CORE organic II

ICOPP

Improved Contribution of Local Feed to Support 100% Organic Feed Supply to Pigs and Poultry

SYNTHESIS REPORT

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ICOPP

ICOPP is the acronym of the project 'Improved Contribution of local feed to support 100% Organic feed supply to Pigs and Poultry' which ran from 2011 to 2014. It was funded through the European CORE Organic II ERA-net programme to support organic research, and led by Aarhus University in Denmark with 15 partners across 10 EU countries.

Photos supplied by project partners.

Contents

1. Executive Summary

Due to the request for using entirely organically produced feed for livestock by 31st December 2017 there is a need to explore and evaluate the practical possibilities in doing that from a production and animal welfare point of view. Thus, this work was initiated to suggest economical viable feeding strategies based on 100% organic feed across Europe, which will supply poultry and pigs the required level of nutrients in different phases of production and support high animal health and welfare.

Through co-operation between 11 partners, a range of feeding experiments were carried out with pigs (sows, piglets and finishers) and poultry (layers and broilers) focused on concentrate feedstuffs, roughage, and foraging from the range. In addition, three crosscutting activities have supported the overall interpretation; these worked on availability of relevant feeds across Europe, comparable information on feeding values of new feed stuffs for practical planning, and economic and environmental assessment of new strategies.

1.1 Organic feed availability and demand in the ICOPP countries and in Europe

In order to evaluate the availability of feeds across Europe existing literature and relevant statistical data on organic feed was compiled; information sources for protein contents of key crops as well as existing data on protein demand of pigs and poultry for the feeding calculations were investigated. Based on these data the balance between feed supply and feed demand was calculated in terms of dry matter, energy, crude protein and essential amino acids: lysine, methionine and methionine + cysteine. This analysis showed that for the countries involved in this project (ICOPP countries) there was a self-sufficiency rate for organic concentrated feed of 69 %. Over 50 % of the total demand for concentrated feed was fed to bovine animals, 16 % was fed to pigs and 31 % to poultry. The self-sufficiency rate for crude protein was 56 %. Except for Lithuania, organic crude protein demand clearly exceeds availability, and an overall gap of approximately 135'000 metric tons of crude protein exists within the ICOPP countries. The supply gap with essential amino acids was even higher than the supply gap with crude protein, being just above 50 % for lysine and about 40 % for methionine.

It is concluded that:

- It seems quite unrealistic that the ICOPP countries will be able to cover the organic protein demand with their own efforts and increase production in the foreseeable future unless major shifts in production take place.
- A large of amount of concentrated feed is fed to ruminants. If a part of the concentrated feed for ruminants (around 1,000,000 metric tons) would be used for feeding non-ruminant animals, a great step forward could be done.
- In order to meet the essential amino acid requirements for the individual animal categories, the types of protein crops that could be produced organically in a country is relevant. There are different feeding possibilities, which were researched in the ICOPP and other research projects, but still there is a need for more innovative solutions.

- The European Commission is envisaging a stricter regulation for feed - with a higher proportion of feed produced on-farm/in the region. However, the results of our calculations have shown that this might be difficult to achieve for some countries.
- Data on organic livestock and the market for livestock products is still scarce. There is a clear need for more and better data and for permanent and reliable data collection efforts in this field.

1.2 Feed evaluation of organically produced feed stuffs

Detailed knowledge of the nutritional value of organic feeds is important to support the practical feeding planning and to evaluate the prospects of new feeds. Thus, an important objective was to gain a deeper insight in the comparative nutritional value of a range of feed stuffs of importance for organic monogastrics feeding EU wide in order to supply nutrient values of relevant feed ingredients that is relevant for a feeding strategy with 100 % feed of organic origin for pigs and poultry. A particular issue was to 'translate' findings from different feeding value systems in order to take advantage of EU wide results instead of only 'local' results as basis for feeding advices in practice.

Digestibility trials were performed of potential novel protein feedstuffs for organic pig and poultry production such as grass peas, sainfoin seeds (whole and dehulled), okara, microalgae, mussel meal and Hermetia illucens pupae and meals. In addition, the chemical composition, including estimated amino acid availability, of a range of more common organically produced protein feed stuffs have been established.

A particular issue was also to gain insight in the digestibility of fibrous feeds with focus on amino acids. For this in vivo trial with pigs were carried out based on direct sampling in the intestines, thus requiring slaughtering of the pigs. This was done in order to avoid unnecessary suffering of the pigs from the experimental work. Generally a high digestibility of protein and amino acids in the grass silage were found.

Based on this work a comprehensive feed table with data on chemical composition and nutritive value are of organic feed stuffs were produces and are available on-lone. A side effect of the work was a clear demonstration of the fact that feeding fibrous feedstuffs such as grass silage or okara to pigs could prevent the development of gastric ulcers in pigs.

1.3 Concentrates

Regarding the issue of supplying organic concentrates 8 feeding experiments with different types of animals were carried out, addressing regionally based feeding strategies which shall ensure an appropriate nutrient supply for pigs and poultry. Main findings were as follows:

Pigs:

- Sainfoin seeds are of high nutritional value, particularly if dehulled (similar to soybean cake), and can partially (up to 15 % in the diet) substitute commonly used protein sources also in feeding of weaners, which otherwise often are most difficult to feed on local feed resources.
- Nutrient content of grass pea seeds is slightly higher than that of Faba beans, but caution must be taken due to antinutritional substances. Grass pea seeds can partially (up to 30%)

substitute commonly used protein if subjected to appropriate heat treatment, also for weaners.

- A high external input nutritional optimized diet versus a low external input and suboptimal diet resulted in better performance of piglets, in particular for week litters, without any differences in health status and mortality of the piglets. Also producing a 20 kg piglet were most economical with the the low external input diet.
- Mussel meal can replace common protein sources in feed for growing/finishing pigs with maintained production results in terms of growth, feed efficiency and carcass quality. Inclusion rate should not exceed 5 % corresponding to max inclusion rate of fish meal.
- For lactating sows peas and faba beans are appropriate protein sources.

Poultry

- Protein from organically produced *Spirulina algae* can fully replace protein from traditional organic sources in broiler diets.
- Refining of ingredients of plant origin enriching the relative content of Methionine seems to be a useful way to supply relevant protein sources for poultry, eg for sunflower seed expeller.
- Insect meal *(Hermetia illucens)* up to 12 % in the diet can replace soybean cake without any difference in egg production, feed conversion, health and taste of eggs.
- Crushed mussel shells (particle size 10-20 mm) supplied in the litter on every day basis to layers affected neither birds' feather cover, nor other welfare parameters or production performance. Crushed mussel shells cannot fully replace dietary calcium as calcium source without impairing bone health and egg shell strength.

1.4 Roughage

Use of roughage is mandatory in livestock organic production, but often the potential of roughage to contribute to the nutritional needs of monogastrics are unclear or not taken into account in the feeding planning. Thus, a number of feeding experiments were performed to illuminate that. The main findings were:

Growing pigs

- For growing pigs inclusion of grass-silage cut at an early stage of development in a mixed diet with concentrates does contribute to the energy and in particular protein supply (and prevent ulcer damages), but the overall production results (daily gain and feed conversion rate) becomes poorer when silage is included with more than 10 %. At the same time activity/competition at the feed trough may increase resulting in more skin lesions.
- In a diet with lucerne silage for growers no difference were found in growth rate when soybean protein were substituted with peas protein, underpinning the fact that forage does contribute to amino acid supply
- No difference in production results for growers were found between using silage of red clover or chicory silage

Poultry

- The methionine content in the protein of early harvested lucerne is higher than that of soya bean cake and almost twice as high as that of peas, and may thus represent an important source to cover the amino acid supply in poultry. This was tested in two experiments with the following findings
- In the diet for layers the early cut silage may be include in a proportion of 20 percent of dry matter without impairing egg production compared to a traditional diet for
- In diets for slow growing broilers early cut lucerne silage can amount to 10-20 pct in the rearing period (week 1 to 4) and up to 30% in the fattening period (week 5 to 8) without impairing the growth.

These production results confirm that the silage make methionine available for the poultry and thus can contribute significantly to cover their nutritional needs. Thus an energy dilution of the diet, concomitant with a proportional reduction in other nutrients, e.g. dig. Methionine, is an option as well to fulfil the requirement of 100% organic diets. This can for example be relevant when including high quality roughage in the feed mixture for layers.

1.5 Foraging in the range

Access to a foraging area represent a possibility for the monogastrcs to partly cover their nutritionals needs by the biomass available here, but very little is known on this issue, in particular how soil invertebrates may contribute. The abundance of soil invertebrates were researched and experiment with pigs and poultry performed on how to utilize the biomass available in the outdoor area.

- Of all the invertebrates studied, earthworms present the most potential in contributing to the nutritional needs of poultry in particular, while having only a minor contribution to pig nutritional needs. One m^2 of most habitats studied would contribute considerably to the daily requirements of laying hens for methionine, and in most cases, completely meet lysine requirements also.
- Low-protein diets stimulate the broilers to forage on the range area and direct foraging can pose an important contribution to protein supply in broilers of slow-growing genotypes without detrimental effects on growth performance.
- For growing pigs direct foraging on well-established lucerne can pose an important contribution to energy and protein supply in fattening pigs if the pigs are fed restrictively with a low-protein feed mixture and if the pigs get regularly access to new land (strip-grazing). However, the restriction in supplemental feed also reduces growth rate significantly. Thus while the feed conversion rate of the supplied concentrate improves, the overall feed conversion rate becomes poorer as was also seen when feeding grass silage to growing pigs. Thus, it seems that for growing pigs the foraging in particular is useful in supplying amino acids.
- For lactating sows fed considerable amounts of concentrate the intake of grass DM in the diet intake varied between 0.2 and 1.6 kg DM sow^{-1} per day as determined by the profile of n-alkanes. These results indicate that also lactating sows that are fed with relatively large

amounts of concentrate are able to utilize some of the nutrients in the sward if this is maintained in a good condition.

1.6 Pathways for strategies for 100 % organic feed supply

Based on the above results some main pathways for strategies for 100 % organic feed supply were suggested and evaluated by looking at 1) how to cover the nutritional needs with organically produced feed stuffs at all stages of their life 2) what organic feed stuffs are available and 3) how can more local feedstuffs be made available

The first aspect is mainly related to difficulties in covering the amino acid requirement of the animals and in particular for the young animals as piglets and young broilers and young hens. There are many options for doing this as documented in the previous sections. Some of the ingredients of organic origin needed to do so may be considerably more expensive than alternative conventional feed stuffs. However, these feed stuffs constitute only a very small part of total feed, e.g. approximately 1 % of the feed in an organic pig production system. Thus, the economic consequences are quite limited.

The main problem is the lack of organic feed stuffs in Europe relatively to the demand both in terms of energy and protein (and in particular methionine) in concentrated feed stuffs which are essential in the present feeding of monogastrics. Therefore, more emphasis should be put on crops that are suitable in organic farming and which has a high yield per ha of feed energy, protein and the relevant amino acids. Legume forages like lucerne represents such a crop and if harvested at an early stage of development it can yield a significant contribution to cover the protein requirements of the monogastrics, while at the same time support animal health and welfare. Also in most cases, due to the impact on the overall cropping system of introducing a forage legume the overall environmental impact of the production is expected to be reduced.

In order to achieve the full potential of basing the feed more on forage crops there is need to investigate possibilities to separate the easy digestible and protein rich part of the forage legumes to be used as the relevant protein source in the stages of life where it is most difficult to comply with the nutrient requirements and where the digestive system is less developed.

2. Background

This project was developed in response to the requirement to base the feeding of organically produced poultry and pigs on feed of 100% organic origin. The derogation from the EU Organic Regulatory Board to allow organic pig and poultry producers to include up to 5% non-organic feed within their rations was due to finish at the end of December 2014. From then on all producers would have been required to feed monogastric animals a 100% organic diet. This deadline has now been extended to 31 December 2017.

The aim of ICOPP was to produce economically profitable feeding strategies based on 100% organic feed across Europe, which will supply poultry and pigs the required level of nutrients in different phases of production and support high animal health and welfare. This was approached through the following tasks:

- Improving knowledge of availability and nutritional value of underutilized or new organic feed ingredients per animal category with a focus on local feed resources.

- Improving understanding of the possible benefits of roughage inclusion in relation to nutritional and behavioural needs as well as its impact on health and welfare.

- Understanding how direct foraging in the outdoor area can contribute to meeting the animals' nutritional needs.

- Assessing the economic and environmental consequences of increased reliance on local organically produced feed.

The working hypothesis was that it is possible, through an extended knowledge of the characteristics of different local feeds and their wider impact on growth, health and welfare and environment, to produce strategies which comply with the aims of high animal welfare, production economy and reduced environmental impacts. Through co-operation between 11 partners, a range of feeding experiments were carried out with pigs (sows, piglets and finishers) and poultry (layers and broilers), focused on concentrate feedstuffs, roughage, and foraging. The insight gained from these activities will be used to analyse and produce feeding strategies adapted to the differences in local feed supply, the economic impact related to different feed procurement, and variations in production structure in different countries/agroecological zones in Europe.

3. Organic feed availability and demand in the ICOPP countries and in Europe

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Hypothesis

Better knowledge of existing and at present underutilized feed sources of organic origin that fulfils requirements for monogastrics in terms of energy, specific amino acids (lysine and methionine), and health supporting characteristics will substantially ease the transition to feeding based on 100% organic feeds, as envisaged in the regulations for organic production (EC 834/2007 and EC 899/2008).

Aims

1. To assess feed availability and demand throughout the countries of the ICOPP project and Europe.
2. To evaluate the availability and suitability of local feeds from organic origin of relevance for pigs and poultry throughout Europe.
3. To evaluate the potential for increasing the self-supply of organic feed components within Europe.

Approach

Organic feed production throughout Europe was assessed with regard to availability and suitability as feed components for monogastrics by using a number of sources. All ICOPP partners provided information from their country on feed production, livestock numbers and feeding strategies. The Research Institute of Organic Agriculture (FiBL) conducted the survey and made the calculations on supply and demand of concentrate feed, crude protein and essential amino acids and consequently the self-sufficiency in the countries participating in the project.

In order to carry out the necessary work,

1. a desk study was performed (compilation of existing data, literature review);
2. a survey among the ICOPP partners was conducted (design of questionnaire, data collection among partners);
3. the demand and supply of concentrate feed, crude protein and essential amino acids was calculated in details for the ICOPP countries, based on information from the partners and further sources;
4. the importance of the ICOPP countries for European organic production was evaluated;
5. an extrapolation to Europe was made for the demand and supply of concentrate feed and crude protein;
6. an estimation was made about the possibility to satisfy the demand for organic feed with European production.

3.1 Methods

Desk study and survey

Baseline data on organic **crop production** were extracted from the database on organic agriculture of the Research Institute of Organic Agriculture (FiBL), which includes annually updated land-use data on organic agriculture in Europe, based on information from Eurostat and national sources. In addition the project partners were asked to supply further details on feed crops such as area and production of crops grown for feed (this distinction is usually not made in the national statistics, exports and imports of feed crops).

Furthermore, baseline data on organic **livestock numbers** were extracted from the FiBL database. In addition the project partners were asked to supply further details on livestock numbers and further indicators such as fattening period, average weight at slaughter or average duration of laying period.

For the survey, a questionnaire was created and the partners provided the data based on interviews with national organic sector bodies and selected stakeholders, and experts (feed mills, national authorisation bodies, scientists). The survey among the project partners was complemented by a literature survey.

Calculation of feed supply and demand

For the calculation of the feed supply/protein availability and demand the following steps were taken:

The total estimated feed volume in metric tons (mt) was provided by the project partners. This was used to calculate the available quantities of total dry matter (in kilograms), energy (Mega joule), crude protein (in kilograms) and of the essential amino acids lysine, methionine and methionine + cysteine (in kilograms). For the calculation, the Swiss Agroscope feed database was used (University of Zürich and Agroscope, 2014).

For the calculation of the required amounts of concentrate feed, crude protein and essential amino acids, animal numbers were used as provided by the ICOPP partners. An average concentrate feed, crude protein and amino acid demand per single unit (e.g. “one fattening pig”) was set, based on a number of sources. For certain units these demands had to be adjusted based on the countries’ feeding practices. In order to calculate the demand, the number of animals was multiplied with the average feed requirements mentioned above.

3.2 Results

The self-sufficiency rate for concentrate feed for each ICOPP country was calculated as a percentage of the actually produced concentrate feed compared with the total demand of concentrate feed. A self-sufficiency rate for concentrate feed of 69 % over all ICOPP countries was calculated. Over 50 % of the total demand (1,923,000 t) for concentrated feed was fed to bovine animals, 16 % was fed to pigs and 31 % to poultry.

The self-sufficiency rate for crude protein was calculated for each ICOPP country as a percentage of the actually produced crude protein relative to the total demand of crude protein. A self-sufficiency rate for crude protein of 56 % over all ICOPP countries was calculated. It is obvious that except for Lithuania, organic crude protein demand clearly exceeds availability, and an overall gap of approximately 135,000 metric tons of crude protein exists within the ICOPP countries. The demand for crude protein was more than 300,000 metric tons; 17 % was fed to pigs, 34 % to poultry and 49 % to bovine animals.

Based on a) the calculations of the concentrate feed production and its crude protein and essential amino acid content and b) the calculations of the demand of the animal categories, it could be shown that the supply gap with essential amino acids is higher than the supply gap with crude protein. The total self-sufficiency of the ICOPP countries is just above 50 % for lysine, about 40 % for methionine and about 55 % for methionine+cysteine.

While the data as calculated for the ICOPP countries seems to be very close to reality because of the detailed data collection as part of the ICOPP project, the extrapolation to Europe is a rough estimation because of the lack of reliable data. There are only few data on feed production in the countries and there are no data on feed imports and exports. The extrapolation shows that there is still a gap of an estimated 30 % of the crude protein even if the export countries will export 80 % of their produced protein crops (including soya and other oilseeds) to the import countries in Europe.

3.3 Conclusions

The following conclusions can be drawn based on the results of the ICOPP study on protein supply and demand in Europe:

- According to the data provided, it seems quite unrealistic that the ICOPP countries will be able to the organic protein demand with their own efforts and increase production in the foreseeable future.
- A large of proportion of concentrate feed is fed to ruminants. If part of the concentrate feed for ruminants (around 1,000,000 metric tons) would be used for feeding non-ruminant animals, a great step forward could be done.
- In order to meet the essential amino acid requirements for the individual animal categories, the types of protein crops that can be produced organically in a country is relevant. Determining factors are the climatic conditions. The area of arable land for high-protein crops is less in the northern parts of Europe and although overall in Europe for example for soybeans. Therefore, other solutions must be found. There are different feeding possibilities, which in the ICOPP and other research projects were researched, but still there is a need for more innovative solutions.
- The European Commission is envisaging a stricter regulation for feed - with a higher proportion of feed produced on-farm/in the region. However, the results of our calculations have shown that this might be difficult to achieve for some countries.
- Considering that there is a protein gap in organic farming, for the organic sector emphasis must be placed to make a certain justifiable amount of imports acceptable.
- Data on organic livestock and the market for livestock products is still scarce. There is a clear need for more and better data and for permanent and reliable data collection efforts in this field.
- Organic livestock numbers in Europe have grown at a slightly lower rate than the organic agricultural land or the area for important feed crops like cereals, oilseeds and protein crops. This could be an indication that there is a chance to increase the self-sufficiency level for feed especially for protein-rich feedstuffs, but more efforts are needed.

4. Feed evaluation of organically produced feed stuffs

Soile Kyntäjä, Tiina Kortelainen, Mikko Tuori, Hilkka Siljander-Rasi, Kirsi Partanen and Erja Koivunen

Hypothesis

Evaluation of feeding value of novel feed resources throughout Europe by a common methodology will facilitate exchange of results across countries, easy knowledge transfer and ultimately make it easier for producers to put together an appropriate diet for monogastrics.

Aims

1. To ensure a uniform determination of the nutritional value of feed ingredients used in feed trials.
2. To gain insight into the comparative nutritional value of a range of feed stuffs of importance for organic monogastrics feeding EU-wide.

Approach

Chemical analyses and in vitro digestibility determinations of a number of organic feed ingredients were performed. The chemical composition together with the *in vitro* digestibilities will enable the evaluation of the nutritional value of these ingredients in relation to similar conventional feedstuffs and will enable the use of tabulated digestibility coefficients. For novel ingredients, digestibility trials in pigs and in poultry were carried out using state of the art methodology.

4.1 Composition and nutritional value of organically produced feed materials for pigs and poultry

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Feed tables are in Appendix I

The main aim of this work is to increase knowledge of organically produced feed materials for pigs and poultry. It is crucial to present reliable feed values as a base for feed formulation. Different phases of production require knowledge of energy values and nutrient composition to achieve high production results as well as good animal health and welfare. The cost of feeds in organic pig and poultry production is approximately 60 to 70% of the total production costs. In order to attain economically favourable outcomes, there is an obvious need to gather exact nutritional data as much as possible.

In addition, an important target for this work was to study novel and innovative feed materials for pig and poultry production. Useful information has been obtained about the nutrient composition of potential novel protein feedstuffs for organic pig and poultry production such as grass pea seeds, sainfoin seeds (whole and dehulled), soybean by-product okara, microalgae, mussel meal and *Hermetia illucens* larvae and meals. *Hermetia illucens* larvae and meals are not yet permitted for use in pig and poultry nutrition. However, they are potential high quality protein sources for feeding of monogastric domestic animals in the future.

