# Organic Knowledge Network on Monogastric Animal Feed
# OK-Net EcoFeed

## Knowledge synthesis

Feeding monogastrics 100% organic and regionally produced feed

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## Preface

The knowledge synthesis is a part of the H2020 project OK-Net EcoFeed. The contents is determined by the need for knowledge in innovation groups (IG) and thematic groups (TG) connected to the project. The knowledge synthesis should enable participants in IG and TG to choose feed materials, feeding strategies, breeds and perhaps even small-scale on-farm equipment for testing when aiming at 100% organic and regionally produced feed for monogastrics. In connection with the knowledge synthesis, there is a slide show as an introduction to the content.

Merete Studnitz
ICROFS, February 2019

**Starfish catch** *Photo: Jan Værum Nørgaard*

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## Executive summary


The transition to 100% organic feed ingredients for organic livestock is expected to take effect from January 1st 2020 in Europe. In order to contribute to the goal of 100% use of organic and regional feed for monogastrics, this knowledge synthesis "Feeding monogastrics 100% organic and regionally produced feed" aims to describe:

- the protein need for organic monogastric animals (pigs, layers and broilers), including different breeds and rearing conditions
- different protein feed resources, mostly new or not commonly used protein sources, their nutrient content, production prerequisites, and their potential feeding value
- small-scale, on-farm equipment for feed processing
- different feeding strategies.

The knowledge synthesis should enable participants in Innovation groups (IG) and Thematic groups (TG) to choose feed materials, feeding strategies, breeds and perhaps even small-scale on-farm equipment for testing when aiming at 100% organic and regionally produced feed for monogastrics.

In the knowledge synthesis it is concluded: When feeding pigs and poultry 100% organic and regionally produced feed, getting enough protein and specific amino acids is a challenge. There are two ways to go and they can be combined. One is to utilize by-products, for example waste from various productions, and explore new protein sources e.g. marine products or to refine already known products such as grass. The other way is to feed the animals less intensively and for this feeding strategy slow-growing breeds fit better. Some slow-growing breeds are already known, some are rediscovered old breeds. The challenge with the slow-growing and less-yielding breeds is that the production is getting smaller and either the farmer will earn less or the prices of eggs and meat will increase.

However, the possibilities for combinations of regionally grown feed, low-yielding breeds with different feeding strategies are many and they need to be explored.

Finally, the knowledge synthesis identify needs for new knowledge on:

- nutritional requirements of alternative breeds. Precise nutrient recommendations for organically produced pigs and poultry do not exist.
- nutritional value of new protein sources for monogastric animals
- various combinations of breeds, grazing and supplemental feed.

Small-scale on-farm equipment to refine locally produced raw materials needs to be developed.


*Photo: Maria Eskildsen*

**Weighing feed for experiments**

# 1. Introduction

This knowledge synthesis "Feeding monogastrics 100% organic and regionally produced feed" aims to describe the protein need for organic monogastric animals (pigs, layers and broilers), including different breeds and rearing conditions, and provide information about different protein feed resources, mostly new or not commonly used protein sources, their nutrient content, production prerequisites, and their potential feeding value. The knowledge synthesis also describes small-scale on-farm equipment for feed processing and different feeding strategies. Finally, the knowledge synthesis will identifies needs for new knowledge and innovations.

The primary target group of the knowledge synthesis is Innovation and Thematic groups connected to the project.

# 2. Background

In 2015, a giant work on availability of organic protein was produced calculating the self-sufficiency rate for crude protein in 11 European countries as a percentage of the actual produced crude protein, relative to the total demand for crude protein. A self-sufficiency rate for crude protein of 56% on average over all 11 countries was calculated. The demand for crude protein was more than 300'000 metric tons. Seventeen percent was fed to pigs, 34% to poultry and 49% to bovine animals (Früh et al, 2015).

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 for crude protein and essential amino acids of the animal categories, it could be shown that the supply gap with respect to essential amino acids is higher than the supply gap for crude protein. The total self-sufficiency rate of the 11 countries was just above 50% for lysine, about 40% for methionine and about 55% for methionine+cysteine (Früh et al, 2015).

Because of a lack of organic protein sources, the transition to 100% organic feed ingredients for organic livestock has been postponed repeatedly in the EU, but is expected to take effect from January 1st 2020 (**E**uropean **U**nion, 2017; Steenfeldt, S., Damgaard Poulsen, H., 2018).

Efficient use of both commonly used and new protein sources such as cereals, legumes and other vegetable products, green biomass or roughage, aquatic feed resources and by-products are needed to satisfy the demand for organic protein and amino acids. The most promising of the new products, and how to feed them, are described in order to make it possible for advisors and farmers to decide for the most appropriate protein sources or feeding strategy.

# 3. Protein requirements

Organic animal production varies widely in the EU and within countries. Except from specific organic regulations on e.g. organic feed, access to roughage and outdoor areas, some production systems are very close to the conventional system regarding breeds, housing environment and performance level. Other systems, depending on regional conditions or private standards, are more diverged from conventional production by for example use of slower growing animals, dual-purpose animals, and free range housing systems. From an economic and environmental aspect, however, it is important to minimise input of surplus protein in relation to animal requirements. The protein value of different feedstuffs in pig and poultry nutrition is clearly correlated to the content of essential amino acids (EAA) and their digestibility in the small intestine. The highest utilization of dietary protein is reached when the ratio between crude protein and energy in the diet is optimal (i.e. protein is neither under- or oversupplied relative to energy). Furthermore, all essential amino acids should ideally be equally limiting, although this may only be achieved in synthetic diets, and these are not acceptable in organic production.

Protein requirements depends on animal species, breed, sex, live weight (maintenance), physiological stage (growth, pregnancy, lactation), performance objectives, housing conditions and nutrition. For instance, growing pigs require more protein than humans because pigs grow much faster, and the same is true for modern pig breeds when compared to slow-growing breeds. Likewise, intact males grow faster than females and therefore require more protein during the finishing growing period. Lactating sows require more protein than gestating sows because a lot of protein is secreted into sow milk. Nutrition-wise, the animal productivity and the feed intake determines the optimal ratio between dietary protein and dietary net energy. Thus, high producing animals require more protein than animals with moderate or low productivity. However, this is not the case for growing pigs, because they (hopefully) will never face a situation where their energy is mobilised. In conventional pig production, more attention is paid to dietary lysine relative to net energy, merely than to dietary protein relative to net energy. The reason is that pigs (and other animals) have requirements for each essential amino acids (lysine, methionine, methionine+cysteine, threonine, leucine, valine, isoleucine, tryptophane, phenylalanine, tyrosine, and histidine). Major part of pig diets consists of cereal and although this depends on which feed ingredients are used, lysine is in most cases the most limiting amino acid, both for growing pigs, gestating sows and lactating sows. This is due to cereals having low levels of lysine in relation to the nutritional needs of the pigs. In contrast to pigs, methionine is typically the first limiting amino acid in poultry, because the requirement is high for feather production. Once the optimal dietary content for the first limiting amino acid is reached, the second, third etc. limiting amino acid can be optimised in conventional pig production by including crystalline amino acids, and this concomitantly reduces the required crude protein level in the diet. However, in organic pig production the use of synthetic amino acids are not allowed , and therefore requirements of all essential amino acids must be met by inclusion of dietary protein. As a corollary, utilization of protein and also energy is lower in organically produced pigs as compared with conventionally produced pigs, and the productivity of organic animals could without doubt be improved considerably if crystalline amino acids could be included, when diets for organic pigs are formulated.

***"Nutrition-wise, the animal productivity and the feed intake determines the optimal ratio between dietary protein and dietary net energy."***

***"…animals have requirements for each essential amino acid…lysine is in most cases the most limiting amino acid for growing pigs… methionine is typically the first limiting amino acid in poultry,…"***

**PIGS**

The nutrient requirements for pigs in organic production systems are probably more or less the same as for pigs in conventional production systems. However, organic pigs have higher energy requirements due to more physical activity and the fact that they are housed in colder environments, especially when housed outdoors during winter time. Since the energy requirement is the most important aspect within pig nutrition, a reasonable assumption is therefore that an organic diet can have a somewhat lower content of nutrients per unit of net energy (MJ NE) but still supply pigs according to their daily nutritional needs.

The requirement of amino acids in feed is often expressed per unit of net energy, which means that the amount of amino acid, e.g. lysine/MJ NE can be increased either by:

1) increasing the total dietary lysine content by selecting ingredients with a high content of lysine or
2) reducing the content of energy, i.e. increase the proportion of feed ingredients with low energy level, while concomitantly increasing the daily amount of feed supplied (in kg/day).

Pigs, and especially sows, have the capacity to adapt to feed with a relatively low energy content by developing a larger digestive tract and thereby increase both feed consumption and energy utilization by increasing the fermentation capacity. For growing pigs and lactating sows, the feed intake is often the limiting factor for their performance, whereas gestating sows are able to consume a sufficient amount of energy. For growing pigs reared organically, the limited energy intake typically causes prolonged rearing time, whereas lactating sows mobilize more energy from their body stores (fat and muscle mass) to support the huge demand of nutrients for milk production.

*"Nowadays, much attention is paid to minimizing the excretion to the environment and it is common to optimize pig feed to make the most economical return, which is achieved below the maximal productivity"*

Current recommended levels of protein (and amino acids) for pigs are based on data obtained in experiments performed under different conditions, e.g. genetic lines, dietary raw materials, health status and management practices (NRC, 2012). Two or 3 decades ago, it was common to include a safety margin for the recommended dietary protein, because at that time the pig industry focused solely on maximizing the growth of pigs. Nowadays, much attention is paid to minimizing the excretion to the environment and it is common to optimize pig feed to make the most economical return, which is achieved below the maximal productivity. For other essential nutrients like vitamin E and micro-minerals it is common to incorporate a safety margin, which is applied due to uncertainty on the exact nutrient content for each feed ingredient or because it is so cheap that it does not pay off to study the real requirement. However, this is not the case for dietary protein, because it is rather expensive.

In practice, many organic pigs are actually over-supplied with crude protein and amino acids which results in wastage of nutrients and unnecessarily high nitrogen (N) emissions. Another negative consequence is that excessive dietary protein reduces the energy utilization of the feed by up to 6% (Pedersen et al., 2019), which means that lactating sows require 6% more feed to reach the same productivity if the dietary protein is not balanced well relative to net energy.

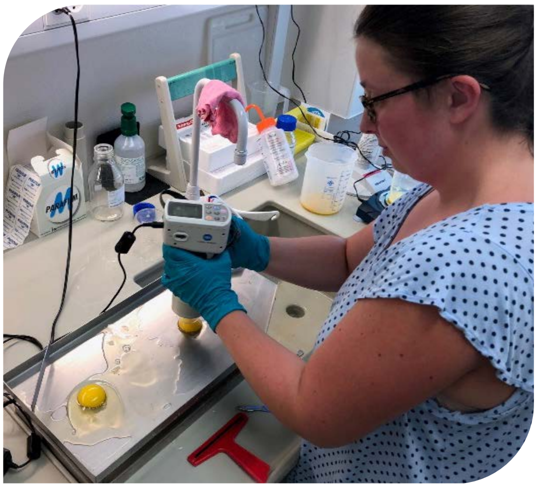
By using the pigs' capacity to consume more feed with a lower energy content and at the same time reduce the amount of amino acids per MJ of net energy, it is possible to use on-farm produced feed ingredients such as cereals, peas and beans to a greater extent. It has been shown that feed with a lower energy density (9.3 MJ NE/kg DM) did not result in a reduced weight gain or feed conversion ratio compared with a more energy dense feed (10.8 MJ NE/kg DM). Further, the recommendations on amino acid supply may need to be adjusted to match prevailing production conditions. For example, Høøk Presto *et al.* (2007) found that the amino acid requirements of modern slaughter pigs reared under organic conditions in Sweden was lower than the recommended levels. In France, the amino acid content recommendations of organic pig feed are lower than those of conventional feed (ITAB, 2014).

*"By using the pigs' capacity to consume more feed with a lower energy content and at the same time reduce the amount of amino acids per MJ of net energy, it is possible to use on-farm produced feed ingredients such as cereals, peas and beans to a greater extent."*

In Denmark it has been discussed recently, whether distinct nutrient recommendations for organically produced pigs should be given, but it is mutually understood that the knowledge at present is not sufficient to allow this.

**LAYERS**

In organic egg production, the genotypes used are often highly efficient with low feed intake and a high egg-production and the nutritional requirements are often considered to be similar to the layer genotypes used in the conventional egg production. However, genotypes that are more suited to free range organic systems exist, they have an innate foraging behaviour, they are less productive and their nutrient requirements are different from the more high-yielding type (Blair, 2008). Often these genotypes are more heavy type birds that can be considered as "dual-purpose", and the male chickens can be used in organic meat production corresponding well with the organic principles. In small scale production, some lower efficient strains could be used (<200 eggs/year), with less nutrient requirement. For less efficient strains it is easier to use local feedstuffs and decrease soya incorporation in the feed. The needs of the layers depend on the live weight of the animal, the farming conditions (temperature), the laying stage and the laying intensity.



**Egg analysis** *Photo: Jan Værum Nørgaard*

**BROILERS**

The growth rate and feed efficiency of the modern broilers has been optimized during genetic selection for decades, resulting in a genotype with a high meat production potential (Havenstein et al., 2003; Zuidhof et al., 2014) and as a result the conventional broilers now reach their target slaughter weight in 35 days (2000-2200g). However, a consequence of the fast growth and efficient metabolism is a high heat production, reduced walking ability and a general decreased activity level, which can increase the risk for food pad lesions and a bad gait score (Fanatico et al., 2008; Steenfeldt & Horsted, 2014). However, slow-growing broilers have different energy and nutrient requirements and it has been shown in several studies that slow-growing broilers were found to spend much more time on out-door areas than faster-growing genotypes, indicating differences in behaviour, such as foraging behaviour (Nielsen et al., 2003, Almeida et al., 2012; Steenfeldt & Horsted, 2014).

## 3.1 Feeding Pigs optimal according to their needs.

A general advice for feeding pigs in organic productions systems is to lower the amount of SID (standardised ileal digestible) lysine/MJ with 10% based on the recommended level for conventional pigs of modern breeds and use this as a starting point, however, the lower the level that is chosen as a starting point, the higher is the demand for feed analysis and follow up on production results.

In organic production in France, some farmers do not use finishing feed (low amino acid content). This practice can ensure lean content if it is difficult to provide a good feed rationing (Delassus, 2011).

### 3.1.1 Pigs - High producing modern and fast growing genotypes

Modern genotypes are selected for rapid and lean growth (high meat-percentage), high feed conversion (gain-to-feed) ratio, high prolificacy and large litter size 5 days after birth, and improved longevity. These selection criteria have clearly increased the protein requirement as compared with ancient genotypes, although at present it is not common to distinguish between breeds when nutrient recommendations are given (NRC, 2012; Tybirk et al, 2018). The selection criteria used have clearly been driven primarily to achieve improvements in conventional production systems. As a consequence of the selection criteria used, more lean pigs are produced today than in the past, and modern pigs are likely more vulnerable to cold weather due to less insulation by subcutaneous fat. The high prolificacy of modern genotype sows may also be a disadvantage for producers, partly because birth weight steadily decreases as the litter size increases (which likely increases mortality of newborn piglets) and partly because it is really challenging to make nurse sows under outdoor conditions.

*"…modern pigs are likely more vulnerable to cold weather due to less insulation by subcutaneous fat."*

Pigs reared organically should expectedly be fed more but less nutrient-dense feed as compared with conventional pigs. If the feed intake of a certain group of organically produced pigs (e.g. growing-finishing pigs) is 10% higher than conventionally reared pigs, it is tempting to use feed with nutrient concentrations 10% below the recommendations, because the higher feed intake and the less nutrient density in combination determines the daily supply of nutrients. This also explains why it would probably be advantageous to supply organic pigs and sows feed with even less density of nutrients during the winter as compared with the feed supplied during the summer.

***"This also explains why it would probably be to supply organic pigs advantageous and sows feed with even less density of nutrients during the winter as compared with the feed supplied during the summer."***

### 3.1.2 Pigs - Slow growing animals

Although the EU regulation encourages use of traditional breeds adapted to local conditions, the main part of the European organically produced pork derives from modern fast-growing breeds. This is widely associated with reduced reproduction performance, growth, feed efficiency, and meat content in traditional and local breeds (reviewed by Leenhouwers & Merks, 2013) challenging the economic competitiveness unless the farmers obtain a premium for the pork produced. Nevertheless, in some European countries, e.g. Italy and UK, local breeds reared in small extensive systems constitute an important part of the organic pork production (Edwards, 2005; FiBL, 2011). In addition, an increasing consumer demand for local niche food products with superior intrinsic and extrinsic quality characteristics (Brečić et al., 2017), may stimulate a further use of local pig breeds in the organic production in the coming years.

**Grazing behaviour** *Photo: Anne Grete Kongsted*

Inevitably, the slower and lower meat deposition in local pig breeds modifies the nutrient requirement compared to modern genotypes, which have undergone decades of intensive genetic selection for fast growth and leanness. It has been suggested that local breeds are likely to experience less metabolic stress when provided with feed generally considered as poor quality feed due to the lower lean tissue growth (Edwards, 2003) and to be more motivated for forage intake as breeding for leanness and improved feed efficiency may have reduced appetite (Kelly et al., 2001). In accordance herewith, crossbreds of the traditional breed Tamworth (sire) and the modern genotypes Landrace and Yorkshire showed increased grazing behaviour compared to a modern crossbred between Duroc (sire), Yorkshire and Landrace in a diverse forage-based pasture system (Kongsted & Jakobsen, 2015). However, the two crossbreds responded similarly to a 33% reduction in concentrate allowance regarding growth performance and feed (concentrate) conversion indicating no major differences in nutrient and energy intakes from foraging in the range (Kongsted et al., 2015).

***"… crossbreds of the traditional breed Tamworth (sire) and the modern genotypes Landrace and Yorkshire showed increased grazing behaviour compared to a modern crossbred between Duroc (sire), Yorkshire and Landrace in a diverse forage-based pasture system."***

The nutritional requirements of local slow-growing breeds remain to be quantified. The running EU project, Diversity of local pig breeds and production systems for high quality traditional products and sustainable pork chains (TREASURE), is currently testing feeding and management strategies to improve performance and meat quality of local breeds (Čandek-Potokar et al., 2017). This needs to be followed by future in-depth research to determine nutritional requirements at different physiological stages and how this interacts with climatic conditions and production system in slow-growing pig breeds.

### 3.1.3 Pigs - Seasonal needs

It is relevant to take three important aspects into account during different seasons, namely 1) climatic conditions (temperature, wind and humidity), 2) availability and digestibility of grass (summer) or roughage (winter), and 3) physical (locomotory) activity, although it should be emphasised that these factors interacts.

Climatic conditions are probably the most important factor to consider, because low temperature increases substantially the amount of energy lost to the surroundings due to thermoregulation, and this will increase the need for extra energy intake. If wind speed and/or humidity is elevated, the energy loss to the surroundings increases due to increased "chilling". In meteorology it is commonly applied to use a chill-factor, which is an index that combines these factors, but so far this has not been adopted when recommending appropriate amounts of feed for organic pigs.

