Integrated Forage and Livestock Production

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ABSTRACT

Integrated forage and livestock production can be considered at the farm level and at the herd or animal level. At the farm level it is relevant to consider the overall utilization of N in the system in relation to crops and livestock. It is demonstrated that in organic dairy production a high transformation efficiency of N from input to edible products can be achieved compared, with conventional production. In addition, combining dairy and pig production allows an even higher N utilization. At the herd level the quality of grass or clover-grass based forage is extremely important. This holds for the overall intake and milk production in dairy cows and for the intake of clover-grass by grazing sows. In addition the composition of the sward should be considered in relation to the influence of specific plant species on the development of endoparasitic infections in ruminants and on the wear strength in relation to free-range pig production.

For dairy production it is proposed that a strategy including only 20% concentrates (or cereals) of the dry matter in a total diet based on clover-grass and clover-grass silage represenst an efficient milk production without impairing the health of the cows.

INTRODUCTION

The way feed and forage production takes place is a key element in organic livestock farming. It is specifically mentioned in the IFOAM principle aims of organic production that a harmonious balance between crop production and animal husbandry should be established and that the biological cycles within the farming system should be encouraged. This is also reflected in ECC-regulation of organic farming, stating that the farm management should mainly rely on internal farm resources rather than on external inputs. In this way, the environmental impact of intensive animal production is expected to be diminished. The detailed regulation includes limits for the maximum animal density per unit of land and on the minimum use of forage. However, it is also stated that the nutritional requirements of the livestock at the various stages of their development should be met to ensure a "quality" production and support the health of the animals.

The fact that all feed from 2005 should be organically grown will – from a economic point of view – make it even more important to a great extent to rely on home-produced feed and thereby to focus on how the forage and livestock production can best be optimized.

THE INTEGRATED APPROACH

An important element in the integrated approach is to consider the nutrient cycle within the farm. In Table 1 we present figures on N-cycling measured on conventional and organic pilot dairy farms in Denmark. The conventional farms typically import more feeds and fertilizer and have a higher milk yield and cash crop export, which is reflected in the N-turnover. The organic farms rely more on clover-grass yielding N to the crop rotation through its capacity for bio-fixation and on home-grown feed.

If we consider the transformation efficiency for N in the animal component (N in edible products compared with N in feed) a slightly lower efficiency is observed in the organic system. This is probably a consequence of a higher milk yield per cow, obtained partly through a more balanced N-feeding in the conventional production system. However, the figures also show that the marginal efficiency of the imported feed is only around 22%.

Table 1. N-balances on organic and conventional Danish dairy farms (Kristensen *et al*., 2003), kg N/ha.

	Conventional (1.5 LU[1]/ha)	**Organic (1.4 LU/ha)**
Animal component		
Input		
Purchased feed	97	49
Home-grown feed	110	123
Output		
Milk	36	30
Meat	10	6
Transformation efficiency	22%	21%
Crop/soil component		
Input		
Fertilizer	89	-
Fixation	23	70
Home produced manure	149	136
Precipitation	16	16
Total	277	223
Output		
Feed	110	123
Cash crop	9	3
Total	119	126
Transformation efficiency	43%	56%
Whole farm		
Transformation efficiency, %	24	30
Surplus, kg	172	108

[1] LU =livestock unit

If we consider the crop component it is clear that the organic system, through its use and choice of crops is able to produce the same or more nitrogenous output even with less N input, compared with the conventional practice. This means a much higher transformation efficiency, which more than balances the reduction in the animal component and leads to a considerably higher whole-farm N-efficiency. These results underline the prospects of considering an increasing integration of livestock and crop production, even if such a practice may result in a lower output per animal.

This idea has been followed further in a simulation study (Kristensen and Kristensen, 1997). The exercise was carried out in relation to the planning of a Danish organic research station which was required to include both pig and dairy production. The overall hypothesis was based on the fact that in dairy production there was a huge amount of N available due to the type of feed produced, whereas in pig production, which has to rely on grain crops to a significant degree, there was a lack of N. Thus, combining the two enterprises should make it possible to increase the overall efficiency. Three systems were compared: a “normal” organic dairy production, a specialized organic pig production, and a mixed production, where in principle the pigs were given the major part of the cereal produced, and the dairy cattle had to rely to a very high extent on forage.