The potential of legumes such as sainfoin, grass pea and sweet lupin seeds for organic pig and poultry production has not been fully explored to date. Because they are not as common feed materials in conventional production as peas and faba beans, there has been lack of published analyses of their chemical composition and feeding values. The same issue concerns some by-products of organic food processing. Okara, a soybean by-product from the production of beancurd (tofu), is a potential high quality protein source for organic production.

Another purpose of this work was to analyse different roughages for pigs and poultry. In organic production, pigs should be fed roughages daily. However, the contribution of roughages to the nutrient supply of pigs and poultry is not exploited efficiently. A good source of information could encourage farmers to extend silage use to organic pig and poultry feeding.

Feed samples were analysed for dry matter, ash, crude protein, ether extract, crude fibre, neutral and acid detergent fibre, lignin, starch, sugars, amino acids, minerals, phytic acid, phytase activity and *in vitro* digestibilities according to Boisen and Fernàndez (1995, 1997) to predict the standardised ileal digestibility of amino acids (Boisen 2007). MTT, Agrifood Research Finland, analysed all the feed ingredients that were used in the feeding experiments throughout the ICOPP project. Full details of the methodology and samples analysed can be found in the full report (Kyntäjä et al 2014) which is available on line: http://jukuri.mtt.fi/handle/10024/484922. By having all samples analysed in the same place, and using the same methodology, it is possible to compare feed ingredients and transfer the results from country to country.

Furthermore, there is often lack of information concerning analysed nutrient composition of organically produced feed materials. This information can be used in feed optimisation for pigs and poultry on farms and by feed manufactures. Feedstuff names have been compiled based on EU feed catalogue (EU 575/2011).

The calculation of feed energy values for pigs and poultry differs between European countries. Nutrient contents are translated into the feeding values according to feed evaluation systems used in different European countries. The tables in Appendix I contain energy and protein values for pigs based on the French, Dutch and Danish feed evaluation systems. Energy values of feeds were also calculated according the British, German and Swiss feed evaluation systems. Energy values for poultry were presented according to the Finnish and Dutch feed evaluation systems.

4.2 Digestibility trials of novel feedstuffs

4.2.1 *In vivo* digestibility trials with pigs

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The feedstuffs for *in vivo* pig digestibility trials at MTT were discussed among partners and it was decided to study novel feedstuffs such as grass silage, grass peas, dehulled sainfoin, okara, mussel meal and *Hermetia* meal. These feedstuffs have no feeding values in conventional feed tables for pigs or poultry. It was also decided to use slaughter technique instead of cannulated pigs to minimise the pain to experimental animals. MTT has carried out *in vivo* digestibility trials with pigs with grass silage, legumes, grass pea seeds, dehulled sainfoin seeds and soybean pulp (Okara), mussel meal, and *Hermetia* larvae meal.

Grass silage

In a trial with grass silage, 6.7, 13.3 and 16.6% of the basal organic diet was replaced by grass silage on a dry matter (DM) basis and apparent total tract digestibilities were determined in body weights of *circa* 40 and 65 kg. The standardised ileal amino acid digestibilities were determined in the end of the trial by feeding pigs semi-purified diets with gradual inclusion of silage. The pigs were unwilling to eat silage that was chopped into 10–15-cm pieces during harvesting. Therefore, silage was re-chopped into 3–6-cm pieces and the highest inclusion level of 20% was lowered to 16.6% to reduce the amount of wastage. The performance results indicated that grass silage could provide some available protein and other nutrients for growing pigs. The feeding of semi-purified diet resulted in development of gastric ulcers in most of the pigs, whereas the incidence of ulcers was decreased when more silage was included in the diet. These findings indicate that feeding silage could prevent the development of gastric ulcers in pigs.

Grass pea seeds, dehulled sainfoin seeds and soybean pulp (okara)

The objective of this study was to determine the apparent total tract digestibility (ATTD) of nutrients and the standardised ileal digestibility (SID) of amino acids in three organically produced protein sources: grass pea seeds, dehulled sainfoin seeds and wet soybean pulp (okara) in growing pigs. The experiment was carried out with a total of 40 individually housed growing pigs (50% gilts and 50% barrows) with initial body weight of ca. 43 kg. The pigs came from litters of Finnish Landrace or Finnish Yorkshire x Finnish Landrace sows inseminated with mixed semen from Duroc x Norwegian Landrace boars. The experiment was carried out according to a randomized complete block design, where blocks were formed from five pigs of similar body weight. Within a block, pigs were randomly allotted to the dietary treatments. Collection of faecal spot samples was done at the end of period 1 on days 14–16. After that pigs were gradually switched to the starch based diets of period 2 for the determination of the SID of amino acids. The basal feed in period 1 consisted mainly of cereals, rapeseed expeller and whey protein concentrate (WPC). Of the experimental diets 10 or 20% was replaced by grass pea seeds or 20% by dehulled sainfoin seeds or okara on dry matter (DM) basis. Period 2 lasted for 7 d and the starch based basal diet was replaced by 15 or 30% of grass pea seeds, 45% of dehulled sainfoin seeds or 45% wet okara on DM basis. Titanium dioxide (3g/kg feed DM) was used as indigestible marker. The basal endogenous losses of amino acids were determined by feeding starch based low protein diet, which contained 5% WPC. At the end of the trial, 3.5 h after the morning feeding, the pigs were stunned by bolt pistol, bled and ileal digesta was collected for digestibility determination. Stomachs were visually estimated for gastric ulcers.

The crude protein content in grass pea seeds, dehulled sainfoin seeds and okara was 295, 396 and 345 g/kg DM, respectively. The content of lysine was 18.5, 20.0 and 20.7 g/kg DM, the content of threonine was 10.9, 13.2 and 13.9 g/kg DM and the content of methionine was 3.7, 7.2 and 5.9 g/kg DM, respectively. Replacing the basal organic diet with the experimental feedstuffs did not affect the ATTD of dry matter and organic matter. Okara and dehulled sainfoin seed diets had the highest crude protein digestibility, 73.5 and 72.9% ($p<0.05$). The crude protein digestibility in the diet with 10% grass pea seeds did not differ from that of dehulled sainfoin seed diet. Crude protein, crude fat and crude fibre digestibility for grass pea seed diets did not differ from each other or from the basal organic diet. Crude fat digestibility was the highest in okara diet, 68.2% ($p<0.01$).

Nutrient digestibility in the experimental feedstuffs was calculated by difference method, when the digestibility of the experimental diet differed from the digestibility of the basal organic diet. In cases of no difference in the digestibility, the digestibility value of the diet was used as the digestibility value of the feedstuff (mean value of the two inclusion levels for grass pea seeds). The crude protein digestibility in okara, dehulled sainfoin seeds and grass pea seeds was 81.5, 79.0 and 67.9%, respectively. The crude fat digestibility was the highest in okara (82.1%).

The apparent ileal digestibility (AID) of essential amino acids was the highest in okara (87–95%) and it did not differ from the values of grass pea seeds (73–84%). The AID of most of the essential amino acids in dehulled sainfoin seeds was clearly lower (41–55%). The basal losses of endogenous amino acids were high in this trial, which resulted in high SID values for essential amino acids especially in okara, over 98%. The SID of essential amino acids in grass pea seeds and dehulled sainfoin seeds was 80–95% and 53–64%.

All pigs fed starch based low protein diet had severe gastric ulcers. Also 38–50% of the pigs fed starch based diets with grass pea seeds and dehulled sainfoin seeds had severe gastric ulcers. No severe gastric ulcers were detected in pigs fed okara diet.

The results indicate that the ileal digestibility of amino acids in pigs is better in grass pea seeds than in dehulled sainfoin seeds. The ileal digestibility of amino acids in okara is very high. The use of okara in feeding promotes gastric health in pigs which is important for the welfare of the animals. The experimental feedstuffs can diversify protein source supply in organic pig feeding. More research is needed to define the optimal level of grass pea seeds and dehulled sainfoin seeds in diets for pigs and also the effects of the anti-nutritional substances in these legumes need to be further explored.

Mussel meal (Mytilus edulis)

The objective of this study was to determine the apparent total tract digestibility (ATTD) of nutrients and the standardised ileal digestibility (SID) of amino acids in organically produced mussel (*Mytilus edulis*) meal in growing piglets. The use of mussel meal in pig feeding is not allowed for the time being, but feed legislation in the EU concerning the use of mussel meal for pigs is in progress.

The experiment was carried out with a total of 24 growing pigs, 13 gilts and 11 barrows, with the initial body weight of ca. 19.4 kg. The pigs were distributed in experimental groups from litters of Finnish Landrace or Finnish Yorkshire x Finnish Landrace sows inseminated with mixed semen from Duroc and Norwegian Landrace boars. Piglets were first fed in the farrowing pen with organic feed for piglets (period 0). The diet was changed to another organic diet when piglets were moved to the fattening unit (2piglets/pen) (period 1). Diets were switched to starch based diets for the determination of the SID. There were two dietary treatments: 1) low-protein diet to determine basal endogenous losses of amino acids, 2) diet in which only protein source was mussel meal ,30% (of diet DM). There were 10 piglets in group 1 and 14 piglets in group 2. Experimental design needed to be changed due to diarrhoea in piglets of the mussel meal group, and the mussel meal diet had to be diluted with a diet containing whey protein concentrate. After the modification of the experimental design there were 3 dietary treatments in pair feeding: 1) low-protein diet to determine basal endogenous losses of amino acids, 2) mussel meal level 1 (12% mussel meal of diet DM) and 3) mussel meal level 2 (18% mussel meal of diet DM) and 8 pigs per treatment. At the end of the trial, 3.5 h after the morning feeding, the pigs were stunned by bolt pistol, bled and ileal digesta was collected for digestibility determination. Stomachs were visually estimated for gastric ulcers.

Mussel meal contained 684 g crude protein, 105 g crude fat and 94 g ash per kg DM. There was 47.8 g of lysine, 17.0 g of methionine, 8.4 g of cystine and 29.8 g of valine per kg diet DM in mussel meal. The apparent ileal digestibility (AID) of essential amino acids was 69.9–84.9% in diet with 12% mussel meal and 77.9–87.2% in diet with 18% mussel meal. The variation of the AID of amino acids was clearly higher in the lower inclusion level of mussel meal compared to the higher inclusion level. The AID of the essential amino acids in mussel meal varied between 66.3–88.5% (mussel meal level 1) and 71.8–87.6% (mussel meal level 2). The AID of lysine and methionine was higher in diet with 18% mussel meal than in diet with 12% mussel meal.

In the present trial the basal endogenous losses of amino acids were remarkably high, and therefore the mean values of the basal ileal endogenous losses of amino acids from three other digestibility trials in the ICOPP project were used for the calculation of the SID of amino acids in mussel meal. Due to high variation and several divergent values in the AID of amino acids in mussel in the lower inclusion level, the SID values for mussel meal were calculated only for the higher inclusion level. The SID of the essential amino acids in mussel meal varied between 80.9%–92.5%. The SID values for lysine, methionine, cystine, threonine and valine were 89.7%, 89.1%, 71.3%, 80.9% and 89.7%, respectively.

Most of the piglets fed low-protein diet had severe gastric lesions in the oesophageal area which are expected to cause pain and reduce the welfare of the piglets. When mussel meal was added to the diets, 62.5 to 75.0% of the piglets had no gastric lesions or the lesions were only minor. Severe gastric lesions were found in approximately one third of piglets fed with mussel meal but no grade 3 lesions were found. The weight of kidneys and the weight of kidneys in relation to live weight increased when mussel meal was added to the diets.

In conclusion, results indicate that mussel meal provides highly digestible amino acids, which can improve the amino acid balance in organic feeds for piglets. The effects of mussel meal on the health of piglets need to be further explored in feeding trials. Mussel meal could diversify the protein supply for organic pig production, but the economic aspects of the production of mussel meal for pig feeding need to be explored. The fine-grained starch based feeds, especially the low-protein feed used for the determination of the basal endogenous losses of amino acids, caused gastric ulcers for the piglets. The research methods should be developed to minimize the disadvantages to animal welfare. The basal endogenous losses of amino acids in piglets also need further research.

Black soldier fly larvae meal (Hermetia illucens)

The objective of this study was to determine the standardised ileal digestibility (SID) of amino acids in organically produced black soldier fly larvae (*Hermeti illucens*) meal in growing piglets. The use of *Hermetia* meal in pig feeding is not allowed for the time being, but feed legislation in the EU concerning the use of *Hermetia* meal for pigs is in progress.

Two batches of *Hermetia* meal arrived from Switzerland (FiBL Research Institute of Organic Agriculture). In batch 1, fat was extracted by mechanical extraction and in batch 2 hexane extraction was used.The experiment was carried out with a total of 40 growing piglets, 17 gilts and 23 barrows, with the initial body weight of ca. 17.2 kg. The piglets were distributed in experimental groups from litters of Finnish Landrace or Finnish Yorkshire x Finnish Landrace sows inseminated with mixed semen from Duroc and Norwegian Landrace crossbred boars. Piglets were first fed in the farrowing pen with organic feed for piglets (period 0). The piglets received the same diet when they were moved to the fattening unit (2piglets/pen) (period 1). Diets were switched to starch based diets for the determination of the SID of amino acids. There were five dietary treatments: 1) low-protein diet to determine basal endogenous losses of amino acids, 2) diet with batch 1 *Hermetia* meal 10.2%, 3) diet with batch 1 *Hermetia* meal 20.4%, 4) diet with batch 2 *Hermetia* meal 9.3%, and 5) diet with batch 2 *Hermetia* meal 18.6% (of diet DM). Diets in groups 2–5 contained also 22.85% (of diet DM) whey protein concentrate (WPC) as a protein source. There were 8 pigs per treatment in pairfeeding. At the end of the trial, 3.5 h after the morning feeding, the piglets were stunned by bolt pistol, bled and ileal digesta was collected for digestibility determination. Liver, kidneys and stomach was weighed and stomach was visually estimated for gastric ulcers.

Hermetia meal batch 1contained 629 g crude protein, 185 g crude fat and 51 g ash per kg DM. Corresponding values for *Hermetia* meal in batch 2 were 705 g, 90 g and 53 g/kg DM, respectively. There was 31.7 g of lysine, 12.0 g of methionine, 3.5 g of cystine and 39.6 g of valine per kg diet DM in *Hermetia* meal batch 1. Corresponding values for *Hermetia* meal batch 2 were 37.8 g, 14.1 g, 3.7 g and 44.2 g/kg DM, respectively.

There were no differences in the apparent ileal digestibility (AID) of amino acids in the experimental diets between the *Hermetia* meal inclusion levels or batches. The sex of the piglets did not affect the AID of amino acids in the experimental diets.

The AID and the SID of the amino acids was higher in *Hermetia* meal batch 1 compared to *Hermetia* meal batch 2. The AID of essential amino acids varied between 83.1–93.2% in batch 1 and 61.2–79.9% in batch 2. The SID of essential amino acids varied between 81.3–94.8% in batch 1 and 64.0–

81.8% in batch 2. The SID of lysine in *Hermetia* meal batch 1 was 81.3%, methionine 90.7%, cystine 49.8%, threonine 82.5% and valine 92.9%. Corresponding values for *Hermetia* meal batch 2 were 77.2%, 81.8%, -10.8%, 64.0% and 73.6%.

Most of the piglets (87.5%) fed low-protein diet had severe gastric lesions in the oesophageal area (grades 2 and 3) which are expected to cause pain and reduce the welfare of the piglets. In diets with *Hermetia* meal 75–100% of the piglets had no gastric lesions or the lesions were only minor. Severe gastric lesions were found in less than one third of the piglets fed with *Hermetia* meal and no grade 3 lesions were found. Feeding *Hermetia* meal to piglets increased the size of liver and kidneys and the proportion of kidneys in relation to live weight.

Results indicate that the fat extraction method in *Hermetia* meal affects the AID and the SID of amino acids, as the digestibility values were lower in hexane extracted *Hermetia* meal compared to mechanically extracted *Hermetia* meal. *Hermetia* meal provides highly digestible amino acids, which can improve the amino acid balance in organic feeds for piglets. *Hermetia* meal could diversify the protein supply for organic pig production, but the economic aspects of the production of *Hermetia* meal for pig feeding need to be explored. The fine-grained starch based feeds, especially the low-protein feed used for the determination of the basal endogenous losses of amino acids, caused gastric ulcers for the piglets. The research methods should be developed to minimize the disadvantages to animal welfare.

4.2.2 Digestibility of mussel meal with broilers

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A digestibility study on mussel meal with broilers was carried out at SLU. A total of 252 Ross 308 broilers were kept in groups of 7 birds in litter floor cages from day 1 to 35. A pelleted control feed, including 5 g/kg feed of the inert dietary marker titanium dioxide, was diluted with 0, 4, 8, 12, 16 or 20% of mussel meal. Due to low acceptability by the chickens of the diets with high inclusion levels of 16 and 24% mussel meal these treatments were removed from the analyses. At 35 days of age gut samples was collected from all 7 birds per cage and pooled into an average for each replicate. The calculated apparent ileal digestibility of crude protein (CP) in the mussel meal was 0.79, which was very close to the digestibility of CP in the control feed with 0% of mussel meal. According to feed tables provided by MTT fish meal has a CP digestibility of 0.88. As previous studies on broiler performance with mussel meal as replacement for fish meal have shown very good results regarding e.g. broiler chicken growth (Jönsson, L. 2009), the low digestibility of CP in mussel meal as compared to fish meal is somewhat surprising. A question arises whether the processing of the mussels into mussel meal was not optimal e.g. regarding temperature at drying.

4.2.3 Digestibility of organic processed feed ingredients in laying hens

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During optimizing of organic layer diets, nutritionists often assume that the chemical composition and digestibility of the organic raw materials are comparable with conventionally produced raw materials. Until now, very few digestibility studies with organically produced raw materials in laying hens have been performed. Furthermore, the current nutritional values for laying hens in the Dutch CVB Feeding Table are based on outdated digestibility studies with adult roosters. It can be questioned whether these values are applicable to modern (organic) laying hens. Digestibility studies with a number of organic layer diets were performed. Besides a basal diet, the digestibility of wheat, maize, peas, rape seed expeller, sunflower seed expeller, sesame seed expeller, heat treated soybean meal, two qualities of corn (moderate and good), barley, triticale, rye, *Vicia faba* and soybean meal expeller were investigated. In these raw materials, faecal digestibility of organic and inorganic mater, crude protein, crude fat, crude fibre, gross energy and amino acids were assessed.

The chemical composition of the tested organically produced raw materials often differed considerably from that of the conventionally produced crops, as stated in the Dutch CVB Table. In wheat, corn, and barley, crude protein content was higher, but in contrast it was lower in rape seed expeller and sunflower seed expeller, compared to the conventional raw materials. Compared to CVB values, starch content was reduced in *Vicia faba* and barley, but increased in triticale and rye. All tested expellers contained much more fat than the conventional crops. These differences indicate that CVB values are not representative for organically produced ingredients, and therefore, these values should not be used for optimizing organic diets.

Faecal digestibility of the tested organically produced raw materials in most cases differed remarkably from the conventional variant. Fat digestibility coefficients of the organically produced peas, barley, rape seed expeller, and sunflower seed expeller were higher compared to the conventionally produced crops, whereas fat digestibility in organic rye was reduced. Digestibility of crude protein was reduced in organic wheat, peas, corn (moderate and good, exp. 2), and rye, compared to the values of the conventional ingredients, whereas protein digestibility was increased in organic sesame seed expeller and soybean meal expeller.

As a result of the differences in chemical composition and digestibility, the metabolisable energy content also differed in the organic crops compared with the conventional crops. MEn content of organic peas was reduced by 5.0 MJ/kg compared to the value in the CVB Table, whereas the MEn content of organic soybean meal expeller was increased by 1.7 MJ/kg higher. Digestibility of the moderate corn differed slightly from the good corn, resulting in a somewhat lower MEn content (13.30 vs. 13.57 MJ/kg). Digestibility coefficients and MEn contents of some raw materials (wheat, corn, peas, sesame seed expeller, and heat treated soybean meal) differed greatly from the CVB Table values. In the case of corn, these differences might be related to the starch content. For the other ingredients, no references are available. Therefore, it is recommended to perform at least 3 digestibility studies per ingredient. This makes it possible to assess lower digestibility coefficients as valid values or as outliers.

This study confirms that the values of the Dutch CVB Table often could not be used to provide digestibility and chemical composition data for ingredients fed to organic laying hens. In this Table, the values for triticale and *Vicia faba* are lacking and so the results for these ingredients in the current study are unique. Compared to the Dutch CVB Table, only slightly differences in digestibility coefficients and MEn values were observed for organically produced barley, sunflower seed expeller, and corn (moderate and good quality). Digestibility coefficients and energy contents were considerably reduced in organic wheat, peas, sesame seed expeller, heat treated soybean meal and rye, whereas these values were clearly improved in organic rape seed expeller and soybean meal expeller. Based on the determined chemical composition of the organically produced ingredients, and based on the digestibility coefficients as presented in this report, the nutritional value of organically produced raw materials can be estimated appropriately in practice. This knowledge allows the nutritionist to optimize well balanced diets that closely fit to the requirements of organic laying hens. A correct balance in diet composition is beneficial to maintaining or improving performance, health status and environmental excretions of these hens.

4.2.4 I*n vivo* analyses of 22 raw materials for broilers

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Three experiments were conducted to evaluate, through a known *in vivo* method, the nutritional value of 22 raw materials (analytical and digestibility value) (Juin et al 2014). In each experiment, 200 day old male broilers of a slow-growing strain (JA 657) were fed basal or experimental diets. Experimental diets included the tested raw material (10 to 30%). The amount of mineral, trace and vitamins were 3% for all diets, and 17 to 20% of protein.