*"In meteorology it is commonly applied to use a chill-factor, which is an index that combines these factors, but so far this has not been adopted when recommending appropriate amounts of feed for organic pigs."*

Fresh grass contains a lot of protein and the digestibility may be surprisingly high when the grass is young. In an unpublished study with grass grown under organic conditions, it was shown that energy and protein digestibility coefficients were as high as 68 and 71%, respectively (Eskildsen et al., 2018). To maintain a high great quality (i.e. keeping protein content and protein digestibility high), grass is commonly cut 2 to 4 times during the summer period. When organic pigs (especially sows) ingested large amounts of high quality grass, it should be taken into account when formulating the composition of the concentrate (dry feed), because grass is more rich in protein and lysine than in net energy, and if this is not taken into account, sows may be exposed to great oversupplies of protein during the summer.

*"…grass is more rich in protein and lysine than in net energy, and if this is not taken into account, sows may be exposed to great oversupplies of protein during the summer."*

Organic pigs and sows have the possibility of being much more physically active than pigs housed indoor. In practice, however, this is only the case for suckling and growing pigs, whereas the physical activity of finishing pigs as well as gestating and lactating sows seems to be rather comparable to pigs reared indoor (Eskildsen, Pers. Comm.). However, it should be stressed that the physical activity clearly is affected by the climatic conditions, as mentioned above. Thus, if it is cold, windy or rainy, sows go out very fast to complete their meal, and then return to their hut. But if the weather is sunny and it is dry with no wind, the pigs and sows like to stay outside, even if the temperature is below zero.

*"…if it is cold, windy and rainy, sows go out very fast to complete their meal, and then return to their hut. But if the weather is sunny and it is dry with no wind, the pigs and sows like to stay outside, even if the temperature is below zero."*

As it is described above, climatic conditions, grass quality and physical activity all affect the seasonal needs for nutrients. Some of these needs (e.g. seasonal changes in mean temperature and availability of grass/roughage) may easily be taken into account, whereas day to day fluctuations (great changes in temperature, wind, rain) is more challenging to incorporate when feeding organic pigs and sows. It should also be noted that different seasonal needs is not at present being implemented when formulating feed for organic pigs in practice.

*"…different seasonal needs is not at present being implemented when formulating feed for organic pigs in practice."*

## 3.2 Feeding poultry optimal according to their needs

The differences between the intensive conventional egg- and meat production and the organic egg- and meat production are many; the most important being access to outdoor areas, genotypes and the range of feed ingredients available for organic diets. The use of synthetic amino acids and some protein sources e.g. good defatted soya bean meal (due to use of chemical solvents) is not permitted in the organic production, which challenges the formulation of well-balanced diets in organic poultry production. Indeed, the nutritional value of organic oilseeds meal is close to that of conventional expeller cake, but lower (Roinsard et al, 2018) and there is not enough organic feedstuffs with a very high amino acid content such as corn gluten or potato protein (Lubac et al, 2016). Besides effects on production, any dietary imbalances may stress laying hens initiating unwanted behaviour such as feather pecking (Ambrosen & Petersen, 1997). The main dietary challenge in organic egg production is to cover the specific amino acid requirements, especially the methionine requirement (Elwinger et al., 2018). Due to the exclusion of pure amino acids from organic diets, there is often an excessive protein content in the diets in order to ensure that the requirements of broilers and layers for essential amino acids are covered. The excessive protein content in organic diets will result in an increased excretion of nitrogen, which can be a problem to the environment due to leaching and increased digestive problems.

### 3.2.1 Laying hens

Most of strains used in organic egg production are the same as in the conventional production. Requirements are high (Table 3.1) and difficult to fulfil without a high level of soya bean cake and an increasing feed cost. The main difficulty is to provide a high level of methionine without increasing the protein content too much. A lower energy content in the feed could increase consumption and allow a higher intake of amino acid (van Krimpen et al, 2015). For a feed intake based on 115 g/day, the methionine level in the feed must be 0,31%, however, with a low energy content (to allow a final intake on 130g/day), the methionine content of the feed could be 0,27% to provide the same intake of methionine. This strategy could be interesting also in relation to the price of protein and energy feedstuffs, because it increases the feed conversion ratio.

**Table 3.1 Energy and nutrient requirements for organic laying hens**
High potential breed: 250 – 300 eggs/year. Fed 125 g/day intake

| | START LAYING<br>Before 42 week (age) | LAYING<br>After 42 weeks (age) |
|---|---|---|
| METABOLIZABLE ENERGY (en kcal EMA) | 2700 - 2900 | 2650 - 2750 |
| CP (en %) max | 20 | 19 |
| Lysine digestible (%) min | 0,65 | 0,62 |
| Methionine digestible (%) min | 0,3 | 0,29 |
| FAT (en %) | 4 - 7 | 4 - 7 |
| Fibre (%) max | 7 | 7 |
| Calcium (en %) min | 3,5 | 3,5 |
| Phosphorus available (%) min | 0,31 | 0,31 |
| Sodium (%) min | 0,13 | 0,13 |

Reference: Bordeaux, C., Roinsard, A. (Eds.), 2015

A different strategy could be carried out to provide 100% organic feedstuffs for hens. A trial carried out by Lessire et al. (2012) aimed to compare the provision of 95% organic feed vs 100% organic feed without increasing the price of the feed. Two feed treatments were compared from week 22 to week 36 of age. This has resulted in a 17% reduction in protein and amino acid levels in the 100% organic feed (Table 3.2).

**Table 3.2 Composition and characteristics of feeds 95% organic and 100% organic (same price of feed)**

| | 95 Organic | 100 Organic |
|---|---|---|
| Components (%) | | |
| Corn | 10,4 | 17,5 |
| Triticale | 40,0 | 40,0 |
| Soya bean cake | 11,8 | 11,0 |
| Sunflower cake | 14,0 | 12,9 |
| Soya oil | 1,88 | 1,6 |
| Extruded soya bean | 6,0 | 6,0 |
| Yeast | 2,0 | - |
| Corn gluten (conventional) | 2,0 | - |
| Potato protein (conventional) | 1,0 | - |
| Shell | 1,0 | 1,0 |
| Carbonate de calcium | 7,62 | 7,50 |
| Phosphate bicalcique | 0,9 | 1,1 |
| Minerals | 1,4 | 1,4 |
| | | |
| Nutritional value (%) | | |
| EM (kCal/Kg) | 2700 | 2700 |
| CP | 18,9 | 16,0 |
| Lysine digestible | 0,77 | 0,65 |
| Methionine digestible | 0,30 | 0,25 |
| Threonine digestible | 0,59 | 0,48 |
| Tryptophan digestible | 0,19 | 0,17 |
| Calcium | 3,95 | 3,94 |
| Phosphorus available | 0,33 | 0,34 |

The number of eggs was significantly reduced as well as their weight (7% less egg mass) and the consumption index was numerically degraded (nearly 9%).

It was possible to obtain similar performances when fed a 95% and a 100% organic feed to layers from 17 to 41 weeks of age (Dusart et al., in press). However, it is necessary to increase the use of soybean meal to 3% at the beginning of the laying period and to 6% after the peak laying period. Similarly, the use of sunflower meal must be 12.5% at the beginning of the laying period and 7.5% after the peak laying period. 100 % organic feed did not impact the welfare, it did not induce feather picking, and thanks to sunflower there was less pododermatitis. However, the feed cost/kg of eggs increased by 6.5%.

### 3.2.2 Laying hens - Organic breeds and dual breeds

The egg production, feed intake and use of outdoor area were studied for two genotypes of laying hens with different nutrient requirements (Steenfeldt & Hammershøj, 2015). The layers were given diets with decreasing content of protein and amino acids and had at the same time access to different kind of roughage (silages, vegetables). The production parameters were significantly affected by both genotype, diet androughage, and it was clear that the "dual-purpose" genotype obtained significantly poorer production results compared to the higher yielding genotypes. The decreasing level of protein and methionine, cysteine and other important amino acids in two of the diets, affected production results for both genotypes (lower laying rate and egg weight, poorer FCR (feed conversion ratio), especially for the groups having access to maize silage plus carrots as roughage, where the daily feed intake was very high (> 100g/hen/day). Due to the large amount of maize silage and carrots eaten by the hens in all groups, a high daily intake of especially insoluble NSP (non-starch polysaccharides (fibres)) from silage was seen. In this case, the insoluble NSP accounted for 87% of total NSP. A high intake of fibres will probably reduce the total intake of nutrients from the diets, having the greatest effect with the diets being lowest in protein and in some essential amino acids. Therefor a restriction in the daily amount of silages and vegetables given could be necessary. However, in order to obtain more balanced diets to organic laying hens, the nutrient content of foraging material should be taken into account in diet formulation.

> ***"…it is possible to use a lot of pea or faba beans in the feed, but the price of the eggs have to be higher than with a high production level, because of a more expensive feed cost."***

Due to the low productivity and poorer feed conversion of the "dual-purpose" genotype, it can be difficult to persuade organic producers to use dual-purpose- genotypes in their organic production, because it will reduce their income considerably. Producing the male chicken for organic meat production concurrently could be a solution, but probably with some challenges, because egg production and meat production are very different.

In small-scale production, some farmers use local breed or accept less productivity of laying hens to improve local feed utilization. In this case, requirements could be less than with a high production level (Table 3.3).

**Table 3.3 Energy and nutrient requirements for French local breeds**

| | START LAYING<br>Before 42 week (age) | LAYING<br>After 42 weeks (age) |
|---|---|---|
| Metabolisable Energy (kcal EMA) | 2700 - 2900 | 2650 - 2750 |
| CP (%) max | 18 | 18 |
| Lysine digestible (%) min | 0,60 | 0,55 |
| Methionine digestible (%) min | 0,28 | 0,25 |
| Fat (%) | 4 - 7 | 4 - 7 |
| Fibre (%) max | 7 | 7 |
| Calcium (%) min | 3,5 | 3,5 |
| Phosphorus available (%) min | 0,31 | 0,31 |
| Sodium (%) min | 0,13 | 0,13 |

Reference: Bordeaux, C., Roinsard, A. (Eds.), 2015

With this strategy, it is possible to use a lot of pea or faba beans in the feed, but the price of the eggs have to be higher than with a high production level, because of a more expensive feed cost.

### 3.2.3 Broilers - High producing modern (fast growing) genotypes.

The interest in alternative production systems has increased in recent years and the consumers request a welfare friendly production. Consumers expect that the broilers have access to attractive outdoor areas, where they can run freely and express their natural behaviour such as dustbathing and searching for feed. It is easier and cheaper to formulate diets for conventional broilers since it is permitted to use pure amino acids in conventional poultry diets, as well as soybean meal, which also have a lower price compared to organic poultry diets. The nutritional requirements for conventional broilers for energy, protein, amino acids, minerals and vitamins are well documented, which is not the case for the different slow-growing broilers that have been introduced in recent years.

*"The nutritional requirements for conventional broilers for energy, protein, amino acids, minerals and vitamins are well documented, which is not the case for the different slow-growing broilers that have been introduced in recent years."*

### 3.2.4 Broilers - Slow growing animals - dual breeds

The requirement for broilers depends not only on the breeds, but also on age and the objectives of the farmers. If farmers accept a higher age at slaughter, it is possible to decrease the nutritional value (lysine and methionine content) of the feed during the growing or finishing phase (Table 3.4). The most important thing is to provide high nutrient content in the starter phase to ensure proper growth.

**Table 3.4 Energy and nutrient requirements for organic broilers (slow growing breed – 2,2kg at 81 days)**

| | Starter (1-4 weeks) | Growing (5-8 weeks) | Finishing (8 – 12 weeks) |
|---|---|---|---|
| Metabolisable Energy (kcal EMA) | 2750-2850 | 2800-2900 | 2700-2800 |
| CP (%) max | 21 - 22 | 19 -20 | 16 |
| Lysine digestible (%) min | 0,90 | 0,82 | 0,65 |
| Methionine digestible (%) min | 0,35 | 0,32 | 0,28 |
| Fat (%) | 2-5 | 2-7 | 2-7 |
| Fibre (%) | 0 - 5 | 0 - 7 | 0 - 7 |
| Calcium (%) | 1,05 – 1,15 | 1,0 | 1,0 |
| Phosphorus available (%) | 0,4 – 0,45 | 0,4 – 0,45 | 0,3 – 0,35 |
| Sodium (%) | 0,15 – 0,18 | 0,15 – 0,18 | 0,15 – 0,18 |

Bordeaux, C., Roinsard, A. (Eds.), 2015

In an experiment two broiler genotypes (slow- and medium growth) foraged different types of vegetation in the finishing period, 80 to 113 days of age and the feed intake and activity level was measured (Almeida et al., 2012). The broilers were fed an organic diet (Protein: 19.7% DM, methionine: 3.0g/kg DM), but were restricted to 50g/bird/day to stimulate foraging activity in the vegetation consisting of grass and clover, chicory and other weeds. It was concluded that limiting protein intake for organic broilers can be an acceptable feeding strategy if the broilers have access to a vegetation with a high nutritious content, where the broilers can forage and cover a part of the requirement for protein and amino acids.

> *"…limiting protein intake for organic broilers can be an acceptable feeding strategy if the broilers have access to a vegetation with a high nutritious content.…"*

Fanatico et al. (2008) also found that a slow-growing genotype was much more active and appeared to forage more, whereas the fast-growing broilers did not go outside very often and when they did, they grouped around the feeder or rested instead of foraging. The study showed a much better bone health in slow-growing broilers, and that low nutrient diets improves the gait score in both slow- and fast growing broilers, demonstrating that it is possible to regulate growth by different feeding strategies. However, feed conversions are often poorer in alternative production systems, since the slower-growing genotypes are less efficient in utilizing the feed compared to conventional broilers, but also because the diets are formulated to be less optimal due to the restrictions mentioned earlier for organic poultry feed. The higher production costs result in higher prices in the supermarkets, so consumers have to pay a premium price for a higher welfare and a better meat quality.

> *"…it is possible to regulate growth by different feeding strategies."*

Germain (2014) conducted a trial on two genetic types of poultry that represented different growth potentials. The animals were slaughtered at two different ages, 89 vs 103 days old, and were fed with two feeds, including one which had a lower protein contents (minus 2 points of CP) and was cheaper. The animals continuously had free access to the open-air runs from 35 days of age. In order to ensure the starting phase, all animals received the same starter feed. Then, 2 types of growing (17.2% versus 19% protein) and 2 types of fattening feed (15.1% versus 17 % protein) were distributed to the broilers. The results demonstrate very small weight difference between the two diets, regardless of the growth length (Figure 3.1 and 3.2).

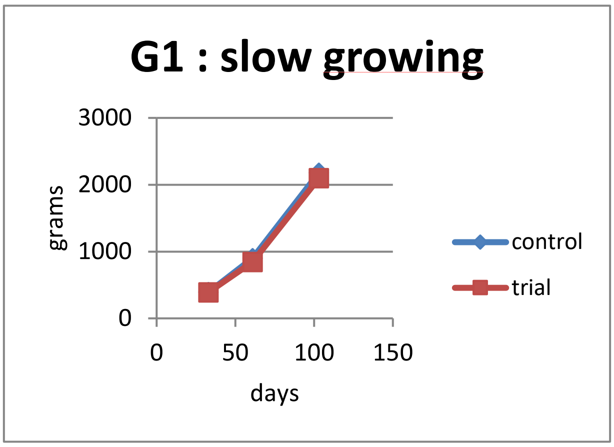



**Figure 3.1**

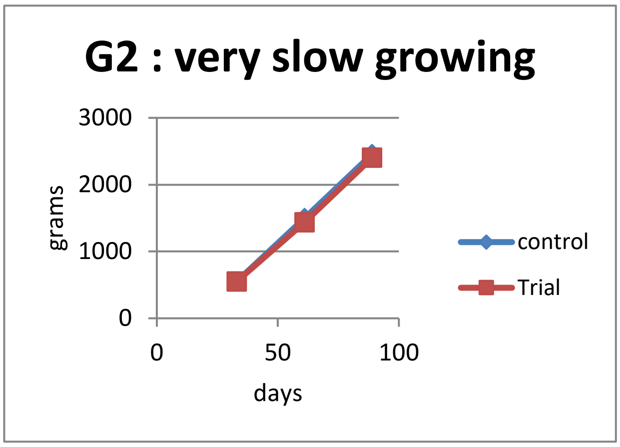



**Figure 3.2**

The feed conversion rate (FCR) is only slightly less satisfying for the low-protein diet: 3.15 vs 3.01 for the 89 days old breed and 3,69 vs 3,48 for the 103 days old breed. Moreover, this diet did not affect the yield at slaughter including fat, thigh and fillet percentages. The intake of proteins from complete feed was slightly lower per broiler, and the feed gain ratio was increased for broiler batches fed with lower protein intake. Nonetheless, despite of the increase of the FCR, by limiting the incorporation of the soya and protein intake a decrease in total feeding cost was achieved: -3% for the 89 days old breed and -4% for the 103 days old breed.

Most slow-growing broilers are slaughtered between 63-92 days of age (110 days for label rouge) depending on their growth potential and the feeding strategy used. The maximum daily weight gain permitted in organic broiler production in e.g. Denmark is 38g/chicken/day. As the nutrient composition of the diet can influence the growth of the broilers, it is important to adjust the diet to the permitted growth rate. To decide on the composition of the diet growth potential and the quality of the vegetation in the outdoor area have to be taken into consideration. At the same time lower nutrient content in the diet will stimulate the activity of the broiler.

### 3.2.5 Poultry seasonal needs

When birds have access to outdoor areas they are exposed to changing weather conditions, which in many countries can be very cold during winter (Northern Europe) and very warm during summer. Energy requirements are general higher in organic and free-range poultry, because they have an increased activity level due to their foraging behaviour, which increase maintenance requirements. The plumage quality is very important for birds ranging outside, since poor feather coverage will increase the need for more energy to keep the body temperature under cold conditions. Van Krimpen et al. (2015) carried out an experiment with laying hens during a summer and a winter period, where layers were fed with eight different diets comprising of two energy levels (10.9 and 12.1 MJ/kg (as-fed basis). Within each of the two energy levels (four diets each) the protein (15.5-19.8%) and methionine (2.6-3.8g/kg) content differed as well. The hens had access to outdoor areas. It was found that the energy content of the diets did not affect the energy intake, whereas this was the case during the winter period, since the energy intake increased in layers fed with the low energy diet. Measured as egg mass (kg egg/kg fed), the highest values during summer was achieved with diets having 3.5g/kg, corresponding to a digestible methionine intake of 421mg/hen/day. In the winter period the highest egg mass was achieved with a digestible methionine intake of 360mg/hen/day, which was realised with the diets having the lowest methionine content, reflecting the difference in feed intake between summer and winter. Both organic layers and broilers can obtain part of their nutritional needs during the summer by eating grass and herbs in the outdoor areas (Horsted et al., 2006; Horsted & Hermansen, 2007; Almeida et al., 2012). In Northern Europe, the climate restricts the availability of plant material in outdoor areas to the summer period. However, since it is mandatory to fed organic birds with some kind of rough material, organic poultry producers allocate certain amounts of different silages to the birds every day, which can contribute with some energy and protein/methionine in addition to the compound feed (Afrose, 2015; Steenfeldt & Hammershøj, 2015).

