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REPORT

Possibilities and limitations of protein supply in organic poultry and pig production

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Foreword

In the EU funded research project "Research to support the revision of the EU Regulation on Organic Agriculture" (Contract no. FP6-502397) the overall objective is to provide recommendations for the revision and further development of the EU Regulation (see www.organic-revision.org).

One of the specific objectives is to provide more knowledge on how to achieve 100 % organic rations in diets for livestock (work package 4). As a part of the work this report has been made. The aim of the report is to provide an overview of the many different aspects of protein supply in organic poultry and pig production. Part 1 describes the objective of organic livestock production and introduces the situation. Part 2 describes protein sources in conventional and organic livestock production. In part 3 the effect of protein supply of groups of poultry and pigs with different protein requirements are described. Part 4 is a discussion about the effect on product quality. Part 5 explains the systems approach. Conclusions and recommendations are given in Part 5, 6 and 7 respectively. A summary is given in part 8.

Together with the report of Susanne Padel (2005): "Overview of supply and demand for concentrated organic feed in the EU" this report makes deliverable 4.1 in the EU founded project Organic Revision.

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DARCOF, September 2005
Head of Centre Erik Steen Kristensen
Co-ordinator of Organic Revision

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Abbreviations

AA: amino acid
ANF: Anti-nutritional factor
CP: Crude protein
DL-Met: DL-methionine
DM: Dry matter
EE: Ether Extract
Lys: Lysine
M+C: Methionine + Cystine
PcVQ: prececal digestibility coefficient
SAA: sulphur-containing amino acids
SBM: Soybean meal
Thr Threonine
Trp: Tryptophan

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1 Introduction

It is one of the general recommendations in animal nutrition that the diet should be formulated according to the specific requirements of animals at the various stages of their development. To which degree the farmer can adapt the nutrient supply to the specific requirements of the animals depends primarily on the production goal and on the availability of nutrient resources. This report gives a general introduction to the present situation for dietary protein supply to poultry and pig production in relation to the principles for organic agriculture and husbandry production. Furthermore it includes partly literature based on research from conventional animal production, as the requirements on the level of the animals are not different in both systems. Moreover, there only few research projects of organic production systems available.

This report is primarily focussing on the question whether a nutrient supply of 100% organic feed can and should be realised. In this context, it is not possible to cover all aspects in detail as the report cannot replace a textbook. The main emphasis is laid on a coherent argumentation based on the leading ideas of organic agriculture. Concerning further relevant aspects it is referred to the report ”Supply and demand for concentrated organic feed in the EU in 2002 and 2003” by Susanne Padel as part of the same EU-project: ‘Research to support the EU-regulation on Organic Agriculture’ (www.organic-revision.org) and to the project “Availability of organically reared livestock” (S. Gomez, JRC, Institute for Prospective Technological Studies, this study is expected to be completed in November 2005).

In conventional animal production, a nutrient supply that is closely related to the requirements is an important tool in the performance-oriented production (FLACHOWSKY, 1998). The objective of animal nutrition is to adapt the nutrient supply as accurately as possible to the requirements resulting from maintenance and performance need. Soybean meal, due to the high protein content and high protein quality, has developed into the most important protein source in the nutrition of monogastric animals. Additionally, synthetic amino acids (DL-methionine) and industrial amino acids (produced from microbial fermentation, L-amino acids) are used to balance the supply of essential amino acids.

While the use of soybean meal and synthetic amino acids is normal practice in conventional animal production, the Council-Regulation No. 2092/91, amended by Council Regulation No. 1804/99 on organic livestock production bans the use of chemically extracted soybean meal and synthetic amino acids on organic farms as livestock must be fed primarily on organically produced feedstuffs (Annex 1, paragraph 4.2). By way of a derogation from paragraph 4.2, for a transitional period expiring on 24 August 2005, the use of a limited proportion of non-organic feedstuffs is authorised where farmers can show to the satisfaction of the inspection body that they are unable to obtain feed exclusively from organic production (paragraph 4.8). The derogation, although with a declining percentage of non-organic feedstuffs over the next years, has been prolonged in July 2005.