Apparent metabolisable energy (AME) of diets was calculated as the difference between GE intake and energy losses in excreta. AME values were then corrected for nitrogen retention (AMEn) using a factor of 34.4kJ/g. Protein utilization was calculated as the ratio between protein intake and protein excreted (with total nitrogen excreted corrected by nitrogen of ureic acid in excreta). Values of the raw materials were then calculated by taking the difference between basal and experimental diets according to the dry matter content (Lessire & *al*, 1985). Investigated raw materials were of different origins and supplied by producers: i) Current protein sources; ii) Unusual or new products; iii) Animal products.

Regarding the energy and protein utilization of a large range of organically produced raw materials, organic soybean meal gave good results but with variability in fat content and protein utilization. For other meals, sunflower, rapeseed, *Cannabis*, *Camelina*, protein content and digestibility were lower than soybean meal. Digestibility may be negatively affected by their ANF (anti-nutritional factor) content. For all tested products, processing (e.g. extrusion, dehulling) improved digestibility of protein and energy. Seeds and beans presented good protein utilization. However their protein content is lower than Soybean meal and their amino acid profile is not optimal for poultry. Forages, if they are of good quality, may represent a contribution to protein supply of broilers. Sea products, like *Crepidula fornicata,* presented high protein content and nutritional value. However to be used in poultry feed, the product must be dried and there is a risk that they may cause a fish taste in poultry meat. Larva of insects may represent an opportunity, but their digestibility is low and not constant.

4.2.5 Digestibility experiment of forage with broilers

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A digestibility experiment was performed indoor in battery cages with 14 week old broilers (genotype I657) fed control diet C consisting of standard organic broiler feed, or diet F1 formulated to have a lower content of protein and amino acids as contrast to the control. Six experimental treatments were included in the digestibility trial (F1, F1+ grass, F1+chicory, C, C + grass, C +chicory). The diet was a combination of pelleted feed and whole wheat (10%), and forage materials (grass or chicory) were given fresh in small portions twice daily with adaptation period of 7days, after which excreta samples were collected during three consecutive days. The grass and chicory intake per bird/day were 25g (C) and 31g (F1) and 42g (C) and 45 g (F1), respectively, where grass constituted between 15-17% of the total feed intake and the chicory between 21-23 % of total feed intake. The feed intake of diet C and F1 was on average 153g/bird/d with no significant difference between treatments.

The organic matter digestibility was significantly ($P<0.001$) higher in broilers given diets F1 (+/- forage) compared to broilers fed the control diet C (+/- forage) with averages being 76.2 and. 69.4%, respectively. The nitrogen retention was significantly higher with diets F1 + chicory (45.5%) and Fi + grass (41.9%) compared to the three control diets (+/- forage), with an average of 34.1%. It was also found that the nitrogen retention in birds fed diet F1 + chicory was significantly higher than the F1 without forage (38.8%), There were no differences in nitrogen retention with diet C either with or without forage. These data indicate that birds fed low protein diets can utilize the nutrients in the forage to some extent as a means to cover their requirement and probably resulting in a more balanced diet, since grass and chicory supplements have positive effects on nitrogen retention (Data on P retention is also available, but calculations not finished). The amino acid digestibility measured showed no significant difference between treatments except for cysteine which differed significantly ($P<0.05$) between some of the treatments and where the highest values were seen with the F1 diets.

4.3 Key Conclusions: Feed Evaluation

A comprehensive feed table is now available on-line to support the feeding planning in organic monogastrics production and in particular to support an appropriate and balanced feeding with amino acids. The table is available in different European feed evaluation systems in order to facilitate its practical use by consultants and farmers and it includes very novel feedstuffs characterized for the first time as well values for more regular fed stuffs. A particular issue was also to gain insight in the digestibility of fibrous feeds with focus on amino acids. Generally a high digestibility of protein and amino acids in the grass silage were found.

5. Pigs: impacts on productivity, health, behaviour and welfare in different production phases

5.1 Impact of different types of local concentrates

Hypothesis

Inclusion of novel (i.e. currently non- or under-utilized) feed components into the diets of pigs must supply quantities of limiting amino acids similar to the amounts currently provided by conventionally produced feed components (Article 43, Regulation 889/2008). The potential contribution of novel, locally produced feed components will vary across different countries, hence emphasizing the need to develop different feeding concepts for different regional conditions. The use of novel feed components should not have negative effects on animal health and product quality.

Aim

To test and evaluate various local feed ingredients and diets of 100% organic origin concerning their suitability for contributing to the nutritional needs of pigs.

Approach

A number of trials tested and evaluated a range of local feed ingredients and diets of 100% organic origin concerning their suitability for contributing to the nutritional needs of pigs. The feeding of piglets is a particular challenge in relation to health aspects and thus considerable emphasis was put on this with three experiments with piglets, and including subsamples to be raised for fattening in order to be able to evaluate the impact on fattening performance and product quality.

5.1.1 The effects of grass pea (*Lathyrus sativus*) and sainfoin (*Onobrychis viciifolia*) in 100% organic diets for weaned piglets

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The effects of different proportions of processed and unprocessed seeds of grass pea (*Lathyrus sativus*) and sainfoin (*Onobrychis viciifolia)* for weaned piglets were studied at BOKU, Austria (Baldinger et al 2012, 2014a, 2014b). The hypothesis was that these feed components could be included into diets for weaned piglets without impairing growth performance or health status and that thermal treatment would improve the use of these legume seeds. Response criteria included growth rate and related performance traits, and health status with a particular focus on gut health and behavioural disorders. Sainfoin seeds with and without hulls were found to be a suitable protein-rich feed component for weaned piglets. Toasted grass peas could be included at a rate of 20-30% in diets without any problems, but diets with 20% raw grass peas resulted in significantly lower performance. Therefore toasting of grass peas prior to feeding is recommended. Sainfoin and grasspea seeds possess specific advantages under difficult growing conditions (marginal, dry or wet soil conditions). This may (partially) compensate their relatively low yields. The nutritional value of sainfoin seeds is substantially higher than that of grasspea seeds, which contain potentially toxic constituents. Processing technologies significantly increase the feeding value of sainfoin (dehulling) and grasspea seeds (thermal treatment). If properly processed, both sainfoin seeds and grasspea seeds can be used to substitute for scarce protein sources (particularly soybean expeller) without affecting growth performance and health of weaned piglets.

5.1.2 A study on six feeding strategies of 100% organic origin for piglets with respect to performance, health status, losses and economy in organic agriculture

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Six different feeding strategies for piglets - three concentrates (standard *versus* high external input *versus* low external input) combined with two roughages (grass-clover-silage *versus* straw) - were tested by **TI**. It was hypothesized that the low-input-strategy would lead to healthy piglets with good growth performance, to reduced time and effort in feed and feeding management, to lower feed costs and to improved economics. In a pre-trial it was demonstrated that a low-external-input feeding strategy with a diet consisting of 87% home grown feed components resulted in healthy and well-performing piglets, even though amino acid supply partially fell below recommendations. In the full trials, the High External Input diet (HEI) gave the best performance, while the Medium and Low External Input diets gave lower but still good performances, regardless the roughage source. Weak piglets and problematical litters particularly benefitted from the HEI. There were no differences in health status and loss rates between the six strategies. Low-external-input-strategies were most economical in producing a standardized 20 kg piglet. Low External Input diets can be recommended, but only if there are outstanding management conditions and no obvious herd health problems. It is a solution for farmers with “pig sense”!

5.1.3 Inclusion of mussel meal in diets for growing/finishing pigs – influence on performance and carcass quality

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Mussel meal as a protein source in diets for growing/finishing pigs of different genotypes was investigated by SLU. Mussel meal has high protein content and a balanced amino acid profile for animal growth, and it was hypothesized that pigs will perform well, with maintained production results in terms of growth, feed use, and carcass and meat quality, when mussel meal replaces conventional protein feed resources. A diet containing 5% mussel meal was compared with a control diet in a trial with 64 growing-finishing pigs. The mussel meal diet was well accepted by the pigs, and the daily weight gain and lean meat percentage was similar for both treatments.

Mussel meal can replace common protein sources in feed for growing/finishing pigs with maintained production results in terms of growth, feed efficiency and carcass quality. Currently no information is available as to whether the sensory quality of meat is affected or not. Mussel meal can substitute fish meal in diets for growing pigs provided that the price of mussel meal is competitive and that the hygienic quality is sufficient. Inclusion of mussel meal should not exceed the levels recommended for fish meal.

5.1.4 Feeding of sows with organic diets containing peas or faba beans during gestation and lactation

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The objective of this study was to examine the influence of legumes and phasing the lactation and gestation feeding on pregnant and lactating sows. The lactation feeding was phased by giving the sows more protein (rape seed expeller) at the last half of lactation time (from 3 weeks lactation to weaning). The feeding of gestation was phased by replacing a part of the gestation feed with lactation feed at the last third of gestation.

The experiment was carried out with total 84 sows. The experiment was focused on sow feeding during lactation (n=74 sows) as only a small number of the sows (n=23) had results from the gestation period. MTT's sow unit was closed at the end of 2013. The results from the gestation period have been calculated and reported but the data was too small to draw firm conclusions.

Live weight and condition changes, fat measurements and piglets weight development were studied using cereal, cold-pressed rapeseed and pea or horse bean and concentrate containing organic feed. The control diet and the experimental diet 1 contained pea (19.7%) and the experimental diet 2 contained faba beans (16.4%). After the 21st day of lactation additional protein feed was given to the sows in the experimental groups (rapeseed expeller 3.4% in exp. 1 and 3.6% in exp. 2 groups). The daily net energy intake of the sows was similar during the 21 days of lactation but from that to weaning the NE intake was higher in the experimental groups 1 and 2 (103.8 MJ and 100.3 MJ/d) than in the control group (96.5 MJ/d). During lactation the sows lost body weight 11.6 kg, 15.6 kg and 13.6 kg in control group and the experimental groups 1 and 2. Total loss of body weight from farrowing to weaning, back and side fat changes (109^{th} day of farrowing to weaning) were not affected by dietary treatment. The litter weight at weaning tended to be higher in the experimental groups 1 and 2 (161.2 kg and 154.6 kg) than in the control group (147.8 kg). In conclusion, the performance and production results of the sows with high daily energy intake were similar in diets containing peas and faba beans. The supply of additional protein feed had no effect on sow performance but tended to increase litter weight at weaning.

5.2 Impact of roughage

Hypothesis
Grass silage and grass-clover based silage can be included in the diets of growing pigs without compromising the production performance, provided that the nutrient content and availability of the silage is adequately known. In addition, the inclusion of silage may improve animal health (in particular gut health) and satiety and improve welfare.

Aim
1. To explore to what extent fibrous roughage can contribute to covering the nutritional requirements (energy and amino acids) of slaughter pigs at different phases of production.
2. To identify the role of roughage in supporting gut health.

Approach
A series of feeding trials were performed including feeding trials for growing finishing pigs with grass and clover-grass silage with a focus on feed intake, growth, meat quality, and nutrient digestibility (energy and amino acids). In addition, the impact on behaviour and health was investigated.

5.2.1 Grass silage for growing finishing pigs
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Inclusion of early harvested grass silage in the diet of growing finishing pigs may reduce the need for import of protein rich feed ingredients and contribute to the closure of regional nutrient cycles. However, information on the nutritive value of grass silage, the potential inclusion level in the diet and consequences for growth performance is scarce. This study was conducted to determine the effect of early harvested grass silage in a completely mixed ration, on performance and nutrient utilisation of growing pigs (Bikker and Binnendijk, 2012, 2014). Organically raised pigs received an increasing proportion of grass silage up to 10 and 20% dry matter in the daily ration in the grower and finisher period, respectively.

The pigs receiving a mixture of grass silage and compound feed ingested 0.3 kg DM/d (13% of their daily ration) as grass silage and realised a similar daily net energy intake as pigs fed compound feed only. However, the silage fed pigs realised a lower daily gain (37 g/d) and a lower calculated net energy utilisation (1.6 MJ/kg) for gain. The carcass weight and dressing percentage of the silage fed pigs was significantly lower whereas the lean meat percentage, corrected for carcass weight, was similar for the two treatment groups. Daily gain corrected for dressing percentage was 50 g/d lower ($P<0.001$) in silage fed pigs.

Several factors may have contributed to the reduction in feed utilisation. The actual intake of feed, especially silage may have been lower than calculated because of feed spillage. Indeed some grass silage was observed in the bedding material of the pen. Furthermore, the digestibility and net energy content of the grass silage may have been lower than 7.9 MJ/kg dry matter as calculated on the basis of proximate composition and previous digestibility studies in sows. Digestibility of fibrous ingredients may be higher in sows than in growing pigs (Shi and Noblet, 1993). A digestibility study in growing pigs should further clarify this aspect. It seems unlikely that the amino acid supply was limiting in the grass silage diet since the muscle thickness and lean meat content were not reduced in silage fed pigs. Finally, pigs receiving the grass silage may have used more energy for maintenance processes; observations of farm staff indicate that inclusion of grass silage increased time required for eating and competition at the feeder. In addition, the increased visceral mass due to ingestion of fibrous feed, as indicate by the lower dressing percentage, may have increased the energy expenditure of the metabolic organs (Jørgensen et al., 1996). A further reduction of the particle size of the grass silage may improve digestion and reduce spillage of the feed material. The optimal feeding system and the nutritive value of grass silage for growing pigs requires further investigation to improve the silage intake and clarify and minimise the loss in animal performance. The feeding system should provide simultaneous and restricted concentrates and ad lib silage to prevent selection and unequal distribution of concentrate over pen-mates.

5.2.2 Comparing soya, beans and peas as a protein source in forage-based rations for pigs

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FAI and ORC carried out an experiment with a lucerne silage diet and different additional protein sources in 3 batches with 50 pigs over two opposing seasons. The hypothesis is that there is a difference in the growth performance of pigs fed soya, beans or peas as part of a silage-based ration. The first round of pig trials took place in August to November 2012 at FAI Farm, Oxford, UK, and a second round took place from February to July 2014. Three diets for pigs were compared, each containing 55% lucerne silage. The control diet contained soya. The remaining two diets contained either peas or beans as alternative protein sources. Growth rates were recorded weekly. No significant differences in pen average daily weight gain were observed during the grower phase (11-14 weeks of age) in each round. During the finisher phase (15 weeks of age and older), the groups of pigs on the beans diet had a significantly lower average daily weight gain than pigs on soya and peas, with no statistical difference in the average daily weight gains of pigs in the latter two groups. Feeding costs were reduced in the beans and peas diets, with the control (commercial) diet associated with the highest costs. Also in this experiment pigs were observed sorting the feed components and start with barley and beans/peas and end with forage.

This suggests that 100 % organic feed for pigs that meets the required level of nutrients in different phases of production and support high animal health and welfare is possible to achieve by combining home grown protein from legumes with lucerne silage. Feeding pigs silage as part of a total mixed ration that includes barley and beans or peas for protein may provide additional benefits as there may be less aggressive behaviour such as tail-biting and can reduce costs by replacing bought-in feed.

5.2.3 Whole crop clover and chicory inclusion in diets for finishing pigs of different breeds – influence on production

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Locally produced ley crops can contribute to a sustainable management of the arable land as well as be a feed resource supplying energy and protein. The aim of this study was to investigate how pig performance, and carcass quality is affected by inclusion of roughage (clover or chicory silage) in diets to finishing pigs of modern breeds (Yorkshire x Hampshire or Yorkshire x Duroc). It was hypothesized that clover and chicory will contribute to the nutrient supply of the pigs. Pigs were fed either a commercial diet (C, 24 pigs in 6 pens) or diets containing 80 % of the commercial diet (on energy basis) and *ad lib* supply of either whole crop red clover (RC, 24 pigs in 6 pens) or whole crop chicory (CH, 24 pigs in 6 pens) silage. The distribution of breeds and genders were equal in all pig groups. Clover silage was well accepted by the pigs, while more residues were noted in pig groups fed chicory.
Pigs in the RC and CH treatments had a lower daily growth than pigs in the C treatment ($p<0.001$). However, even though the conventional feed allowance was 20 % lower in the silage treatments compared to the C treatment, the daily growth was only 10 % and 16 % lower in the RC and CH treatments, respectively. This indicates that silage contributed with nutrients to the pigs. The analyses of conventional feed conversion ratios (FCR) show that pigs in the RC treatment had a lower FCR (2.23 kg feed / kg growth) than pigs in both the CH (2.40 kg feed / kg growth) and C (2.53 kg feed / kg growth) treatment ($p=0.005$). There were no differences in growth between breeds (Hampshire or Duroc sire) or interactions between breed and treatment. Carcass weight was higher in C and RC pigs than in CH pigs ($p=0.027$), whereas killing-out percentage was higher in C pigs ($p=0.007$) than in CH or RC pigs. Meat percentage did not differ between feeding treatments.

Both clover and chicory silage contribute with nutrients to the pigs even though red clover seems to have a higher potential than chicory. Thus red clover and chicory do not only contribute with important nitrogen fixation in crop production, they can also contribute with energy and protein to pigs.

5.3 Foraging in the range area

Hypothesis

Feed items in the range area in terms of plant material and soil living organisms have a higher protein/energy ratio than traditional feeds for pigs, and especially soil living organisms have a very high content of first limiting amino acids, methionine and lysine. As pigs seek feeds above as well as below the soil surface, the hypothesis is that foraging in the range area can contribute significantly to the nutritional needs of these animals and that differences among breeds exist due to differences in exploring behaviour and growth patterns.

Aim

To evaluate to what extent foraging in the range area can contribute to the nutritional needs of different genotypes of pigs.

Approach

The potential of utilizing the natural foraging behaviour of pigs as a method to supplement the animal diet with essential amino acids from an enhanced range area was investigated using a range of approaches.

1. Analysis of the range area as a feed source for pigs i.e. identifying how on-farm habitats may be used to enhance feed provision; what feed resources the range offers in terms of flora and fauna; what is the nutritional value of these resources, with a special focus on amino acids; what is the seasonal availability.
2. Experiments with sows, piglets and growing pigs, including different genotypes, with or without access to forage.
3. Experiments with small flocks of different genotypes of growing pigs given access to a range area with different agricultural crops. In the experiments, data on productivity, feed selection, foraging behaviour and animal welfare was collected, and N and P excretion and the nutritional contribution from the range area and the degree of self-reliance will be estimated.

5.3.1 Assessment of resources from the range

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On-farm habitats, including woodlands, agroforestry, headlands, field margins and agri-environment scheme options such as game bird cover strips, support a wide diversity of floral and faunal resources that may provide opportunities to enhance feed provision from the range for monogastrics. There have been many biodiversity studies of these habitats and a desk study collated these data and information to test the hypothesis that the range can contribute to the nutritional needs of pigs and poultry.

Thirteen research papers provided data on abundance and/or biomass of soil invertebrates on farmland in northern Europe (Binet et al., 1997, Didden, 2001, Frouz, 1999, Moreby et al., 1994, Schmidt et al., 2001, Smith, 2007, Crowley et al., In prep, Giller, 1996, Jakobsen, 2014, van Eekeren et al., 2010, Brown, 1999, Fuller and Smith, 2012, Ruedy and Smith, 2012). These data are summarised in Table 5.3.1. Earthworms were the most abundant invertebrates in all habitats, with means of between 207/m^2 in arable fields to 270/m^2 in non-cropped in-field habitats such as field margins and buffer strips. Densities varied considerably however (min 63 to max 548/m^2), reflecting differences in soil type as well as management. Insect larvae were also present in high numbers in grassland habitats, while litter-dwelling invertebrates such as woodlice and centipedes were more numerous in non-cropped habitats where leaf litter is able to accumulate.

Table 5.3.1. Mean abundance/m^2 of ground invertebrates in on-farm habitats summarising data from literature review.

	Cropped-arable		Cropped-pasture		Non-cropped – in-field		Non-cropped – woody elements	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Earthworms	**207.4**	63.3 – 548	**259.7**	90.7 – 480	**269.5**	149 – 337.2	**221.8**	107.9 – 294.5
Coleoptera Adults	**37.76**	21.93 – 55.82	**31.40**		**60.23**	33.19 – 79.96	**55.11**	9.48 – 136.8
Centipedes	**15.41**	11.85 – 18.96	**37.33**		**32.54**	13.47 – 59.85	**84.35**	32.59 – 151.7
Millipedes	**18.37**	14.22 – 22.52	**11.26**		**40.12**	6.52 – 77.63	**16.59**	5.92 – 36.15
Woodlice	**2.96**	0 – 5.93	**7.703**		**117.7**	35.56 – 243.6	**240.4**	43.26 – 614.5
Insect Larvae	**9.48**	4.74 – 14.22	**85.33**		**35.48**	4.74 – 66.37	**23.70**	18.37 – 30.22

Abundance data collated from the literature have been converted into feed resources/m^2 using the average weight/individual and nutritional analyses from the primary research project in 6.3.1 (Table 5.3.2). This is based on a number of assumptions, and therefore is only a very rough generalisation of available resources within farmland habitats. For example, body weights may vary considerably from species to species, as may nutritional values.