## 4. Feedstuffs

Even though many feedstuffs with high protein content are available, still more protein for feeding animals is needed. In Europe, we tend to agree that converting land for agriculture at the expense of the rainforest in South America is not the way forward to produce soy protein to feed our livestock. A prevailing opinion is also that fish caught with the only purpose of being fed to animals is not a sustainable way to produce meat. These issues create a need for searching for new sustainable protein sources, which can lead to regional or at least European self-sufficiency. There is a great variety in production potential when it comes to climate and availability of land for horticulture and sea for marine production. Thus, the dietary inclusion with locally or regionally produced organic feedstuffs will vary from country to country. Several of the potential feedstuffs may, in addition to supplying nutrients, also solve important challenges for the industry and society with their impact on environment and circular bio economy. In this chapter, new or not commonly used feedstuffs with high protein content are described. A summary of the feedstuffs described in Chapter 4 is shown in Table 4.1.

**Table 4.1 Summary of feedstuffs described in Chapter 4.**

| Name of feed stuff | Crude protein concentration in dry matter | The standardized ileal digestibility of crude protein, pigs | The standardized ileal digestibility of crude protein, layers | Can be fed to | Read |
|---|---|---|---|---|---|
| **Starfish** | 38-70% | 0.80 | 0.70 | Pigs, layers | 4.1 |
| **Mussels** | 58-66% | 0.83 | 0.71 | Pigs, layers | 4.2 |
| **Seaweed** | 7-38% | | | Ongoing experiments (2019), pigs | 4.3 |
| **Green Protein** | 30-54% | | | Pigs, layers | 4.4 |
| **Acorn** | 5% | 0.73 | | Iberian growing pigs can peel the acorns | 4.5 |
| **Tomato silage** | 18.78% | | | Pigs, except piglets | 4.6 |
| **Whey** | 9.4% | 0.89 | | Pigs | 4.7 |
| **Grape pomace** | 11.2% | 0.15 | low | Pigs, except piglets | 4.8 |
| **Olive pomace** | 7.5% | | | Pigs, except piglets | 4.9 |
| **Waste from soy beverage** | 33% | | | Poultry and pigs | 4.10 |
| **Waste from rice beverage** | 63% | | | Poultry and pigs | 4.11 |
| **Waste from oats beverage** | 31% | | | Poultry and pigs | 4.12 |
| **Soy bean cake** | 44% | | | Poultry and pigs | 4.13 |
| **Sunflower cake** | 33.7% | | | Poultry and pigs | 4.14 |
| **Corn germ oil cake** | 18.9% | | | Poultry and pigs | 4.15 |
| **Scraps of spelt pasta** | 12.5% | | | Poultry and pigs | 4.16 |

## 4.1 Starfish

### 4.1.1 Description - nutrient specification

Starfish (Asterias rubens) are characterized by a crude protein concentration in the range of 38-70% and an ash concentration of 20-42% in dry matter depending on season. The highest concentration of crude protein and the lowest concentration of ash is found in February. The ash is not sand but a high concentration of calcium. The concentration of fat is 9-11% in dry matter and poly-unsaturated fatty acids are found (Holtegaard et al. 2008; Nørgaard et al., 2015; van der Heide et al., 2018b). The standardized ileal digestibility of crude protein in starfish meal is 0.80 in pigs (Nørgaard et al., 2015), and in layers the apparent digestibility of organic matter is 0.70 and nitrogen corrected apparent metabolisable energy (AMEn) is around 23 MJ/kg (Afrose et al., 2016).

### 4.1.2 Where to find

Since 2015, starfish have been caught in the Danish fjords and made into starfish meal used in aquaculture. It is allowed to harvest starfish in areas already used for shellfish production (European Commission, 2017). This warrants an appropriate quality of the seawater because this is under constant monitoring when mussels are being produced for human consumption. Starfish meal is commercially available although the tonnage is limited. In Denmark, a factory dedicated for processing starfish into meal is being built at Skive and is expected to run in early 2019.

### 4.1.3 Can be fed to

Two growth performance experiments have been conducted on starfish for pigs. The first showed that 5% but not 10% starfish meal could be fed to piglets, which were individually housed under experimental conditions (Sørensen & Nørgaard, 2016), and the second experiment confirmed that 5% but not 7.5% starfish meal could be fed to piglets housed under commercial conditions (van der Heide et al., 2018a). The reason for the maximum inclusion level is the high content of calcium, which limits the uptake and utilization of phosphorus (Sørensen & Nørgaard, 2016), and it is recommended to limit starfish meal inclusion according to the calcium recommendations.

A recent experiment with layers fed 4 or 8% starfish meal during 12 weeks (hen age 20–32 weeks) showed a production performance equal to feeding fish meal. Quality parameters of the egg such as weight of egg and yolk, yolk colour, and shell strength were also similar to eggs from layers fed fish meal (Afrose et al., 2016).

**Starfish** *Photo: Jan Værum Nørgaard*

#### 4.1.4 Can be used as supplement to or substitute for

In feeding experiments, starfish meal have been compared with fish meal, and this may be the most obvious feedstuff to be substituted by starfish meal. However, the content of crude protein will also contribute to a reduction in e.g. soybean cake.

#### 4.1.5 Anti-nutritional factors

Since starfish intended for feed should be caught in sea areas under strict quality control (European Commission, 2017), the content of heavy metals and toxins should not be a problem especially when included in diets at levels of 5-8%, which have been reported as optimal levels. The content of calcium have been shown to define the maximum inclusion level of starfish meal for piglets because too high calcium levels may reduce phosphorus blood plasma concentrations (Sørensen & Nørgaard, 2016).

#### 4.1.6 Sustainability

Starfish are predating on mussels, and this became a problem for the mussel industry, who found great populations of starfish. In 2013 the Danish authorities approved that starfish could be caught in certain areas with production of mussels in amounts corresponding to 3000 ton dry starfish meal per year.

#### 4.1.7 Competing with food

Starfish is not used for food for humans. However, when starfish are harvested more mussels will be available for humans.

#### 4.1.8 Supplementary issues on starfish for feed

Starfish caught from wild origin cannot be organically certified, but because they are not of agricultural origin, they can still be fed to organic animals like in the case of fishmeal. The use of starfish for livestock is not new. During the shortage of feedstuffs during and after World War II starfish were included in feed for livestock and a few experiments were carried out to document the effect in especially poultry. In the Danish fjords, starfish were caught as feedstuff until mid 1980s when the problems with TSE (transmissible spongiform encephalopathies) and the following restrictions of feeding fish to ruminants forced the fishing of starfish to cease.

In December 2016, starfish were approved by the EU Commission as a feed ingredient in diets for pigs and poultry. Starfish meal is categorized in a group along with fish. This is unfortunate because of restrictions in the TSE legislation, making it difficult for the feed industry to handle starfish meal because it cannot be located in connection with manufacture of feed for ruminants, although starfish are invertebrates and thus safe products.

***"Starfish meal can be used for both pigs and egg layers at the expense of fishmeal with similar production results.."***

#### 4.1.9 Conclusions on starfish

Starfish meal can be used for both pigs and egg layers at the expense of fishmeal with similar production results. The product is not organically certified but is allowed to be included because it is not of agricultural origin. Starfish meal is commercially available but only to a limited extent.

### 4.2 Mussels

#### 4.2.1 Description - nutrition specification

The mussel meal is characterised by a crude protein content of 58-66% in dry matter, a low mineral concentration, and for pigs and poultry, a balanced amino acid profile. The crude fat content of 12-16% in dry matter includes a relatively large amount of polyunsaturated fatty acids and especially the omega-3 fatty acids eicosapentaenoic (EPA) and docosahexaenoic (DHA) (Passi et al., 2002; Nørgaard et al., 2015). Mussels also contain carotenoids, such as β-carotene, lutein A, zeaxanthin, and xanthophyll like astaxanthin (Jönsson, 2009). The ileal digestibility of crude protein in pigs is 0.83 (Nørgaard et al., 2015). When fed at a 4% inclusion level to layers, mussel meal have an apparent digestibility of organic matter of 0.71 and an AMEn of 19.5 MJ/kg (Afrose et al., 2016). Furthermore, the blue mussels contain carotenoids and chlorophyll, as they are filter feeders and consume algae (Matsuno, 1989).

### 4.2.2 Where to find

Blue mussels can be grown on floating lines or nets where the naturally occurring mussel larvae colonize ropes or plastic tubes or nets from late spring. Mussels filter the seawater for algae and can be harvested year round and already from the first coming winter, preferable before the risk of ice coverage occurs. When mussels are harvested, they need to be processed to allow storage. The production of mussel meal in the Danish fjords is potentially 15.000 ton de-shelled dry mussel meal per year (Petersen et al., 2014).

### 4.2.3 Can be fed to

The effect of mussel meal on the production performance has been evaluated in a few animal studies. When feeding 4, 8 or 12% mussel meal to egg layers, mussel meal maintained the production performance of layers compared to fish meal. The yolk colour was greatly affected and became more red with increasing proportions of mussel meal. To avoid off-flavour in eggs, up to 8% mussel meal was concluded as being the maximum amount (Afrose et al., 2016). Layers fed 3, 5 or 7% mussel meal had no change in egg production parameters compared to fish meal, and 7% mussel meal increased yolk pigmentation (Jönsson et al., 2011). A third study on layers fed 3, 6, or 9% mussel meal replacing fish meal 1:1 showed increased yolk pigmentation with increased level of mussel meal, and 6% mussel meal performed better than 6% fish meal (Jönsson & Elwinger, 2009). In pigs, 5% mussel meal fed to pigs from 37 to 107 kg resulted in growth performance similar to a commercial diet (Wallenbeck et al., 2014). At Aarhus University in 2019, in collaboration with industrial partners, four experiments on mussel meal fed to layers and pigs will be carried out.

### 4.2.4. Can be used as supplement to or substitute for

A mussel meal without shells can be used to substitute fishmeal and other high-value protein sources, although a correction for lower crude protein content is needed. A mussel meal with full or partly reduced shell fraction may better replace fishmeal in diets for egg layers rather than pigs.

### 4.2.5 Anti-nutritional factors

The shell fraction will cause very high ash/mineral content and this is known to reduce digestibility of the diet as such but may also specifically reduce digestion and absorption of minerals though interaction mechanisms. Mussels should be cultivated or caught in sea areas under strict quality control (European Commission, 2017), and thus the content of heavy metals and toxins should not be a problem especially when included in diets at levels of 5-8%, which have been reported as optimal levels.

### 4.2.6 Sustainability

Placement of mussel farms should be in nutrient-rich water of a quality, which is good enough to meet the EU regulations for mussel farming. An experiment in a Danish inland fjord using a mussel farm on 18 hectare showed an annual production of 61 tons fresh mussels per hectare. The harvest of these mussels removed 600-900 kg N and 30-40 kg P per hectare of mussel farm (Petersen et al., 2014). When

*"An experiment in a Danish inland fjord using a mussel farm on 18 hectare showed an annual production of 61 tons fresh mussels per hectare. The harvest of these mussels removed 600-900 kg N and 30-40 kg P per hectare of mussel farm "."*

mussels are cultivated with the purpose to remove especially N and P from seawater, they are termed mitigation mussels, and are expected to play a major role in reducing eutrophication problems.

#### 4.2.7 Competing with food

Although blue mussels are considered a delicate food, the mussels intended for animal feed will not affect the market for human consumption. The reason is that mussels grown for environmental reasons are harvested at a growth stage where they are too small to be included in the commercial food production.

#### 4.2.8 Supplementary issues

Production facilities for blue mussels are existing but needs optimization to make an attractive business plan. However, experiences from Danish efforts in producing mitigation mussels indicate that it is possible. The current major challenge is to process the mussels. Shells should be removed or at least the fraction should be reduced in the mussel meal, and low-cost and high-throughput processing equipment needs to be developed.

#### 4.2.9 Conclusions

The published experiments points towards mussel meal being a good protein source, including important amino acids, and has a great potential in diets for especially organic (young) pigs and poultry where it can substitute fish meal. The yolk colour is positively affected. Finally, the production of mitigation mussels indicate great positive effects on the marine environment.

### 4.3 Seaweed

#### 4.3.1 Description - nutrition specification

The concentration of nutrients varies according to species. In Table 4.2 several species are listed, and it appears that one species, a red seaweed called Porphyra, contains 40% crude protein (Gaillard et al. 2018). Another, Sugar kelp, is a brown algae which is characterized by its containment of 14-38% ash in dry matter and a crude protein concentration of 7-13% in dry matter. The concentration of sodium, potassium and iodine is high (Tayyab et al., 2016). Sea lettuce is a green algae with typically more than 15% crude protein and an amino acid profile close to that of soy bean meal (Makkar et al., 2016; Ventura & Castañón, 1998). Sea lettuce has high concentrations of sulphur, calcium, magnesium, sodium, and chloride (Bikker et al.,016; Tayyab et al., 2016). Based on these key figures of nutrient content, it appears obvious that some seaweed species can be termed as protein sources, and they may provide important minerals and contain beneficial bioactive components.

#### 4.3.2 Where to find

Asia is producing 99% of the 25 million ton fresh seaweed, which is produced annually worldwide. In Europe, the greatest production is in Norway and France. European seaweed is often collected manually from natural habitats but can also be cultivated on farms by a laborious rope-based facility. The potential of seaweed production is very dependent on the quality of seawater, which should have high salinity, low temperature, and low nutrient concentration to allow clear water for sun light. These environmental conditions determine the annual production in the range from 3 to 30 ton fresh weight per hectare of seaweed farm (Nielsen, 2015).

#### 4.3.3 Can be fed to

Numerous experiments have shown health improving effects of feeding seaweed extracts at low dietary inclusion levels, because seaweed contain bioactive components displaying antimicrobial effects. Feeding experiments with intact seaweed appears to be lacking. In 2019 at Aarhus University an experiment on piglets and calves fed intact seaweed at 5% inclusion level is conducted. The content of the alginates, fucoidans and laminarins, and polyphenols in brown algae and the galactans and xylans in green algae displays some interesting bioactive properties, which can be utilized in maintaining good health status in livestock (Holdt & Kraan, 2011). It is therefore of great importance that the bioactive compounds are taken into account when processing seaweed into their final products.

#### 4.3.4 Can be used as supplement to or substitute for

There is a great variation among the seaweed species. Some seaweed can contribute to the protein supply to animals whereas others contain only little protein. The seaweed would probably not be included in diets with the aim of replacing the traditional protein sources, but rather as a supplement.

#### 4.3.5 Anti-nutritional factors

Seaweed often contain a high ash/mineral content, which is known to reduce digestibility of the organic matter, but the high mineral content may also specifically reduce digestion and absorption of minerals though interaction mechanisms. It is important to grow seaweed in good quality seawater because seaweeds tend to accumulate minerals including toxic heavy metals.

#### 4.3.6 Sustainability

Cultivation of seaweed in large scale on dedicated production facilities will have potential for important removal of nutrients from the sea. However, the location of those facilities should be in clear water, which is often less nutrient rich compared to the water ideal for mussel production.

#### 4.3.7 Competing with food

The current use of seaweed is primarily for human consumption, either as intact seaweed or as extracts. However, efforts are put into increased production efficiency and upscaling allowing production of larger tonnage. If seaweeds should have an environmental impact, they should be produced in large quantities which would probably exceed the marked for human consumption.

#### 4.3.8 Supplementary issues

None.

***"…for organic animals, seaweeds may be important to secure a high health status … in addition to supplying proteins and minerals"***

#### 4.3.9 Conclusions

Production of seaweed is currently mainly for human consumption because of high production costs. However, for organic animals, seaweeds may be important to secure a high health status and thus seaweed should also be acknowledged for it potential health promoting effects in addition to supplying proteins and minerals.

### 4.4 Green Protein

#### 4.4.1 Description - nutrition specification

Protein concentrate from grass, clover or fields with a mixture of clover and grass can be extracted by biorefining using screw pressing and extraction of proteins by centrifugation or filtering of the liquid fraction, which is either acidified by lactic acid or heat treated to precipitate proteins. Aarhus University has in collaboration with other Danish knowledge institutions and companies carried out several experiments, where feed value of protein extracted from legumes and grasses has been evaluated in ruminants and monogastrics. Several experiments are ongoing, and some results have been published in scientific papers and in a recent report from SEGES (Aarhus, Denmark).

In the experiments, the crude protein concentration of the extracted protein was 30-54% in dry matter, ash was approximately 8-15% and crude fat ranged from 6-14 %. The chemical composition is very dependent on harvest conditions (dry/wet weather, machinery) and input material (plant species, maturity, isolation of leaves). The content of the nutritionally important amino acids lysine and methionine were comparable to the values found in soy (Damborg et al, 2018; Fog et al 2019). The chemical composition for red clover and clover grass (Fog, E. et al 2019) is presented in Table 4.3.

### 4.4.2 Where to find

Despite the great awareness of green protein concentrate from legumes and grass, no commercial biorefinery is found. However, the development of the techniques for biorefinery is rapidly moving towards a commercial use. Future facilities could be on individual organic farms or larger facilities in co-operation among a group of organic farmers. The potential is greater if the biomasses from the green biorefinery can be allocated to ruminants fed the fibrous pulp fraction and the green protein concentrate to monogastrics like pigs and/or poultry.