The preferable use of home-grown feedstuffs and limitations in the choice of bought-in feedstuffs can be the cause of considerable variation in the composition of the diets, and considerably restrict the possibilities for the adaptation of the feed ration to the specific requirements. Due to the limited availability of essential amino acids in particular, there is concern that nutritional imbalances encountered in practice might lead to deteriorating animal health and welfare. On the other hand, there is also the concern that allowing conventional feedstuffs to be fed in organic livestock production will result in intensification of production. The intensification might cause the same problems in organic production as conventional production already shows (animal health problems, risk of residues and GM contamination etc.). Thus, the use of non-organic feedstuffs may have a damaging effect on consumer confidence in organic products of animal origin.

In the following the nutritional-physiological effects of a variation in protein supply with respect to growth performance and protein accretion in broilers, turkeys, laying hens, and pigs are examined by means of a literature review. Additionally, the potential effects of the protein content in the diet on product quality, animal health and environmental damage are addressed.

It is the aim of the report to provide an overview of the many different aspects of the protein supply in organic poultry and pig production. Many different aspects are taken into account to elaborate possibilities to handle the use of organic and non-organic feedstuffs with respect to the objectives and framework conditions of organic livestock production. However, due to the complex interactions not all aspects can be covered. There is room and need for explanation and for further research.

1.1 Objectives of organic livestock production

Organic livestock production represents an alternative to progressive intensification in conventional animal production. In contrast to the performance-oriented conventional production, the system-oriented approach is based on voluntary self-limitation in the use of various means of production in order to achieve an animal- and environment-compatible production of qualitatively high-grade animal products in a largely closed farm system (SUNDRUM, 1998). The realization of this approach usually requires a complete re-organization of the farm, in which crop requirements have to be tailored to the concerns of animal husbandry and the extent and direction of animal husbandry adapted to home-grown feedstuffs. The aim is to achieve animal- and environment-compatible production of animal products principally through precautionary and avoidance strategies.

With respect to environmental compatibility the avoidance strategy is based on a conscious limitation of external resources (including mineral nitrogen fertilizers and additional commercial feedstuffs) and avoiding risk-laden production means (including pesticides and performance stimulators). In addition, the presence of certain residues of synthetic chemical from sources other than agriculture should be avoided. Consequently, the renunciation of specific means of production, which have been developed to increase productivity, will inevitably lead to increased production costs, which have to be passed on to the consumer in the form of higher prices.

- The Council-Regulation on organic livestock production provides the legal basis for an originally privately developed economic approach. Among the various paragraphs of the regulation on the bases and objectives for organic animal husbandry are:
- Article 6 (b): ..only products composed of substances mentioned in Annex I or listed in Annex II may be used as… feedstuffs, feed material…feed additives…
- Article 6 (d): ..genetically modified organism and/or any product derived from such organism might not be used…

Detailed specifications about conversion, origin of animals, feeding practices, use of commercial fertilizers and precautions against and treatment of illnesses are provided in Annex I of the Council-Regulation. With respect to the related problem the following paragraphs are of particular relevance: - 1 General principles

paragraph 1.1: Livestock production forms an integral part of many agricultural holdings practising organic farming.

- paragraph 1.4: Organic stock farming is a land-related activity.
- paragraph 3.1: In the choice of breeds account must be taken of the capacity of animals to adapt to local conditions; their vitality, and their resistance to disease. In addition, breeds and strains of animals should be selected to avoid specific diseases or health problems associated with some breeds or strains used in intensive production (e.g. ...). Preference is to be given to indigenous breeds and strains.
- paragraph 4.1: Feed is intended to ensure quality production rather than maximize production, while meeting the nutritional requirements of the livestock at various stages of their development.
- paragraph 4.2: Livestock must be fed on organically produced feedstuffs.
- paragraph 4.5: The feeding of young mammals must be based on natural milk, preferably maternal milk. All mammals must be fed on natural milk for a minimum period,

depending on the species concerned: three months for bovines and equidae, 45 days for sheep and goats and 40 days for pigs.