The results relating to level of production and cycling of N are given in Table 2.

Table 2. Results of model calculated production and N-balances of different farming systems (after Kristensen and Kristensen, 1997).

System	Dairy	Pig	Dairy/Pig (mixed)
Grass/clover, %	60	20	40
Import of animal manure, kg N/ha	0	45	0
Herd - cows/sows per ha	0.81/0	0/0.71	0.44/0.45
Feed			
- SFU/ha produced[1]	5.298	3.201	4.836
- SFU/ha imported	517	1.075	714
Production			
Milk, kg cow	7.357	-	6.286
Kg/ha	5.980		2.772
Meat kg/ha	239	1.239	120/784 (904)
N-balance, kg/ha			
Input			
Purchased feed	28	52	2/33 (35)
Atmospheric deposition	21	21	21
Fixation	89	30	54/5 (60)
Imported manure	0	45	0
Total	138	148	114
Output			
Milk	32	0	15
Meat	6	33	3/21 (24)
Total	38	33	39
Input - output	101	115	76
Efficiency			
N output/input	0.27	0.22	0.34

[1] SFU = Scandinavian Feed Unit (Barley net energy equivalent)

The output is given as kg of product, as milk and/or meat per animal or per ha. In addition, the output from the system is given as N in animal products per hectare, representing the amount of animal protein produced for human consumption. The model calculations indicate that the mixed dairy and pig system makes it possible to produce a higher amount of protein in animal products per ha (39 kg N), compared with the specialized dairy (38 kg N) or pig system (33 kg N). Moreover, it seems that this system results in the smallest difference between N-input and N-output. The better overall N-efficiency in the mixed system is primarily related to the better ability of this crop rotation to take advantage of the N left in the pre-crops, which means a lower risk of leaching/denitrification.

This approach is, of course, one of several approaches to be considered in an integrated production. In the following, strategies for a high self-supply in dairy production and systems of pig production are discussed.

RESULTS FROM DANISH PILOT DAIRY FARMS AIMING FOR A HIGH SELF-SUPPLY OF FEED

Results from commercial organic dairy farms that focus on a high self-supply of feed are given in Table 3. All feed given to the herd was organically produced since this was a prerequisite for obtaining a premium price for the organic milk at the dairy.

Table 3. Feeding, milk yield and land use in four commercial Danish organic dairy herds 2001-2002.

Herd	**I**	**II**	**III**	**IV**
Cows/herd	160	76	83	131
<u>Intake per cow</u>				
- DM, kg	6860	6790	6480	6640
- Energy, SFU	5780	5840	5930	6060
% of DM				
- Pasture	20	16	20	32
- Silage	54	51	45	44
- Cereal	11	22	16	12
- Others	15	11	19	12
% SFU self produced	87	88	93	84
<u>Production per cow</u>				
- kg ECM	8180	7720	7920	7600
- Fat %	4.21	4.21	3.95	4.35
- Protein %	3.29	3.30	3.17	3.27
Efficiency ECM/kg DM	1.19	1.14	1.22	1.15
<u>Land use, ha/cow</u>	1.34	1.24	1.22	1.39
- Clover-grass	0.62	0.66	0.77	0.90
- Whole crop silage	0.44	0.13	0.19	0.36
- Cereal	0.22	0.45	0.26	0.13
- Others	0.06			
<u>Crop production</u>				
- Clover-grass, kg DM/ha	6000	7000	6300	7700
- Cereals, kg/ha	4700	3900	4400	4400

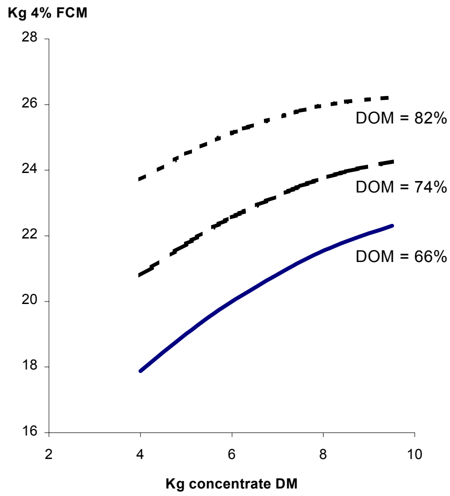
The results are from the period May 2001 to October 2002 and illustrate that a high productivity is possible at herd and field level when between 84% and 93% of the energy intake of the cows is produced on the farm. The remaining part of the intake was primarily low protein concentrates based on Danish organically produced crops such as cereals, peas and rape seed cake.