**Table 4.2 Crude protein and amino acid composition of different seaweed species collected in spring and autumn** (Gaillard et al. 2018)

| Species | Season | CP (g/kgDM) | Ala | Arg | Asp | Cys | Glu | Gly | His | Ile | Leu | Lys | Met | Phe | Pro | Ser | Thr | Val |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | (g/16 g N) | | | | | | | | |
| *Cladophora* | Spring | 341 | 4.15 | 4.62 | 11.6 | 3.30 | 11.0 | 5.18 | 1.11 | 2.84 | 5.11 | 4.54 | 1.38 | 3.29 | 4.53 | 3.37 | 3.73 | 4.43 |
| | Autumn | 272 | 4.25 | 4.21 | 12.1 | 3.53 | 10.6 | 5.38 | 1.13 | 2.96 | 5.33 | 4.74 | 1.45 | 3.54 | 4.13 | 3.46 | 3.83 | 4.55 |
| *Alaria* | Spring | 164 | 11.0 | 4.18 | 9.83 | 1.43 | 13.1 | 4.73 | 1.36 | 3.70 | 6.21 | 4.57 | 1.92 | 4.02 | 3.51 | 4.31 | 4.11 | 5.03 |
| | Autumn | 115 | 14.2 | 1.91 | 6.40 | 1.93 | 31.6 | 2.79 | 0.97 | 1.67 | 2.65 | 3.23 | 0.87 | 2.03 | 1.68 | 3.05 | 2.89 | 2.98 |
| *Laminaria* | Spring | 157 | 9.96 | 3.11 | 8.10 | 2.01 | 9.84 | 3.81 | 1.02 | 2.81 | 4.70 | 3.49 | 1.21 | 3.14 | 3.13 | 3.40 | 3.50 | 3.95 |
| | Autumn | 80 | 7.57 | 3.79 | 11.5 | 3.01 | 12.1 | 4.97 | 1.49 | 3.61 | 6.12 | 4.63 | 1.66 | 4.07 | 3.97 | 4.56 | 4.65 | 5.15 |
| *Mastocarpus* | Spring | 180 | 4.35 | 5.93 | 8.60 | 2.60 | 8.02 | 6.60 | 1.60 | 2.89 | 4.51 | 5.77 | 1.27 | 3.82 | 3.68 | 4.25 | 3.62 | 4.15 |
| | Autumn | 164 | 4.27 | 5.67 | 8.22 | 2.53 | 7.87 | 6.16 | 1.56 | 2.87 | 4.46 | 5.61 | 1.27 | 4.01 | 3.62 | 4.29 | 3.52 | 4.10 |
| *Palmaria* | Spring | 265 | 6.57 | 4.96 | 9.92 | 3.08 | 11.0 | 5.59 | 1.21 | 3.41 | 5.41 | 5.26 | 1.55 | 3.71 | 6.76 | 4.60 | 4.03 | 5.26 |
| | Autumn | 149 | 6.11 | 4.83 | 10.7 | 3.44 | 12.4 | 5.38 | 1.27 | 3.41 | 5.42 | 4.75 | 1.54 | 3.76 | 4.45 | 4.65 | 3.83 | 5.34 |
| *Pelvetia* | Spring | 110 | 5.15 | 3.33 | 7.94 | 1.18 | 22.8 | 3.83 | 1.12 | 3.01 | 5.10 | 3.63 | 1.75 | 3.37 | 2.82 | 3.58 | 3.43 | 4.14 |
| | Autumn | 68 | 5.34 | 3.67 | 8.49 | 1.43 | 13.0 | 4.33 | 1.34 | 3.50 | 5.88 | 4.14 | 2.04 | 3.90 | 3.34 | 4.10 | 3.97 | 4.79 |
| *Porphyra* | Spring | 397 | 12.3 | 5.54 | 8.75 | 1.59 | 10.7 | 5.59 | 1.13 | 3.50 | 6.33 | 4.59 | 1.83 | 3.49 | 3.71 | 4.46 | 4.91 | 5.71 |
| | Autumn | 271 | 8.90 | 5.40 | 8.46 | 1.71 | 9.92 | 5.73 | 1.16 | 3.51 | 6.32 | 4.55 | 1.84 | 3.64 | 3.90 | 4.48 | 5.01 | 5.84 |
| *Saccharina* | Spring[a] | 145 | 8.63 | 3.70 | 8.86 | 1.93 | 10.6 | 4.51 | 0.99 | 3.34 | 5.66 | 4.02 | 1.45 | 3.61 | 3.88 | 3.91 | 4.21 | 4.64 |
| | Autumn | 82 | 8.83 | 3.11 | 10.1 | 2.28 | 21.4 | 4.33 | 1.20 | 2.97 | 5.18 | 3.85 | 1.58 | 3.47 | 3.14 | 3.98 | 4.28 | 4.74 |
| *Ulva* | Autumn | 122 | 8.25 | 5.10 | 12.2 | 1.84 | 11.5 | 5.86 | 1.36 | 4.07 | 6.97 | 4.37 | 2.13 | 5.02 | 4.78 | 4.92 | 5.54 | 6.30 |
| SEM | | 21 | 0.63 | 0.26 | 0.53 | 0.18[a] | 0.93 | 0.20 | 0.06 | 0.17 | 0.28 | 0.19 | 0.09 | 0.19 | 0.33 | 0.16 | 0.22 | 0.22 |
| P value | Specie | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 |
| | Season | < 0.01 | 0.30 | 0.02 | 0.37 | < 0.01 | < 0.01 | 0.38 | 0.04 | 0.21 | 0.19 | 0.67 | 0.69 | 1.00 | 0.02 | 0.29 | 0.63 | 0.87 |
| | S x S[b] | 0.22 | 0.01 | < 0.01 | < 0.01 | 0.24 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | < 0.01 | 0.01 | < 0.01 |
| | Year | 0.04 | 0.12 | 0.79 | 0.71 | < 0.01 | 0.66 | 0.25 | 0.01 | 0.65 | 0.47 | 0.68 | 0.04 | 0.28 | 0.12 | 0.13 | 0.30 | 0.72 |

[a]SEM for *Saccharina* Spring is 1.44 due to missing 2014 Spring sample.
[b]S × S: interaction between specie and season, AA: Amino acids.

### 4.4.3 Can be fed to

The green protein concentrate with origin from the liquid proportion of the screw-pressed green biomass may be appropriate for monogastrics such as finisher pigs, sows and layers. The proportion of other amino acids in relation to the lysine content (Fog et al., 2018) indicate a low lysine content compared to the nutrient requirements of pigs. For egg layers, clover-grass protein concentrate is calculated to provide more dietary methionine but less cysteine than what can be obtained from soybean cake (Fog et al., 2018). In the OrganoFinery 12% green protein concentrate was supplied to egg layers without compromising productivity. Furthermore, the yolk colour become more intense when fed the green protein concentrate. In the MultiPlant project (Stødkilde, 2018), broiler chickens had similar performance when 13% of the crude protein was provided by clover-grass protein concentrate (36% crude protein), but lower performance when this proportion was increased to 26%. It is estimated that more value can be created, i.e. a higher price of the green protein concentrate, when feeding poultry compared to pigs considering substitution of the traditional feedstuffs (Fog et al., 2018).

### 4.4.4 Can be used as supplement to or substitute for

The clover-grass protein concentrate should be used in combination with several other protein sources to compensate for the low lysine and cysteine concentration. For egg-layers, the inclusion of clover-grass protein concentrate is on the expense of soybean cake, soybeans, and to some degree fish meal (Fog et al., 2018).

### 4.4.5 Anti-nutritional factors

The efficiency of protein and fibre separation is important for the product quality. A high proportion of fibres will reduce the usability of clover-grass protein concentrate for especially younger pigs and chickens (Stødkilde et al, 2017).

### 4.4.6 Sustainability

Besides being a potential source of dietary protein, clover-grass has a low level of nitrogen leaching compared to other crops, and this aspect is a major driving force in developing and establishing the concept of biorefinery.

### 4.4.7 Competing with food

Production of green protein does not compete with food except land use for clover-grass production.

### 4.4.8 Supplementary issues

In an experiment where chickens were fed clover-grass protein concentrate (Stødkilde et al, 2019) the meat was enriched with the omega-3 fatty acid alpha-linolenic acid. This may be interesting in relation to human consumption of meat and egg from animals fed clover-grass protein concentrate.

### 4.4.9 Conclusions

Currently, there is no commercial biorefinery of clover-grass into green protein concentrate. However, there is a good will and a clear potential in establishing production facilities, and the positive effects on the environment is a main driver for research. The quality of green protein concentrate points towards use in diets for both organic pigs and poultry.

**Table 4.3. Tablized values of chemical composition of blue mussel, starfish, seaweed products and green protein concentrate products (g/kg dry matter)**

| | Mussel meal [1,2,3,4] | Starfish meal [1,5,6,7,8] | Sea lettuce meal [9,10,11] | Sugar kelp meal [10,11] | Red clover protein meal [12] | Clover grass protein meal [12] |
|---|---|---|---|---|---|---|
| Dry matter, % | 94.5 | 93.9 | 65.9 | 92.2 | | |
| Crude protein | 665 | 491 | 176 | 104 | 419 | 404 |
| Ash | 88 | 355 | 295 | | 97 | |
| Crude fat | 119 | 89 | 16 | | 69 | |
| NDF | 45 | | 274 | 166 | | |
| Calcium | 6.4 | 103.7 | 24.8 | 14.1 | | |
| Phosphorus | 10.2 | 13.3 | 2.1 | 3.5 | | |
| Sodium | 11.7 | 17.0 | 17 | 48.5 | | |
| Potassium | 21.2 | 9.6 | 14.9 | 88.3 | | |
| Magnesium | 1.8 | 5.0 | 20.5 | 39 | | |
| Chloride | 22 | 12.0 | 16.3 | 129 | | |
| Sulphur | 10.5 | | 50.5 | | | |
| Iron, mg | 340 | 492 | 800 | 117 | | |
| Cupper, mg | 6.5 | | 17 | 2 | | |
| Manganese, mg | 29.4 | 36.3 | 93.5 | 11 | | |
| Zinc, mg | 139 | 102 | 31 | 12 | | |
| Iodine, mg | | 7.6 | | | | |
| Selenium, mg | 2.7 | 1.9 | <100 | | | |
| Cysteine | 8.2 | 4.9 | 11 | 0.1 | 2.5 | 2.2 |
| Histidine | 12.2 | 8.5 | 3.7 | 0.4 | 9.4 | 9.1 |
| Isoleucine | 26.9 | 14.9 | 4.8 | 1.5 | 20.5 | 20.9 |
| Leucine | 41.7 | 28.3 | 9.7 | 3.7 | 32.8 | 34.3 |
| Lysine | 46.4 | 28.6 | 7.1 | 2.9 | 24.2 | 23.9 |
| Methionine | 15.2 | 10.6 | 3 | 1.4 | 7.5 | 8.2 |
| Phenylalanine | 23.3 | 17.1 | 6.7 | 2.3 | 22.9 | 23 |
| Threonine | 29.2 | 21.0 | 7.1 | 1.7 | 17.9 | 17.7 |
| Tryptophan | 7.3 | 4.7 | | | | |
| Tyrosine | 32 | 13.5 | 2.6 | 1 | | |
| Valine | 29 | 23.6 | 8.2 | 2.3 | 25 | 24.8 |

[1] Nørgaard et al., 2015; [2] Waldenstedt & Jönsson, 1998; [3] Jönsson et al., 2011; [4] Kyntäjä et al., 2014; [5] Holtegaard et al., 2008; [6] Sørensen & Nørgaard 2016; [7] van der Heide et al., 2018a; [8] van der Heide et al., 2018b; [9] Tayyab et al., 2016; [10] Makkar et al., 2016; [11] Jard et al., 2013; [12] Fog et al., 2018.

## 4.5 Acorn (Quercus spp.)

### 4.5.1 Description - nutrition specification

The acorn is the fruit of the *Quercus* trees. *Q. ilex* and *Q. suber* are, in turn, the most frequent in the areas of Mediterranean pasture, currently forming an agro-ecosystem in the Iberian peninsula called *dehesa,* with 3.5 and 1 million hectares in Spain and Portugal respectively, used for free grazing fattening pigs (a system called *montanera*). The density of trees in these areas is generally between 25 and 40 per hectare, and their annual production is estimated at 10-15 kg/tree, although it is highly variable depending on the climate, the age of the tree or its pruning. The acorn production is concentrated in the autumn-winter months. The composition of the acorns varies considerably from one genera of *Quercus* to others and throughout the *montanera* or mast period. As this period passes, the content in ether extract, sugars and starch increases, while the content of tannins decreases.

The decorticated green acorn contains around 40% moisture and its main components are starch (61%) and sugars (glucose and sucrose, 5.2%). It has an appreciable fibre content, quite lignified, as a result of which about 25% by weight of the fruit corresponds to the shell. The decorticated kernel contains 50% less fibre than the whole acorn. These animals can gain about 65 kg (from 100 to 165 kg of weight) in three months with a diet based on acorns and green grass. The acorns are deficient in protein with 5% content. Approximately one quarter is linked to the cell wall, which together with the presence of tannins reduces its digestibility in non-ruminant species. For nutritional content see Table 4.4.

**Table 4.4 Nutritional values for pigs - Values for Acorn - *Quercus ilex rotundifolia***

Chemical composition (%DM)

| Water content in fresh material | Ash | CP | EE* | Fat (%EE)** |
|---|---|---|---|---|
| 37.5 | 1.6 | 2.6 | 4.8 | 90 |

*EE: Ether Extract, Fat (%EE): Percent of fat in EE

| | CF | NDF | ADF | ADL | Starch | Carbohydrates |
|---|---|---|---|---|---|---|
| ∑***= 94.9 | 7.5 | 18.6 | 9.8 | 5.2 | 27.0 | 2.8 |

∑***=Humidity+Ash+CP+EE+NDF+Starch+Carbohydrates

| Fatty acids | $C_{16:0}$ | $C_{18:0}$ | $C_{18:1}$ | $C_{18:2}$ |
|---|---|---|---|---|
| % Fat | 15.0 | 3.0 | 62.0 | 16.0 |
| % Feedstuff | 0.65 | 0.13 | 2.68 | 0.69 |

Macrominerals (%DM)

| Ca | P | Na | Cl | Mg | K | S |
|---|---|---|---|---|---|---|
| 0.07 | 0.08 | 0.01 | 0.02 | 0.05 | 0.80 | 0.05 |

Protein value

| Digestibility coefficient of protein (%) Pigs: 73 | | |
|---|---|---|
| Composition | | |
| Amino Acids | (%PB) | (%) |
| Lys | 4.40 | 0.11 |
| Met | 2.00 | 0.05 |
| Met+Cys | 4.40 | 0.11 |
| Tre | 3.15 | 0.08 |
| Trp | 0.95 | 0.02 |
| Ile | 4.40 | 0.11 |
| Val | 4.75 | 0.12 |
| Arg | 6.00 | 0.16 |

### 4.5.2 Where to find

Dehesa or montando agro-ecosystem and Mediterranean forest in Southwestern Iberian Peninsula. There are other sub-species around the Mediterranean basin.

### 4.5.3 Can be fed to

Pigs, Iberian growing pigs peel the acorns, but that is not easy for piglets.

### 4.5.4 Can be used as supplement to or substitute for

Acorns can be used as the main feed for growers in the autumn and winter depending on availability.

### 4.5.5 Anti-nutritional factors

Part of the lignin content corresponds to tannins. The content of tannins, mostly hydrolyzable, is around 3% of the fresh acorn and its presence gives a bitter taste to the fruit, which does not affect the consumption since the Iberian pigs in *montanera* shell the seed previously to its ingestion.

### 4.5.6 Sustainability

It is a natural resource and free-range pig production contributes to the conservation of the dehesa and montado agro-ecosystem.

### 4.5.7 Competing with food

None

### 4.5.8 Supplementary issues

The composition is very variable attending to the different species of *Quercus* and the moment in the montanera period.

### 4.5.9 Conclusions

Iberian pig fattening system with free grazing of acorns is a traditional practice very close indeed to organic regulations. The system is comparable with agroforestry which is developing in northern Europe. The system cannot be copied as a protein supply system.

### 4.5.10 References

Fundación Española para el Desarrollo de la Nutrición Animal (FEDNA), 2018. Bellota de encina entera. Accessed February 13, 2019. http://www.fundacionfedna.org/ingredientes_para_piensos/bellota-de-encina-entera.

Rodriguez-Estevez, V., Sanchez-Rodriguez, M., Arce, C., Garcia, A.R., Perea, J.M., Gomez-Castro, A.G., 2012. Consumption of Acorns by Finishing Iberian Pigs and Their Function in the Conservation of the Dehesa Agroecosystem, Agroforestry for Biodiversity and Ecosystem Services, Martin Leckson Kaonga, IntechOpen, DOI: 10.5772/34877. Accessed February 13, 2019. https://www.intechopen.com/books/agroforestry-for-biodiversity-and-ecosystem-services-science-and-practice/consumption-of-acorns-by-finishing-iberian-pigs-and-their-function-in-the-conservation-of-the-dehesa.

## 4.6 Tomato silage

### 4.6.1 Description - nutrition specification

Tomato silage is made from residues from tomato production and from tomatoes with defects. Tomato silage can depending on the treatment be kept in optimal conditions for months. Tomato silage is humid and even the best silage needs to be mixed with any fodder or feed before applying to feeders.

The nutritional value and digestive performance of the tomato silage depends on how much straw, hay or other feed components in the mixture. For nutritional content, see Table 4.5.

**Table 4.5 Nutritional value of tomato pulp**

| | CP (%DM) | OM (%DM) | NDF (%DM) | ADF (%DM) | IVD (%DM) |
|---|---|---|---|---|---|
| **Tomato pulp*** | 18.78 | 90.2 | 46.43 | 39.92 | 55.59 |
| **Tomato pulp (85%) + Straw (15%)** | 5.76 | 90.41 | 75.08 | 48.44 | 40.94 |

Pulp*= single component silage without extra fibre source.

### 4.6.2 Where to find

Tomato industries or directly from agricultural fields.

### 4.6.3 Can be fed to

Pigs (except piglets).

### 4.6.4 Can be used as supplement to or substitute for

It depends on the actual nutrition content.

### 4.6.5 Anti-nutritional factors

None.

### 4.6.6 Sustainability

It is a recycled and easily treated by-product.

### 4.6.7 Competing with food

Tomato silage is as waste product that cannot be eaten by humans.

### 4.6.8 Supplementary issues

The conservation of the tomato silage is a hotspot, due to high content in humidity.

### 4.6.9 Conclusions

Once conservation problems of the tomato remains are solved with a good silage treatment, this can be kept in optimal conditions for months. The tomato silage is a good material to feed pigs as it has similar quality to lucerne hay.

The information used here originates from Spain and the references are in Spanish. It might be relevant in other tomato producing countries

#### 4.6.10 References

Álvarez, S., Méndez, P., Fresno, M. Ensilado de destrío de tomate para la alimentación caprina. Instituto Canario de Investigaciones Agrarias. Accessed February 13, 2019. https://www.icia.es/icia/GanAfrica/Ensilado_Tomate.pdf.

Barroso, F. G., Martínez, T. F., Megías, M. D., Martínez-Teruel, A., Madrid, M. J., & Hernández, F., 2008. El potencial del ensilado de tomate en la alimentación de pequeños ruminates. Albeitar, 115, 68-71. Accessed on February 13, 2019 https://www.researchgate.net/profile/Fg_Barroso/publication/28308767_El_potencial_del_ensilado_de_tomate_en_la_alimentacion_de_pequenos_rumiantes/links/5a1333e5aca27217b5a10909/El-potencial-del-ensilado-de-tomate-en-la-alimentacion-de-pequenos-rumiantes.pdf

## 4.7 Whey

### 4.7.1 Description - nutrition specification

Whey is the product obtained by the drying of the residue from the manufacture of cheese, curd, casein or similar processes. In these processes's, fat and casein are extracted by coagulation. Therefore, the serum contains lactose (63-70%), soluble proteins (10-12%, albumins and globulins) and ashes (8-12%).

Compared to cow's whey, sheep whey usually has a higher protein content (2 percentage units on average) and a lower ash content, while the lactose content is similar or slightly lower. Therefore, it contains slightly more energy and in total more amino acids but less calcium and phosphorus. If the process of conservation of the serum is not adequate, as it happens in small dairies, the microbial contamination is greater and part of the organic matter can undergo transformations that reduce its nutritional value. For nutritional content, see Table 4.6.

Sometimes, whey is used directly in the feeding of pigs with a complementary feed to balance the ration. In these cases, the increase in transport costs must be considered, given the high moisture content of this ingredient (93%), hygiene, bacteriological quality, high mineral content and acidity of the product.

Two types of whey are marketed: sweet and acid. The sweet whey comes from the manufacture of hard cheeses and are the most common in some countries (i.e., Spain). Acid whey is obtained from the manufacture of soft cheeses and fresh cheeses and as waste from the manufacture of casein (casein whey).

Its chemical composition is highly variable, due to its hygroscopicity (which depends on the manufacturing process and makes it difficult to handle it in the factory) and bacteriology. The best indicator of its conservation status is its acidity, and, above all, its concentration lactates, which should be less than 3%. Regarding the appearance, it should be observed absence of impurities, lumps and particles of different colour, especially black, which indicate an excessive treatment. The smell must be clean and the taste salty, depending on the minerals content.