- paragraph 4.8: Until 24 August 2005 the use of a limited proportion of conventional feedstuffs is authorised where it is unable to obtain feed exclusively from organic production.
- paragraph 4.10: For poultry, the feed formula used in the fattening stage must contain at least 65% cereals.
- paragraph 4.11: Roughage, fresh or dried fodder, or silage must be added to the daily ration for pigs and poultry.
- paragraph 4.13: Conventional feed materials of agricultural origin can be used for animal feeding only if listed in Annex II. Part C, section 1 ...
- paragraph 6.1.9: For poultry, the minimum age at slaughter shall be: 81 days for chickens, ... 140 days for turkeys and roasting geese ... Where producers do not apply these minimum slaughter ages, they must use slow-growing strains.

A running check of the general framework incorporated into the Council-Regulation is intended to ensure that existing shortcomings be reduced and newer scientific developments integrated into the Council-Regulation.

1.2 Difference between organic and conventional livestock production

In organic livestock production the objectives of a land based system, the avoidance of specific means of production, and the priority of quality production rather than maximizing production are of overriding importance. To deal with a limited availability of resources is therefore a main feature of organic livestock production. In contrast to conventional production, maximization of protein accretion is only a subordinate objective. Differences in the priorities between conventional and organic livestock production and a comparison between the hierarchy related to objectives are presented in table 1.1.

Tab. 1-1: Differences in priorities between conventional and organic production system

Conventional	Organic
i. Minimizing production costs	i. System-oriented production, based on land use and use of organic feedstuffs
ii. Maximizing productivity of farm animals	ii. Maximizing efficiency within the whole farm system
iii. Maximizing performance (carcass yield, number of eggs)	iii. Optimizing product and process quality (animal health and welfare, environmentally friendly production, naturalness)
iiii. Optimizing single quality traits	iiii. Reducing production costs

With regard to the different objectives, different priorities, and different framework conditions, it has to be taken into account that organic and conventional livestock production belong to completely different farm systems. Therefore, the traditional approach which reduces agricultural problems to the level of single production traits or feeding strategies is not directly comparable and compatible with the organic approach. In the same way, general conclusions derived from conventional production system are not directly compatible and therefore have not the same validity in organic livestock production.

1.3 Protein supply of monogastric animals

Implications of a limited availability of feedstuffs in organic poultry and pig production on growth performance, traits of product quality, and animal health depend to a high degree on the capacities of the animals in the various stages of their development to adapt to and compensate for changes in the nutrient supply. Knowledge about interactions between digestibility, retention and protein accretion is necessary to understand the possible implications and are therefore described briefly in the following chapter.

As protein accretion is of high importance in the growth process and in the productivity of monogastric animals, the supply with protein plays a major role in animal nutrition. In the digestive tract of poultry and pigs crude proteins ingested with the diet are almost completely broken down into amino acids and peptides and absorbed as such in the small intestine. The absorbed amino acids pass into the amino acid pool and are primarily used in the intermediate metabolism as required for the body's own protein biosynthesis. Another part of the absorbed amino acids is transferred or broken down into various molecules. Most of the amino acids can be built up by the organism itself; they are designated as non-essential amino acids. The amino acids that cannot be synthesized by the organism are designated as essential, because viability of the organism depends on their intake via nutrition. For the constitution of the body's own proteins essential amino acids have to be available in sufficient quantity and in a certain ratio to each other. In the case of inadequate provision of one of more essential amino acids, the protein biosynthesis and thus the growth of the organism is restricted. The following amino acids are essential for poultry and pigs: methionine, lysine, isoleucine, leucine, threonine, phenylalanine, tryptophan, valine, histidine and arginine. Glycine and serine are only essential for poultry (GfE, 1999). Furthermore, cystine and tyrosine are semi-essential because they can only be synthesised from methionine and phenylalanine. To determine the requirement, amino acids are sub-divided into first-, second- and next-limiting amino acids. In the case of poultry, methionine and cystine are (sulphur containing amino acids) are regarded as the strongest limiting one (Schutte et al., 1994; Bertram et al., 1995; Jeroch & Dänicke, 2002). With pigs, lysine is the first- and methionine or threonine are the second-limiting amino acids (GfE, 1987; NRC, 1998).

