., Jensen, H.F., Møller, H.B., Andersen, L., Mikkelsen, G.H., 2000. Concept for ecological pig production in one-unit pens in twelve-sided climate tens. Design and layout. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 65–75. Tjele, Denmark.

Andersen, L., Jensen, K.J., Jensen, K.H., Dybkjær, L., Andersen, B.H., 2000. Weaning age in organic pig production. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 119–123. Tjele, Denmark.

Andresen, N., 2000. The foraging pig. Doctoral thesis. Swedish University of Agricultural Sciences Uppsala, Agraria 227. 40 pp.

Andresen, N., Ciszuk, P., Ohlander, L., 2001. Pigs on grassland—animal growth rate, tillage work and effects in the following winter wheat crop. Biol. Agric. Hortic. 18, 327–343.

Bestman, M.W.P., Wagenaar, J.P., 2003. Farm level factors associated with feather pecking in organic laying hens. Livest. Prod. Sci. 80, 133–140.

Blasetti, A., Boitani, L., Riviello, M.C., Visalberghi, E., 1988. Activity budgets and use of enclosed space by wild boars (sus scrofa) in captivity. Zoo Biol. 7, 69–79.

Boelling, D., Groen, A.F., Sørensen, P., Madsen, P., Jensen, J., 2003. Genetic improvement of livestock for organic farming systems. Livest. Prod. Sci. 80, 79–88.

Braund, J.P., Edwards, S.A., Riddoch, I., Buckner, L.J., 1998. Modification of foraging behaviour and pasture damage by dietary manipulation in outdoor sows. Appl. Anim. Behav. Sci. 56, 173–186.

Brouns, F., Edwards, S.A., English, P.R., 1994. Effect of dietary fibre and feeding system on activity and oral behaviour of group housed gilts. Appl. Anim. Behav. Sci. 39, 215–223.

Carlson, D., Lærke, H.N., Poulsen, H.D., Jørgensen, H., 1999. Roughages for growing pigs, with emphasis on chemical composition, ingestion and faecal digestibility. Acta Agric. Scand., A. Anim. Sci. 49, 129–136.

Clark, M.S., Gage, S.H., 1996. Effects of free-range chickens and geese on insect pests and weeds in an agro-ecosystems. Am. J. Altern. Agric. 11, 39–47.

Danielsen, V., Hansen, L.L., Møller, F., Bejerholm, C., Nielsen, S., 2000. Production results and sensory meat quality of pigs fed different amounts of concentrate and ad lib clover grass or clover grass silage. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 79–86. Tjele, Denmark.

Danish Poultry Council, 2003. Yearly Report (in Danish). Copenhagen, Denmark, 151 pp.

Eriksen, J., 2001. Implications of grazing by sows for nitrate leaching from grassland and the succeeding cereal crop. Grass Forage Sci. 56, 317–322.

Eriksen, J., Kristensen, K., 2001. Nutrient excretion by outdoor pigs: a case study of distribution, utilisation and potential for environmental impact. Soil Use Manage. 17, 21 – 29.

Eriksen, J., Petersen, S.O., Sommer, S.G., 2002. The fate of nitrogen in outdoor pig production. Agronomie 22, 863 – 867.

Gustafson, G.M., Stern, S., 2003. Two strategies for meeting energy demands of growing pigs pasture. Livest. Prod. Sci. 80, 167 – 174.

Hansen, L.L., Magnussen, C.C., Andersen, H.J., 2001. [Meat and eating quality of organically produced pigs] (in Danish). In Økologisk og udendørs svineproduktion. Internal report 145. Danish Institute of Agricultural Sciences. 145, 39–40.

Hirt, H., Hördegen, P., Zeltner, E., 2000. Laying hen husbandry: group size and use of henruns. In: Alföldi, T., Lockeretz, W., Niggli, U. (Eds.), Proceedings 13th International IFOAM Scientific Conference, Basel, p. 363.

Horrel, I., A'Ness, P., Edwards, S.A., Eddison, J., 2001. The use of nose-ringing in pigs: consequences for rooting, other functional activities, and welfare. Anim. Welf. 10, 3 – 22.