**Table 4.6 Nutritional values - Whey**

Chemical composition (%DM)

| Water content in fresh material | Ash | CP | CP-NDF | Fat* (%EE) |
|---|---|---|---|---|
| 4.4 | 12.0 | 9.4 | 0.9 | 95 |

Fat* (%EE): Percent of fat in EE (Ether Extract)

| Fatty acids | $C_{14:0}$ | $C_{16:0}$ | $C_{16:1}$ | $C_{18:0}$ | $C_{18:1}$ | $C_{18:2}$ | $C_{18:3}$ | $C_{\geq 20}$ |
|---|---|---|---|---|---|---|---|---|
| % Fat | 23.8 | 27.5 | 3.1 | 10.6 | 26.4 | 3.2 | 1.0 | 2.0 |
| % Feedstuff | 0.20 | 0.24 | 0.03 | 0.09 | 0.23 | 0.03 | 0.01 | 0.02 |

Macrominerals (%DM)

| Ca | P | Na | Cl | Mg | K | S |
|---|---|---|---|---|---|---|
| 1.60 | 0.91 | 0.9 | 1.9 | 0.15 | 2.2 | 0.3 |

Energetic value (Mcal/kg DM)

| ME | DE | NE | NE sows |
|---|---|---|---|
| 31600 | 3205 | 2250 | 2250 |

Protein value

| Digestibility coefficient of protein (%) Pigs |
|---|
| 89 |

| | | | Pigs | | | |
|---|---|---|---|---|---|---|
| | Composition | | AID* | | SID** | |
| Amino acids | (%PB) | (%) | (%PB) | (%) | (%PB) | (%) |
| Lys | 7.44 | 0.70 | 87 | 0.61 | 90 | 0.63 |
| Met | 1.63 | 0.15 | 88 | 0.13 | 90 | 0.14 |
| Met+Cys | 3.52 | 0.33 | 81 | 0.27 | 90 | 0.30 |
| Tre | 5.72 | 0.54 | 82 | 0.44 | 89 | 0.48 |
| Trp | 1.31 | 0.12 | 84 | 0.10 | 88 | 0.11 |
| Ile | 5.67 | 0.53 | 82 | 0.44 | 89 | 0.47 |
| Val | 5.14 | 0.48 | 82 | 0.4 | 87 | 0.42 |
| Arg | 2.15 | 0.20 | 86 | 0.17 | 87 | 0.18 |

*AID: Apparent ileal digestibility
**SID: Standardized ileal digestibility

### 4.7.2 Where to find

Cheese factories.

### 4.7.3 Can be fed to

Pigs in general.

### 4.7.4 Can be used as supplement to or substitute for

It depends on the formulation of the ration.

### 4.7.5 Anti-nutritional factors

None, but salt level should be considered.
The excess of whey usually causes pasty stools and diarrhea in adult animals but it is not a pathological problem.
Whey can contain nitrites and biogenic amines, which is directly proportional to the degree of aging of the product.

### 4.7.6 Sustainability

Interesting low cost by-product that is produced in large quantities in Mediterranean countries and traditionally has been used to feed pigs.

### 4.7.7 Competing with food

None.

### 4.7.8 Supplementary issues

The composition is very variable attending to the process of obtaining or conservation. The excess of whey usually causes pasty stools and diarrhoea in adult animals.

### 4.7.9 Conclusions

Interesting low cost by-product when it is fresh and with moisture.

The information used here originate from Spain and the reference is in Spanish. It might be relevant in other cheese producing countries

### 4.7.10 References

Fundación Española para el Desarrollo de la Nutrición Animal (FEDNA), 2018. Lactosuero ácido. Accessed February 13, 2019.http://www.fundacionfedna.org/ingredientes_para_piensos/lactosuero-%C3%A1cido

## 4.8 Grape pomace - marc

### 4.8.1 Description - nutrition specification

The integral grape pomace is the by-product of wine making. The yield of the process is around 30 kg/100 l. It consists of a mixture of stalk, pulp and seeds in variable proportions (25, 55 and 20%, on average, respectively). Its characteristics vary considerably depending on the type of wine produced (red or white), the variety of grapes and the type of separation process used.

The grape pomace is characterized by a high content of cell wall components. An important part of its neutral deterged fibre (NDF) consists of acid deterged lignin (ADL), in which significant amounts of cutin and tannins are included. Lignin has no nutritional value for animals, and for grape pomace tannins are contained in lignin, which is an anti-nutritional factor.

The protein content of the grape by-products is in the order of 10%, being slightly higher in skins than in seeds. However, its digestive use is very low in all species, both due to the high proportion of protein bound to the cell wall (more than 50%), as well as the presence of tannins. Likely, the proportion of not degradable protein is relatively high.

The grape granules, and to a lesser degree the integral grape pomace, have an appreciable ethereal extract content (11 and 6%, respectively). Polyunsaturated fatty acids predominate the fat content and this is easily goes rancid.

The ash content is higher in skin than in seeds (6.8 vs. 3.2%). All feeds in this group are poor in phosphorus, sodium, chlorine and magnesium. Some items may contain high levels of Cu (up to 150 mg/kg) depending on crop conditions.

Overall, the nutritional value of the ingredients of this group is low. These also have a problem of lack of classification that hinders their nutritional assessment. For nutritional content, see Table 4.7.

*Photo: From the Core Organic Cofound project, BioVine*

**Table 4.7 Nutritional values for pigs - Grape pomace - marc**

Chemical composition (%DM)

| Water content in fresh material | Ash | CP | EE | Fat (%EE) |
|---|---|---|---|---|
| 8.2 | 5.8 | 11.2 | 10 | 95 |

Fat* (%EE): Percent of fat in EE (Ether Extract)

| | CF | NDF | ADF | ADL | Starch | Carbohydrates |
|---|---|---|---|---|---|---|
| ∑**= 92.8 | 32.5 | 57.1 | 50.5 | 31.5 | 0.0 | 3.0 |

∑**=Humidity+Ash+CP+EE+NDF+Starch+Carbohydrates

| Fatty acids | $C_{16:0}$ | $C_{18:0}$ | $C_{18:1}$ | $C_{18:2}$ |
|---|---|---|---|---|
| % Fat | 7.5 | 4.0 | 19.0 | 67.5 |
| % Feedstuff | 0.53 | 0.29 | 1.35 | 4.81 |

Macrominerals (%DM)

| Ca | P | Na | Cl | Mg | K | S |
|---|---|---|---|---|---|---|
| 0.7 | 0.15 | 0.05 | 0.01 | 0.10 | 1.13 | 0.33 |

Energetic value (Mcal/kg DM)

| ME | DE | NE | NE sows |
|---|---|---|---|
| 950 | 860 | 490 | 580 |

Protein value

| Digestibility coefficient of protein (%) Pigs |
|---|
| 15 |

| | Composition | |
|---|---|---|
| Amino Acids | (%PB) | (%) |
| Lys | 4.07 | 0.46 |
| Met | 1.52 | 0.17 |
| Met+Cys | 3.10 | 0.35 |
| Tre | 2.79 | 0.31 |
| Trp | 0.67 | 0.08 |
| Ile | 4.37 | 0.49 |
| Val | 7.90 | 0.88 |
| Arg | | |

### 4.8.2 Where to find

Wine industry.

### 4.8.3 Can be fed to

Pigs (except piglets).

### 4.8.4 Can be used as supplement to or substitute for

It depends on the formulation of the ration.

### 4.8.5 Anti-nutritional factors

Tannins and cutin. The concentration of tannins can exceed 5%; these are mainly condensed, so these can be linked to the proteins in the diet and prevent their digestion. The proportions of hemicellulose and cellulose are relatively low (6-8 and 16-19%, respectively).

### 4.8.6 Sustainability

Highly sustainable, it involves the use of a waste as a by-product.

### 4.8.7 Competing with food

None.

### 4.8.8 Supplementary issues

None.

### 4.8.9 Conclusions

Interesting low cost by-product that is produced in large quantities in Mediterranean countries and traditionally has been used to feed pigs.

The information used here originates from Spain and the reference is in Spanish. It might be relevant in other wine producing countries.

### 4.8.10 References

Fundación Española para el Desarrollo de la Nutrición Animal (FEDNA), 2018. Orujo de uva. Accessed February 13, 2019. http://www.fundacionfedna.org/ingredientes_para_piensos/orujo-de-uva

## 4.9 Olive pomace - marc

### 4.9.1 Description - nutrition specification

**Olive pomace** *Photo: Vicente Rodríguez-Estévez*

The olive pomace is a by-product resulting from the extraction of oil from the olive, formed by pulp, skin and bone. It is an inhomogeneous product; its quality depends on the oil and residual water it contains, and on the proportion of the fractions mentioned below (Table 4.8).

By-product with 38% dry matter content, with a low crude protein content (7-8%), an ethereal extract of 10% with a high oleic content, and an ash content of 5%. It is a fibrous product with 55% neutral detergent fibre and 45% acid detergent fibre. The lignin content is very high (17%).

The energy value is low due to the high fibre content and its level of lignification, although the fat content compensates in part for its low digestibility. The protein value is also low, and low intestinal digestibility.

**Table 4.8 Nutritional values for pigs - Olive pomace - marc**

Chemical composition (%DM)

| Humidity | Ash | CP | EE |
|---|---|---|---|
| 61.8 | 4.84 | 7.5 | 10 |

| CF | NDF | ADF | ADL | NFC | Starch |
|---|---|---|---|---|---|
| 32.8 | 55.4 | 44.6 | 17.1 | 22.8 | 4.27 |

| Fatty acids | $C_{16:0}$ | $C_{16:1}$ | $C_{18:0}$ | $C_{18:1}$ | $C_{18:2}$ | $C_{18:3}$ | $C_{\geq 20}$ |
|---|---|---|---|---|---|---|---|
| % Fat | 12.6 | 1.1 | 2.8 | 68.3 | 13.4 | 1.2 | 1.6 |
| % Feedstuff | 1.26 | 0.11 | 0.28 | 6.83 | 1.34 | 0.12 | 0.16 |

Macrominerals (%DM)

| Ca | P |
|---|---|
| 0.29 | 0.24 |

### 4.9.2 Where to find

Olive oil industry.

### 4.9.3 Can be fed to

Pigs (except piglets).

### 4.9.4 Can be used as supplement to or substitute for

It depends on the formulation of the ration.

### 4.9.5 Anti-nutritional factors

None, but high fibre and lignin content. The nutritional value depends on the percentage included of pulp, skin and bone.

### 4.9.6 Sustainability

Highly sustainable, it involves the use of a waste as a by-product.

#### 4.9.7 Competing with food

None.

#### 4.9.8 Supplementary issues

#### 4.9.9 Conclusions

Interesting low cost by-product that is produced in large quantities in Mediterranean countries and traditionally has been used to feed pigs.

The information used here originate from Spain and the reference is in Spanish. It might be relevant in other olive growing countries

#### 4.9.10 References

Fundación Española para el Desarrollo de la Nutrición Animal (FEDNA), 2018. Orujo de aceituna. Accessed February 13, 2019. http://www.fundacionfedna.org/subproductos_fibrosos_humedos/orujo-de-aceituna.

### 4.10 Waste from soy beverage process

#### 4.10.1 Description - nutrient specification

The soy beverage production process is composed by several steps: 20% of seeds are cooked (85-90°C), and 80% water is used; after they are milled (85-90°C). The output of this process passes in a decanter or in a centrifugal separator, and the soy beverage is separated from the waste. Waste residual is rich in protein 33%, fibre 50%, and lipids 10%. In order to increase the stability of the waste product and in order to use it as feedstuff in animal nutrition, it is recommended to dry waste residual. (Harthan & Cherney, 2017).

#### 4.10.2 Where to find

Vegetable beverage factories.

#### 4.10.3 Can be fed to

Poultry and pigs.

#### 4.10.4 Can be used as supplement to or substitute for

In order to reduce the dependence from soy and pea protein, waste from beverage soy process, can be used as a cheap protein source.

#### 4.10.5 Anti-nutritional factors

None.

#### 4.10.6 Sustainability

Using waste from beverage soy process (food industry scraps), as feed source for animals, can contribute to reduce the dependence from global seeds markets and makes the process more sustainable.

### 4.10.7 Competing with food

The current use of waste residual from beverage soy process, named Okara, is in human consumption. In fact it is a suitable dietary additive in biscuits and snacks because it reduces calorie intake and increases dietary fibre.

### 4.10.8 Supplementary issues for feed

None.

### 4.10.9 Conclusions

The human consumption of soy beverage increase. Waste residual of this process can increase in value and become a cheap protein source for animal nutrition; at the same time, it makes the food industry more profitability.

## 4.11 Waste from rice beverage process

### 4.11.1 Description - nutrient specification

The rice beverage production process is composed by several steps: 12-15% of rice meal is cooked (85-100°C for 30-40 minutes), and 85-88% water is used; after Amylase is added at 45-65°C for 7-12 hours. The output of this process passes in a centrifugal separator, and the rice beverage is separates from the waste (4-5%). Waste residual has a high protein percentage 63%.

### 4.11.2 Where to find

Vegetable beverage factories.

### 4.11.3 Can be fed to

Poultry and pigs.

### 4.11.4 Can be used as supplement to or substitute for

In order to reduce the dependence from soy and pea protein, waste from rice beverage process can be used as a cheap protein source.

### 4.11.5 Anti-nutritional factors

None.

### 4.11.6 Sustainability

Using waste from rice beverage process (food industry scraps) as feed source for animals, can contribute to reduce the dependence from global seeds markets and make the process of rice beverage more sustainable.

### 4.11.7 Competing with food

None.

### 4.11.8 Supplementary issues for feed

None.

#### 4.11.9 Conclusions

The human consumption of rice beverage increase. Waste residual of this process can increases in value and become a cheap protein source for animal nutrition; at the same time, it makes the food industry more profitable.

### 4.12 Waste from oats beverage process

#### 4.12.1 Description - nutrient specification

The production process is similar to the soy beverage process. Oats is mixed with water and after that milled. The output is added with enzymes that break the oat starch in to smaller components. After that, a separation process, to obtain the oat beverage, removes bran. Bran removed by the separator is rich in protein 31%, and can be used as a feedstuff for animals.

#### 4.12.2 Where to find

Vegetable beverage factories.

#### 4.12.3 Can be fed to

Poultry and pigs.

#### 4.12.4 Can be used as supplement to or substitute for

In order to reduce the dependence from soy and pea protein, waste from oat beverage process, can be used as a cheap protein source.

#### 4.12.5 Anti-nutritional factors

None.

#### 4.12.6 Sustainability

Using waste from oat beverage process (food industry scraps) as feed source for animals, can contribute to reduce the dependence from global seeds markets and make the process more sustainable.

#### 4.12.7 Competing with food

None.

#### 4.12.8 Supplementary issues

None.

#### 4.12.9 Conclusions

The human consumption of oat beverage increase. Waste residual of this process can increase in value and become a cheap protein source for animal nutrition; at the same time, it makes the food industry more profitable.

## 4.13 Soy bean cake

### 4.13.1 Description - nutrient specification

Soy oil cake is a waste product of the soy de-oiling process. Soy oil cake can be very useful in animal nutrition as a protein source (Table 4.9). The soy cake can derived from three different process: a cold pressing process, a pre-toasting process, or a pre-extrusion process.

All three techniques have several advantages like:

i. balance between protein and essential amino-acids rich in lecithin, phospholipids, vit. E
ii. higher protein and amino acid absorption
iii. Inactivation of antigrowth factor (anti-urease)
iv. Increase protein digestibility
v. Cake more solid, Physically, more resistant to the breakup. Regards the pre toasting process and the pre-extrusion
vi. Inactivation of bacteria, virus, yeast, mould
vii. Water loss around 50%
viii. Inactivation of enzyme which modify nutritional properties
ix. Higher starch availability and digestibility

**Table 4.9. Soy bean cake composition**

| Soy bean cake composition | |
|---|---|
| Dry matter | 93.2% |
| Crude Protein | 44% |
| Crude fibre | 6% |
| Ash | 6% |
| Crude fat | 9% |
| N.D.F. | 12,7% |
| A.D.F. | 7,5% |
| Lignin | 0,7% |
| Starch | 4,6% |
| Total sugar | 8,7% |
| Gross energy (Kcal/Kg) | 4700 |
| Gross energy MJ/Kcal | 19,7 |
| Phosphorus (P) | 6,5 g/kg |
| Calcium (Ca) | 3,4 g/kg |
| Lysine | 27,3 g/Kg |
| Methionine | 6,3 g/Kg |
| Tryptophan | 5,9 g/Kg |
| Energy metabolisable (ME) adult pig: | 3900 Kcal/Kg |
| Energy metabolisable (ME) adult pig | 16,3 MJ |

Reference: Accessed February 14, 2019.
https://feedtables.com/content/soybean-meal-oil-5-20

#### 4.13.2 Where to find

Oil mills.

#### 4.13.3 Can be fed to

Poultry and pigs.

#### 4.13.4 Can be used as supplement to or substitute for

In order to reduce the dependence from soy meal and pea protein.

#### 4.13.5 Anti-nutritional factors

None.

#### 4.13.6 Sustainability

The cake can feed animals with food scraps in order to reduce the competition with human soy consumption.

#### 4.13.7 Competing with food

None.

#### 4.13.8 Supplementary issues for feed

None.

#### 4.13.9 Conclusions

Soy oil has an important market all around the world, and the cake production is significant. They are rich in protein, with low humidity percentage and can be a cheap protein source for farmers.

### 4.14 Sunflower cake

#### 4.14.1 Description - nutrient specification

The sunflower de-oiling process has as a waste cake. This one can be very useful in animal nutrition as a protein source (Table 4.10); in fact, it has an amino acid availability similar to those of soybean. Its lysine content is relatively low. The sunflower cake can derived from three different extraction process: a cold pressing process, a pre-toasting process, or a pre-extrusion process.

*Photo: Colourbox*

**Table 4.10. Sunflower cake composition**

| Sunflower cake composition | |
|---|---|
| Dry matter | 93,8% |
| Crude Protein | 33,7% |
| Crude fibre | 18,5% |
| Crude fat | 8% |
| Ash | 6% |
| N.D.F. | 32,7% |
| A.D.F. | 21,8% |
| Lignin | 7% |
| Starch | 3,5% |
| Total sugars | 6,9% |
| Gross energy Kcal/Kg | 4690 |
| Gross energy (MJ/Kg) | 19,6 |
| Calcium | 3,9g/Kg |
| Phosphorous | 9,9g/Kg |
| Energy metabolisable (ME) adult pig | 2990 Kcal/Kg |
| Energy metabolisable (ME) adult pig | 11,7 MJ |

Reference: Accessed on February 14, 2019.
https://feedtables.com/content/sunflower-meal-oil-5-20-dehulled

### 4.14.2 Where to find

Oil mills.

### 4.14.3 Can be fed to

Layers, broilers and pigs. It can replace 50–100% of soybean, depending on the type of diet and the nature of the other ingredients.

### 4.14.4 Can be used as supplement to or substitute for

In order to reduce the dependence from soy meal and pea protein.

### 4.14.5 Anti-nutritional factors

None.

### 4.14.6 Sustainability

The cake can feed animals with food scraps in order to reduce the competition with human soy consumption.

### 4.14.7 Competing with food

None.

#### 4.14.8 Supplementary issues for feed

None.

#### 4.14.9 Conclusions

Sunflower oil has an important market all around the world, and the cake production is significant. The cakes are rich in protein, with low humidity percentage and can be a cheap protein source for farmers especially in country where soy cannot be produced.

### 4.15 Corn germ oil cake

#### 4.15.1 Description - nutrient specification

The de-oiling corn germ process has as a waste corn germ cake. Corn seeds have to rest 30 hours in warm water (50°C), and after that the separation between germ and seed is available. The dried germ is now pressed to obtain corn germ oil, and as a residual product the cake with high protein 20% (Table 4.11).