All amino acids (AA) needed for protein biosynthesis have to be available in synthesis compatible fashion. Equally, a sufficient energy provision is necessary. If one of the essential amino acids is missing, the protein synthesis may be reduced or the degradation of protein may be increased. The extent of the protein synthesis or accretion is thus dependent to a large extent on a balanced protein and energy provision via feed.

The amino acid content of feedstuffs alone does not provide enough information to predict the nutritional value of the feedstuffs for protein biosynthesis. In the first place, information about the requirement for individual amino acids is not sufficiently precise, and in the second place exact information about the availability of amino acids from the feedstuffs is necessary (Jeroch et al., 1999). The availability is related to both the digestibility and the availability in the intermediate metabolism. In the past various criteria were developed to assess protein quality: nitrogen retention, biological value or net protein utilization. For the practical concerns of animal nutrition, however, these criteria have not become established.

Basically, there are two methods for determining the requirement of AA: *the factorial method*, in which the requirement for the various performances (maintenance, growth and protein accretion) is determined separately and then aggregated, and *the empirical method*, in which the amino acid in question is administered in various stages and its effect on the performance parameters and physiological criteria investigated (PAULICKS et al., 2002). Without doubt, the first method is the more flexible, because its results can be adapted better to the various conditions of feeding practice (breed, performance level, maintenance conditions). The more precise method, however, is the knowledge of feed intake and the proportion between absorbed and not absorbed amino acids. This varies according to a number of factors, such as genotype, age, live weight, environmental influences and energy and AA supply. The most important factors for the different species are discussed below.

1.3.1 Digestibility of amino acids

Digestion and absorption have a serious effect on the availability of amino acids in the intermediate metabolism. ARC (1981) defines the available amino acids as the part of the amino acids in the total ration that contributes to maintaining or forming new tissue and is not bound to the components preventing digestion, absorption or utilization by the animal, because not all absorbed amino acids are used for protein synthesis.

In agricultural practice, digestibility is used as the criterion for availability (TANKSLEY & KNABE, 1984). This can lead to miscalculation, because digested and absorbed amino acids are not completely available for protein synthesis. For example, thermally damaged amino acids are digestible and absorbable, but not effective. According to AWT (1998) the thermally damaged amino acids can be detected only by determining the physiologically effective amino acids. The relation between absorbed and non-absorbed amino acids depends, among others, on the feedstuff components and their preparation together with the variety, fertilization and content of anti-nutritional substances. To determine digestibility two methods were used in the past:

In the case of faecal digestibility (seeming/apparent total digestibility) the digested parts are calculated from the difference between feed intake and the excretion of the nutrients via faeces, and these are related to the intake (KIRCHGESSNER, 1997). This method is not very informative, because non-absorbed amino acids are decomposed in the large intestine by micro-organisms, but remain unrecorded in the final balance.

A second method of examining digestibility is to determine the coefficients of ileal (prececal) digestibility (PcVQ). Therefore the gut content is removed from surgically prepared animals at the end of the small intestine (ileum). Because the absorption of the amino acids is limited to the small intestine, transfer of the amino acids to the large intestine can in this way be avoided (MOSENTHIN & SAUER, 2000). To investigate PcVQ of protein in poultry, faeces-N are separated from the urine-N by the so-called colostomy (GRUHN et al., 1990).

In this context the in vitro methods of BOISEN & FERNANDEZ (1995) are relevant to predict the apparent ileal digestibility of protein and amino acids in feedstuffs and feed mixtures.

The digestibility of amino acids in pigs and their physiological effectiveness and suitability to digestive processes can be detected much more exactly by determining prececal digestibility than by examining faecal digestibility (MOSENTHIN & SAUER, 2000; SCHULZ et al., 2000; MOSENTHIN & RADEMACHER, 2003). But the use of the standard method for examining the ileal amino acid digestibility with respect to varying amino acid content in the feed ration is associated with great difficulties. Thus, the variation of the digestive values in the individual amino acids in feedstuffs is clearly larger than the variation between different feedstuffs (see Table 1-2). For example, the analysis of rapeseed meal yielded for methionine a range of PcVQ from 76% to 93 % and for wheat from 79% to 92 %, whereas the median values of this feed were at 82% or 85 %. Microbial effect on faecal digestibility is influenced by the proportion available nitrogen and energy in the hind-gut digestion. Surplus protein increase degradation and absorption of ammonia leading to increased faecal protein digestibility. Surplus energy (in easily fermentable fibre diets increases microbial protein synthesis and reduces the faecal protein digestibility (BOISEN, 2005).