The key component in these systems is the clover-grass. It occupies between 46% and 65% of the land use and more than half of the DM intake. The herd production was between 7600 and 8180 kg energy corrected milk (ECM) with a high efficiency: 1.44 to 1.22 kg ECM per kg DM intake.

OPTIMIZED USE OF FORAGE AND COMPLEMENTARY FEED IN DAIRY PRODUCTION

Several approaches can be taken. One approach is for a given group of cows to decide how best to produce and use the forage in the short term. Much research can support decisions on the short term response. A very important result in this respect is the finding that the digestibility of grass and clover-grass silage has a remarkable influence on the intake of silage both in dry matter intake and, in particular, in energy intake when fed *ad libitum*. Kristensen and Nørgaard (1987) showed in their classic experiments with increased level of concentrates to dairy cows in combination with silage differing in organic matter digestibility, that it was not possible through higher allowance of concentrates to compensate for a low digestibility of silage when striving towards a high milk yield (Figure 1).

Figure 1. Effect of silage digestibility (DOM) and amount of concentrate on milk production, per cow daily.



A difference in DOM of 16 percentage units (66% versus 82%) caused a difference in FCM production of approximately 6 kg at 3.5 kg concentrate DM. This difference was reduced to just below 4 kg FCM at 9.5 kg concentrate DM. In order to obtain the same yield with grass silage with 70% digestibility of OM as with 82% digestibility of OM, the amount of concentrates should be increased from 3.5 to 9.5 kg DM.

Although these results were obtained using silage produced by use of fertilizers there is no reason to believe that the principles will not be valid in organic conditions also. Therefore, the results deserve considerable attention when planning feed supply based on a high proportion of home-grown feed in dairy production.

Mogensen *et al*. (2003) used a different approach. Based on the yields of cereals, rape-seed and clover-grass that could be produced on a given area of land for feed, a feeding experiment was conducted on each of two organic dairy farms. The rations were formulated so that the expected feed consumption could be produced at the same area per cow, assuming crop yields typical for organic conditions in Denmark, i.e. 3,700 kg DM/ha of cereal, 2,200 kg DM/ha of rape seed, and 6200 kg DM/ha of clover-grass (as silage) calculated as net yield (feed available at the fodder board).

The corresponding diets are shown in Table 4. For technical reasons the roughage could not be entirely clover-grass silage, but included in addition barley and pea whole-crop silage as well as grass pellets.

The results indicate that although cereal can be given as the largest amount of feed and feed energy produced, it is perhaps not always the most efficient supplement when the feeding is based on home-grown crops. Inclusion of crushed rapeseed contributes especially to dietary fat in the diet, which tends to increase milk yield but at the same time to reduce fat and protein concentration in milk, the overall response in fat-corrected milk not being influenced. This pattern of response is typical when adding unsaturated fatty acids to the diet of dairy cows. In conclusion, the income from milk in the two situations should not be different and there were no indications that the different feeding regimens changed the risk of diseases of the cows. Consequently, the growing conditions for the complementary feeds in terms of economy and risk might be the most important factor in the choice of feed production.

Table 4. Feed intake and milk yield comparing different diets representing feed from the same area per cow, per cow daily (after Mogensen, 2003[x]).

Diet	Cereal	Cereal and rape seed
Intake	(N=73)	(N =74)
Cereals, kg DM	4.0	1.2
Rape seed, kg DM	-	1.2
Roughage (estimated), DM	16.0	16.7
Total, DM	20.0	19.2
ME, MJ	227	222
Yield		
Milk, kg	25.7	26.8
FCM, kg	25.4	25.4
Fat, %	4.14	3.85
Protein, %	3.20	3.06

x) combined results of two experiments (on two organic dairy farms)

Another approach is to investigate the consequences of long term strategies for feed production and feeding. However, there is only a limited number of long-term studies, particularly with regard to organic production. Sehested *et al*. (2003) reported the results of one such long-term investigation of the means to rely as much as possible on home-grown feed, carried out on the Danish Organic Research Station, (Rugballegård). Three strategies were compared:

- No supplementation to a clover- grass mixture (grazed or given as silage).
- Low level of supplementation to the above diet (3 kg concentrates mixtures in the first 24 weeks of lactation).