**Table 4.11. Corn germ cake composition**

| Corn germ cake composition | |
|---|---|
| Dry matter | 87.8% |
| Crude protein | 18.9% |
| Crude fibre | 7,9% |
| Crude fat | 2,5% |
| Ash | 5,7% |
| N.D.F. | 35% |
| A.D.F. | 9,3% |
| Lignin | 1,1% |
| Starch | 18% |
| Total sugar | 1,7% |
| Gross energy Kcal/Kg | 3930 |
| Gross energy MJ | 16,4 |
| Calcium | 1,4 g/Kg |
| Phosphorus | 8,6 g/Kg |
| Energy metabolisable (ME) adult pig | 2730 Kcal |
| Energy metabolisable (ME) adult pig | 11,4 MJ |

Reference: Accessed February 14, 2019
https://feedtables.com/content/corn-gluten-feed

#### 4.15.2 Where to find

Oil mills

### 4.15.3 Can be fed to

Poultry and pigs

### 4.15.4 Can be used as supplement to or substitute for

In order to reduce the dependence from corn, soy meal and pea protein.

### 4.15.5 Anti-nutritional factors

None.

### 4.15.6 Sustainability

The corn germ cake can feed animals with food scraps in order to reduce the competition with human soy and corn consumption.

### 4.15.7 Competing with food

None.

### 4.15.8 Supplementary issues

None.

### 4.15.9 Conclusions

Corn oil has an important market all around the world, and the cake production is significant. The cakes are rich in protein and starch with low humidity percentage and can be a cheap protein and energy source for farmers.

## 4.16 Scraps of spelt pasta

### 4.16.1 Description - nutrient specification

All scraps that comes from pasta production process can be an interesting source for animal feed. Especially they can be a cheap source of energy and carbohydrates (Table 4.12).

**Table 4.12. Scraps spelt pasta composition per 100 g**

| Scraps spelt pasta composition (per 100 g) | |
|---|---|
| Protein | 12,5 grams |
| Fat | 2 grams |
| Saturates | 0,3 grams |
| Carbohydrate | 68 grams |
| Sugar | 2,5 grams |
| Energy | 350 kcal |

#### 4.16.2 Where to find

Pasta factory.

#### 4.16.3 Can be fed to

Poultry and pigs.

#### 4.16.4 Can be used as supplement to or substitute for

Corn and wheat.

#### 4.16.5 Anti-nutritional factors

None.

#### 4.16.6 Sustainability

In order to reduce the competition with human corn and wheat consumption; scraps of spelt from pasta production process can feed the animals.

#### 4.16.7 Competing with food

None.

#### 4.16.8 Supplementary issues for feed

None.

#### 4.16.9 Conclusions

Scraps of spelt from pasta production process are a cheap source in energy and carbohydrates for farmers. The scraps can reduce the feed cost depending on corn and wheat market prices.

# 5. Small-scale on-farm processing technique (toasting, de-oiling)

## 5.1 Toasting legumes

Toasting is a heating process, which at the right temperature can make amino acid more available.

Usually there are two toasting method:

1. Dry heat: in this case heat will be transferred by conduction, convection or radiation and the temperature will be around 200°C. This process reduces the protein degradability, and increases the protein digestibility within a significant availability of essential amino acids (ex. Lysine). If the toasting last too long, the Maillard reaction might occur resulting in formation of D-amino acids complexes (low availability within high temperature and pH), and a significant reduction of amino acids digestibility.
2. Steam: usually used after oil extraction from oil seeds.

## 5.2 De-oiling organic soybean

Usually there are three soybean de-oiling processes:

1. Cold pressing: the first step consists in cleaning seeds; after that they are cracked at environmental temperature. The output is pressed without adding artificial heat. All heat come from the pressing process. Last step is natural filtering of oil, and the de-oiled cake can be used as protein source in animal nutrition. This kind of cake has several advantages like:
    a. balance between protein and essential amino-acids rich in lecithin, phospholipids and vitamin E.
    b. Higher protein and amino acid absorption
2. Pre-toasting, pressing: the first step consists in cleaning seeds; after that seeds are toasted at 70°C to achieve 4% humidity. Seeds are cracked and after they are pressed in 2 minutes maximum. Last step is natural oil filtration, and the de-oiled cake can be used as protein source in animal nutrition. This kind of process has several advantages like:
    a. Inactivation of antigrowth factor (anti-urease).
    b. Decrease protein degradability.
    c. Increase protein digestibility.
    d. Cake more solid.
    e. Inactivation of bacteria, virus, yeast and mould.
    f. Water loss around 50%.
    g. Inactivation of enzyme which modify nutritional properties.
3. Pre-extrusion, pressing: the first step consists in cleaning seeds; after that they are cooked with steam, 50-60°C and 25-30% humidity. Seeds are cracked and pressed. The rest of de-oiling process can be dried at 180°C for 10-20 seconds and after that, expanded with 12% more water loss. This kind of process decreases protein degradability, and increase protein digestibility. Furthermore, this process made starch gelatinized, with higher starch availability and digestibility.

### 5.3 Dried roughage

Dried roughage is an interesting feedstuff for animal nutrition. Roughage is cut with high humidity from 25-35% to > 50%). The roughage can be pre dried in the field to reduce water percentage, and hereafter send to the drying plant, or it can go directly to the drying plant. In the drying process, roughage is treated with warm air (200-900°C) for 15 minutes up to 2 hours. At the end of this process, roughage could be packaged in a cube (long fibre), or milled to make pellets. Usually different combinations of temperature and time of treatment are available.

- Dehydration at low temperature: 130°C-200°C for 40-120 minutes, this kind of process could work for small system.
- Dehydration at high temperature: 800-900°C for a few minutes with continuously movement of roughage.

There are several advantages in dehydration process:

- Roughage cutting period is more flexible
- Less risk due to weather
- Roughage safety
- Inactivation of anti-nutritional factors
- More roughage stability due to less water percentage
- Less risk due to moulds and mycotoxins

However in dehydration process there are some disadvantage:

- Protein denaturation due to high temperature during the process
- Microbiological sterilization
- Final product too fragile
- Less palatability
- Colour modification

## 5.4 Fermented roughage – silage

The production of silage has increased over the past years, while the production of hay has decreased substantially. Silage is a technique for preservation of fresh forage crops by acidification, which is achieved under anaerobic environment and the production of lactic acid bacteria. The fermentation enables high nutritional value and good hygienic quality of forage and an “all-year-round” feed, which is important in terms of quality and economy of animal products. After harvest, the fresh green biomass is pre-dried in the field to approximately 35% dry matter (DM) content. The ensiling then starts when air is excluded, for example when the grass is filled in silos or wrapped in plastic film (large round bales baled).

## 5.5 Separation of fibre from protein

Alfalfa has a better amino acid profile for feed than soya, but alfalfa is not commonly used for monogastrics because alfalfa contains too much fibre in proportion to protein and is therefore not advantageous from a performance point of view. Alfalfa also contains a lot of water, which is inconvenient compared to soya seeds. Alfalfa can be grown locally in Europe and therefore attractive as protein source for monogastics if the protein can be separated from the fibres.

An on-site technic called the Massai concept is capable of doing this separation. The process allows the alfalfa harvest to be transformed into two products. One is high in protein, which can be mixed with monogastric feed and another which is high in fibre and suitable for ruminant animal feed or can be used as biomass.

The Massai- concept is patented and the owner estimates that under normal to good crop conditions, one hectare of alfalfa using his Massaï process yields approximatively the same quantity as that contained in one ton of cold pressed soybean cake. The massai- concept is a part of an ongoing (2018-2021) Core Organic Cofund project „ProRefine”.

## 5.6 Processing starfish, mussels, seaweed

Mussels, starfish and seaweed need to be processed before they can be stored. Production into dry meal is a well-known preserving method, but also making the products into acidic silage may be interesting. There are, however, great challenges.

> ***“…there may be a potential use of a shell-containing mussel product for poultry.”***

Starfish and seaweed are fairly simple to dry when using existing industrial technologies. Drying and grinding starfish at a fishmeal factory is a well-known process to produce starfish meal. The blue mussels are more difficult to handle because of the shells. When used for pig feed, the meat should be separated from the shell fraction, but there may be a potential use of a shell-containing mussel product for poultry. Removal of shells can efficiently be done by boiling, which is a well-known process in mussels for human consumption. In the boiling process, there is risk of losing both protein and lipids. Other processing methods to remove shells can be based on physical separation by e.g. sedimentation of crushed fresh mussels or screw pressing of the fresh mussels, enzymatic processes, or by dry fractionation. In Sweden, work on processing blue mussels into meal has resulted in a patent on separation of meat and shells by a temperature-mediated hydrolysis (Lindahl, 2013).

An alternative to a dry mussel meal product can be a wet silage product stabilized by organic acids, as also known from salmon-based products (Nørgaard et al., 2012). Experiences from drying starfish shows that the product is sensitive to temperature and the starfish meal becomes very dark at too high temperatures indicating Maillard reactions, in which especially lysine becomes unavailable to the animal. Addition of organic acids to the fresh and minced mussels and a following stirring process results in a silage with a partly hydrolysis of the protein fraction into free amino acids and peptides. This has in blue mussels increased the standardized ileal digestibility of crude protein to 0.86 in mussel silage compared to 0.83 in mussel meal (Nørgaard et al., 2015). Starfish are not suitable for acid hydrolysis because of their high content of calcium carbonate. Making silage by lactic acid bacteria fermentation may result in positive effects on the composition of gut microbiota. Seaweed is relatively easy to ferment because of its high concentration of carbohydrates. The fermentation of intact sugar kelp into pig feed, has been commercialized by the Danish company Fermentation Experts.

***"The Maillard reaction a chemical reaction between amino acids and reducing sugars that gives browned food its distinctive flavour. Wikipidia 1.2.19"***

Starfish are easy to handle at fish meal factories, but it may be difficult to process starfish at such facilities because of low tonnage and a fishing season overlapping with the traditional fishery. Therefore, alternative processing methods may be relevant. It appears, however, that the physical characteristics of starfish makes them difficult to handle, when they are minced using a screw press, which would otherwise produce a protein rich liquid fraction for use in e.g. liquid pig feeding and a dry pulp fraction to be used as e.g. fertilizer.

# 6. Feeding strategies, management how to provide feedstuff

When formulating feeding strategies for organic pigs and poultry it is important to take into account the characteristics of organic farming, e.g. animals must have access to roughage and outdoor areas, and to consider these characteristics as important factors when meeting the animals' nutritional requirements with 100% organic and regionally produced feed.

## 6.1 Pigs - Roughage as feed

Ley crops such as grass and legumes can contribute as energy and nutrient source as well as play an important role for improved animal welfare by increased possibilities for feed related and explorative behaviours (Olsen et al., 2000; Høøk Presto et al., 2009). One "on-farm" applicable way to feed pigs grass and legumes is for example feeding them silage however, pigs' consumption level of silage varies according to which crop is used, nutrient properties and feeding technique. Further, the form of the silage (i.e. intact, chopped etc.) will influence pigs' consumption level (Rundgren 1988; Wallenbeck et al., 2014; Presto Åkerfeldt, Pers. Comm.). According to Wallenbeck et al. (2014), pigs fed diets with 20 % grass/clover silage inclusion level (energy basis) performed similarly to pigs fed a 100 % cereal-based diet, however, the form in which the silage was fed affected the ability of the pigs to consume the silage. Dried, ground grass/clover

**Feeding roughage** *Photo: Maria Eskildsen* fed mixed with cereal based feed in pelleted form gave higher pig performance than chopped silage mixed with cereals in a total mixed ration (TMR) and intact silage fed in silage racks. Pelleted feed has the potential to be fed in modern automatic feeding systems, but in organic production, pigs must be fed roughage to meet their behavioural needs, which makes inclusion of roughage meal in the diet a less desirable option. Findings from Presto Åkerfeldt (Pers. Comm.) indicates that the total mixed ratio (TMR) where silage, with an even finer structure than chopped, has been mixed with the other feed ingredients is well consumed by growing pigs and has a potential for on-farm application.

***"…provision of silage in an environment enriched with straw can further improve pig welfare."***

Several studies support that social behaviour and time budgets of growing and finishing pigs are affected when silage is a part of the feed. The behaviour of 128 pigs was observed through video recordings. Pigs fed intact or chopped silage spend a larger proportion of their time active, compared with pigs fed silage in pelleted form or fed only cereal-based feed and with lower amount of social interactions and lower number of wounds from violent social interactions on their bodies, as e result. Additionally, the results from Presto Åkerfeldt (Pers. Comm.) supports that silage, although the finer structure and fed as TMR, had positive effects on pig behaviour. Thus, additional provision of silage in an environment enriched with straw can further improve pig welfare (Presto et al, 2013).

## 6.2 Pigs - Direct foraging in outdoor area

Although the majority of organic pigs in the EU are reared in housing systems with access to outdoor runs, *free-range* production represents an important part of organic practice in several countries e.g. in Denmark, Sweden and UK. To reduce the risk of nutrient leaching from free-ranged pigs it is important to limit the animal density in these systems. Consequently, free-ranged pigs 'occupy' relative large outdoor areas with a potential high availability of biomass to forage directly.

In intensive free-range systems, the most common forage crops are grasses (mainly ryegrass) or a mixture of grasses and clover. In terms of crude protein content, grass clover is indeed an interesting foraging crop especially in early growth stages (Table 6.1). However, the characteristic rooting behaviour of the pig may rapidly destroy the pasture unless the pigs are snout-ringed, which on the other hand raises animal welfare concerns and conflicts with the organic principles. In comparison, another protein-rich forage crop for grazing, Lucerne, is more robust towards the pigs' rooting behaviour due to its deep root system if well-established (Jakobsen et al., 2015). When considering biomass actually available for foraging, below ground crops like Jerusalem Artichokes tubers and sugar beet roots become interesting, also due to potential very large crop yields (Table 6.1). Finally, soil invertebrates, e.g. earthworms in permanent pasture areas, represent a potential contribution to the nutritional needs of pigs (Table 6.1).

**Table 6.1** Dry matter (DM) and crude protein (CP) contents in various pig forage crops and crop availability

| | Grass (Ryegrass) | Grass clover | Lucerne | Jerusalem artichokes | Sugar beet roots | Carrots | Chicory roots | Earth-worms |
|---|---|---|---|---|---|---|---|---|
| DM, % | 22,3-34 | 12,2-32 | 18-25 | 17,2-25,8 | 17,7-24 | 10-15 | 24,2 | 27 |
| CP, g kg DM$^{-1}$ | 43-135 | 55-241 | 154-276 | 40-154 | 51-87 | 53-105 | 48 | 404 |
| DM, kg ha$^{-1}$ | 1,630(1) | 939-2,429(1) | 1,293(1) | 5,736-7,100 | 8,400-10,000 | 8,000 | 4,682 | 209-492 |
| CP, kg ha$^{-1}$ (2) | 192 | 400 | 325 | 660 | 600 | 600 | 225 | 162 |

1) Based on crop samples before paddock occupation. If cut to produce silage the yields are considerable higher. 2) Based on mean DM yields. References: NJF, 1969; Farnworth et al, 1994; Kosaric et al., 1984; Carlson et al., 1999; Danielsen et al., 2000; Honeyman & Roush, 1999; Møller et al., 2000; Edwards, 2002, 2003; Fernandez et al., 2006; Kongsted et al., 2013; Jakobsen et al., 2015; Kyntäjä et al., 2014; Jakobsen et al. 2015; Kongsted et al., 2015; Smith & Bauer, 2015;

*Nutritional contribution*

The nutritional contribution of direct foraging largely depends on pigs' motivation for *crop intakes*. Studies have shown that restricting supplementary concentrate in terms of quantity (Kongsted et al., 2013; 2015) and protein content (Kongsted & Jakobsen, 2015) encourage pig foraging behaviours and crop intakes. Thus, when fed restrictively, snout-ringed pregnant sows had daily grass clover intakes of 1.5-2 kg DM corresponding to approximately 50-75 % of the daily DM intake (Edwards, 2003; Fernandez et al., 2006) and daily Lucerne intakes up to 4,2 kg DM (Honeyman & Roush, 1999). In comparison, free-ranged un-ringed pregnant sows showed daily fodder beetroot intakes of approximately 5 kg DM day$^{-1}$ when provided with 0.2 kg supplementary concentrate (Chambers, 1987). To our knowledge, forage intakes of free-ranged *lactating* sows have not been quantified, however it is likely that lactating sows' motivation for foraging behaviour is markedly lower compared to pregnant sows' due to the large amount of supplementary feed provided to assure milk production.

The establishment of a rotational grazing system, on grassland rich in legumes, was carried out for pregnant sows at the Trinottières station for two consecutive years (Roinsard et al, 2019). To enhance the value of grazing, the experimental feed distributed was rationed to 80% of the control groups (groups outside the grazing period) and was less rich in protein (10.2% MAT vs. 13.6% for the control). The objectives were to: (i) assess the impact on zootechnical performance; (ii) assess the contribution of grazing to feed requirements; (iii) quantify grass intake; and (iv) describe sow preferences for specific species. Grazing sows had the same gain in back fat but a slightly lower live weight gain, linked to a lower motivation to graze at the end of gestation. The needs of grazing sows were calculated using INRAPorc software. As a result, grazing provided on average 22% of the Metabolisable Energy and 33% of the digestible lysine. The biomass ingested was 1.75 kg of MS/day/sow with high variability (maximum 4.1 kg of MS). Finally, sows expressed a very strong preference for legume consumption. The implementation of effective pasture management for pregnant sows reduces feed costs (by 16%) and feed requirements. Vigilance should be exercised at the end of gestation (increase the quantity of feed) to ensure a safe weight gain for sows.

*"…sows expressed a very strong preference for legume consumption."*

Due to lower gastrointestinal tract capacity, forage intakes of *growing pigs* are in general lower compared to sows. However, when fed restrictively with supplementary concentrate, growing-finishing pigs had Lucerne (Jakobsen et al., 2015) and Jerusalem artichoke tuber (Kongsted et al., 2013) intakes of 0.5 and 1.3 kg DM day$^{-1}$, respectively, corresponding to 20 and 60 % of the daily DM intakes.

**Pigs like sugar beets** *Photo: Anne Grete Kongsted*

Besides crop availability and intakes, *nutrient digestibility* of the forage crops influences the nutritional contribution from direct foraging. This varies not only between crops but also within crops depending on stage of growth. In a Danish study, crude protein varied from 142 g kg DM$^{-1}$in May-June to 194 g kg DM$^{-1}$ in Aug-Sept and the corresponding *in vitro* faecal protein digestibility coefficients from 79 to 83% (Fernandez et al., 2006). Standardized *in vitro* ileal crude protein digestibility coefficients of 77% (fresh) and 81-86% (silage) have been reported for Lucerne in UK (Kyntäja et al., 2014) and Germany (Weltin et al., 2014), respectively. There have only been very few studies of digestibility using fresh root crops like sugar or fodder beets for pigs. Kesting et al. (1986) found digestibility coefficients of 88-92% and 58-85% of DM and crude protein, respectively. Additionally, *In vitro* analyses of sugar beet root *pulp* showed an ileal protein digestibility of 81 (Schelde et al., 2011).