Table 5.3.2. Feed resources and nutritional value of soil invertebrates from a number of on-farm habitats

	DM g/indiv	Cropped: arable				Cropped: pasture				Non-cropped: in-field				Non-cropped: woody elements			
		DM g/m^2	CP g/m^2	LYS g/m^2	MET g/m^2	DM g/m^2	CP g/m^2	LYS g/m^2	MET g/m^2	DM g/m^2	CP g/m^2	LYS g/m^2	MET g/m^2	DM g/m^2	CP g/m^2	LYS g/m^2	MET g/m^2
Earthworms	0.14	29.04	15.10	0.99	0.26	36.35	18.90	1.24	0.33	37.73	19.62	1.28	0.34	31.06	16.15	1.06	0.28
Coleoptera Adults	0.11	4.15	1.62	0.09	0.02	3.45	1.35	0.08	0.02	6.63	2.58	0.15	0.04	6.06	2.36	0.13	0.04
Centipedes	0.03	0.46	0.18	0.01	0.00	1.12	0.44	0.02	0.01	0.98	0.38	0.02	0.01	2.53	0.99	0.06	0.02
Millipedes	0.03	0.55	0.21	0.01	0.00	0.34	0.13	0.01	0.00	1.20	0.47	0.03	0.01	0.50	0.19	0.01	0.00
Woodlice	0.03	0.09	0.03	0.00	0.00	0.23	0.09	0.01	0.00	3.53	1.38	0.08	0.02	7.21	2.81	0.16	0.04
Insect Larvae	0.1	0.95	0.46	0.03	0.01	8.53	4.10	0.26	0.08	3.55	1.70	0.11	0.03	2.37	1.14	0.07	0.02

Of all the invertebrates studied, earthworms present the most potential in contributing to the nutritional needs of pigs.

5.3.2 Field assessments of feed resources and laboratory analysis of nutritional value of feed items (vegetation and soil organisms) from relevant habitats.

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Vegetation and soil invertebrate samples were collected from plots in Denmark and England and analysed for amino acids, dry matter and nitrogen content at the laboratory at Aarhus University in Denmark. Methods of analyses followed Commission Regulation 152/2009 for sampling and analysis for official controls of feedstuffs. These analyses are summarised in Table 5.3.3.

Table 5.3.3. Feed resources in the range area and nutritional value of foraging crops and soil organisms

	Country	Crop	DM, %	Nutrient content, g/kg DM				Yield g/m²				Reference
				Energy, MJ ME	CP	Lys	Met	DM	CP	Lys	Met	
Vegetation												
Lucerne, long	DK[a]	-	19.3	7.7	275	13.9	3.6	129	36.4	1.91	0.49	Jakobsen et al., 2014
Lucerne, short	DK	-	21.5	9.1	301	17.4	4.4					
Dandelion[d]	DK	-	16.3	9.0	255	14.0	4.6	26	6.7	0.37	0.12	Jakobsen et al., 2014
Grass	DK	-	22.3	7.0	135	7.1	2.2	163	22.6	1.16	0.36	Jakobsen et al., 2014
Soil organisms												
Earthworms[c]	DK	Lucerne (dandelion)	27	7.9[b]	421[b]	25.1[b]	7.3[b]	51.3	21.3	1.29	0.37	Jakobsen et al., 2014
Earthworms[c]	DK	Grass	27.4	7.9[b]	463[b]	25.1[b]	7.3[b]	29.3	13.8	0.74	0.21	Jakobsen et al., 2014
Earthworms[f]	UK	Agroforestry	26.0[e]		517[e]	33.6[e]	9.37[e]	30.3	15.6	1.02	0.28	Bauer 2014
Earthworms[f]	UK	Woodland						18.9	9.7	0.63	0.18	Bauer 2014
Earthworms[f]	UK	Grass						23.1	11.9	0.78	0.22	Bauer 2014
Arthropods[f]	UK	Agroforestry	38.6[e]		391[e]	22.4[e]	6.00[e]	10.2	4.0	0.23	0.06	Bauer 2014
Arthropods[f]	UK	Woodland						3.9	1.5	0.09	0.02	Bauer 2014
Arthropods[f]	UK	Grass						26.0	10.2	0.58	0.16	Bauer 2014
Molluscs[f]	UK	Agroforestry	14.0[e]		626[e]	37.0[e]	9.23[e]	0.9	1.4	0.03	0.01	Bauer 2014
Molluscs[f]	UK	Woodland						1.7	2.9	0.06	0.02	Bauer 2014
Molluscs[f]	UK	Grass						0.9	1.4	0.03	0.01	Bauer 2014
Insect larvae[f]	UK	Agroforestry	25.2[e]		481[e]	29.6[e]	8.56[e]	3.1	1.5	0.09	0.03	Bauer 2014
Insect larvae[f]	UK	Woodland						7.3	2.1	0.22	0.06	Bauer 2014
Insect larvae[f]	UK	Grass						4.3	3.5	0.13	0.04	Bauer 2014

[a]In DK, vegetation samples and soil samples were collected through September 2013.

[b]Values for MJ ME, Lys and Met are from a pooled sample from lucerne and grass paddocks.

[c]'Yield' of earthworms represents availability in soil samples measuring 20x20x20 cm.

[d]Dandelion was growing in lucerne paddocks. Hence yields are pooled with regard to lucerne and dandelion.

[e]Values for % DM, Lys and Met are from a pooled sample from agroforestry, woodland and grassland habitats

[f]Yields of invertebrates are averages from monthly samples taken Sept 2013 to March 2014 in soil samples measuring 25x25cm

5.3.3 Intake of soil and grass by sows on pasture.

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This study aimed to provide a first estimate of the intake of grass and soil by free-range lactating sows. There are two hypotheses: H1= Hay complementation decreases stress and aggressiveness between animals; H2=Hay complementation has a better beneficial effect for more traditional races (less prolificacy and better maternal instinct). Animals were fed *ad libitum* with a commercial feed immediately after parturition and water was available *ad libitum*. The estimate of the intake of grass and soil was carried out in two steps: first the contribution of grass DM in the diet (i.e. grass and feed) using the profile of n-alkanes and then the contribution of soil in the total intake (i.e. soil, grass and feed) using the concentration of acid insoluble ash (AIA).

The animals ingested on average 7.8 (±2.2) kg of feed dry matter (DM) per sow and per day. The amount of ingested grass varied between 0.2 and 1.6 kg DM per sow and day which highlights the large variation in the response of the animals. The sows ingested less grass in July in comparison to October (respectively 0.4 and 1.0 kg DM/day, $P<0.05$). Different reasons could explain this difference: the summer heat (22.55°C max temperature in July versus 12.2°C in autumn) may reduce the intake although no effect was observed on feed. Moreover, grass was less available and slightly more fibrous which could also have decreased the intake. Finally, the parity range of sows differed slightly between both periods.

The soil intake was on average 0.3 kg per day without a significant difference between both periods despite a slight tendency of higher intakes in October (0.28 versus 0.41 kg/day). Nevertheless, individual variations were smaller in July than in October (respectively 0.16 and 0.36 kg/sow and day). An outlier of 1 kg daily soil intake was observed for one sow in October.

The grass intake seemed to vary depending on the quality of the growth of plants, similarly to the situation with ruminants. The soil intake seems to be restricted to 300 to 400 g per sow per day in good conditions on pasture. Nevertheless, strongly increased values can be reached confirming some very high values in adverse conditions reported in the literature. The maintenance of a good quality plant cover is therefore an important means to ensure that sows favour grass intake and to reduce the risk of exposure of the animals to pollutants via soil intake. Further studies are planned to learn more about the nutritional supply by pasture grass.

5.3.4 Silage for gestating sows

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A comparative study was conducted for one year on the experimental farm Les Trinottières (CA 49) to assess zootecnic, economic and animal welfare impact of the use of silage in a gestating sow feeding system.

Two genotypes of sows were used during the experimental design: LW x LF (large white x french landrace) and (LF x DR) x LW (3ways Duroc). Sows within the silage feeding system ("Silage") were fed with 90% of concentrate, compared to the control diet, and silage (50% DM) ad libitum. The protein content of the harvested silage was very low because there was a low proportion of white clover in grassland and the cut was too late. The trials showed that the consumption of silage can be extremely variable between groups, and indicated that the consumption of silage is positively influenced by:

- a high rank of the sows;
- a low availability of grass of high quality;
- a decrease of the distribution of concentrate;
- low rainfall to enhance the appeal of silage.

Concerning pregnancy, groups with silage realized the same weight gains and ELD gain as the control groups (with a tendency to superior performances). There was a high variability in sow's responses to the two feeding systems. Concerning lactation, sows fed with silage during pregnancy had better mobilized their body reserves. A possible explanation is the weight at farrowing: "silage sows" were fattier and could have a lower feed consumption. For LW x FL sows, the ranks were higher. Performances were the same with a tendency of higher weight gain for silage feeding system. During lactation, the loss of weight was higher than for control. There was a high variability of the responses for sows.

In the groups observed during gestation, the feeding system didn't affect the aggressive behaviour of sows. Silage distribution can compensate the potential negative effects of a high level of concentrate restriction on animal welfare. The methods to distribute silage were interesting, because it was possible for subordinate sows to go to the "silage place" and have a high consumption of silage.

For a system with 50 sows (such as in the experimental farm), the silage feeding strategy allowed a saving of 90 kg of concentrate per sow during pregnancy, so a total of 4.5 tonnes for all the sows, corresponding to a saving of 2000 € with the deduction of silage production cost for a farmer who buys the concentrate from a mill.

5.3.5 Experiments with growing pigs fed two levels of crude protein in the feed

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It is hypothesized that by choosing the right foraging area, the need for crude protein in the supplemental feed can be substantially reduced without impairing production results and animal health under range conditions. Results with 36 growing pigs foraging on either well-established lucerne or new-established grass and fed either a standard organic mixture (high protein: 20.5% of DM) or a mixture of barley and wheat (low protein: 10.7% of DM) from approximately 60 to 90 kg live weight showed that pigs fed low protein diets rooted significantly more than pigs on high protein diets. However, the effect of feed protein level was larger in grass (44 *versus* 19% of all observations) compared to lucerne (28 *versus* 16% of all observations). Feed protein level had no significant effect on grazing behaviour but pigs on lucerne grazed significantly more than pigs on grass (10 *versus* 4 % of all observations). A significant interaction between forage crop and feed protein level was found on daily weight gain and feed conversion ratio. Compared to the pigs on a high protein diet, the pigs on low protein treatment had 33% lower daily weight gain (589 *versus* 878 g) and 44% poorer feed efficiency (3.75 *versus* 2.59 kg feed per kg weight gain) in grass paddocks but only 18% lower daily weight gain (741 *versus* 900 g pig^{-1}) and 16% poorer feed efficiency (2.95 *versus* 2.54 kg feed per kg weight gain) in lucerne paddocks. Intake of lucerne in terms of dry matter was estimated to 20% of total dry matter intake (2,600 g fresh weight ~ 470 g DM). For energy, intake amounted to 14% of total energy intake. Regarding protein, lucerne intake represented 41% of total crude protein intake and for lysine the value was 48%. The pigs foraging on lucerne and fed low protein diet used 169 g less feed crude protein per kg weight gain than the pigs on high protein diet. The results indicate that direct foraging on lucerne can pose an important contribution to protein supply in organic growing pigs.

5.4 Key Conclusions: Pigs

Regarding the issue of supplying organic concentrates main findings were as follows:

- Sainfoin seeds are of high nutritional value, particularly if dehulled (similar to soybean cake), and can partially (up to 15 % in the diet) substitute commonly used protein sources also in feeding of weaners, which otherwise often are most difficult to feed on local feed resources.
- Nutrient content of grass pea seeds is slightly higher than that of Faba beans, but caution must be taken due to antinutritional substances. Grass pea seeds can partially (up to 30%) substitute commonly used protein if subjected to appropriate heat treatment, also for weaners.
- A high external input nutritional optimized diet versus a low external input and suboptimal diet resulted in better performance of piglets, in particular for week litters, without any differences in health status and mortality of the piglets. Also producing a 20 kg piglet was most economical with the low external input diet.
- Mussel meal can replace common protein sources in feed for growing/finishing pigs with maintained production results in terms of growth, feed efficiency and carcass quality. Inclusion rate should not exceed 5 % corresponding to max inclusion rate of fish meal.
- For lactating sows peas and faba beans are appropriate protein sources

Use of roughage is mandatory in livestock organic production, but often the potential of roughage to contribute to the nutritional needs of monogastrics are unclear or not taken into account in the feeding planning. Key conclusions are:

- For growing pigs inclusion of grass-silage cut at an early stage of development in a mixed diet with concentrates does contribute to the energy and in particular protein supply (and prevent ulcer damages), but the overall production results (daily gain and feed conversion rate) becomes poorer when silage is included with more than 10%. At the same time activity/competition at the feed trough may increase resulting in more skin lesions.
- In a diet with lucerne silage for growers no difference were found in growth rate when soybean protein were substituted with peas protein, underpinning the fact that forage does contribute to amino acid supply
- No difference in production results for growers were found between using silage of red clover or chicory silage

Also the **access to a foraging** area represent a possibility for the pigs to partly cover their nutritionals needs by the biomass available here. Main findings are:

- For growing pigs direct foraging on well-established lucerne can pose an important contribution to energy and protein supply in fattening pigs if the pigs are fed restrictively with a low-protein feed mixture and if the pigs get regularly access to new land (strip-grazing). However, the restriction in supplemental feed also reduces growth rate significantly. Thus while the feed conversion rate of the supplied concentrate improves, the overall feed conversion rate becomes poorer as was also seen when feeding grass silage to growing pigs. Thus, it seems that for growing pigs the foraging in particular is useful in supplying amino acids.

- For lactating sows fed considerable amounts of concentrate the intake of grass DM in the diet intake varied between 0.2 and 1.6 kg DM sow^{-1} per day as determined by the profile of n-alkanes. These results indicate that also lactating sows that are fed with relatively large amounts of concentrate are able to utilize some of the nutrients in the sward if this is maintained in a good condition.

6. Poultry: impacts on productivity, health, behaviour and welfare in different production phases

6.1 Impact of different types of local concentrates

Hypothesis

Inclusion of novel (i.e. currently non- or under-utilized) feed components into the diets of poultry must supply quantities of limiting amino acids similar to the amounts currently provided by conventionally produced feed components (Article 43, Regulation 889/2008). The potential contribution of novel, locally produced feed components will vary across different countries, hence emphasizing the need to develop different feeding concepts for different regional conditions. The use of novel feed components should not have negative effects on animal health and product quality.

Aims

To test and evaluate various local feed ingredients and diets of 100% organic origin concerning their suitability for contributing to the nutritional needs of poultry.

Approach

A number of trials tested and evaluated a range of local feed ingredients and diets of 100% organic origin concerning their suitability for contributing to the nutritional needs of poultry.

6.1.1 Mussel shells as a combined occupational and calcium source in floor kept laying hens

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Mussel meal has proven to be an excellent high quality protein source to organic laying hens. In the process of producing mussel meal the mussel shells are being discarded. From an ecological point of view also exploitation of the mussel shells would be to prefer. Feather pecking in laying hens remains a significant issue for the egg industry. The behaviour itself is believed to be a form of misdirected feeding behaviour arising due to lack of occupation. In order to improve the occupation rate in laying hens held in a single tier floor system, mussel shells were given in the litter area. The mussel shells may also serve as a good calcium nutritional source for the hens.

An experiment was conducted with 900 floor reared Dekalb White layers kept in a single tier litter floor system from 16-75 weeks of age. The birds were kept in 18 groups divided into three treatments; **C**= organic diet at *normal* Ca level; $\mathbf{C}^{-}$= organic diet with a *reduced* Ca content and 700 g crushed mussel shells (10-20 mm) daily distributed in the litter of the pen; $\mathbf{C}^{+}$= organic diet at *normal* Ca level and mussel shells distributed in the litter. Production, egg shell quality, corticosterone levels, fear reactions (measured by novel object tests), plumage and keel bone condition, pecking wounds, foot and litter condition were recorded throughout the production cycle.

There were no significant differences found between treatments as regards production, novel object reactions, corticosterone levels (feces), plumage condition or pecking wounds. However, the birds given **C** $^{-}$ had a higher incidence of keel bone deviations than **C** and **C**$^{+}$, reduced egg shell breaking strength and lower dry matter content of feces and litter.

In conclusion, the fact that the birds fed a limited amount of Ca in the diet (**C** $^{-}$) seemed not to be able to compensate that by consuming enough of the mussel shells implied by the impaired bone strength and egg shell quality. Separate feeding in hoppers of the shells combined with a slightly finer structure may have increased palatability although the possible occupational effect from birds being more active in the litter might have been less. Still, at the larger particle size used this effect did not significantly reduce feather pecking, i.e. plumage condition. The lower dry matter content in feces affecting the litter negatively may be a result from unbalanced nutritional status in the gut.

6.1.2 A study on the impact of three 100% organic feeds on broiler performance and welfare

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In this study, the impact of locally sourced 100% organic feed on broiler performance and welfare was investigated. Three 100% organic feeds were compared: a control diet with globally sourced ingredients including soybean expeller, a diet based on locally sourced (i.e. within Europe) organic ingredients, and a diet based on locally sourced organic ingredients and algae (*Spirulina* spp.). Algae could make a useful addition to poultry diets because their amino acid profile compares favourably with that of most food proteins including soybean. This suggests that algae may make a good substitute for soybean in poultry rations with regards to maintaining a desirable amino acid profile within the feed.

Preliminary feed trials with organic broilers (Hubbard JA 757) were carried out in two seasons; summer 2012 and winter 2013. The summer trial recorded no significant difference in total weight gain between the three diets, and no significant differences in welfare parameters (breast feather coverage and hock lesions). The winter trial found a significant difference in total weight gain with the local feed diet resulting in a lower weight gain than the local feed with algae diet, and a significantly higher feed conversion ratio for the local feed compared to the control diet. Again there were no significant differences in welfare parameters. The local feed with algae performed well compared with the soybean control, even in winter conditions. As these were only preliminary trials, there is a need for more research, including impact on carcass quality and other quality indicators. The current limitations of using algae are due to availability, economic feasibility and certification issues, but there is an increasing interest in use of algae for bioenergy so potential for much development in the sector. The best potential is to target algae production for specific amino acids to top up basic crude protein provision from other local sources.

6.1.3 Replacement of soybean oil cake by *Hermetia illucens* meal in diets for layers

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Insect proteins are supposed to be valuable protein sources for monogastric animals (Makkar et al., 2014). Among insects which could potentially be used for feeding livestock, the black soldier fly (*Hermetia illucens*) is particularly promising, because it can be reared on materials that are unsuitable for human nutrition (e.g. by-products from food processing) and because of its amino acid composition, which is similar to soybean (Veldkamp et al., 2012). However, legal restrictions hinder the use of insect protein in compound feed for livestock at present.

A feeding experiment was carried out with experimental flocks of 10 laying hens at the end of their laying period. For each of four replicates, 30 white hens (Lohmann Selected Leghorn LSL; 64 - 74 weeks old) were purchased from commercial organic flocks and randomly distributed to one of three feeding groups. Each group was housed in an experimental unit equipped with perches, litter, nests, feeders and drinkers. Hens had permanent access to a covered outdoor area. Three types of experimental feed were produced: 'control': a standard control feed containing 36 g/100g soybean oil cake (dietary crude protein [CP] 200g/kg), 'H12', a feed containing 12g/100g Hermetia meal and 18 g/100g soybean oil cake (CP in diet: 200 g/kg), and 'H24', a feed with 24 g/100g Hermetia meal replacing 100% of the soybean (CP in diet: 230 g/kg). Hermetia meal was produced from air dried pre-pupae fed on by-products from pasta production; meal was partly de-fatted to contain 11 g/100g crude fat. The experiment started after one week of adaptation. Hens were then fed experimental diets for 3 weeks. Feed consumption was measured during the 3-week feeding phase. Egg production and animal condition were recorded daily. Live weight was recorded weekly. Data were analysed with the software SPSS© in a general linear model with group as fixed effect (n= 4 replicates).

A tendency for higher feed intake with H24 compared to control was found. Laying performance, feed intake per egg, egg weight and liveweight changes did not differ between the groups. No signs of health disorders occurred and mortality was zero.

Table 6.1.3.1 shows the technical results.

Table 6.1.3.1 Effects of *Hermetia*-enriched diets on layer performance (n=4 series)

Parameter	Group			Statistical values	
	Control	H12	H24	S.E.	p-value
Feed intake [g/d]	107	116	131	9.8	0.091
Feed intake [g/egg]	134	148	159	16.7	0.327
Laying performance [%]	79.0	83.4	84.4	8.20	0.791
Egg weight [g]	65.9	67.2	68.7	1.78	0.303
Liveweight change [g/21 days]	-5.0	22.5	30.0	52.37	0.787
Mortality [%]	0	0	0	-	-

Both compound feeds containing *Hermetia* meal were eaten by the hens. Although statistical analysis shows no significant differences, it is striking that all recorded parameters are lowest in the control group and highest at the highest proportion of *Hermetia* meal in the diet.

There were no differences in feather scores between the groups, which all improved during the experimental period (data not shown).

Faeces were scored weekly in a semi-quantitative way. Faeces were always considered "normal" (consistency, colour) in the control groups, whereas black faeces (with or without diarrhoea) were found in the *Hermetia* groups. This led to an increased proportion of dirty eggs (black spots).

Sensory analyses carried out by a trained panel (ZHAW, Wädenswil, Switzerland) revealed no difference in taste between eggs from H12 and the control group. However, yolks in the *Hermetia* group were obviously paler than in the control. This may be due to differences in the content of natural pigments in the compound feeds. According to the feed manufacturer, it would be easily feasible to correct this in a commercial feed.

In conclusion the partial or full replacement of soybean cake by meal from *H. illucens* in a diet for layers did not affect their feed intake, feed efficiency or laying performance and egg weights. These results indicate that insect larvae could serve as a valuable replacer for soybean products in layers diets. However, further research on long-term feeding effects and on resulting egg quality is necessary to approve insect larvae as a practicable source of feed protein.