Tab. 1-2: Apparent ileal digestibility of amino acids from cereals and protein-rich feedstuffs used in pig diets

Digestibility (%)		Lysine				Methionine				Threonine			
Feedstuff	**n$^{1)}$**	$\overline{X}$	s	min	max	$\overline{X}$	s	min	max	$\overline{X}$	s	Min	Max
Barley	20	66	10.1	38	79	78	6.0	67	88$^{2)}$	64	8.6	44	76
Maize	8	68	1.9	50	82	85	4.3	79	92	65	9.6	53	79
Rye	2	69	6.7	65	73	80	0.9	79	80	62	1.0	62	63
Triticale	6	72	6.7	62	81	82	3.1	77	85	62	11.1	46	74
Wheat	22	73	6.5	62	84	85	3.5	79	92	72	6.7	51	78
Faba beans	6	80	3.6	77	87	67	7.1	61	77$^{3)}$	73	11.5	57	84
Peas	9	81	3.6	73	84	73	2.5	68	76	65	4.1	60	74
Fish meal	7	83	5.0	77	89	88	5.2	82	94$^{3)}$	78	3.6	73	84
Rapeseed meal	14	73	3.1	69	81	82	4.7	76	93$^{4)}$	67	3.7	60	74
Soybean meal	30	84	3.4	76	91	86	4.3	77	97$^{5)}$	75	3.9	68	83

$^{1)}$ No. of samples investigated; $^{2)}$ No. of samples investigated = 18; $^{3)}$ No. of samples investigated = 4; $^{4)}$ No. of samples investigated = 11; $^{5)}$ No. of samples investigated = 27; $^{6)}$ No. of samples investigated = 7

Source: MOSENTHIN & SAUER, 2000

MOSENTHIN & SAUER (2000) explained the variation within the same feed by the effect of processing of the feed (grinding, heating and pelleting), growth factors (climate and fertilisation) varieties and contents of ANF's. Furthermore, different methods for collecting digesta from the small intestine may influence these results (MOSENTHIN et al., 1997). HERMANN & WÜNSCHE (1991) and SCHULZ et al. (2000) highlight the effect of heat damage on digestibility, lysine being one of the most frequently damaged amino acids. SCHULZ et al. (2000) recommend the use of prececal digestibility only for certain feedstuffs, i.e. those whose digestion values show strong deviation in both digestion methods and a high percentage in the feed ration. Currently, calculations worldwide are based on table values for standardised (true) ileal digestibility of amino acids (SDAA) of individual feedstuffs together with amino acid composition based on N-analysis of the actual sample of feedstuffs.

1.3.2 Ideal protein

Ideal protein is defined by the composition of essential amino acids relative to the requirement for crude protein, i. E. g lysine per 160 g N). For this reason various working groups have developed recommendations for optimal amino acid patterns in feed rations for various species of different age and performance (Wang & Fuller, 1990; Kirchgessner et al., 1995; Gramzow, 2001). Theoretically, the genetic performance capacity can be used optimally with a feed ration in which the need for individual amino acids is covered without deficiency or excess.

For the amino acid profile of an ideal protein the individual amino acid need is usually oriented to the lysine requirement. This has the advantage that only for lysine the absolute requirement values have to be determined. If the absolute requirement value of lysine is increased or reduced, the ratio of the other amino acids is altered accordingly. After the lysine content has been established in relation to the energy content, the other essential amino acids are fixed in relation to lysine. Compositions of the "ideal protein" for various breeds are given in Table 1-3. Knowledge of the "ideal protein" helps to fix corresponding content values for the other essential amino acids or, in the case of a deficiency, to estimate their effect on the protein accretion and performance.