- Normal level of supplementation to the above diet (8 kg concentrates mixtures in the first 24 weeks of lactation).

The grazing sward was composed of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*). The average content of white clover above grazing height was 36%, on a dry matter basis.

Feed intake, milk production, and feed conversion on a per cow and year basis are shown in Table 5. Increasing the level of concentrates from 100 kg DM to 2,400 kg DM per cow reduced intake of clover-grass and silage by 800 kg DM resulting in an increase in total DM intake of 1,400 kg and in energy intake of 41%. As a result, milk yield was increased by 32%. However, looking at the group with only a small supplement (1,000 kg), which increased total intake of energy by 13%, the milk yield increased by 22%. In fact, the overall feed conversion rate was considerably increased at the small supplement diet compared with both a higher and a lower concentrate supplementation. This really illustrates the law of diminishing returns.

Table 5. Feed intake and milk yield per cow and year (after Sehested *et al*., 2003).

	Supplementation					
Strategy	**No**		**Small**		**Normal**	
Feed intake	**kg DM***	**MJ NE***	**kg DM***	**MJ NE***	**kg DM***	**MJ NE***
Silage	2.9	18	2.7	16	2.4	14
Grazing	1.5	11	1.4	10	1.2	9
Fodder beets	0.2	2	0.2	2	0.2	2
Concentrates	0.1	1	1.0	8	2.4	19
Total	4.8	32	5.3	36	6.2	45
Milk yield						
Kg	5030		6027		6646	
(Energy corr.)	5090		6230		6723	
"Feed efficiency" (Winter)						
Feed utilization, %	98		97		84	
kg ECM per DM	0,97		1.08		1.04	

* 1.000

The non-supplemented group had a lower incidence of clinical diseases compared with the other two groups, which did not differ significantly. The main differences were in limb and metabolic diseases. No difference in mastitis-related diseases occurred and no differences in somatic cell counts were found. In terms of effects on reproduction, numbers of days to first insemination after calving, and calving interval, decreased with increased feed supplementation. At no supplementation the milk quality, in terms of the content of free fatty acids, was impaired compared with normal level of supplementation.

The group with moderate supplementation showed results very much comparable to the modelled results for combined pig and dairy production as detailed in Table 2. This strategy appears to represent a good balance between feed and dairy production with respect to overall efficiency, animal health, and product quality. This means that the system should include cereal or comparable concentrate feed.

MAINTAINING LIVESTOCK HEALTH AT GRASS

Helminth infection in young stock is the most common health problem in organic livestock (Younie and Hermansen, 2000). Grazing management is a main component of worm control strategy and the system must be designed primarily to minimize parasite infection. This can be achieved by preventive, evasive or diluting strategies. Preventive strategies involve the movement of uninfected animals to swards uncontaminated with worm larvae, e.g. by alternating cattle, sheep, other livestock species and/or conservation cuts from year to year on any one field. In an evasive strategy, stock are moved from a contaminated area to a clean sward, e.g. a silage aftermath. Dilution involves restricting the stocking rate of susceptible animals, for example by mixing young stock with another species (e.g. heifers and sows), or mixing young and adult stock of the same species, or simply be reducing stocking rate *per se* (Roepstorff *et al*., 2000).

The overall forage production strategy needs to take these considerations into account. In some situations this may be difficult and there is also a need to consider other approaches such as breeding for resistance to parasites in the sheep flock (Eady *et al.*, 2003) and exploiting the effect of different pasture species and herbs on the development of endoparasite infections in ruminants. Although there is no full understanding of the mechanisms, it has been shown that plant species with a high content of condensed tannins (e.g. *Lotus pedunculatus*, *Lotus corniculatus*, and *Cichorium intybus*) can in some cases reduce the parasite burden of the livestock. In the light of these results there is a need to focus more on the species composition of the ley.

OUTDOOR PIG PRODUCTION

Outdoor pig production – at least for the sow part – fits very well some of the aims of organic farming, but also represents some challenges that need to be met.