6.2 Impact of roughage

Hypothesis

Grass silage and grass-legume silage can be included in the diets of laying hens and broilers without compromising the production performance, provided that the nutrient content and availability of the silage is adequately known. In addition, the inclusion of silage may improve animal health (in particular gut health) and satiety and improve welfare.

Aim

- To explore to what extent fibrous roughage can contribute to covering the nutritional requirements (energy and amino acids) of poultry at different stages of production.
- To identify the role of roughage in supporting gut health.
- To investigate effects on product quality.

Approach

The role of legume-grass silage was investigated in feeding trials with laying hens and a slow growing genotype of broilers with a focus on feed intake, production and product quality.

Results

6.2.1 Lucerne silage for broilers and laying hens

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Lucerne harvested at a very early stage contains comparatively high levels of lysine and methionine while the fibre content is relatively low. Per 100g crude protein, the methionine content of these plants is higher than that of soybean cake and almost twice as high as that of peas. Consequently, lucerne has high potential as a regionally produced source for methionine. This study investigated the use of early cut lucerne silage in feeding organic poultry at the University of Applied Sciences Weihenstephan-Triesdorf, Germany.

Broilers

Broilers consumed high amounts of the early-cut lucerne-silage. Silage consumption increased with the age of the animals and was between 10 and 20% of the daily dry matter intake in the rearing period (week 1 to 4) and up to 30% in the fattening period (week 5 to 8). Therefore, an adjustment of the concentrate feed (increasing its energy content) was required to cope with the increasing silage intake. The results from the experiment indicate that the animals can convert the amino acids from the silage into meat.

Laying hens

Laying hens also consumed significant amounts of lucerne-silage/day (as a daily DM intake: 15-20%). This may contribute significantly to the supply of the essential amino acids (lysine and methionine). Additionally, the offer of silage is attractive for the animals and promotes animal welfare (activities, prevention of feather pecking) and animal health (intestine, foot pads). The laying performance and egg weights of animals fed with this silage system were comparable to the performance achieved by feeding a complete feed mixture. By using a concentrate feed mixture that is adapted to balance the lower energy content of the silage, a silage intake up to 20% of the total daily dry matter feed intake can be reached in the feeding of laying hens.

Laying hens and broilers fed with alfalfa-silage provided eggs and meat with higher levels of omega 3 fatty acids than their counterparts without alfalfa-silage.

6.3 Foraging in the range area

Hypothesis

Feed items in the range area in terms of plant material and soil living organisms have a higher protein/energy ratio than traditional feeds for poultry, and especially soil living organisms have a very high content of first limiting amino acids such as methionine and lysine. As poultry seek feeds above as well as below the soil surface it is the hypothesis that foraging in the range area can contribute significantly to the nutritional needs of these species and that differences among breeds exist due to differences in exploring behaviour and growth patterns.

Aim

To evaluate to what extent foraging in the range area can contribute to the nutritional needs of different genotypes of broilers.

Approach

The potential of utilizing the natural foraging behaviour of pigs and poultry as a method to supplement the animal diet with essential amino acids from an enhanced range area was investigated using a range of approaches:

1. Analysis of the range area as a feed source for poultry i.e. identifying how on-farm habitats may be used to enhance feed provision; what feed resources the range offers in terms of flora and fauna; what is the nutritional value of these resources, with a special focus on amino acids; what is the seasonal availability. See Section 5.3.1 for results.
2. Experiments with broilers, including different genotypes, with or without access to forage.
3. Experiments with small flocks of different genotypes of broilers given access to a range area with different agricultural crops. In the experiments, data on productivity, feed selection, foraging behaviour and animal welfare were collected, and N and P excretion and the nutritional contribution from the range area and the degree of self-reliance were estimated.

6.3.1 Feed resources in the range: soil invertebrate abundance and biomass in agroforestry, pasture and woodland habitats

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The abundance and biomass, and subsequent analyses of nutritional value of soil invertebrates within three on-farm habitats were assessed monthly between September 2013 and March 2014 on a poultry farm in Oxford UK. A total of 1001 invertebrates were sampled from the three habitats over the seven month period, with earthworms being the most abundant group (439 individuals). There was seasonal variation in abundance, with beetles and spiders abundance decreasing during the winter months, while earthworm numbers increased from autumn into winter. An analysis of variance (ANOVA) showed statistically significant differences in abundances between habitats for earthworms, spiders and insect larvae with significant differences between agroforestry and woodland for earthworms (higher abundances in agroforestry), pasture and woodland for spiders (higher abundances in pasture) and woodland and agroforestry for insect larvae (higher abundance in woodland). The data on abundance and biomass from the three habitats were translated into potential feed values using crude protein and amino acid values from nutritional analyses of invertebrate material (Table 5.3.2). The potential feed values per m^2 increases from September to March, reflecting the increase in abundance of earthworms (Fig. 6.3.1).

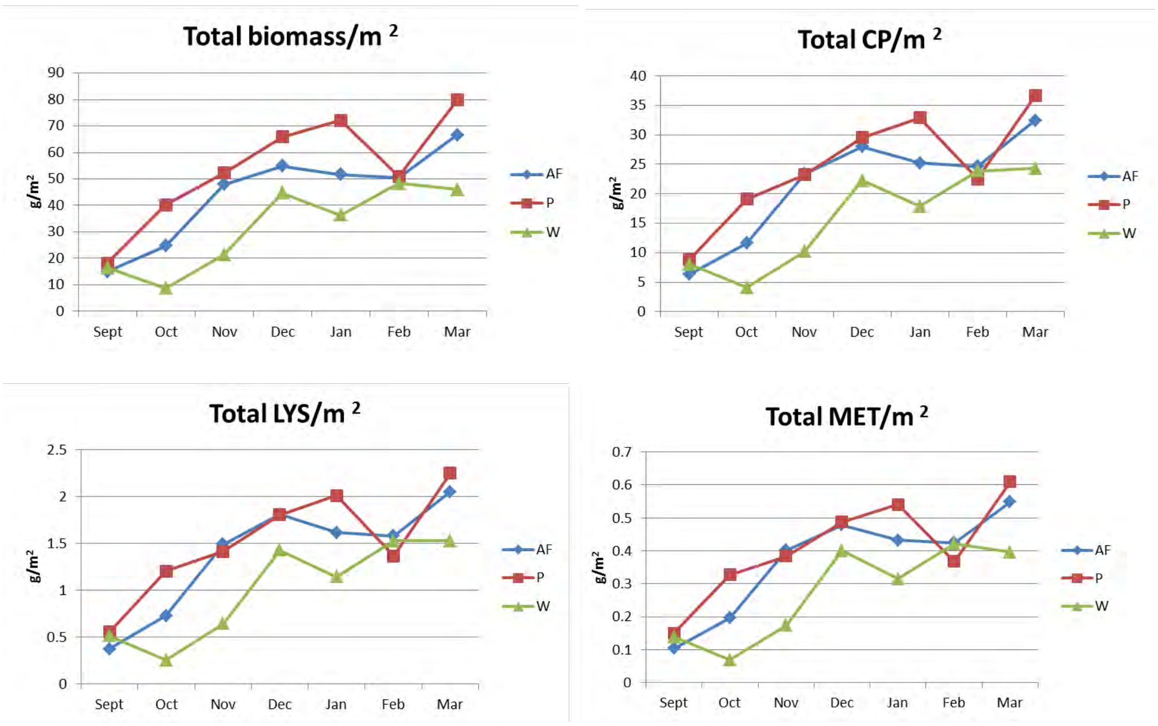

Fig. 6.3.1. Nutritional value (g/m^2) of invertebrates in agroforestry (AF), woodland (W) and pasture (P) habitats sampled monthly from September 2013 to March 2014. CP = Crude protein; LYS = lysine, MET = methionine

Of all the invertebrates studied, earthworms present the most potential in contributing to the nutritional needs of poultry in particular, while having only a minor contribution to pig nutritional needs. One square metre of most habitats studied would contribute considerably to the daily requirements of laying hens for methionine, and in most cases, completely meet lysine requirements also (Table 6.3.2).

Table 6.3.2. Value of earthworms in meeting the protein and amino acid requirements of laying hens

Habitat	Resource g/m^2			% daily requirements		
	CP	LYS	MET	CP	LYS	MET
Agroforestry	15.6	1.02	0.28	95	134	85
Woodland	9.7	0.63	0.18	59	83	55
Pasture	11.9	0.78	0.22	72	103	67

6.3.2 Foraging in the range area for organic broilers. Impact of feeding strategy and genotype

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A study was conducted by INRA Magneraud, to investigate the potential contribution of grassland to the fulfilment of the nutritional needs of poultry. The objective of the study was to assess the impacts of a lower protein feed on the growth performance and the use of the range area, and to assess to what extent this free-range area can compensate for dietary intake. The trials were conducted on two genetic types of poultry with different growth potentials. The animals were slaughtered at two ages (*89* versus 103 days old) and were fed with two feeds, one of which had lower protein content (minus 2 points of CP) and was cheaper. The animals had continuous free access to the open-air runs from 35 days old, and all animals received the same starter feed.

Results show very little weight differences between the two diets, regardless of the growth rate. The feed conversion rate (FCR) is only slightly less satisfying for the low-protein diet: 3.15 compared with 3.01 for the 89 days old breed and 3.69 compared with 3.48 for the 103 days old breed. Moreover, diet did not affect the yield after slaughter with regards to fat, thigh and fillet percentages. Intake of proteins from the complete food is slightly lower per broiler, the feed gain ratio having been increased for poultry batches fed with lower protein intake. Nonetheless, despite the increase of the FCR, limiting the incorporation of soya and protein intake caused a decrease in total feeding cost: -3% for the 89 days old breed and -4% for the 103 days old breed.

The monitoring of the rangelands by grass height measurements showed that the two open-air runs where animals were fed with low-protein diets were used more. Therefore it seems possible that the broilers counterbalanced the lower protein intake of their food by further exploration of the grassland and by eating the plants. However, there is no effect of the genotype.

Another trial was conducted by reducing the protein intake further, and thus the soya oilcake intake, getting a protein content of 16.4 in growing intake and 14.1 in fattening intake. To complete the study, another diet was also tested, totally removing soya oilcake during the fattening phase. The protein content was also of 17.53 in growing intake and 15.5 in fattening intake. Since the fattening period is the period that uses the most feed, a decrease of the use of soya oilcake during this period could turn out to be really cost-saving. The breed used for this study was G41. The performances obtained after 18, 56 and 84 days were 506, 1480 and 2423 g for the low-protein diet and 515, 1543 and 2551 g for the 0% soya oilcake diet. The indexes, established on the whole period, are respectively 3.204 and 3.219.The monitoring of the rangelands shows once again an overuse of the rangeland for the low-protein diet, especially at the end of the breeding cycle, around 71 days of age.

6.3.3 Performance of foraging poultry fed diets with graduated levels of protein and amino acids

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It is hypothesized that by choosing the right genotype and foraging area, the need for methionine in supplemental feed can be substantially reduced without impairing production results and animal health under range condition. Two slow-growing genotypes (RedBroJA: RJA and I657) with different growth potentials were used in a Danish broiler experiment and a total of 720 broilers were allocated to 18 outdoor plots from 28 days of age. All chickens were reared in indoor facilities from 0-28 days fed the same organic starter and grower diet. The I657 is considered to be the slower growing genotype. The weight of the day-old chick was 42 and 36g for RJA and I657 respectively and a weight of approximately 700g (RJA) and 515g (I657) were reached at 28 days, when they were introduced to three experimental diets when moved to the outdoor area. A small house was placed on each plot with feeding troughs and water equipment and the broilers had free access to the surrounding pasture field consisting of grasses and herbs. The experiment lasted until 14 weeks of age. Six experimental treatments were allocated at random to the 18 outdoor plots to provide 3 replicates using 3 different feeding strategies i.e. for each genotype. The treatments included the control diet C consisting of standard organic broiler feed, diet F1 formulated to have a lower content of protein and amino acids as contrast to the control, and diet F2 (mixture of control and F1). All diets were diluted with 10% whole wheat. The chemical analyses of the two diets showed that the protein content was a little higher than expected from the calculated content (C: 20.4 compared with 19.8%, F1: 14.9 compared with 13.9%, as is basis). However, the protein content in F1 was still low according to recommended requirements. The methionine and cysteine content on the other hand was close to the calculated values.

The lower protein and amino acid content in diet F1 resulted in lower daily weight gain (WG) compared to the control for both genotypes in the period from 28-98 days, where the broilers were given the experimental diets. I657 chickens fed diet F2 did not differ from the control, which was still the case with the RJA genotype. The final weights (98 days) of the RJA broilers were 4150g (C), 3902g (F1), and 3968g (F2), compared to 2909g (C), 2674 g (F1) and 2845g (F2) for the I657 genotype, showing the difference in growth rate between the two genotypes, being significantly different (P>0.0001) during all weeks in the whole experiment. During the first month of the experiment (28-56 days) the difference in daily WG between the treatments were higher, being as high as 25% for REDJA (F1: 37.9 compared with C: 50.4g) and 16% for I657 (F1: 27.9 compared with C: 33.4g), indicating that diet F1 had too low a level of protein and essential amino acids to cover their requirements at a younger age. The difference was reduced as the birds grew older. The effect of diet F2, being in between diet C and F1 with regard to nutrient content resulted in WG for I657 not being significantly different from the control, whereas this was the case with RJA, indicating a higher protein and amino acid requirement for the genotype with the highest growth rate. The daily feed intake (FI) per bird from 28-98 days, was on average 171 (RJA) and 113g (I657), respectively. The feed conversion ratio (FCR: g feed/g gain) was relatively similar between the 6 treatments, where the overall average from 28-98 days was 3.68 for RJA and 3.50 for I657. The poorest FCR was seen with RJA given diet F2 (3.82), being significantly different from FCR of all diets fed I657. The daily methionine intake in g/bird was calculated to be in the range from 216-291mg/bird/day for I657 and 330-451mg/bird/day for RJA, the diet with the lowest content of methionine (F1) resulting in the lowest daily intake. The recommended methionine requirement for slow growing broilers genotypes are often based on recommendations for fast growing broil strains as Ross 308 slaughtered at 36 days (NRC, 1994), which most likely is not useful when discussing the daily methionine requirement for more slow growing genotypes as used in the present study. The methionine requirement for fast growing broilers is 0.32% in the finisher period. Some few studies have been looking into the methionine requirement of more slow growing birds and found that the requirement are close to the fast growing broilers in the starter phase, but decreasing with age, being 0.26 and 0.30% for slow- and medium grown genotype in the grower phase and 0.22 and 0.25% in the last growth period. In the present study the methionine intake per kg feed were on average 0.25% (C), 0.23% (F2) and 0.21% (F1) for both genotypes, being close to the values obtained in other studies.

Excreta were collected from the outdoor plots during the last weeks of the experiment and comparing for instance the I657 given F1 and C diets, respectively, there was a clear difference in the percentage distribution of feed items in the samples, as a much higher content of plant material was found in excreta from birds on diet F1, whereas the opposite was the case with the control diet, where plant material constituted a much smaller part. These results indicate that the I657 broilers given the low protein diet were selecting more feed items from pasture compared to I657 broilers given the more optimal diet, probably in order to have some contribution of nutrients from plant material. Only very few insect remnants were found, which could be due to the season being late summer. During the summer period it is expected that the birds would have been eaten more insects and worms. Chemical analysis of e.g. grass and chicory leaves showed a protein content around 21% DM and a methionine and cysteine content being on av. 3.6 and 2g amino acid /kg DM, and it is hypothesized that the birds have received some nutrients by foraging on the pasture, however, it was not possible to estimate the quantity eaten. Ideally, the content of protein and methionine in diets for organic slow- and medium broilers should be formulated according to age with higher levels for young birds and decreasing levels for older birds. The study showed that diet F2 could be sufficient for the slow-growing genotype also taking into account contribution of nutrients from the outdoor areas, however, the outdoor pasture must be of high quality.

Examination of plumage quality (feather cover and cleanliness) and incidence of food pad lesions were performed every second week during the experiment and showed a large difference between the two genotypes. RJA having a higher growth rate resulting in a final weight around 4kg at 14 weeks had a poorer plumage quality compared to I657 especially on the breast. RJA birds was less active due to the fast growth and were often observed sitting close to the house, where the ground were more dirty due to no grass and a higher concentration of manure . Less active birds increase the risk to become more dirty compared to more active birds and since the walking ability of RJA was observed to be hampered to some extent in the last weeks of the experiment compared to I657 birds, it was concluded that the RJA birds overall had a poorer welfare. However, the mortality in the study was low being on average 2.6% for all treatments. The daily WG for RJA for the whole growth period (0-14 weeks, the rearing period included) was 41.9 (C), 39.4 (F1) and 40.1g (F2), being higher than the maximum daily gain of 35g permitted in organic production. For the I657 genotype the values were 29.3 (C), 27.0 (F1) and 28.7g (F2), clearly showing the difference in growth potential between the genotypes both considered slow growing. The RJA chickens could probably more be characterized as a medium growing genotype.

6.3.4 Feed selection (preference study) by broilers

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An experiment was performed over two days (collection during one day) in order to study the effect of giving birds either grass (representative of monocotyledonous), chicory leaves (representative of dicotyledonous) and meal worm larvae (representative of insects), together with diet F1. The aim of the study was to measure the amount of feed selected by the birds in quantitative terms (diet F1 and the supplements) and collect excreta for microscopy analysis in order to estimate the relative distribution of food items, when the intake is known. Any remnants of food items were identified and the relative areas (%) of fragments of feed, wheat, leaves, insect parts (mandibles, scales etc.) were estimated under microscope. Diets, plant material and mealworms were fed ad lib. The results from the preference trial showed a higher preference for chicory compared to grass confirming the results from the digestibility experiment. The intake of mealworms was very high and constituted 69% of total feed intake (as is basis). The protein content of mealworms is relatively high (>50% DM) and can be considered as a valuable protein source. Chemical analysis of earthworms, larvae, beetles and snails from outdoor areas, reveal high protein and amino acid content and suggest that they could be important protein sources contributing to the amino acid requirement of foraging broilers, as seen in the preference study with meal worms.

Evaluating the method of identifying feed items in excreta collected from outdoor pastures used by broilers, it can be seen from the preference study, where the feed intake is known, that the percentage of both grass and chicory constituents are much larger in excreta compared to the actual intake, whereas the meal worm remnants identified in the excreta constitute a relatively smaller part compared to the actually intake of diet and meal worm larva, respectively. These results indicate that the plant material is digested to a smaller extent compared to the diet. Comparing with the results obtained with excreta from broilers going on the outdoor area, the relative intake of plant material compared to the diets have been smaller than found from the microscopy analyses of excreta. However, since this is the case with both diets, the results still indicate a different feeding behaviour between the two treatments diets F1 and C, where the broilers fed diet F1 have a higher intake of different foraging material.

6.4 Key Conclusions: Poultry

Regarding the issue of supplying organic concentrates main findings were:

- Protein from organically produced Spirulina algae can fully replace protein from traditional organic sources in broiler diets.
- Refining of ingredients of plant origin enriching the relative content of Methionine seems to be a useful way to supply relevant protein sources for poultry, eg for sunflower seed expeller.
- Insects meal *(Hermetia illucens)* up to 12 % in the diet can replace soybean cake without any difference in egg production, feed conversion, health and taste of eggs.
- Crushed mussel shells (particle size 10-20 mm) supplied in the litter on every day basis to layers affected neither birds' feather cover, nor other welfare parameters or production performance. Crushed mussel shells cannot fully replace dietary calcium as calcium source without impairing bone health and egg shell strength.

Use of roughage is mandatory in livestock organic production, but often the potential of roughage to contribute to the nutritional needs of poultry are unclear or not taken into account in the feeding planning. The methionine content in the protein of early harvested lucerne is higher than that of soya bean cake and almost twice as high as that of peas, and may thus represent an important source to cover the amino acid supply in poultry. This was tested in two experiments with the following findings

- In the diet for layers the early cut silage may be include in a proportion of 20 % of dry matter without impairing egg production compared to a traditional diet for
- In diets for slow growing broilers early cut lucerne silage can amount to 10-20 % in the rearing period (week 1 to 4) and up to 30% in the fattening period (week 5 to 8) without impairing the growth.

These production results confirm that the silage make methionine available for the poultry and thus can contribute significantly to cover their nutritional needs. Thus an energy dilution of the diet, concomitant with a proportional reduction in other nutrients, e.g. dig. Methionine, is an option as well to fulfil the requirement of 100 % organic diets. This can for example be relevant when including high quality roughage in the feed mixture for layers.

Also the **access to a foraging** area represent a possibility for the poultry to partly cover their nutritionals needs by the biomass available here. Main findings were:

- Of all the invertebrates studied, earthworms present the most potential in contributing to the nutritional needs of poultry. One m^2 of most habitats studied would contribute considerably to the daily requirements of laying hens for methionine, and in most cases, completely meet lysine requirements also.
- Low-protein diets stimulate the broilers to forage on the range area and direct foraging can pose an important contribution to protein supply in broilers of slow-growing genotypes without detrimental effects on growth performance.

7. Integrated impact assessment (economic, environmental, animal welfare)

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Hypothesis

It is possible to suggest feed supply and feeding strategies based on 100% organic feed for monogastrics that are economically viable, result in low overall environmental impact, and support animal welfare.