Hughes, B.O., Dun, P., 1983. A comparison of laying stock: housed intensively in cages and outside on range. Research and Development Publication No. 18. West of Scotland Agricultural College, Auchincruive, Ayr.

IFOAM, 2000. Basic standards. Basel.

Jensen, H.F., Andersen, B.H., Hermansen, J.E., 2002. Concept for one-unit pen on controlled outdoor areas integrated in the land use. Proc. 14th IFOAM Organic World Cong. Victoria, Canada. ISBN: 0-9695851-5-2, p. 86.

Kongsted, A.G., Larsen, V.A., 1999. Pattegrisedødelighed i frilandssohold. DJF- rapport (Husdyrbrug). 11. 56 pp.

Kristensen, I., 1998. Organic egg, meat and plant production—biotechnical results from farms. In: Kristensen, T. Report of the Danish Institute of Agriculture Science, vol. 1, pp. 95 – 169. in Danish.

Larsen, V.Aa. 2001. Produktionssystemer og resultater for frilands- og økologisk produktion [Production systems and results from outdoor and organic production]. In Økologisk og udendørs svineproduktion—Hvor står vi? Internal report No 145 from seminar: [Organic and outdoor pig production—What is our situation?] held at Danish Institute of Agricultural Sciences, Tjele, August 2001.

Larsen, V.Aa., Jørgensen, E., 2002. Reproduction performance of outdoor herds. Livest. Prod. Sci. 78, 233 – 243.

Larsen, V.A., Kongsted, A.G., 2000. Sows on pasture. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 99 – 105. Tjele, Denmark.

Larsen, V.A., Kongsted, A.G., Kristensen, I.S., 2000. Udendørs sohold—Balancer på mark-og bedriftsniveau. In: Sommer, S.G., Eriksen, J. (Eds.), Husdyrgødning og kompost. Næringsstofudnyttelse fra stald til mark i økologisk jordbrug, FØJO-rapport, vol. 7, pp. 67 – 76.

Lauritsen, H.B., Sørensen, G.S., Larsen, V.Aa., 2000. Organic pig production in Denmark. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 113 – 118. Tjele, Denmark.

Lee, P., Cormack, W.F., Simmins, P.H., 1995. Performance of pigs grown outdoors during conversion of land to organic status and indoors on diets without growth promoters. Pig News Inf. 16 (2), 47 – 49.

Martin, J.E., Edwards, S.A., 1994. Feeding behaviour of outdoor sows: the effects of diet quantity and type. Appl. Anim. Behav. Sci. 41, 63 – 74.

Michelsen, M., Hamm, U., Wyner, E., Ruth, E., 1999. The European Market for Organic Products: Growth and Development. University of Hohenheim, Germany. 199 pp.

Millet, S., Hesta, M., Seynaeve, M., Ongenae, E., De Smet, S., Debraekeleer, J., Janssens, G.P.J., 2003. Performance, meat and carcass traits of fattening pigs with organic versus conventional housing and nutrition. Livest. Prod. Sci. 87, 109 – 119.

Møller, F., 2000. Housing of finishing pigs within organic farming. In: Hermansen, J.E., Lund, V., Thuen, Erling (Eds.), Ecological Animal Husbandry in the Nordic Countries, Proceedings from NJF-seminar No 303, 16–17 September 1999, DARCOF report, vol. 2, pp. 93 – 98.

Mul, M.F., Spoolder, H.A.M., 2000. Het gebruik van neusringen in mogelijke alternatieven om beschadigend wroetgedrag bih zeugen met weidegang te voorkomen. Prakt. Varkenshoud. (Proefverslag nummer P 1.250, 24 pp.).

Odén, K., Vestergaard, K.S., Algers, B., 1999. Agonistic behavíour and feather pecking in single-sexed and mixed groups of laying hens. Appl. Anim. Behav. Sci. 62, 219 – 231.

Ogel, S., 1997. Aménagement des parcs en élevage de truies plein air. Résultats de Recherche en Production Porcine. 5 pp.

Olsen, A.W., 2001. Behaviour of growing pigs kept in pens with outdoor runs I. Effect of access to roughage and shelter on oral activities. Livest. Prod. Sci. 3, 245 – 254.