Typically, in Denmark sows are kept in outdoor systems all year round, and pigs are moved to an indoor pig unit with an outdoor yard when they are weaned at seven weeks of age. In this way the sows automatically have access to grazing in the summer period, and the farmers have only one production system for their sow herd instead of having both a system for summer housing and a system for winter housing. The layout of the paddocks depends on soil type and the available land on the individual farm. The paddocks are normally moved to a new field every spring, often in a two-year crop rotation - one year with barley with an under-sown grass-ley and one year with sows on pasture. The stocking rate is adjusted to an excretion of 140 kg N in pig manure per ha each year (often practised as 280 kg N/ha every second year).

One of the major concerns in keeping sows on grass in intensively managed production has been the potential environmental impact due to high excretions of plant nutrients, especially N and P in the manure. The environmental impact of outdoor pig production is related to the amount of nutrients in the supplementary feed and the stocking density. Recent investigations have shown a surplus of 330-650 kg N per ha of land used for grazing sows on organic farms (Larsen *et al*., 2000). Although this level is lower than that of average conventional outdoor sow herds, this nutrient surplus definitely represents an environmental risk, as it has proved difficult to obtain optimal efficiency of the nutrients deposited during grazing. The adverse consequences of this include considerable nutrient losses from grazed pastures and undesirably low nutrient availability in the rest of the crop rotation.

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 by leaching (Watson and Edwards, 1997). In paddocks for lactating sows, a high level of grass cover is one of the factors which seems 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*., 2003).

Larsen and Kongsted (2001) investigated the importance of grass seed mixture on the grass cover in paddock with lactating sows under Danish conditions. The traditional mixture of perennial ryegrass, Kentucky bluegrass, red fescue, and white clover (WC) was compared with a mixture of meadow fescue + WC, a mixture of red fescue + WC, and a short-turf ryegrass +WC. The effect of grass-mixture on the grass cover in the paddocks was very little compared to other management factors such as time of moving huts etc. It was concluded that the mini-turf mixture was a good choice for farrowing paddocks since this mixture had less disposition to culm-formation and had at least the same wear strength as the other mixtures.

As regards growing-pigs at pasture, several investigations indicate that growth rate obtained in outdoor systems can be comparable to the growth rate for indoor production. Although the growing pig can consume grass and other herbage to meet up to 20% of its daily day matter intake (Carlson *et al*., 1999), the overall contribution to the energy supply of the pig when fed *ad libitum* than with concentrate mixtures is normally much lower, ranging from 2-8%. This means that most of the feed needs to be supplied as concentrates given to the pigs at pasture, and consequently a high risk of environmental impact can be expected unless measures are taken to counteract this.

We are investigating strategies for combining grazing and rearing in barns from the perspective of reducing the risk of environmental impact, and at the same time allowing the growing pigs to have plenty of space when they are young and most active. In the experiment piglets are moved indoors at weaning, or at 40 kg liveweight, or at 80 kg liveweight, or stay at pasture until slaughter.