Aim

To develop economically profitable feeding strategies based on 100% organic feed applicable to organic monogastric production systems across Europe that at the same time support animal health and welfare and have improved environmental impacts compared to the current prevailing systems.

Approach

The analysis was based on the results obtained in the ICOPP project and a few other works, in particular results from a Danish project 'Suberb and Marketable Meat from Efficient and Robust Animals' that also included feeding trials for monogastrics. Most of the ICOPP results are generic and applicable throughout Europe and systems for pigs and broilers in relation to feeding are also very similar. The following aspects were considered:

1. How to cover the nutritional needs with organically produced feed stuffs at all stages of their life.
2. What organic feed stuffs are available?
3. How can more local feedstuffs be made available?

7.1 Results

Considering the aspect of covering the nutritional needs for monogastrics in all stages of their life with feeds of organic origin, there are many options as documented in the previous chapters. The main challenge here is to feed piglets and young hens feed with the required amino acid profile. Some of the ingredients of organic origin needed to do so may be considerably more expensive than alternative conventional feed stuffs. However, these feed stuffs only constitute a very small part of total feed, e.g. approximately 1 % of the feed in an organic pig production system. Thus, the economic consequences are limited.

The main problem is the lack of organic feed stuffs in Europe relative to the demand both in terms of energy and protein in concentrated feed stuffs which are essential in the present feeding of monogastrics as documented in Chapter 3. Furthermore, looking at the individual amino acids, there is in particular a lack of methionine with a self-sufficiency of 40% against a self-sufficiency of total protein of 56% and a self-sufficiency of overall concentrated feed stuffs of 68% in the ICOPP countries. Against this background, it is a crucial finding in ICOPP that it is possible to a much larger extent than presently done to cover the protein requirements of monogastrics by early cut leguminous silage like lucerne which under most growing conditions yield much more protein and methionine per ha than other protein crops. For example, in a pig production system we demonstrated that silage overall could contribute 14 % of the protein requirement without compromising production results and similar results have been found in organic egg production or broiler production. Due to the N-fixing properties of legumes and the positive effect on soil fertility and weed control to include a perennial crop in a cereal based crop rotation, it will in most cases be both economical and environmentally beneficial to include a crop like lucerne in organic feed production for monogastrics. The challenge might instead be exactly how to handle the silage in the feeding systems at the farm, and there is a need explore this in more detail.

Despite the benefits of this type of roughage from a protein point of view, it is a drawback that the utilization of the fibre fraction by the monogastrics is low and in particular in the growing pigs. Thus, it is not easy achieve the full potential of the energy production by these crops. Presently there are several initiatives on-going in Europe to investigate how the protein rich parts of green biomass like grass and clover grass can be separated and used as protein feed for monogastrics, while the fibrous part can be used as feed for ruminants or used for other purposes. In view of the very good amino acid composition of the clover grass or lucerne, such a technology seems to present an interesting way to increase the overall feed supply for organic livestock. In addition, the fact that both pigs and poultry can find valuable nutrients in the range if this has sufficient quality should not be ignored.

7.2 Key Conclusions

It is possible to rely on organic feed stuffs of European origin to cover the needs of monogastrics in all stages of their production cycle from a production and economical point of view. The main challenge is to have access to sufficient concentrated feeds like cereal, grain legumes and oil seeds at a European level. Since there is a lack of feed energy, protein and specifically methionine for feeding purposes in Europe, more emphasis should be put on crops that are suitable in organic farming systems and which have a high yield per ha of feed energy, protein and the relevant amino acids. Legume forage like lucerne represents such a crop and if harvested at an early stage of development it can yield a significant contribution to cover the protein requirements of the monogastrics, while at the same time support animal health and welfare. Also in most cases, due to the impact on the overall cropping system of introducing a forage legume the overall environmental impact of the production is expected to be reduced.

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9. Project Information

9.1 Funding

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APPENDIX I: Tables of composition and nutritional values of organically produced feed materials for pigs and poultry

Soile Kyntäjä, Kirsi Partanen, Hilkka Siljander-Rasi, Taina Jalava

Abbreviations used in chemical composition tables

	unit	description		unit	description
ADF	g	acid detergent fiber	**kg**		kilogram
ADF-N	g	nitrogen in acid detergent fiber	**Leu**	g	leucine
ADL	g	acid detergent lignin	**Lys**	g	lysine
Ala	g	alanine	**Met**	g	methionine
Arg	g	arginine	**mg**		milligram
Ash	g	crude ash	**Mg**	g	Magnesium
Asp	g	aspartic acid	**Mn**	mg	Manganese
Ca	g	Calcium	**Na**	g	Sodium
CF	g	crude fibre	**NDF**	g	neutral detergent fiber
CP	g	crude protein	**P**	g	Phosphorus
Cu	mg	Copper	**Phe**	g	phenylalanine
Cys	g	cystine	**Pro**	g	proline
DM		dry matter	**S**	g	Sulphur
EE	g	crude fat after acid hydrolysis	**Se**	mg	Selenium
Fe	g	Iron	**STA**	g	starch
g		gram	**SUG**	g	sugars
Glu	g	glutamic acid	**Thr**	g	threonine
Gly	g	glycine	**Tyr**	g	tyrosine
His	g	histidine	**Val**	g	valine
Ile	g	isoleucine	**Zn**	mg	Zinc
K	g	Potassium			

Abbreviations used in feed evaluation tables

	unit	description
dDM	%	Digestibility of dry matter
DE	MJ	Digestible energy
dig Cys	g	faecal digestible cystine
dig Lys	g	faecal digestible lysine
dig Met	g	faecal digestible methionine
dN	%	digestibility of Nitrogen
dOM	%	digestibility of Organic matter
ED	%	Digestibility of energy
EW		Energy value for pigs
FEso		Feed units for sows
FEsv		Feed units for growing pigs
ME	MJ	Metabolizable energy
MJ		Megajoule
NE	MJ	Net energy
NEv	MJ	Net energy value for fat accretion in pigs
SIDCP	%	standardized ileal digestibility of crude protein
SID Cys	g	standardised ileal digestible cystine
SID Lys	g	standardised ileal digestible lysine
SID Met	g	standardised ileal digestible methionine
SIDThr	g	standardised ileal digestible threonine
SIDVal	g	standardised ileal digestible valine

Chemical composition of organic feed ingredients

Table 1. Chemical composition of organically produced cereals and protein feed ingredients.

no Name	%	g/kg DM								
	DM	Ash	CP	EE	CF	STA	SUG	NDF	ADF	ADL
1.1.1 Barley FI 2011	85.9	30	112	21	53	670	33	223	63	10
1.11.1 Wheat FI 2011	88.1	22	137	23	31	707	37	141	32	0
1.4.1 Oats FI 2011	86.5	34	117	63	88	564	21	271	100	21
2.14.2 Rape seed meal UK 2012	91.6	66	377	96	118		92	312	182	51
2.14.2 Rape seed, expeller FI 2012	90.7	70	340	163	105		99	249	160	43
2.18.8 Soya bean pulp FI 2011	19.9	38	352	157	146	11	129	295	172	
2.8.1 Linseed UK 2012	89.6	51	384	128	72	21	42	198	97	31
3.11.1 Peas FI 2012	83.7	35	224	24	43	601	65	124	51	0
3.11.1 Peas UK 2012	85.4	30	170	24	71	462	59	153	66	0
3.13.1 Grass pea AT 2011	89.0	31	296	19	68	491	48	244	77	2
(n=2) min-max	86.8-91.1	30-32	295-297	17-21	65-70			204-285	76-79	
3.15.1 Sainfoin AT 2011	93.4	51	312	69	190	111	80	344	205	29
3.15.1 Sainfoin, dehulled AT 2011	90.6	42	405	82	75	163	102	155	75	3
(n=3) CV %	2.4	4.5	3.1	7.3	6.2	5.2	6.7	3.7	2.2	141.4
3.7.1 Faba beans UK 2012	84.9	32	277	24	87	397	48	158	92	0
3.7.1 Faba beans FI 2011	83.5	45	320	17	82	456	45	144	88	0
3.9.1 Sweet lupins UK 2012	85.8	40	362	62	147	27	64	244	171	6
4.8.1 Potato, raw FI 2011	18.6	57	76	8	23	563	164	60	31	7
4.8.2 Potato, cooked FI 2011	18.9	58	95							

Table 2. Chemical composition of organically produced roughages.

no Name	%	g/kg DM								
	DM	Ash	CP	EE	CF	STA	SUG	NDF	ADF	ADL
6.10.1 Lucerne fresh UK 2012	20.4	119	276	47	139		21	212	149	17
6.10.1 Lucerne silage UK 2012	52.1	111	158	50	273		39	445	287	43
6.10.1 Lucerne silage 2nd harvest UK 2012	23.3	127	204	45	297		4	427	304	53
6.10.1 Lucerne silage 2nd harvest extruded DE 2012	26.5	147	250	53	302		1	411	311	71
(n=2) min-max	25.7-27.3	145-149	246-253							
6.10.1 Lucerne silage 2nd harvest chopped DE 2012	23.1	152	261	50	286		1	391	301	71
6.10.1 Lucerne silage 3rd harvest DE 2012	35.1	136	244							
6.10.1 Lucerne silage 3rd harvest extruded DE 2012	46.8	142	231	38	201		8	329	229	49
6.10.1 Lucerne silage 3rd harvest chopped DE 2012	43.1	131	226	40	216		9	332	241	47
6.10.1 Clover-grass silage DE 2012	27.1	130	137	37	283		53	459	282	
6.10.1 Extruded silage DE 2013	35.8	113	231	41	300			394		
6.10.1 Chopped silage DE 2013	43.4	112	231	45	289			384		
6.10.4 Lucerne pellets UK 2012	90.6	115	167	28	282		55	498	322	66
6.6.3 Grass, wilted and ensiled NL 2011	26.7	130	218	63	219			363	225	19
(n=3) CV %	11.3	24.8	7.7	9.3	5.1			6.0	7.5	48.3

Table 3. Chemical composition of new feed materials.

no Name	%	g/kg DM									
	DM	Ash	CP	EE	CF	STA	SUG	NDF	ADF	ADL	ADF-N
7.1.1 *Algae Spirulina* UK 2012	93.6	75	704	75	1	37	5		0	0	14
7.1.1 *Algae Chlorella scenedesmus* NL 2012	93.6	286	396	75	8	12	5	354	111	56	11
9.16.2 *Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	91.8	124	446	342	*102		8	*191	*88	*18	7
9.16.2 *Hermetia illucens* meal ´MBM´ defatted CH 2012	92.5	168	627	43	*130		11	*259	*93	*0	10
9.16.2 *Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	86.5	40	482	396	*112		8	*212	*101	*50	8
9.16.2 *Hermetia illucens* meal ´CHO´ defatted CH 2012	89.5	60	710	41	*182		12	*325	*199	*29	13
9.16.2 *Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	88.0	88	405	410	*112		10	*151	*91	*13	7
9.16.2 *Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	90.3	137	659	20	*172		15	*235	*142	*23	12
10.11.1 Mussel *Mytilus edulis* meal SE 2013	92.9	94	684	105				59	17		
10.11.1 Mussel *Mytilus edulis* meal SE 2012	95.6	96	681	115			8	31	0	0	

MBM = grown on meat and bone meal
CHO = grown on carbohydrate rich material
Kitchen waste = grown on kitchen waste

*Insects contain relatively high amount of fibre as measured by CF, NDF, ADF and ADL, but the components of these fibres are unknown. It has been assumed that most of the fibre in insects is chitin, which represents cellulose structure. ADF fraction from insects contains nitrogen (ADF-N) (Finke 2007).

Because the fibre composition of *Hermetia illucens* meal and larvae and Algae *Chlorella scenedesmus* is different compared to reference feed (fish meal), the feed value of these feed ingredient may be overestimated.

Amino acid composition of organic feed ingredients

Table 4. Amino acid composition of organically produced cereals and protein feed ingredients.

no	Name	g/ 100 g CP																
		Lys	Thr	Met	Cys	Ile	Val	Leu	Phe	Tyr	His	Arg	Ala	Asp	Glu	Gly	Ser	Pro
1.1.1	Barley FI 2011	3.7	3.4	2.1	2.0	3.5	4.8	6.6	4.5	3.4	2.2	5.2	4.2	6.6	20.4	4.1	3.9	8.8
1.11.1	Wheat FI 2011	2.6	2.8	1.9	2.0	3.4	4.2	6.5	4.3	3.1	2.3	4.8	3.4	5.2	28.9	4.0	4.5	9.3
1.4.1	Oats FI 2011	5.1	3.9	2.2	2.8	4.5	5.7	8.4	5.8	4.1	2.7	8.3	5.4	10.1	21.4	5.4	5.5	5.5
2.14.2	Rape seed meal UK 2012	5.0	4.4	2.1	2.0	3.8	5.1	6.7	3.9	3.1	2.6	5.8	4.2	7.3	16.1	4.8	4.3	6.0
2.14.2	Rape seed, expeller FI 2012	6.3	4.9	2.4	2.1	4.5	5.7	7.7	4.5	3.8	2.9	6.9	5.0	9.1	18.0	5.6	4.7	6.0
2.18.8	Soya bean pulp FI 2011	5.9	3.7	1.5	1.2	4.4	4.6	7.4	4.9	3.4	2.5	7.4	4.2	10.8	16.8	4.3	5.0	4.9
2.8.1	Linseed UK 2012	3.6	3.6	1.9	1.4	4.1	4.9	5.6	4.5	2.5	2.1	9.5	4.3	9.6	19.0	5.6	4.6	3.6
3.11.1	Peas FI 2012	7.8	4.2	1.4	1.7	4.6	5.1	7.8	5.3	4.2	2.7	8.4	4.7	12.6	17.8	4.9	5.4	4.5
3.11.1	Peas UK 2012	7.7	4.2	1.5	1.4	4.2	5.0	7.2	4.9	3.9	2.6	6.9	4.6	11.9	16.8	4.6	5.1	4.1
3.13.1	Grass pea AT 2011	6.4	3.7	1.2	1.6	4.0	4.5	6.6	4.2	3.3	2.7	7.6	4.1	11.2	15.9	4.4	4.9	4.0
	(n=2) min-max	6.3-6-6	3.7-3.7	1.1-1.2	1.5-1.6	3.8-4.2	4.4-4.6	6.4-6.8	4.1-4.4	3.1-3.5	2.6-2.7	7.1-8.1	3.9-4.2	11.1-11.4	15.3-16.5	3.9-4.5	4.8-4.9	4.0-4.1
3.15.1	Sainfoin AT 2011	5.3	3.5	1.8	1.3	3.6	4.2	6.4	3.7	3.2	3.8	10.8	3.7	10.5	17.5	4.7	4.8	4.5
3.15.1	Sainfoin, dehulled AT 2011	5.2	3.4	1.8	1.2	3.5	4.1	6.2	3.6	3.0	3.9	10.8	3.5	10.4	18.1	4.5	4.9	4.4
	(n=3) CV %	3.4	2.9	2.4	9.4	5.5	3.1	4.1	3.5	7.9	3.5	5.5	5.9	2.9	1.8	4.7	2.2	0.7
3.7.1	Faba beans UK 2012	6.7	3.6	1.0	1.0	4.2	4.8	7.2	4.4	3.7	2.6	8.8	4.1	11.9	17.6	4.4	5.1	4.3
3.7.1	Faba beans FI 2011	6.2	3.5	0.9	1.1	4.1	4.6	7.4	4.2	3.7	2.6	10.0	4.0	10.9	16.5	4.2	4.7	4.1
3.9.1	Sweet lupin UK 2012	4.5	3.2	0.7	1.0	3.9	3.7	6.4	3.6	3.5	2.5	10.7	3.2	10.1	20.4	4.0	4.8	3.9
4.8.1	Potato, raw FI 2011	5.9	3.5	2.3	1.3	4.0	6.2	5.4	4.2	4.0	2.3	7.9	3.2	22.7	18.4	3.1	4.9	3.9

Table 5. Amino acid composition of organically produced roughages.

no	Name	g/ 100 g CP																
		Lys	Thr	Met	Cys	Ile	Val	Leu	Phe	Tyr	His	Arg	Ala	Asp	Glu	Gly	Ser	Pro
6.10.1	Lucerne fresh UK 2012	5.7	3.9	2.0	0.7	4.4	5.7	7.6	5.1	3.5	2.2	4.5	5.3	9.9	9.3	4.5	3.5	4.2
6.10.1	Lucerne silage UK 2012	5.0	4.1	1.9	1.0	4.2	5.4	7.2	4.6	3.6	1.9	3.4	5.3	9.6	8.0	4.3	4.0	5.6
6.10.1	Lucerne silage 2nd harvest UK 2012	2.9	3.2	1.5	0.5	3.9	4.9	6.6	4.0	4.5	1.8	1.8	5.2	7.5	5.5	4.2	1.9	4.2
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	2.3	2.1	1.7	0.6	4.3	7.5	6.9	4.1	1.9	1.0	3.0	10.9	4.2	5.1	4.3	2.2	3.2
	(n= 2) min-max	2.2-2.4	1.9-2.2	1.7-1.7	0.5-0.7	4.2-4.4	5.7-9.3	6.8-7.0	4.0-4.3	1.8-2.1	1.0-1.0	3.0-3.0	10.3-11.5	4.0-4.5	4.4-5.8	4.2-4.3	2.0-2.4	2.0-4.5
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	2.0	1.7	1.7	0.5	4.1	9.9	6.6	3.8	1.5	0.9	2.9	11.1	3.6	4.6	4.1	1.8	2.4
6.10.1	Lucerne silage 3rd harvest DE 2012	5.2	4.3	1.6	0.8	4.2	5.5	7.4	4.6	2.6	1.9	2.8	5.4	11.0	9.4	4.9	4.3	5.0
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	5.0	4.1	1.9	0.6	4.2	5.4	6.9	3.7	3.2	1.8	3.1	5.6	10.9	8.8	4.4	4.3	5.1
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	4.9	4.1	1.8	0.7	4.3	5.9	7.0	4.4	2.2	1.9	2.5	5.8	9.5	8.0	4.4	4.3	5.3
6.10.1	Extruded silage DE 2013	2.0	3.7	1.8	0.6	4.2	9.5	6.4	4.1	1.5	0.9	2.6	7.3	10.1	6.7	4.0	2.7	5.2
6.10.1	Chopped silage DE 2013	5.0	4.1	1.8	0.7	4.2	5.5	6.7	4.3	2.8	1.7	1.8	4.9	13.3	7.4	4.0	3.8	5.5
6.10.1	Clover-grass silage DE 2012	4.1	3.4	1.6	0.6	4.1	5.4	7.0	4.0	3.1	1.0	1.7	6.1	8.5	7.0	3.8	3.4	5.7
6.10.4	Lucerne pellets UK 2012	3.8	3.8	1.9	1.0	3.9	4.9	6.4	4.2	2.8	2.0	5.7	4.5	9.9	13.4	5.0	4.2	5.4
6.6.3	Grass, wilted and ensiled NL 2011	4.8	3.9	1.6	0.4	4.1	5.3	7.0	4.2	3.7	1.6	1.5	6.1	10.0	7.9	4.3	3.6	4.4
	(n=3) CV %	2.7	1.6	3.8	10.8	1.1	0.9	1.0	1.4	4.1	5.6	8.4	3.3	2.0	5.1	1.5	0.3	0.9

Table 6. Amino acid composition of new feed materials.

no	Name	g/ 100 g CP Lys	Thr	Met	Cys	Ile	Val	Leu	Phe	Tyr	His	Arg	Ala	Asp	Glu	Gly	Ser	Pro
7.1.1	*Algae Spirulina* UK 2012	4.4	4.6	2.4	1.2	5.2	5.9	8.1	4.1	4.2	1.5	6.7	7.0	9.5	12.8	4.6	4.6	3.5
7.1.1	*Algae Chlorella scenedesmus* NL 2012	5.6	4.9	2.2	1.1	3.7	5.5	7.3	4.6	3.3	1.3	5.3	6.6	10.3	10.8	5.8	4.5	4.7
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	5.1	3.9	2.0	0.5	4.3	6.0	6.9	4.1	5.9	2.8	4.8	5.9	9.4	9.7	5.9	3.9	5.3
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	5.3	3.9	1.9	0.5	4.4	6.2	7.0	4.2	6.3	2.9	4.9	6.0	9.8	10.1	6.1	4.1	5.4
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	4.9	3.7	1.8	0.5	4.2	6.0	6.8	3.8	5.9	2.7	4.5	5.9	8.7	9.1	6.0	3.9	5.4
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	5.1	3.9	1.8	0.5	4.4	6.4	7.1	4.0	6.3	2.9	4.7	6.2	9.2	9.8	6.4	4.2	5.7
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	5.7	4.0	2.0	0.5	4.5	6.3	7.3	4.1	6.9	3.0	5.2	6.3	9.9	10.7	6.5	4.3	5.8
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	5.4	3.9	1.8	0.5	4.3	6.2	6.9	4.1	6.8	3.0	4.9	6.2	9.5	10.5	6.3	4.3	5.7
10.11.1	Mussel *Mytilus edulis* meal SE 2013	7.0	4.5	2.5	1.2	3.9	4.4	6.3	3.4	3.4	1.7	6.6	4.6	9.5	11.8	5.8	4.6	3.8
10.11.1	Mussel *Mytilus edulis* meal SE 2012	7.0	4.3	2.3	1.1	3.9	4.2	6.2	3.4	3.5	1.7	6.6	4.5	9.5	11.4	5.6	4.5	3.6

Mineral content of organic feed ingredients

Table 7. Mineral content of organically produced cereals and protein feed ingredients.