Olsen, A.W., Dybkjær, L., Simonsen, H.B., 2001. Behaviour of growing pigs kept in pens with outdoor runs II. Temperature regulatory behaviour, comfort behaviour and dunging preferences. Livest. Prod. Sci. 3, 255 – 264.

Pedersen, H.L., Olsen, A., Horsted, K., Pedersen, B. & Hermansen, J., 2002. Combined production of broilers and fruit. NJF-seminar no. 346, Organic production of fruit and berries. Årslev 22 October 2002.

Petersen, S.O., Kristensen, K., Eriksen, J., 2001. Denitrification losses from outdoor piglet production: spatial and temporal variability. J. Environ. Qual. 30, 1051 – 1058.

Rivera Ferre, M.G., Edwards, S.A., Mayes, R.W., Riddoch, I., Hovell, F.D., 2000. Grass utilisation by outdoor sows in different seasons measured by the n-alkaline technique. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 87 – 92. Tjele, Denmark.

Roepstorff, A., Monrad, J., Sehested, J., Nansen, P., 2000. Mixed grazing with sows and heifers: parasitological aspects. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 41 – 44. Tjele, Denmark.

Sather, A.P., Jones, S.D.M., Schaefer, A.L., Colyn, J., Robertsen, W.M., 1997. Feedlotperformance, carcass composition and meat quality of free-range reared pigs. Can. J. Anim. Sci. 77, 225 – 232.

Sehested, J., Søegaard, K., Danielsen, V., Kristensen, V.F., 2000. Mixed grazing with sows and heifers effects on animal performance and pasture. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 35–40. Tjele, Denmark.

Sehested, J., Søegaard, K., Danielsen, V., Roepstorff, A., Monrad, J., 2004. Mixed grazing with heifers and sows: herbage quality, sward structure and animal weight gain. Livest. Prod. Sci. 88, 223–238.

Sommer, S.G., Søgaard, H.T., Møller, H.B., Morsing, S., 2001. Ammonia volatilization from pigs on grassland. Atmos. Environ. 35, 1959–1968.

Sørensen, P., Kjær, J.B., 2000. Non-commercial hen breed tested in organic system. In: Hermansen, J.E., Lund, V., Thuen, E. (Eds.), Ecological Animal Husbandry in the Nordic Countries, DARCOF Report, vol. 2, pp. 59–63. Tjele, Denmark.

Stern, S., Andresen, N., 2003. Performance, site preferences, foraging and excretory behaviour in relation to feed allowance of growing pigs on pasture. Livest. Prod. Sci. 79, 257–265.

Stolba, A., Wood-Gush, D.G.M., 1984. The identification of behavioural key features and their incorporation into a housing design for pigs. Ann. Rech. Vet. 15, 287–298.

Studnitz, M., Jensen, K.H., Jørgensen, E., Jensen, K.K., 2003. The effect of nose ringing on explorative behaviour in gilts. Anim. Welf. 12, 109–118.

Tober, O., 1996. Zirkadiane Rhythmik ausgewählter Verhaltensweisen von güsten und tragenden Sauen in ganzjähriger Freilandhaltung. Tierärtztl. Umsch. 51, 111–116.

Trujillo, R.G., 2000. Organic livestock production in Spain. Proceedings of the Second NAHWOA Workshop, http://www.veeru.reading.ac.uk/organic/proc/garcia.htm.

Watson, C., Edwards, S.A., 1997. Outdoor pig production: what are the environmental costs? Environmental and Food Sciences, Research Report. Scottish Agricultural College, pp. 12–14.

Willer, H., Richter, T., 2003. Europe. The World of Organic Agriculture 2003—Statistics and Future Prospects. Minou Yussefi and Helga Miller, pp. 73–93.

Williams, J.R., Chambers, B.J., Hartley, A.R., Ellis, S., Guise, H.J., 2000. Nitrogen losses from outdoor pig farming systems. Soil Use Manage. 16, 237–243.

Younie, D., Hermansen, J.E., 2000. The role of grassland in organic livestock farming. Grassl. Sci. Eur. 5, 493–509.

Zihlmann, U., Weisskopf, P., Menzi, H., Ingold, U., 1997. Bodenbelastung durch freilandschweine. Agrarforschung 4, 459–462.