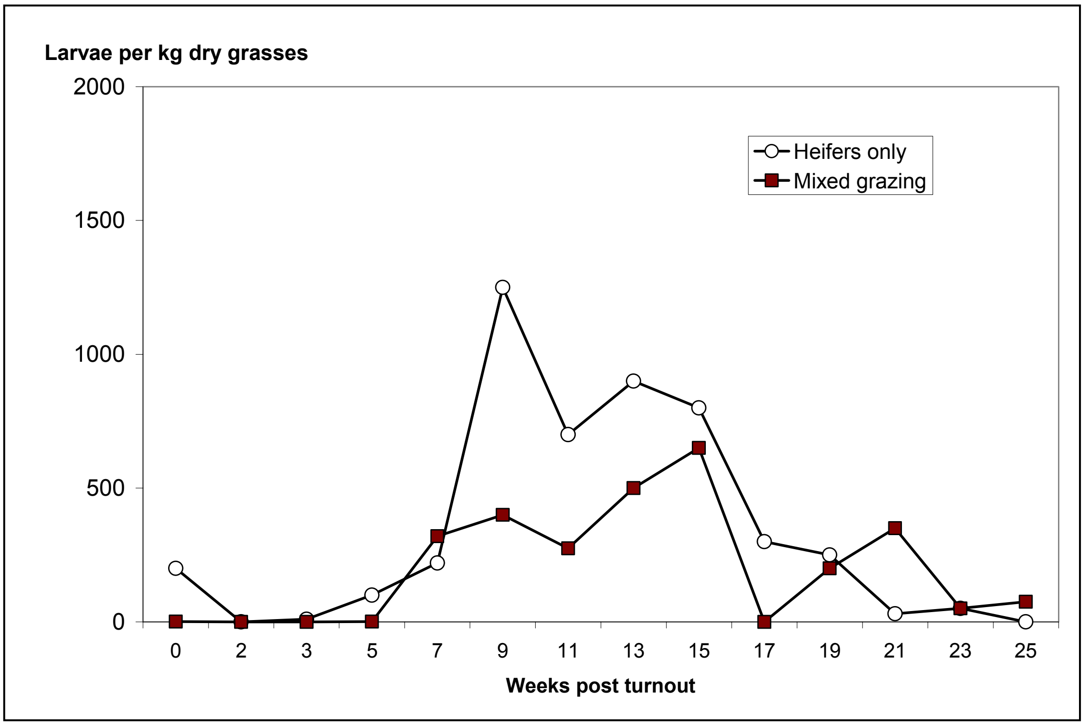
The preliminary results show a normal growth rate (approximately 750 g daily gain) and no marked differences between the pigs fed *ad libitum* outdoors or *ad libitum* indoors. However, the feed intake per kg gain was increased by 13% when fed *ad libitum* outdoor. On the other hand, outdoor pigs, which were restricted in energy intake, had the same feed conversion rate as the indoor pigs and, in addition, a significantly higher lean content (approximately 4 units), but growth rate was of course reduced (by 16%). A very interesting finding occurred in the strategy where pigs were kept outdoors until 80 kg live weight followed by *ad libitum* feeding indoors. This strategy resulted in a feed conversion rate comparable to indoor feeding, and the overall daily gain was reduced by only 10-15% compared with *ad libitum* feeding indoors. These results indicate that there are options that can be used in order to obtain very good production results from outdoor-kept finishers.

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

Table 6. Liveweight gain and estimated grass intake for grazing heifers and pregnant sows grazing separately or mixed (average of two experiments; after Sehested *et al,* (2003)).

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

Figure 2. Numbers of infective *O. ostertagi* larvae per kg dry grass on two pastures grazed by heifers only or by a mixed herd of pregnant sows and heifers (after Roepstorff *et al*., 2000).



Several ways for better integration of pig production within the land use need to be considered. In the case of pregnant sows, which can be handled in relatively large flocks, one perspective 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 reduces the parasite burden of the heifers and results in an overall better sward quality compared with grazing separately (Roepstorff *et al*., 2000; Sehested *et al*., 2003). The liveweight gain and the estimated grass intake for heifers and pregnant sows grazing together or separately are summarized in Table 6, and in Figure 2 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 sows' grass-intake corresponded to half of the energy requirement. The peak of larvae infection of importance for the heifers per kg grass DM was in the mixed system, 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 differences in parasite burden in the sows were observed.

These results were obtained from sows fitted with a nose ring, but since this strategy seems suitable in combination with a low stocking rate for the pigs, one may expect a lower overall incidence of rooting and, consequently, that similar results could be obtained with un-ringed sows.

Following the results on grass-sward compositions one proposal can be that for pregnant sows the sward should have a considerable growth of highly digestible species which can support the nutrient supply of the pig. In the case of lactating sows the intake of energy from the grass will in any case be modest, and the main emphasis could be put on the wear strength of the sward.

CONCLUSIONS

Integrated forage and livestock production should be considered at farm level and herd/animal level, respectively. At the farm level an appropriate balance of different crops or different livestock species makes it possible to obtain a high production efficiency, expressed as N transformation (input into edible products) and milk yield per kg DM consumed. This supports a livestock production with a lower environmental impact than conventional high-input systems.

At the herd or animal level there is a need to be very much aware of the "quality" of the forage. This relates to intakes of grass and clover-grass in ruminants as well as in sows, especially non-lactating sows. The inclusion of clover is particularly important in this respect. However, additional features of the sward species related to their impact in endo-parasitic infections in ruminants need to be considered, although there is a need for much more knowledge in this field.

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