no	Name	g/kg DM			%	U/kg DM	g/kg DM				mg/kg DM				
		Ca	P	Phytic acid	Phytate P/total P	Phytase	Mg	S	K	Na	Fe	Cu	Zn	Mn	Se
1.1.1	Barley FI 2011	0.4	4.3	11.3	0.74	1261	1.3	1.3	5.7	0.04	66	4.3	37.5	11.9	0.011
1.11.1	Wheat FI 2011	0.3	4.3	11.6	0.76	1449	1.5	1.4	4.8	0.02	42	4.6	36.5	30.0	0.011
1.4.1	Oats FI 2011	0.6	4.3	10.5	0.68	118	1.3	1.5	5.7	0.04	153	5.0	34.3	29.5	0.015
2.14.2	Rape seed meal UK 2012	6.9	8.8	24.2	0.77	41	4.5	7.4	11.1	0.03	196	5.6	57.5	65.9	0.419
2.14.2	Rape seed, expeller FI 2012	7.5	12.8	34.5	0.76	< 0,0	4.9	5.1	12.2	0.06	107	5.8	56.6	39.7	0.035
2.18.8	Soya bean pulp FI 2011	3.3	3.8				1.5	2.6	12.3	0.24	118	11.3	30.8	25.1	
2.8.1	Linseed UK 2012	3.0	6.6	18.0	0.78	< 0,0	4.4	3.7	10.3	0.82	186	19.3	71.9	31.4	0.122
3.11.1	Peas FI 2012	0.6	5.6	11.7	0.58	22	1.3	1.8	11.8	0.02	73	9.1	41.5	5.1	0.012
3.11.1	Peas UK 2012	1.3	4.0	8.9	0.62	118	1.1	1.4	9.5	0.01	32	7.0	30.9	6.4	0.011
3.13.1	Grass pea AT 2011	1.5	3.6	7.0	0.55	12	1.3	2.2	9.2	0.07	101	9.7	43.3	16.1	0.058
3.15.1	Sainfoin AT 2011	7.6	5.5	11.8	0.61	230	1.8	2.6	10.9	0.03	105	8.3	47.4	27.2	0.062
3.15.1	Sainfoin, dehulled AT 2011	1.4	7.3	16.9	0.65	113	1.7	3.3	13.2		77	9.4	61.1	21.1	0.096
	(n=2) min-max	1.3-1.4	7.0-7.6	16.2-17.6	0.65-0.66		1.6-1.8	3.2-3.5	12.8-13.6		73-82	9.2-9.6	59.4-62.7	20.8-21.3	0.089-0.102
3.7.1	Faba beans UK 2012	1.3	4.2	10.0	0.68	17	1.0	1.4	10.7	0.03	50	10.9	36.3	9.5	<0.01
3.7.1	Faba beans FI 2011	1.0	8.0	22.3	0.79	< 0,0	1.5	2.0	13.0	0.04	65	16.9	57.8	11.0	0.012
3.9.1	Sweet lupin UK 2012	3.0	5.3	12.0	0.64	96	1.8	2.7	10.1	0.16	80	6.0	30.8	54.9	0.079
4.8.1	Potato, raw FI 2011		2.47	1.6	0.18		1.06	1.7	23.0	0.03	120	6.8	16.2	6.0	<0.01

Table 8. Mineral content of organically produced roughages.

no	Name	g/kg DM			%	U/kg DM	g/kg DM				mg/kg DM				
		Ca	P	Phytic acid	Phytate P/total P	Phytase	Mg	S	K	Na	Fe	Cu	Zn	Mn	Se
6.10.1	Lucerne fresh UK 2012	22.6	4.2	0.3	0.02	262	2.4	2.2	26.0	0.1	80	9	28	19	0.03
6.10.1	Lucerne silage UK 2012	12.5	4.6	0.8	0.05	38	1.9	2.4	26.8	0.3	146	9	34	30	0.02
6.10.1	Lucerne silage 2nd harvest UK 2012	14.1	4.2	0.1	0.00	165	2.0	2.5	35.2	0.2	315	8	30	19	0.08
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	11.1	3.9	0.1	0.01		2.2	3.3	38.9	0.1	972	10	25	45	
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	12.2	4.5	0.1	0.01		2.5	3.6	41.9	0.1	761	10	24	45	
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	10.6	3.3	0.1	0.01		2.4	2.3	31.7	0.1	1496	9	22	55	
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	10.6	3.4	0.2	0.01		2.4	2.5	33.9	0.1	687	8	19	44	
6.10.1	Clover-grass silage DE 2012	9.1	2.6				2.1	1.6	34.1	0.3	1031	7	30	75	
6.10.4	Lucerne pellets UK 2012	13.1	3.7	7.6	0.57	53	3.0	2.6	16.7	0.6	1417	24	40	68	0.12
6.6.3	Grass, wilted and ensiled NL 2011			0.1		145									0.01

Table 9. Mineral content of new feed materials.

no	Name	g/kg DM						mg/kg DM				
		Ca	P	Mg	S	K	Na	Fe	Cu	Zn	Mn	Se
7.1.1	*Algae Spirulina* UK 2012	1.8	9.6	2.6	6.7	13.8	5.7	920	3.4	16.6	26.4	0.15
7.1.1	*Algae Chlorella scenedesmus* NL 2012	82.7	9.8	2.5	4.2	7.7	6.5	6166	7.9	68.7	906.4	0.12
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	37.1	6.7	2.7	2.9	6.9	0.8	98	9.3	67.2	128.0	
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	52.9	8.9	3.6	4.0	7.7	0.9	172	13.7	95.7	171.7	
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	6.3	5.6	2.3	3.0	7.1	1.3	74	9.5	78.4	162.6	
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	10.1	8.2	3.5	4.6	8.6	1.5	119	14.7	125.9	242.0	
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	24.0	4.8	2.3	2.7	6.5	1.0	156	8.4	69.5	195.4	
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	38.4	6.9	3.5	4.3	8.2	1.3	302	13.3	111.3	319.7	
10.11.1	Mussel *Mytilus edulis* meal SE 2012	3.8	11.3	1.8	10.5	6.4	21.2	340	6.5	138.8	29.4	2.71

Energy and protein values of organic feed ingredients for pigs

The French feed evaluation system: Energy and protein values

Table 10. Energy values and standardised ileal digestible amino acids of organically produced cereals and protein feed ingredients (EvaPig®).

no	Name	MJ/kg DM						g/kg DM					Reference feed ingredient
		DE grow. pig	ME grow. pig	NE grow. pig	DE adult pig	ME adult pig	NE adult pig	SID Lys	SID Thr	SID Met	SID Cys	SID Val	
1.1.1	Barley FI 2011	14.7	14.2	11.0	15.1	14.5	11.3	3.1	2.8	2.0	1.9	4.3	Barley
1.11.1	Wheat FI 2011	16.0	15.5	12.1	16.3	15.7	12.3	2.9	3.2	2.3	2.5	4.9	Wheat
1.4.1	Oats FI 2011	14.5	14.0	10.7	15.1	14.3	10.9	4.4	3.2	2.2	2.5	5.2	Oats
2.14.2	Rape seed meal UK 2012	14.9	13.7	8.6	15.8	14.2	9.1	14.3	12.3	7.0	6.1	14.7	Rapeseed meal
2.14.2	Rape seed expeller FI 2012	16.6	15.4	10.1	17.4	15.8	10.5	16.0	12.6	7.0	5.8	15.0	Rapeseed meal
2.18.8	Soya bean pulp FI 2011	16.7	15.5	10.6	18.6	17.0	11.7	18.6	11.3	5.0	3.7	14.3	Soyabean meal
2.8.1	Linseed UK 2012	17.9	16.4	10.8	18.3	16.6	11.1	10.7	10.4	6.0	4.1	14.6	Linseed meal, exp. extr.
3.11.1	Peas FI 2012	16.6	15.9	11.9	17.1	16.2	12.1	14.5	7.1	2.5	2.7	8.7	Pea
3.11.1	Peas UK 2012	15.9	15.3	11.3	16.5	15.8	11.7	10.9	5.5	2.0	1.7	6.5	Pea
3.13.1	Grass pea AT 2011	16.3	15.4	11.0	16.6	15.6	11.2	16.7	9.1	2.9	3.5	11.0	Faba bean, white flowers
3.15.1	Sainfoin AT 2011	13.9	13.1	9.1	14.7	13.8	9.5	14.5	9.0	4.7	3.1	10.7	Faba bean, white flowers
3.15.1	Sainfoin, dehulled AT 2011	18.4	17.2	11.8	18.7	17.3	11.9	19.1	11.6	6.15	3.9	13.8	Faba bean, white flowers
3.7.1	Faba beans UK 2012	15.9	15.1	10.8	16.3	15.4	10.9	15.7	8.0	2.2	2.0	10.4	Faba bean, white flowers
3.7.1	Faba beans FI 2011	16.5	15.5	11.0	16.8	15.7	11.1	17.4	9.3	2.4	2.7	12.0	Faba bean, white flowers
3.9.1	Sweet lupin UK 2012	16.2	15.0	9.3	17.6	16.0	10.2	14.1	9.7	2.1	3.1	11.2	Lupin, blue
4.8.1	Potato, raw FI 2011	15.7	15.4	11.9	15.9	15.5	12.0	3.5	2.1	1.5	0.7	3.7	Potato tuber, dehydrated

Table 11. Energy values and ileal standardised ileal digestible amino acids of organically produced roughages (EvaPig®).

		MJ/kg DM						g/kg DM					
no	Name	DE grow. pig	ME grow. pig	NE grow. pig	DE adult pig	ME adult pig	NE adult pig	SID Lys	SID Thr	SID Met	SID Cys	SID Val	Reference feed ingredient
6.10.1	Lucerne fresh UK 2012	12.1	11.1	6.5	12.9	11.6	6.9	10.6	7.5	4.2	0.7	10.9	Alfalfa, dehydr., CP 22-25% DM
6.10.1	Lucerne silage UK 2012	8.9	8.2	4.5	10.1	9.1	5.1	4.1	3.9	2.3	0.5	5.6	Alfalfa, dehydr., CP < 16% DM
6.10.1	Lucerne silage 2nd harvest UK 2012	8.3	7.7	4.3	9.6	8.6	5.0	3.7	4.3	2.4	0.4	7.0	Alfalfa, dehydr., CP 18-19% DM
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	7.7	7.1	4.3	9.1	8.3	5.0	4.0	3.8	3.3	0.5	16.1	Alfalfa, dehydr., CP 22-25% DM
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	8.1	7.4	4.3	9.4	8.4	5.0	3.5	3.0	3.3	0.5	18.0	Alfalfa, dehydr., CP 22-25% DM
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	9.6	8.9	5.3	10.7	9.7	5.9	7.8	6.5	3.3	0.5	8.7	Alfalfa, dehydr., CP 22-25% DM
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	9.5	8.8	5.2	10.6	9.7	5.9	7.4	6.5	3.2	0.6	9.4	Alfalfa, dehydr., CP 22-25% DM
6.10.1	Clover-grass silage DE 2012	7.2	6.7	4.0	8.6	7.9	4.8	4.3	3.5	1.8	0.6	5.8	Grass, dehydr.
6.10.5	Lucerne pellets UK 2012	7.9	7.3	4.0	9.2	8.3	4.7	3.6	4.1	2.4	0.6	5.4	Alfalfa, dehydr., CP 17-18% DM
6.6.3	Grass, wilted and ensiled NL 2011	9.3	8.5	5.0	10.5	9.4	5.6	8.1	6.4	3.0	0.7	9.0	Grass, dehydr.

Table 12. Energy values and standardised ileal digestible amino acids of new feed materials (EvaPig®).

		MJ/kg DM						g/kg DM					
no	Name	DE grow. pig	ME grow. pig	NE grow. pig	DE adult pig	ME adult pig	NE adult pig	SID Lys	SID Thr	SID Met	SID Cys	SID Val	Reference feed ingredient
7.1.1	Algae *Spirulina* UK 2012	18.6	16.9	10.9	18.6	16.8	10.8	28.6	30.0	15.4	7.2	38.4	Fish meal, CP 65%
7.1.1	Algae *Chlorella scenedesmus* NL 2012	13.7	12.9	9.0	13.7	12.9	9.0	20.6	17.7	8.2	3.7	19.9	Fish meal, CP 62%
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	21.5	19.9	14.9	21.5	19.8	14.8	21.1	15.8	8.4	2.0	24.8	Fish meal, CP 62%
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	16.2	14.7	9.4	16.2	14.7	9.3	30.7	22.3	11.2	2.9	35.6	Fish meal, CP 62%
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	24.0	22.1	16.5	24.0	22.0	16.4	21.9	16.4	8.3	2.0	26.8	Fish meal, CP 62%
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	18.3	16.4	10.2	18.3	16.4	10.2	33.8	25.5	11.6	3.4	41.5	Fish meal, CP 62%
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	23.1	21.4	16.4	23.1	21.4	16.3	21.3	15.0	7.6	1.9	23.5	Fish meal, CP 62%
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	16.4	14.8	9.2	16.4	14.8	9.2	33.3	23.6	11.3	3.0	37.5	Fish meal, CP 62%
10.11.1	Mussel *Mytilus edulis* meal SE 2013	18.8	17.0	11.1	18.8	17.0	11.1	44.5	28.1	15.8	7.2	27.4	Fish meal, CP 65%
10.11.1	Mussel *Mytilus edulis* meal SE 2012	18.9	17.2	11.3	18.9	17.1	11.2	44.1	27.2	14.2	6.7	35.3	Fish meal, CP 65%

The Dutch feed evaluation system: Energy and protein values

Table 13. Energy values and standardised ileal digestible amino acids of organically produced cereals and protein feed ingredients (CVB).

no	Name	kg DM EW	MJ/kg DM NEv	g/kg DM SID Lys	SID Met	SID Cys	SID Thr	SID Val	Reference feed ingredient
1.1.1	Barley FI 2011	1.22	10.7	3.1	2.0	1.8	3.0	4.3	Barley
1.11.1	Wheat FI 2011	1.30	11.5	3.0	2.3	2.5	3.3	5.0	Wheat
1.4.1	Oats FI 2011	1.22	10.7	4.8	2.2	2.5	3.4	5.5	Oats
2.14.2	Rape seed meal UK 2012	0.99	8.8	14.0	6.5	5.3	11.6	13.8	Rapeseed expeller
2.14.2	Rape seed, expeller FI 2012	1.19	10.5	15.7	6.5	5.0	11.8	14.0	Rapeseed expeller
2.18.8	Soya bean pulp FI 2011	1.35	11.9	18.2	4.9	3.5	11.1	13.9	Soyabean meal
2.8.1	Linseed UK 2012	1.01	8.9	11.4	6.0	4.7	11.0	14.2	Linseed exp.
3.11.1	Peas FI 2012	1.26	11.1	14.2	2.3	2.6	7.0	8.7	Peas
3.11.1	Peas UK 2012	1.25	11.0	10.7	1.9	1.6	5.5	6.5	Peas
3.13.1	Grass pea AT 2011	1.16	10.2	16.8	3.0	3.3	9.1	11.3	Horse beans, white
3.15.1	Sainfoin AT 2011	1.33	11.7	14.7	4.8	3.0	9.0	11.1	Horse beans, white
3.15.1	Sainfoin, dehulled AT 2011	1.41	12.4	18.8	6.3	3.6	11.4	14.0	Horse beans, white
3.7.1	Faba beans UK 2012	1.17	10.3	16.4	2.3	2.0	8.3	11.2	Horse beans, white
3.7.1	Faba beans FI 2011	1.15	10.2	17.5	2.5	2.6	9.3	12.5	Horse beans, white
3.9.1	Sweet lupin UK 2012	1.07	9.4	14.4	2.0	3.1	10.0	11.4	Lupins, CP < 335 g/kg
4.8.1	Potato, raw FI 2011	1.04	9.1	2.9	1.2	0.5	1.7	2.8	Potatoes, dehydr.

Table 14. Energy values and standardised ileal digestible amino acids of organically produced roughages (CVB).

no	Name	kg DM	MJ/kg DM	g/kg DM					Reference feed ingredient
		EW	NEv	SID Lys	SID Met	SID Cys	SID Thr	SID Val	
6.10.1	Lucerne fresh UK 2012	0.70	6.0	7.3	3.9	0.2	5.9	9.1	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Lucerne silage UK 2012	0.56	4.9	3.6	2.2	0.1	3.5	5.0	Alfalfa meal, dehydrated, CP 140-160 g/kg
6.10.1	Lucerne silage 2nd harvest UK 2012	0.54	4.7	2.7	2.3	0.1	3.5	5.9	Alfalfa meal, dehydrated, CP 160-180 g/kg
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	0.55	4.8	2.7	3.1	0.1	2.8	10.9	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	0.56	4.9	2.4	3.1	0.1	2.4	15.1	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	0.61	5.3	5.3	3.1	0.1	5.2	7.3	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	0.60	5.3	5.0	3.0	0.1	5.1	7.8	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Clover-grass silage DE 2012	0.50	4.4	2.7	1.3	0.3	2.2	3.6	Grass meal CP < 140 g/kg
6.10.4	Lucerne pellets UK 2012	0.57	5.0	2.9	2.3	0.2	3.5	4.7	Alfalfa meal, dehydrated, CP 140-160 g/kg
6.6.3	Grass, wilted and ensiled NL 2011	0.68	6.0	5.0	2.2	0.3	4.0	5.5	Grass meal CP < 140 g/kg

Table 15. Energy values and standardised ileal digestible amino acids of new feed materials (CVB).

no	Name	kg DM	MJ/kg DM	g/kg DM					Reference feed ingredient
		EW	NEv	SID Lys	SID Met	SID Cys	SID Thr	SID Val	
7.1.1	Algae *Spirulina* UK 2012	1.17	10.3	27.5	14.8	6.2	28.8	37.3	Fish meal, CP > 680 g/kg
7.1.1	Algae *Chlorella scenedesmus* NL 2012	0.91	8.0	19.8	7.8	3.2	16.9	19.3	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	1.80	15.8	20.3	8.0	1.7	15.2	24.0	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	0.96	8.5	29.5	10.7	2.5	21.4	34.5	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	2.03	17.9	21.1	7.9	1.7	15.8	26.0	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	1.07	9.4	32.4	11.1	2.9	24.5	40.3	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	2.01	17.7	20.5	7.3	1.6	14.4	22.9	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	0.93	8.2	32.0	10.8	2.6	22.6	36.4	Fish meal, CP < 580 g/kg
10.11.1	Mussel *Mytilus edulis* meal SE 2013	1.21	10.7	42.7	15.1	6.2	27.0	26.6	Fish meal, CP 630-680 g/kg
10.11.1	Mussel *Mytilus edulis* meal SE 2012	1.24	10.9	42.3	13.6	5.7	26.1	25.4	Fish meal, CP 630-680 g/kg

The Danish feed evaluation system: Energy and protein values

Table 16. Energy values and standardised ileal digestible amino acids of organically produced cereals and protein feed ingredients (VSP).

no	Name	FEsv	FEso	SID Lys (g/kg DM)	SID Met (g/kg DM)	SID Cys (g/kg DM)	SID Tre (g/kg DM)	SID Val (g/kg DM)	Reference feed ingredient
1.1.1	Barley FI 2011	1.20	1.20	3.0	2.0	1.8	2.8	4.0	BYG, vår, gns. 2011-2013
1.11.1	Wheat FI 2011	1.33	1.31	2.8	2.2	2.3	3.1	4.7	HVEDE, gns. 2011-2013
1.4.1	Oats FI 2011	1.03	1.06	4.5	2.1	2.3	3.1	5.3	HAVRE, 2013
2.14.2	Rape seed meal UK 2012	0.96	1.02	15.1	7.2	6.4	12.9	15.2	RAPSSKRÅFODER, lavt glukosinolatindhold
2.14.2	Rape seed, expeller FI 2012	1.12	1.18	16.7	7.1	6.0	13.0	15.3	RAPSSKRÅFODER, lavt glukosinolatindhold
2.18.8	Soya bean pulp FI 2011	1.49	1.49	19.3	5.2	3.8	11.9	14.9	SOJASKRÅFODER, afskallet toastet
2.8.1	Linseed UK 2012	1.35	1.35	13.5	7.1	5.5	12.8	18.2	HØRFRØ
3.11.1	Peas FI 2012	1.20	1.21	15.9	2.7	2.9	7.7	9.5	ÆRTER
3.11.1	Peas UK 2012	1.21	1.22	11.7	2.1	1.7	5.8	6.9	ÆRTER
3.13.1	Grass pea AT 2011	1.07	1.09	15.0	2.5	3.3	8.2	10.0	HESTEBØNNER, gennemsnit af 3 sorter
3.15.1	Sainfoin AT 2011	1.15	1.17	13.1	4.0	3.0	8.1	9.8	HESTEBØNNER, gennemsnit af 3 sorter
3.15.1	Sainfoin, dehulled AT 2011	1.17	1.19	17.0	5.4	3.6	10.4	12.6	HESTEBØNNER, gennemsnit af 3 sorter
3.7.1	Faba beans UK 2012	1.08	1.10	14.5	1.9	2.0	7.4	9.8	HESTEBØNNER, gennemsnit af 3 sorter
3.7.1	Faba beans FI 2011	1.04	1.06	15.7	2.1	2.6	8.4	11.0	HESTEBØNNER, gennemsnit af 3 sorter
3.9.1	Sweet lupin UK 2012	0.91	1.02	12.9	1.9	2.8	8.9	10.1	LUPIN, blå

Table 17. Energy values and standardised ileal digestible amino acids of organically produced roughages (VSP).