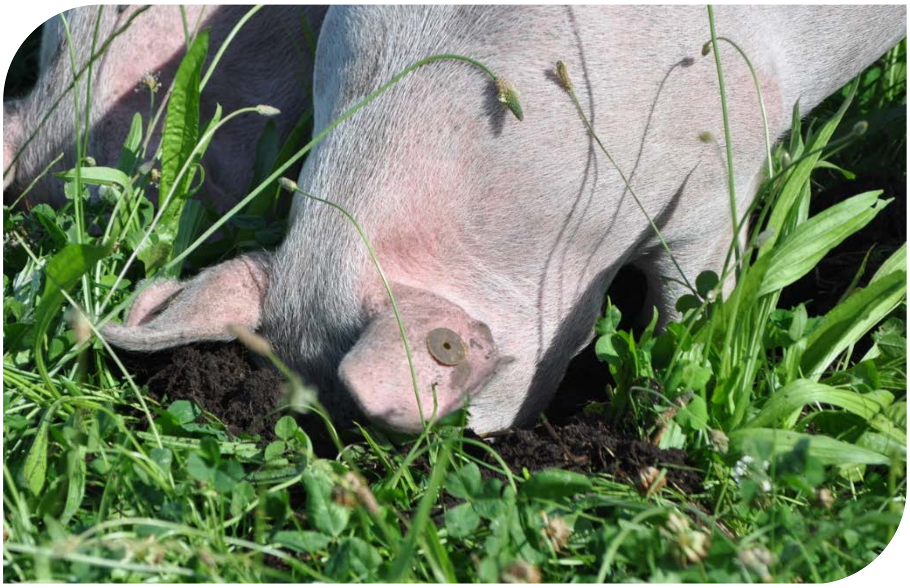
Based on the above-mentioned it is obvious that forage crops have the potential to make a substantial contribution to the energy and amino acid requirements of pregnant sows. Assuming a daily DM intake of 2 kg, foraged crops could potentially cover between 40% (Rye grass) and 80% (sugar beet roots) of energy requirements and between 24% (carrots) and 182% (lucerne) of lysine requirements (Table 6.2).

**Table 6.2 Intakes from direct foraging in the range as contribution to energy and protein requirements of pregnant sows with an assumed daily DM intake of 2 kg (for earthworms a DM intake of 0.2 kg)**

| | Grass (Ryegrass) | Grass clover | Lucerne | Jerusalem artichokes | Sugar beet roots | Carrots | Chicory roots | Earth-worms |
|---|---|---|---|---|---|---|---|---|
| % of requirements | | | | | | | | |
| Energy | 40 | 47 | 47 | 80 | 73 | 67 | 73 | 5 |
| Lysine | 61 | 109 | 182 | 40 | 17 | 24 | | 46 |
| Methionine | 38 | 75 | 100 | | 13 | | | 27 |
| Area required, $m^2$ $day^{-1}$ | 12.5 | 10.0 | 15.4 | 3.3 | 2.0 | 2.0 | 4.4 | 5.0 |

Requirements are based on the Danish recommendations (energy: 3 FU, dig. Lysine: 3.3 g/FU, dig. Methionine: 1.6 g/FU, 1 FU correspond to 7.X MJ NE) and an assumed utilization of amino acids of 0.6 for all foraging crops.

Although considerably less than for pregnant sows, forage crops have the potential of making a moderate contribution to the energy and amino acid requirements of *growing-finishing* pigs (Table 6.3). Assuming a daily DM intake of 0.5 kg, grazed pastures could potentially cover up to 12% of energy and 18% of lysine requirements (Lucerne) when only considering the aboveground biomass. This increases substantially when including the below ground potentially nutritional contribution from e.g. roots and soil organisms like earthworms (Table 7.3). In comparison, root crops like Jerusalem artichokes could potentially cover up to 54% of energy requirements and 10% of lysine requirements.



**Rooting for earthworms?** *Photo: Anne Grete Kongsted*

**Table 6.3 Intakes from direct foraging in the range as contribution to energy and protein requirements of *growing-finishing* pigs (50-110 kg LW) with an assumed daily DM intake of 0.5 kg or 1.3 kg for pastures and root crops, respectively (for earthworms a DM intake of 0.2 kg)**

| | Grass (Ryegrass) | Grass clover | Lucerne | Jerusalem artichokes | Sugar beet roots | Carrots | Chicory roots | Earth-worms |
|---|---|---|---|---|---|---|---|---|
| % of requirements | | | | | | | | |
| Energy | 10 | 12 | 12 | 54 | 49 | 45 | 49 | 5 |
| Lysine | 6 | 11 | 18 | 10 | 4 | 6 | | 22 |
| Methionine | 6 | 12 | 16 | | 5 | | | 21 |
| Area required, $m^2$ $day^{-1}$ | 3.1 | 2.5 | 3.8 | 2.2 | 1.3 | 1.3 | 2.9 | 5.0 |

Requirements are based on the Danish recommendations (energy: 2.9 FU, dig. Lysine: 7.2 g/FU, dig. Methionine: 2.2 g/FU, 1 FU correspond to 7.X MJ NE) and an assumed utilization of amino acids of 0.5 for all foraging crops.

In growing-finishing pigs, the restricted access to supplementary concentrate required to motivate forage behaviour has a positive effect on the meat percentage but may reduce daily gain (Kongsted et al., 2013; 2015). This emphasizes the importance of tailoring the amount and the nutritional composition of the supplementary concentrate to the nutritional value of the forage crop and biomass actually available for foraging.

Taking into account nutrient intakes from foraging the range seems an obvious strategy to facilitate 100% organic feeding in free-range systems. Intake of nutrients from direct foraging can cover more than 80% of energy requirements (root crops) or 100% of lysine and methionine requirements (grazed Lucerne) in pregnant sows. For growing-finishing pigs, intakes of nutrients from direct foraging may potentially cover 50% of energy requirements (Jerusalem artichokes) or 35-40% of lysine and methionine requirements (Lucerne) when including estimated contribution from soil organisms. If the farmers adopt restrictive feeding to stimulate intakes from the range, it is important to allow adequate time and space for feed consumption, reducing competition for feed. As continuous access to an attractive forage crop stimulates pig foraging behaviour, it is important to consider and develop mobile systems.

## 6.3 Pigs - Phase feeding

To meet the needs for optimal growth in pigs, one strategy is to apply a feeding plan with two or more phases where the feed contains lower crude protein (CP) and essential amino acids (EAA) content with increasing age of the pigs. This will reflect the actual need for protein and amino acids for pigs at different live weights. However, duo to a great variation in live weight within a batch of slaughter pigs, many of the pigs will theoretically be either under- or oversupplied with CP and EAA. In practice, composing different feeds due to the different phases might be difficult to manage.

## 6.4 Pigs - Single feeding and compensatory growth

Contrary, to phase feeding, single feeding implies restricted dietary EAA in the early growing-finishing period, followed by excess dietary EAA during the later finishing period. From a practical point of view, single feeding during the entire raising period would simplify feed manufacturing, feed handling and diet formulation at farm level. Research has demonstrated that limiting the supply of EAA during early growth may be fully compensated for by increased protein retention (Martinez-Ramirez et al., 2008, 2009) and faster growth during later growth phases, and that pigs can show a compensatory growth response after a period of protein restriction (Fabian *et al*., 2002, 2004; Therkildsen *et al*., 2004; Reynolds & O'Doherty, 2006; Millet *et al*., 2011; Millet & Aluwé, 2014). Results from a study by Presto Åkerfeldt (Pers. Comm.) showed that single-fed growing-finishing pigs had the capacity for compensatory growth and had similar performance and carcass traits as phase-fed growing-finishing pigs, irrespective of dietary lysine and CP content. The growth performance and carcass traits were unaffected by a reduction in dietary CP from 15.5 to 13.8 g SID CP/g SID lysine and a reduction in lysine from 0.89 to 0.78 g SID lysine/MJ NE. Consequently, this also implied that soya meal inclusion could be reduced, replaced by cereal and regionally produced feedstuffs (Presto Åkerfeldt, Pers. Comm.). A trial carried out in France (Roinsard, 2018) aimed to compare the interest of 100% organic single feed vs 2 phases 100% organic feed (weaner and growing feed). The growth, FCR and lean content were not impacted by the feed management. The single feed were composed with less protein (16.7% vs 19.7%) and less digestible lysine (0.70 vs 0.85 g SID Lysine/MJ NE). This strategy permits to reduce soya intake by pig (43.2 kg/pig vs 50.0 kg/pig) and increase pea intake (36.4 kg/pig vs 2.8 kg/pig).

## 6.5 Poultry - Feeding strategies

*"If the outdoor area is attractive with fresh grass and herbs or some crops, it can be considered as roughage."*

In organic egg production in the EU, the birds have to be kept under free-range conditions providing at least 4m$^2$ per bird. Integrated plant and poultry production systems (AgroForestry), where outdoor areas planted with a combination of trees (e.g. energy willow) altering with open areas with grass clover and herbs, can have several advantages for animal welfare and nutrient balance. The planted outdoor area appears more attractive and due to increased activity and use of a larger part of the area laying hens will be more evenly distributed (Hegelund et al., 2006; Nagle et al. 2012). The type of vegetation and the amount of trees and bushes planted in the hen-yard differs among the countries in the EU. In Denmark it has been decided from 1st January 2018 that 70% of the outdoor area has to be covered with vegetation, where 50% is planted with trees and bushes and the remaining part can be grass and herbs.

Further, it is mandatory within the EU, that organic birds have daily access to vegetation, fresh or dried hay or different silages or vegetables in addition to the compound feed. Since laying hens and slow growing broilers can consume a considerable amount of roughage by developing the gizzard size (Horsted, 2006; Steenfeldt et al., 2007: Almeida et al., 2012), the supplementation of high quality roughage or access to an out-door area with grass and herbs, can contribute with some energy and nutrients to the diets.

If the outdoor area is attractive with fresh grass and herbs or some crops, it can be considered as roughage. However, for most farmers it can be difficult to keep the outdoor vegetation in a sufficient quality as especially laying hens eat all green material very fast and their foraging behaviour with scraping activities will destroy the grass cover in the long term. Further, during autumn and winter in Northern Europe, there only little vegetation will be available in outdoor areas.

**Foraging chickens** *Photo: Helene Uller-Kristensen*

## 6.6 Laying hens - Roughage as feed

In a series of studies with laying hens having access to different kinds of roughage, feather pecking was reduced and plumage condition improved considerably (Wechsler and Huber-Eicher, 1998; Aerni et al., 2000; Kohler et al., 2001; Steenfeldt et al., 2007). Rough materials are expected to give birds a feeling of satiety and make them occupied by foraging; consequently, birds get less time for feather pecking. In the future, it can be speculated that roughage materials will not only be considered as being occupying material for birds but also a source of nutrients as well as having significant environmental and welfare benefits for birds.

*"…it can be speculated that roughage materials will not only be considered as being occupying material for birds but also a source of nutrients as well as having significant environmental and welfare benefits for birds."*

In some countries, e.g. Denmark, minor amounts of roughage is fed to laying hens two to three times a day by automatic systems and the energy values of the roughages are taken into account in the practical formulation of organic layers' diets. In the long term, the content of protein and amino acids in roughage should also be incorporated in the feed formulation since some silages and vegetables have a high quality with regard to these nutrients (Steenfeldt & Hammershøj, 2015; Afrose, S., 2015). Due to varying contents of amino acids and dietary fibres, a good quality roughage has the potential of supplying a certain proportion of nutrient to poultry. The chemical composition of different silages and vegetables is presented in Table 6.4 (Steenfeldt et al., 2007; Steenfeldt & Hammershøj, 2015; Afrose, 2015).

**Table 6.4 Chemical composition of silages and vegetables**

| Constituents | Maize silage | Barley-pea silage | Alfalfa silage | Grass-herb silage | Hemp-silage | Carrots | Beetroot | Kale |
|---|---|---|---|---|---|---|---|---|
| Dry matter | 32.5 | 23.3 | 30.1 | 36.8 | 35.5 | 9.7 | 10.9 | 15.0 |
| Ash | 3.8 | 7.8 | 12.4 | 9.4 | 13.0 | 7.1 | 9.2 | 10.0 |
| Protein[1] | 9.2 | 14.4 | 25.0 | 18.2 | 18.9 | 7.5 | 15.7 | 26.8 |
| Methionine | 1.5 | 1.6 | 3.6 | 2.4 | 2.6 | 0.8 | 0.7 | 3.6 |
| Cystine | 1.2 | 1.5 | 1.7 | 1.2 | 1.7 | 0.7 | 1.0 | 3.2 |
| Lysine | 3.1 | 7.4 | 8.1 | 8.3 | 5.6 | 2.6 | 3.4 | 13.6 |
| Threonine | 3.3 | 4.8 | 5.4 | 7.1 | 4.9 | 2.2 | 2.7 | 8.9 |
| Starch | 29.2 | 13.7 | 8.8 | 10.7 | 7.5 | t | 0.6 | 4.2 |
| Cellulose | 17.3 | 19.0 | 17.3 | 18.8 | 17.3 | 7.3 | 5.2 | 6.1 |
| Soluble-NSP | 1.9 | 4.6 | 7.9 | 7.1 | 6.8 | 10.9 | 7.3 | 18.7 |
| Insoluble-NSP | 34.0 | 33.0 | 27.4 | 27.4 | 30.1 | 10.0 | 11.3 | 11.8 |
| Total NSP[2] | 35.9 | 37.6 | 35.3 | 31.3 | 36.9 | 20.9 | 18.6 | 30.5 |
| Lignin | 8.0 | 10.1 | 10.9 | 11.9 | 16.7 | 1.9 | 1.6 | 2.8 |
| Dietary fibre[3] | 43.9 | 47.7 | 46.2 | 50.3 | 53.6 | 22.8 | 20.2 | 33.3 |

Values given represent average analyses from different batches. [1]N*6.25. [2]NSP=Non-starch polysaccharides. [3]Dietary fibre = Total NSP + lignin. Constituent in: g/100g dry matter. For amino acid: g/kg dry matter

In experiments with laying hens offered ad libitum access of different kind of roughage, it was found that 31-48% of the total intake of the organic diet and forage ("as-fed" basis) was roughage represented by maize-, barley-pea- and alfalfa silages and carrots (Steenfeldt et al., 2007; Steenfeldt & Hammershøj, 2015). The nutrient content of the roughage was not taken into account in formulation of the layer diets, and the result on production parameters differed between the two experiments.

To ensure the methionine requirement in the practical organic production of egg and meat, organic diets are often formulated with excessive protein, which can result in an oversupply of nitrogen excreted to the environment (Blair, 2008). In the above-mentioned study from 2015, the diets were formulated to contain decreased protein content to study the possibility of lowering the protein content as a more sustainable production of organic eggs, where access to roughage was expected to contribute with nutrients to the hens.

However, in this study egg production decreased with the lowest protein diet (18% vs. 16%), where the daily methionine intake per hen was 406mg (18% protein) and 317mg (16% protein), coming from the diets. Taken into account the methionine contribution from the silages and carrots the daily methionine intake increased to 436 mg and 351 mg, respectively, so the foraging material contributed with some nutrients, but not sufficiently to increase production parameters with the low protein diet.

In a subsequent study a new feeding strategy was introduced, where the chemical composition of different silages and vegetables was taken into account in formulation of the experimental diets, resulting in more optimal diets with regard to protein, amino acids and energy (Afrose, 2015). The protein content in the experimental diets ("as-fed") varied from 17.3% (hemp-silage) to 22.6% (maize-cob silage) compared to the control with 18.4% protein. The egg production ranged from 86.7%-90.1% and there was no significant difference between any of the experimental diets (diet + roughage) compared to the control (without access to roughage). The daily methionine intake varied between 380mg/hen (beetroot) to 567mg/hen (kale), where the contribution from silages and vegetables ranged from 1-11% (mg/hen/day). In this study, the silages and vegetable contributed with different nutrients. It can be concluded that it was possible with most of the diets to include the roughage as an ingredient in the diet formulation and fulfil the hens' requirements for protein and amino acids to obtain an acceptable egg production.

***"It can be concluded that it was possible with most of the diets to include the roughage as an ingredient in the diet formulation and fulfil the hens' requirements for protein and amino acids to obtain an acceptable egg production."***

*Nutrient digestibility*

The content of dietary fibre in roughage can vary to a high extent and especially silages contain significant amounts of dietary fibre (Table 7.4). It has been suggested that soluble NSP, and smaller components as sugars, are fermented especially in the ceaca and may contribute with energy to the hens through production of short chain fatty acids (Jørgensen et al., 1996; Lazaro et al., 2003). In contrast, insoluble NSP cannot enter the ceaca due to their size and are only fermented to a small extent in poultry (Choct et al., 1996). The sustainability of using roughage and vegetables as supplements to organic layer diets largely depends on the digestibility of nutrients in the roughage used.

In Steenfeldt & Hammershøj (2015), large amount of roughage eaten by laying hens, resulted in a high daily intake of especially insoluble NSP present in the silages (~ 87% of total NSP), however, the digestibility of the different nutrient was affected to a different degree, having only minor effect on starch digestibility, which was high in all groups. It has been reported that diets with a high content of especially insoluble fibre sources as oat hulls or access to wood shavings have a positive effect on the starch digestibility in both broilers and layers (Hetland & Svihus, 2001; Hetland et al., 2002; 2003), which is explained by a higher gizzard activity and longer retention time.

Steenfeldt & Hammershøj (2015) did not demonstrate a significant effect of genotype, diets or roughage on N-retention, which varied between 21.3 to 36.7%, being in the same range as reported by Koreleski & Swiatkiewicz (2009). However, the N content in excreta was significantly influenced by both diet, genotype and roughage, indicating that the N intake for some groups was higher than the requirement, increasing the excretion of N (Steenfeldt & Hammershøj, 2015). Regarding digestibility of the amino acids methionine, cysteine, lysine and threonine, it varied between 72-80%, highest with the control diet without reduced protein content, however also the group with the lowest intake of roughage.

In the study by Afrose (2015), the nutrient content of different silages and vegetables were taken into account in the feed formulation. In this experiment the N retention varied from 38-49% and digestibility of methionine between 83.8 (carrot as roughage) and 88.4 (kale as roughage), being higher than found in the study by Steenfeldt & Hammershøj (2015).

It can be concluded that roughage supplementation to diets improved the nutritional value of the diet as indicated by a higher nutrient digestibility. In particular, hemp silage and kale supplemented diets showed positive effects on apparent metabolisable energy and nitrogen retention in laying hens. Thus, the study reinforces previous findings that forage supplemented diets can be digested to some extent to provide required nutrients to enhance production performances in laying hen. Including the nutrient vale of the roughage in feed formulation is an advantage, since a more optimal nutrient composition will be closer to the hens' requirement.

***"…roughage supplementation to diets improved the nutritional value of the diet as indicated by a higher nutrient digestibility."***

The diets of organic hens are often formulated to fulfil the requirements for nutrients recommended for the conventional production. Since hens in organic systems have a higher activity and are exposed to high variation in temperatures when foraging and exploiting outdoor areas, higher dietary energy and methionine content than recommended for conventional birds is reported necessary in order to obtain optimal egg production (Elwinger et al., 2008; Al-fasar & Rose, 2002).

## 6.7 Laying hens - Foraging in outdoor area

Access to an attractive range area with abundant forage vegetation may contribute to the overall nutrient supply of poultry. However, the full advantage of such a strategy may be related to small flocks of poultry and integration into other branches of production such as trees, fruit crops, energy crops and other crops (Pedersen et al., 2004; Horsted et al., 2012).

Although laying hens are able to consume considerable amounts of roughage (Steenfeldt and Hammershøj, 2015: Afrose, 2015), information of intake of grasses and herbs from outdoor areas by laying hens is scarce. A study has been carried out to determine the feed intake of organic layers, when given a normal layer diet, or a diet consisting of whole wheat plus oyster shells (to ensure shell quality). Both groups had access to different types of vegetation on the outdoor area. It was estimated that nutrient restricted laying hens in some periods had up to 70 % of the lysine and methionine requirements and approximately 25% of their calcium requirement covered through foraging the outdoor area, which consisted of different plots with grass/clover, pea/vetch/oats, lupine and quinoa (Horsted & Hermansen, 2007). However, it was not only due to the crops themselves, but also to the fact that poultry had the possibility to find other feed items in the outdoor area such as insects and earthworms providing additional nutrients. The estimated daily intake of different types of herbage and two different feeding strategies are shown (Table 6.5), using the amount of herbage found in the crop of laying hens in the evening (Horsted, 2006) after the methods by Antell and Ciszuk (2006).

**Foraging** *Photo: Sanna Steenfeldt*

**Table 6.5 The estimated daily intake of different types of herbage in two different feeding strategies**

| Vegetation (month and year of sampling) | Pelleted layer diet (g DM) | Whole wheat and oyster shells (g DM) | Average (g DM) |
|---|---|---|---|
| Grass/clover (*June/July, 2004*) | 14 (*5.2*) | 21 (*5.2*) | 17 (*3.6*)$^{ad}$ |
| Mixture of forbs (*June/July, 2004*) | 14 (*5.2*) | 22 (*5.2*) | 18 (*3.6*)$^{ad}$ |
| Grass/clover (*August, 2004*) | 41 (*5.2*) | 50 (*5.2*) | 46 (*3.6*)$^{b}$ |
| Chicory (*August, 2004*) | 42 (*5.2*) | 73 (*5.2*) | 57 (*3.6*)$^{c}$ |
| Pea/vetch/oats (*July, 2005*) | 12 (*5.2*) | 19 (*5.2*) | 15 (*3.6*)$^{a}$ |
| Grass/clover (*August, 2005*) | 17 (*5.2*) | 26 (*5.2*) | 21 (*3.6*)$^{ad}$ |
| Lupin (*August/September, 2005*) | 12 (*5.2*) | 29 (*5.2*) | 21 (*3.6*)$^{ad}$ |
| Quinoa (*September/October, 2005*) | 23 (*5.2*) | 30 (*5.2*) | 27 (*3.6*)$^{d}$ |
| Average | 22 (1.8) | 34 (1.8) | $P<0.001$ |

It was concluded that high-producing layers have a huge capacity for finding and utilising considerable amounts of feed items from a cultivated outdoor area. The wheat-fed hens were able to cover two-thirds of their lysine and methionine requirement from foraging material. However, an adaptation period was needed to develop the digestive system and for behavioural adaptation. To propose adjustments to nutrient levels in supplementary feed, when hens have access to different foraging vegetation, the level of nutrient restriction needs to be further studied since crop analyses revealed different food preferences for hens fed layer feed or wheat.

***"It was concluded that high-producing layers have a huge capacity for finding and utilising considerable amounts of feed items from a cultivated outdoor area."***

Several important results were obtained in the ICOPP project (Smith et al 2014), where it was concluded that foraging birds obtain nutrients from pasture, seeds, insects and other small invertebrates. Crude protein content of edible insects ranges from 30% to 80%, and the amino acid profiles of insects are better matched to poultry requirements than the amino acid profiles of legumes or cereals. Laying hens are able to consume considerable amounts of fresh grass, which may account for 12-13% of their total dry matter intake. Moreover, additional feed resources, such as maize silage, lucerne, dried grass and carrots, can enhance natural behaviour (more time busy with feed intake), which reduce the risk of feather pecking and provision of fibres enhances gut flora and gut health (Smith et al, 2015).

In addition to nutrient obtained by foraging, improved welfare of laying hens is another important goal, when layers are given access to outdoor areas with abundant vegetation. In a study by Breitsameter et al. (2014) it was found that the botanical composition and quality affect the behaviour of free-range hens. Fifteen different plots representing nine grasses and five herb species (14 plots) and one mixed were used to study behaviour and welfare of laying hens. It was concluded that the botanical composition as well as the degradation of the vegetation over time had a significant effect on foraging behaviour of the hens defined as scratching, plant pecking and plant and ground pecking together. Herbs and grasses with soft leaves were preferred for plant pecking. When degradation of plant cover increased over time, ground pecking increased, whereas scratching and plant pecking decreased, underlying the importance of choice of plant species, which both have a quality that stimulate plant pecking and eating and at the same time have a high resistance to degradation (due to scraping etc.) and therefore provide a stable and sustained vegetative cover.

## 6.8 Broilers - Foraging in outdoor area

Several factors affect a bird's ability to forage including palatability, the plant type, plant species, the nutritional content, height and stage of growth of the plant, the nutrient content of the diet and the nutrition requirement of the bird. Different genotypes of poultry have different foraging behaviour and consumption rate. Genetics has also been said to play a role in chicken's ability and efficiency in balancing their intake in order to cover their specific nutritional requirement in free choice feeding system (Pousga et al., 2005).

Within a flock, individuals show a range in their capacity to select their own feed. When birds are not introduced to forage during the growing period, it takes time for a flock of birds to adapt to a new feed on pasture and some producers may give their bird access to chopped roughage daily in the rearing period in order to adapt the chickens to more rough materials. Research has shown that feed intake by broilers is positively correlated with age (Almeida et al., 2012). Moreover, shade and protective cover encourages foraging (Dawkins et al., 2003), most likely from the protective effect of shelters (Riverra-Ferre et al., 2007) and shorter forages are preferred to longer one when given the choice. Clovers and alfalfa can be considered forages of high quality due to high protein content (pasture legumes).

One advantage in the use of outdoor area lies on the opportunity to select other nutrients through foraging apart from the feed provided which can also come along with picking live organisms. Early access to pasture can increase the outdoor area usage because chicken get familiar with it (Adas, 2002). Feed searching, soil scratching, pecking and dustbathing can be noticed among other behaviours. Poultry may obtain small amounts of energy from pasture and have the ability to utilize amino acid, such as methionine, lysine and threonine found in the forage (Buchanan et al., 2007), but the utilization of nutrients from pasture intake also depends on the quality of the outdoor pasture (Rivera-Ferre et al., 2007).

In a study three organic broilers genotype (JA757, T851, SU51) with different growth potential and different feeding strategies (Normal Protein (NP) vs Low Protein (LP)) had access to a large outdoor area with herbs. Feed intake, growth and welfare was investigated (Steenfeldt & Horsted, 2014). The results so far indicate that feed intake from outdoor area and animal welfare is dependent on type of allocated feed and growth rate of the broiler genotype. Thus, gait scores and foot and plumage condition showed that the fastest growing broiler genotype had some problems when fed normal broiler feed, whereas this was not the case for the other genotypes. The fastest growing broilers also ate more pelleted broiler feed compared to the slower growing breeds, which in contrast ate more whole wheat. Broilers fed LP feed had a higher intake of feed from the outdoor area indicated by the crop content.

The chemical composition of herbs from the outdoor area indicate that grasses and herbs could contribute to the broilers nutrient supply to some extent (Table 6.6). Analyses of the content of the chickens' crop also showed that insects, earthworms and snails were part of the feed intake from the range area. Snails had a very high protein (44.8 %of DM) and methionine content (6.37g/kg of DM).

**Slow growing broilers** *Photo: Helene Uller-Kristensen*

**Table 6.6 Chemical analyses of herbs from the outdoor area**

| Herbs | Dry matter | Protein | Methionine | Cysteine |
|---|---|---|---|---|
| Caraway | 16.0 | 17.7 | 3.37 | 1.56 |
| Red clover | 16.6 | 29.6 | 4.68 | 2.27 |
| Chicory | 11.8 | 19.2 | 3.78 | 1.63 |
| Plantain | 11.3 | 19.5 | 3.33 | 1.86 |
| Ryegrass | 14.8 | 21.2 | 3.99 | 2.02 |
| Burnet | 21.3 | 18.8 | 3.42 | 1.99 |
| Birdsfoot trefoil | 17.2 | 22.2 | 3.74 | 2.57 |
| Lucerne | 19.9 | 20.1 | 3.37 | 2.49 |

Protein: g/100g dry matter, amino acid: g/kg dry matter

These analyses indicate that flora and fauna in the outdoor area to some extent contribute to the broilers nutrient supply. Analyses of the content of the broilers crop confirmed that the broilers selected different feed items from the range area and in addition to grass and different herbs (dicotyledonous) also insects and worms, larvae and snails were identified in the crop content. Results from two genotypes, 85 days of age are shown in Figure 6.1a and 6.1b.

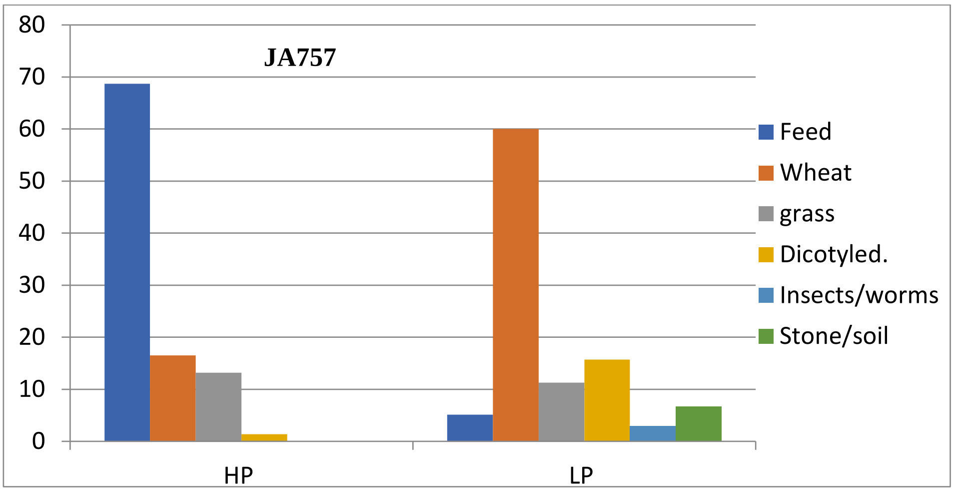



**Figure 6.1a Crop content from JA757 (fast growing) at 85 days of age**

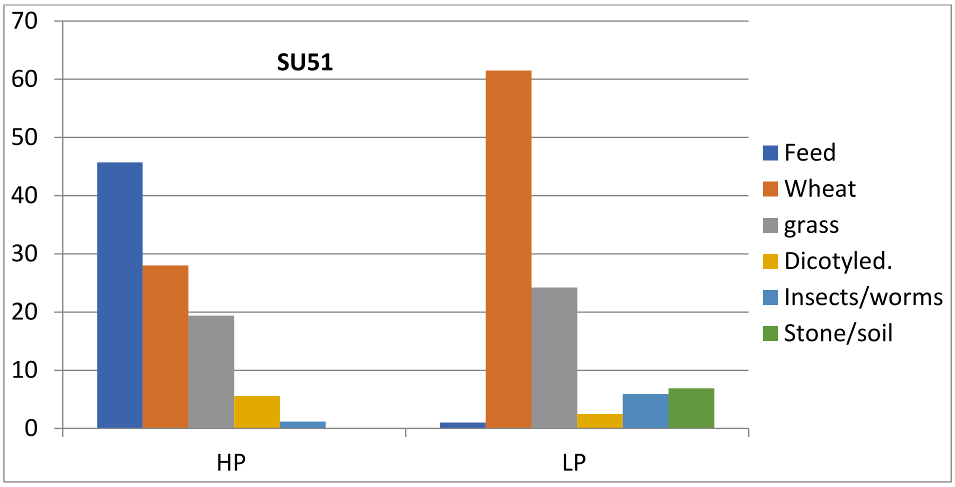



**Figure 6.1b Crop content from SU51 (slow growing) at 85 days of age**

The results from the feed selection also indicated a genotype difference with regard to foraging activity and feed preferences. In general, the broilers fed with LP feed showed greater foraging activity on the outdoor area compared to the genotypes with a higher growth potential.

In the ICOPP project an experiment was conducted to examine the effects of different feeding strategies on the foraging ability and nutrient digestibility of slow growing organic broilers (genotypes -RedBro, I657) having free access to outdoor area consisting of grasses and herbs. 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) a mixture of control and F1. All diets were diluted with 10% whole wheat. The daily weight gain for genotype Redbro for the whole growth period (0-14 weeks, the rearing period included) was 41.9g (C), 39.4g (F1) and 40.1g (F2), being higher than the maximum daily gain of 35g permitted in organic production in Denmark. For the I657 genotype the values were 29.3g (C), 27.0g (F1) and 28.7g (F2), clearly showing the difference in growth potential between the genotypes both considered slow growing. The RedBro chickens could probably more be characterized as a medium growing genotype.

A preference study was performed with a selected number of broilers from the main experiment in order to study the effect of giving the birds either grass (representative of monocotyledonous), chicory leaves (representative of dicotyledonous) and meal worm larvae (representative of insects) together with diet F1. The results from the study showed a higher preference for chicory compared to grass, however, the intake of mealworms was very high as seen in Table 6.7. The protein content of mealworms is relatively high and can be considered as a valuable protein source. According to Veldkamp et al (2012), the protein content can vary from 44-69% DM. 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.

**Table 6.7 Intake (g/bird) of diet F1 (formulated to have a lower content of protein and amino acids as contrast to the control), grass, chicory and mealworm**

| Treatments | F1+grass | F1+ chicory | F1 + mealworms |
|---|---|---|---|
| Intake, as is basis: | | | |
| Diet F1 | 63.8 | 65.9 | 32.2 |
| Grass | 14.9 | - | - |
| Chicory | - | 23,6 | - |
| Mealworm | - | - | 71.1 |
| Supplements, % of total intake | 19 | 26 | 69 |
| Intake, DM basis: | | | |
| Diet F1 | 56.7 | 58.6 | 28.6 |
| Grass | 3.0 | - | - |
| Chicory | - | 2.0 | - |
| Mealworm | - | - | 21.3 |
| Supplements, % of total intake | 5 | 3 | 43 |

The experiment showed that broilers with less protein in their diets strive to compensate for additional nutrients through the supplement. Hence, the use of low protein diets in organic broilers production can enable the slow growing broiler to explore or utilize the nutrients in the forage on the attractive outdoor area. Thus, stimulating foraging activity using low protein diet with slow growing genotype could be one of the strategies to achieve or ease the transition to 100% organic feed supply to organic broilers in the future.

***"…stimulating foraging activity using low protein diet with slow growing genotype could be one of the strategies to achieve or ease the transition to 100% organic feed supply to organic broilers in the future."***

Almeida et al. (2012) carried out a study with one slow and one medium growth genotypes with access to two different mixed vegetation (grass/clover or chicory) on the outdoor area and obtained results comparable with the study by Steenfeldt & Horsted (2014), but using a different feeding strategy. The broilers were fed the same standard organic diets, but were restricted to 50g/bird/day to stimulate the birds to forage. The contribution of nutrients from the forage intake was investigated. Whole wheat was available ad. libitum. It was found that the foraging behaviour differed between the two genotypes, where the medium growth genotype was less active during the day, spending more time in the mobile houses or being close to the houses, but increased the foraging activity in the evening. In contrast, the slow growing genotype was in general active with foraging during the whole day. Based on crop content, it was found, however, that the total intake of forage g/bird/day was higher for the medium growth genotype (9g for females and 20g for males), compared to the amount found for the slow growing genotype (~ average 8g). The results could be explained by the restricted feeding of the standard diet, stimulating the birds to forage for nutrients, especially protein, where the genotype with the highest growth potential (medium growth) had a higher requirement for the amino acids and therefore probably were more undersupplied by the standard feed than the slow growing genotype. An important point was stated by Almeida et al., (2012), as it was mentioned that since broilers can consume considerable amounts of forage as part of their daily nutrient intake, it is uncertain if this strategy can be implemented in larger broiler flocks, where it can be difficult to maintain a sufficient cover of vegetation on the outdoor area.

***"…slow growing genotype was in general active with foraging during the whole day."***

In an interesting study by Castellini et al. (2016), the adaptation to outdoor rearing systems was studied in eight chicken genotypes with different growth potentials (slow- medium- and fats growing). Many different traits (e.g. oxidative status, native immunity and blood parameters) were included to study the effect in the different genotypes, in addition to behaviour, welfare measures (e.g. plumage condition, body lesions) and performance. Based on the different traits, an adaptability index was calculated and showed the best result for the slow-growing strains, intermediate in medium- growing and the worst in fast-growing strains. So the study confirm that slow-growing genotypes are more robust and can better adapt to organic systems with a higher physical activity on the outdoor area with vegetation, followed by medium-growing broilers, whereas the fast-growing broilers was least robust and less adapted.

***"slow-growing genotypes are more robust and can better adapt to organic systems with a higher physical activity on the outdoor area with vegetation"***

## 7. Knowledge and innovation gaps - conclusions

The most important research need identified is knowledge on the nutritional requirements of alternative breeds. Precise nutrient recommendations for organically produced pigs and poultry do not exist.

Research to determine nutritional requirements at different physiological stages, and how this interacts with climatic conditions, different feeding strategies, production systems, dual purpose and slow-growing breeds is needed.

There is a need to study the nutritional value of new protein sources for monogastric animals, and there is a great need to study various combinations of breeds, grazing and supplemental feed.

Finally, there is a need for the development of small-scale on-farm equipment to refine locally produced raw materials.

## 8. Conclusion

When feeding pigs and poultry 100% organic and regionally produced feed, getting enough protein and specific amino acids is a challenge. There are two ways to go and they can be combined. One is to utilize by-products, for example waste from various productions, and explore new protein sources e.g. marine products or to refine already known products such as grass. The other way is to feed the animals less intensively and for this feeding strategy slow-growing breeds fit better. Some slow-growing breeds are already known, some are rediscovered old breeds. The challenge with the slow-growing and less-yielding breeds is that the production is getting smaller and either the farmer will earn less or the prices of eggs and meat will increase.

However, the possibilities for combinations of regionally grown feed, low-yielding breeds with different feeding strategies are many, and they fit well with the organic principle: "Organic farming should be based on living ecological systems and circuits, working with them, imitating them and helping them to maintain". Many experiments have shown that both growing pigs, sows, broilers and laying hens perform well on a diet that contains less protein and amino acids than prescribed for monogastric animals in conventional production systems, if at the same time they are able to forage on outdoor areas covered with crops. The foraging animals will also find protein and essential amino acids when they eat worms and snails in the soil.

The knowledge synthesis does not provide a simple recipe for how monogastric animals can be fed 100% organic and regionally produced feed and at the same time ensure animal welfare as well as achieve the necessary earnings. The knowledge synthesis points to several sub-solutions that can be tested individually or in combination.

There is a need to know more about alternative breeds' nutritional needs, to test more protein sources as feed for pigs and poultry, to develop small-scale on-farm equipment to refine feed materials and to research multiple combinations of breeds and different feed compositions.

*Photo: Sanna Steenfeldt*

*Photo: Maria Eskildsen*

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