no	Name	FEsv	FEso	SID Lys	SID Met	SID Cys	SID Tre	SID Val	Reference feed ingredient
				g/kg DM					
6.10.1	Lucerne fresh UK 2012	0.33	0.45	9.9	3.4	1.1	6.8	9.8	LUCERNEGRØNMEL (lucernepiller)
6.10.1	Lucerne silage UK 2012	0.36	0.49	4.1	1.6	0.8	3.3	4.4	LUCERNEGRØNMEL (lucernepiller)
6.10.1	Lucerne silage 2nd harvest UK 2012	0.34	0.46	3.4	1.8	0.6	3.7	5.8	LUCERNEGRØNMEL (lucernepiller)
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	0.34	0.46	3.6	2.6	0.9	3.2	11.4	LUCERNEGRØNMEL (lucernepiller)
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	0.32	0.44	3.2	2.7	0.8	2.7	16.0	LUCERNEGRØNMEL (lucernepiller)
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	0.31	0.43	7.0	2.6	0.9	5.7	7.5	LUCERNEGRØNMEL (lucernepiller)
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	0.32	0.44	6.5	2.5	0.9	5.6	8.0	LUCERNEGRØNMEL (lucernepiller)
6.10.1	Clover-grass silage DE 2012	0.37	0.49	2.8	1.0	0.4	2.3	3.7	GRÆSGRØNMEL (grønpiller)
6.10.4	Lucerne pellets UK 2012	0.31	0.44	3.3	1.7	0.9	3.4	4.3	LUCERNEGRØNMEL (lucernepiller)
6.6.3	Grass, wilted and ensiled NL 2011	0.41	0.53	6.2	2.1	0.5	5.0	6.9	GRÆSGRØNMEL (grønpiller)

Table 18. Energy values and standardised ileal digestible amino acids of new feed materials (VSP).

no	Name	FEsv	FEso	SID Lys	SID Met	SID Cys	SID Tre	SID Val	Reference feed ingredient
				g/kg DM					
7.1.1	Algae *Spirulina* UK 2012	1.36	1.32	29.6	16.5	7.7	31.7	40.2	FISKEMEL
7.1.1	Algae *Chlorella scenedesmus* NL 2012	1.10	1.06	21.0	8.6	3.9	18.4	20.5	FISKEMEL
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	1.96	1.88	21.7	8.8	2.1	16.6	25.7	FISKEMEL
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	1.16	1.12	31.7	11.9	3.1	23.5	37.1	FISKEMEL
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	2.21	2.13	22.6	8.8	2.2	17.3	27.9	FISKEMEL
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	1.31	1.26	35.0	12.4	3.6	27.0	43.4	FISKEMEL
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	2.18	2.10	21.8	8.0	2.0	15.7	24.4	FISKEMEL
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	1.15	1.11	34.4	12.0	3.2	24.9	39.2	FISKEMEL
10.11.1	Mussel *Mytilus edulis* meal SE 2013	1.41	1.36	46.0	16.8	7.7	29.7	28.6	FISKEMEL
10.11.1	Mussel *Mytilus edulis* meal SE 2012	1.43	1.38	45.5	15.2	7.2	28.7	27.3	FISKEMEL

In vitro digestibilities and calculated standardised amino acid digestibilities

Table 19. *In vitro* digestibilities and standardised ileal digestibility of protein and amino acids of organically produced cereals and protein feed ingredients (Boisen, 2007).

no	Name	*In vitro* ileal digestibility, %		*In vitro* total tract digestibility, % dOM	SIDCP	Standardised ileal digestibility, %									
		dDM	dN		%	lys	tre	met	cys	ile	leu	val	his	fen	tyr
1.1.1	Barley FI 2011	77	85	85	71	74	67	78	74	75	76	75	75	76	77
1.11.1	Wheat FI 2011	85	93	90	86	85	82	89	87	88	88	87	88	88	88
1.4.1	Oats FI 2011	72	91	78	75	82	73	84	82	82	83	81	82	83	83
2.14.2	Rape seed meal UK 2012	62	83	81	77	79	76	80	78	79	79	79	79	78	79
2.14.2	Rape seed, expeller FI 2012	65	85	85	78	82	79	82	80	81	81	81	81	80	81
2.18.8	Soya bean pulp FI 2011	50	90	87	81	85	79	84	78	85	85	83	85	85	85
3.11.1	Peas FI 2012	76	94	91	87	91	86	89	87	90	90	89	90	90	91
3.11.1	Peas UK 2012	76	94	91	84	90	84	87	83	88	89	87	88	88	89
3.13.1	Grass pea AT 2011	70	89	80	82	86	81	83	82	85	85	84	85	84	85
3.15.1	Sainfoin, dehulled AT 2011	79	93	93	90	92	89	92	89	91	91	90	92	91	91
3.7.1	Faba beans UK 2012	76	86	91	81	84	79	81	78	83	83	82	83	83	83
3.7.1	Faba beans FI 2011	71	90	87	84	87	82	83	81	86	87	85	86	86	87
4.8.1	Potato, raw FI 2011	52	85	64	44	64	32	67	35	59	55	62	58	55	64
4.8.2	Potato, cooked FI 2011	85	94	95	83	87	77	88	78	86	84	87	86	85	87

Table 20. *In vitro* digestibilities and standardised ileal digestibility of protein and amino acids of organically produced roughages (Boisen, 2007).

no	Name	*In vitro* ileal digestibility; %		*In vitro* total tract digestibility, %	SIDCP	Standardised ileal digestibility, %									
		dDM	dN	dOM	%	lys	tre	met	cys	ile	leu	val	his	fen	tyr
6.10.1	Lucerne fresh UK 2012	60	86	83	77	81	75	81	63	81	81	80	80	81	81
6.10.1	Lucerne silage UK 2012	41	81	58	57	66	54	69	42	67	68	65	62	65	68
6.10.1	Lucerne silage 2nd harvest UK 2012	39	83	60	63	63	55	70	25	70	71	69	67	68	74
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	40	83	62	67	63	49	74	39	74	74	75	59	71	67
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	40	84	60	69	61	44	75	33	75	75	74	57	72	64
6.10.1	Lucerne silage 3rd harvest DE 2012	51	84	75	71	76	70	76	57	76	77	75	73	75	74
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	43	81	69	65	72	64	73	39	72	72	71	68	68	71
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	47	83	68	68	74	67	75	46	74	75	74	71	73	69
6.10.1	Extruded silage DE 2013	44	85	64	73	61	65	76	43	75	75	79	59	73	63
6.10.1	Chopped silage DE 2013	45	86	66	74	76	69	77	50	77	77	76	72	75	75
6.10.1	Clover-grass silage DE 2012	41	85	57	57	65	48	67		68	69	67	44	64	67
6.10.4	Lucerne pellets UK 2012	38	82	53	58	63	53	69	44	67	67	65	63	65	65
6.6.3	Grass, wilted and ensiled NL 2011	48	87	70	71	77	69	77	26	77	78	77	72	76	78

Table 21. *In vitro* digestibilities and standardised ileal digestibility of protein and amino acids of new feed materials (Boisen, 2007).

no	Name	*In vitro* ileal digestibility, %		*In vitro* total tract digestibility, %	SIDCP	Standardised ileal digestibility, %									
		dDM	dN	dOM	%	lys	tre	met	cys	ile	leu	val	his	fen	tyr
7.1.1	Algae *Spirulina* UK 2012	77	77	78	75	76	75	76	74	76	76	76	75	76	76
7.1.1	Algae *Chlorella scenedesmus* NL 2012	58	60	62	53	57	54	57	50	55	56	56	52	55	56
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	85	78	85	76	77	75	77	71	77	77	77	77	76	77
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	79	78	77	76	77	75	77	71	77	77	77	77	76	77
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	83	77	83	75	76	74	76	69	76	76	76	76	75	76
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	72	75	74	72	73	72	74	67	74	74	74	74	73	74
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	87	82	87	80	81	80	81	76	81	81	81	81	80	81
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	78	81	77	79	80	79	79	74	80	80	80	80	79	80
10.11.1	Mussel *Mytilus edulis* meal SE 2012	89	90	91	89	90	89	90	89	89	89	89	89	89	89

The British feed evaluation system: Energy values

Table 22. Energy values of organically produced cereals, protein feed ingredients and roughages for pigs (The British Society of Animal Science).

no	Name	ED %	DE MJ/kg DM	NE MJ/kg DM	Reference feed ingredient (Sauvant 2004)
1.1.1	Barley FI 2011	81	14.8	11.2	Barley
1.11.1	Wheat FI 2011	88	16.3	12.3	Wheat, soft
1.4.1	Oats FI 2011	64	12.4	9.4	Oats
2.14.2	Rape seed meal UK 2012	68	14.6	8.9	Rapeseed meal
2.14.2	Rape seed, expeller FI 2012	68	15.3	10.1	Rapeseed meal
2.18.8	Soya bean pulp FI 2011	85	19.2	12.5	Soybean meal
2.8.1	Linseed UK 2012	73	15.8	10.1	Linseed, ful fat
3.11.1	Peas FI 2012	88	16.2	11.6	Pea
3.11.1	Peas UK 2012	88	16.0	11.4	Pea
3.13.1	Grass pea AT 2011	86	16.2	11.0	Faba bean, white flowers
3.15.1	Sainfoin AT 2011	86	17.3	10.8	Faba bean, white flowers
3.15.1	Sainfoin, dehulled AT 2011	86	17.8	11.4	Faba bean, white flowers
3.7.1	Faba beans UK 2012	86	16.3	10.9	Faba bean, white flowers
3.7.1	Faba beans FI 2011	86	16.2	10.7	Faba bean, white flowers
3.9.1	Sweet lupin UK 2012	77	15.7	9.4	Lupin, blue
6.10.1	Lucerne fresh UK 2012	51	9.5	5.3	Alfalfa, dehydr., CP 22-25 % dry matter
6.10.1	Lucerne silage UK 2012	40	7.4	3.8	Alfalfa, dehydr., CP <16 % dry matter
6.10.1	Lucerne silage 2nd harvest UK 2012	44	8.1	4.0	Alfalfa, dehydr., CP 18-19 % dry matter
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	51	9.5	4.8	Alfalfa, dehydr., CP 22-25 % dry matter
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	51	9.4	4.7	Alfalfa, dehydr., CP 22-25 % dry matter
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	51	9.1	4.9	Alfalfa, dehydr., CP 22-25 % dry matter
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	51	9.3	5.0	Alfalfa, dehydr., CP 22-25 % dry matter
6.10.1	Clover-grass silage DE 2012	38	6.8	3.3	Grass, dehydrated
6.10.4	Lucerne pellets UK 2012	40	7.2	3.4	Alfalfa, dehydr., CP <16 % dry matter
6.6.3	Grass, wilted and ensiled NL 2011	38	7.1	3.6	Grass, dehydrated

Table 23. Energy values of new feed materials (The British Society of Animal Science).

no	Name	ED %	DE MJ/kg DM	NE MJ/kg DM	Reference feed ingredient (Sauvant 2004)
7.1.1	Algae *Spirulina* UK 2012	85	18.6	10.8	Fish meal, protein 65 %
7.1.1	Algae *Chlorella scenedesmus* NL 2012	85	13.7	8.5	Fish meal, protein 65 %
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	85	21.5	15.5	Fish meal, protein 65 %
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	85	16.2	9.1	Fish meal, protein 65 %
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	85	24.0	17.5	Fish meal, protein 65 %
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	85	18.3	10.2	Fish meal, protein 65 %
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	85	23.1	17.3	Fish meal, protein 65 %
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	85	16.4	8.9	Fish meal, protein 65 %
10.11.1	Mussel *Mytilus edulis* meal SE 2013	85	18.8	11.1	Fish meal, protein 65 %
10.11.1	Mussel *Mytilus edulis* meal SE 2012	85	18.9	11.3	Fish meal, protein 65 %

The German feed evaluation system: Energy values

Table 24. Energy values of organically produced feed ingredients and new feed materials for pigs (GfE).

no	Name	ME MJ/kg DM
1.1.1	Barley FI 2011	15.2
1.11.1	Wheat FI 2011	15.6
1.4.1	Oats FI 2011	15.6
2.14.2	Rape seed mealUK 2012	15.8
2.14.2	Rape seed, expeller FI 2012	16.8
2.18.8	Soya bean pulp FI 2011	17.2
2.8.1	Linseed UK 2012	16.6
3.11.1	Peas FI 2012	15.6
3.11.1	Peas UK 2012	14.1
3.13.1	Grass pea AT 2011	15.6
3.15.1	Sainfoin AT 2011	15.4
3.15.1	Sainfoin, dehulled AT 2011	16.4
3.7.1	Faba beans UK 2012	15.3
3.7.1	Horse beans FI 2011	15.4
3.9.1	Sweet lupins UK 2012	15.4
4.8.1	Potato, raw FI 2011	14.3
7.1.1	Algae *Spirulina* UK 2012	16.8
7.1.1	Algae *Chlorella scenedesmus* NL 2012	12.6
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	19.8
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	14.6
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	22.1
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	16.3
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	21.3
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	14.7
10.11.1	Mussel *Mytilus edulis* meal SE 2013	16.9
10.11.1	Mussel *Mytilus edulis* meal SE 2012	17.1

The Swiss feed evaluation system: Energy values

Table 25. Energy values of organically produced feed ingredients and new feed materials for pigs (Switzerland).

no	Name	DE MJ/kg DM
1.1.1	Barley FI 2011	14.8
1.11.1	Wheat FI 2011	16.3
1.4.1	Oats FI 2011	12.8
3.11.1	Peas FI 2012	16.2
3.11.1	Peas UK 2012	14.7
3.13.1	Grass pea AT 2011	14.8
3.15.1	Sainfoin, dehulled AT 2011	16.0
3.7.1	Faba beans UK 2012	14.3
3.7.1	Horse beans FI 2011	14.2
4.8.1	Potato, raw FI 2011	15.3
4.8.2	Potato, cooked FI 2011	15.5
7.1.1	Algae *Spirulina* UK 2012	18.6
7.1.1	Algae *Chlorella scenedesmus* NL 2012	14.0
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	16.3
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	18.3
9.16.2	*Hermetia illucens* meal ´kichen waste´ defatted CH 2012	16.4
10.11.1	Mussel *Mytilus edulis* meal SE 2013	18.9
10.11.1	Mussel *Mytilus edulis* meal SE 2012	19.0

Energy values for Poultry

3.5.1 The Finnish feed evaluation system: Energy values

Table 26. Energy values of organically produced feed ingredients and new feed materials for poultry (MTT).

no	Name	ME MJ/kg DM
1.1.1	Barley FI 2011	14.0
1.11.1	Wheat FI 2011	14.6
1.4.1	Oats FI 2011	13.4
2.14.2	Rape seed meal UK 2012	10.0
2.14.2	Rape seed, expeller FI 2012	11.3
2.18.8	Soya bean pulp FI 2011	10.5
2.8.1	Linseed UK 2012	10.7
3.11.1	Peas FI 2012	13.2
3.11.1	Peas UK 2012	12.8
3.13.1	Grass pea AT 2011	11.9
3.15.1	Sainfoin AT 2011	10.9
3.15.1	Sainfoin, dehulled AT 2011	12.7
3.7.1	Faba beans UK 2012	11.6
3.7.1	Horse beans FI 2011	11.6
3.9.1	Sweet lupins UK 2012	8.7
4.8.1	Potato, raw FI 2011	14.5
6.10.1	Lucerne fresh UK 2012	4.4
6.10.1	Lucerne silage UK 2012	3.5
6.10.1	Lucerne silage 2nd harvest UK 2012	3.5
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	4.3
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	3.7
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	3.8
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	3.8
6.10.1	Clover-grass silage DE 2012	3.1
6.10.4	Lucerne pellets UK 2012	3.3
6.6.3	Grass, wilted and ensiled NL 2011	4.0
7.1.1	Algae *Spirulina* UK 2012	15.3
7.1.1	Algae *Chlorella scenedesmus* NL 2012	12.3
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	19.3
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	13.4
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	21.4
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	14.9
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	21.0
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	13.4
10.11.1	Mussel *Mytilus edulis* meal SE 2013	15.5
10.11.1	Mussel *Mytilus edulis* meal SE 2012	15.7

The Dutch feed evaluation system: Energy and protein values

Table 27. Energy and protein values of organically produced cereals and protein feed ingredients for poultry (CVB).

no	Name	Broilers	Poultry	Laying hens	dig Lys	dig Met	dig Cys	Reference feed ingredient
		MJ/kg DM			g/kg DM			
1.1.1	Barley FI 2011	11.3	14.0	14.1	2.7	1.8	1.6	Barley
1.11.1	Wheat FI 2011	13.8	14.8	14.9	3.0	2.3	2.3	Wheat
1.4.1	Oats FI 2011	12.7	13.4	13.7	3.6	2.0	2.1	Oats
2.14.2	Rape seed meal UK 2012	9.7	10.1	10.6	15.0	6.7	5.2	Rapeseed expeller
2.14.2	Rape seed, expeller FI 2012	11.3	11.6	12.4	16.8	6.6	4.9	Rapeseed expeller
2.18.8	Soya bean pulp FI 2011	8.9	12.0	12.2	17.8	4.6	3.4	Soyabean meal
2.8.1	Linseed UK 2012	-	9.3	9.9	7.8	4.0	3.1	Linseed expeller
3.11.1	Peas FI 2012	12.6	13.3	13.4	14.5	2.7	2.8	Peas
3.11.1	Peas UK 2012	12.3	12.9	13.0	10.9	2.2	1.8	Peas
3.13.1	Grass pea AT 2011	12.3	13.2	13.2	15.9	3.0	3.3	Horse beans
3.15.1	Sainfoin AT 2011	11.4	11.5	11.8	13.9	4.8	2.9	Horse beans
3.15.1	Sainfoin, dehulled AT 2011	13.3	13.5	13.8	17.7	6.3	3.5	Horse beans
3.7.1	Faba beans UK 2012	12.1	12.9	12.9	15.5	2.3	2.0	Horse beans
3.7.1	Faba beans FI 2011	11.9	12.8	12.9	16.6	2.5	2.5	Horse beans
3.9.1	Sweet lupins UK 2012	9.2	8.9	9.1	14.6	2.2	3.2	Lupins, CP < 335 g/kg

Table 28. Energy and protein values of organically produced roughages for poultry (CVB).

no	Name	Broilers	Poultry	Laying hens	dig Lys	dig Met	dig Cys	Reference feed ingredient
		MJ/kg DM			g/kg DM			
6.10.1	Lucerne fresh UK 2012	-	6.4	6.4	10.6	3.7	1.2	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Lucerne silage UK 2012	-	3.4	3.4	4.1	1.6	0.8	Alfalfa meal, dehydrated, CP 140-160 g/kg
6.10.1	Lucerne silage 2nd harvest UK 2012	-	4.3	4.4	3.6	1.9	0.7	Alfalfa meal, dehydrated, CP 160-180 g/kg
6.10.1	Lucerne silage 2nd harvest extruded DE 2012	-	5.1	5.2	3.9	2.8	1.0	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Lucerne silage 2nd harvest chopped DE 2012	-	5.2	5.3	3.5	2.9	0.8	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Lucerne silage 3rd harvest extruded DE 2012	-	5.6	5.7	7.8	2.9	1.0	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Lucerne silage 3rd harvest chopped DE 2012	-	5.5	5.6	7.4	2.8	1.0	Alfalfa meal, dehydrated, CP >180 g/kg
6.10.1	Clover-grass silage DE 2012	-	3.2	3.3	2.5	1.0	0.3	Grass meal CP < 140 g/kg
6.10.4	Lucerne pellets UK 2012	-	3.4	3.4	3.3	1.7	0.9	Alfalfa meal, dehydrated, CP 140-160 g/kg
6.6.3	Grass, wilted and ensiled NL 2011	-	3.8	3.9	4.7	1.6	0.4	Grass meal CP < 140 g/kg

Table 29. Energy and protein values of new feed materials for poultry (CVB).

no	Name	Broilers	Poultry	Laying hens	dig Lys	dig Met	dig Cys	Reference feed ingredient
		MJ/kg DM			g/kg DM			
7.1.1	Algae *Spirulina* UK 2012	14.0	15.8	16.2	28.0	15.4	7.4	Fish meal, CP > 680 g/kg
7.1.1	Algae *Chlorella scenedesmus* NL 2012	11.3	12.4	12.8	19.9	8.0	3.8	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* larvae ´MBM´ dried, full fat CH 2012	18.0	19.6	21.3	20.4	8.2	2.0	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* meal ´MBM´ defatted CH 2012	12.6	13.8	14.0	30.2	11.0	3.0	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* larvae ´CHO´ dried, full fat CH 2012	20.1	21.8	23.8	21.2	8.0	2.1	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* meal ´CHO´ defatted CH 2012	13.6	15.5	15.7	32.7	11.3	3.5	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* larvae ´kitchen waste´ full fat CH 2012	19.8	21.3	23.3	20.6	7.4	2.0	Fish meal, CP < 580 g/kg
9.16.2	*Hermetia illucens* meal ´kitchen waste´ defatted CH 2012	12.2	13.9	14.0	32.3	11.1	3.1	Fish meal, CP < 580 g/kg
10.11.1	Mussel *Mytilus edulis* meal SE 2013	14.2	16.1	16.6	43.5	15.8	7.5	Fish meal, CP 630-680 g/kg
10.11.1	Mussel *Mytilus edulis* meal SE 2012	14.3	16.2	16.8	43.1	14.2	6.9	Fish meal, CP 630-680 g/kg