Tab. 1-3: Optimal amino acid pattern in feed protein for various breeds

	Broilers	Turkeys	Laying Hens	Growing Pigs
Lysine (6,5 g/16g N)	100	100	100	100
Methionine		36	44	
Methionine + Cystine	72	69	74	50-55
Threonine	67	63	-	65-70
Tryptophan	16	16	16	17-19
Valine	77	77	-	65-75
Isoleucine	67	63	76	50-60
Leucine	100	114	-	95-110
Histidine	31	35	-	30-40
Tyrosine + Phenylalanine	105	-	-	95-110
Source	Firmann & Bowling, 1998	Gramzow, 2001	Kirchgessner et al., 1995	Susenbeth, 2002

The basic prerequisite for growth, reproduction, lactation and egg production of farm animals is the guaranteed basic provision (maintenance requirement) of energy and nutrition. The nutrient supply that goes beyond the maintenance requirement is the basis for protein accretion, milk or egg production as well as reproduction.

1.3.3 Sulphur-containing amino acids

For protein biosynthesis the organism requires the amino acids to be provided in a specific ratio. Strong deviations from this ratio can lead to malfunctions, which, if they have a negative effect on growth, utilization, feed intake and other physiological parameters, are designated as imbalances (D'MELLO, 2003). The sulphur-containing amino acids (in the following named as SAA) methionine and cystine are especially important in organic animal husbandry. First, methionine is the first-limiting amino acid in poultry and the second-limiting in pig production, and second, its availability under organic conditions is more restricted than in conventional production (see chapter 4). SAA are the most important sources of organically bound sulphur in the organism and occur in different proportions in plant protein. Methionine is an essential and cystine a semi-essential amino acid, because cystine can be synthesized from methionine by a conversion process in the animal organism (CHAMRUSPOLLERT et al., 2002). Reversal of this reaction from cystine to methionine is not possible. Methionine as the basis for protein biosynthesis also functions as methyl group-donator for compounds important in the metabolism, such as choline, creatine and adrenalin (LEWIS, 2003).

Theoretically, the total requirement for sulphur-containing amino acids can be covered by methionine alone, but not cystine alone. Usual feedstuffs normally have a sufficient quantity of cystine, which means that the need for methionine is somewhat reduced (CHAMRUSPOLLERT et al., 2002; LEWIS, 2003). The need for methionine and cystine as sulphur-containing amino acids is often summarized in the literature. The required methionine : cystine ratio is, however, variously estimated. The calculations range between 40:60 and 60:40. The data vary according to breed and age (WHEELER & LATSHAW, 1981; KOCH & TANNER, 1987; KIRCHGESSNER et al., 1989). There are two enantiomers D- and L-methionine. Only L-methionine is used directly by the organism. But the D form can, unlike other essential amino acids, be converted in the body indirectly into L- methionine.

1.3.4 Protein turnover

The protein accretion of the organism is in a state of permanent renewal, i.e. protein synthesis and protein decomposition are constantly parallel in the tissues. Whether the protein accretion of a tissue or organism increases or decreases depends on whether the synthesis rate or the decomposition rate is higher. In the case of fully grown animals there is a balance. The excess of amino acids unused for biosynthesis is decomposed (JEROCH et al., 1999).

Whereas the synthesis of protein underlying the protein accretion is well documented in the literature, the contrary catabolic processes have received only little attention so far (BERGEN & MERKEL, 1991; ODDY, 1999). The flow balance that results on building up and decomposition is designated as "turnover" (CLAUS, 1996b). Fig. 1-1 shows schematically the high level of decomposition processes in relation to the proportion retained dependent on age.

Although the fractional synthesis and decomposition rate decreases with increasing age, the absolute protein synthesis rates increase because of the hypertrophy of the skeleton musculature and reach a plateau when the maximum protein accretion is reached. It becomes obvious that at all stages of the development a high level of synthesis is required in order to compensate for protein decomposition.

The protein accretion is the result of the ratio of protein synthesis rate and decomposition rate at different levels (WATERLOW et al., 1978). Because the synthesis process takes place using energy (per Mol of inbuilt amino acid 5 Mol ATP are required) a differing energy consumption may be necessary according to composition and decomposition rate even with the same protein accretion (JEROCH et al., 1999). The protein turnover is physiologically desirable so that functionally and structurally important proteins are exchanged before defects can emerge through protein degeneration in the physiological system (CLAUS, 1996b).

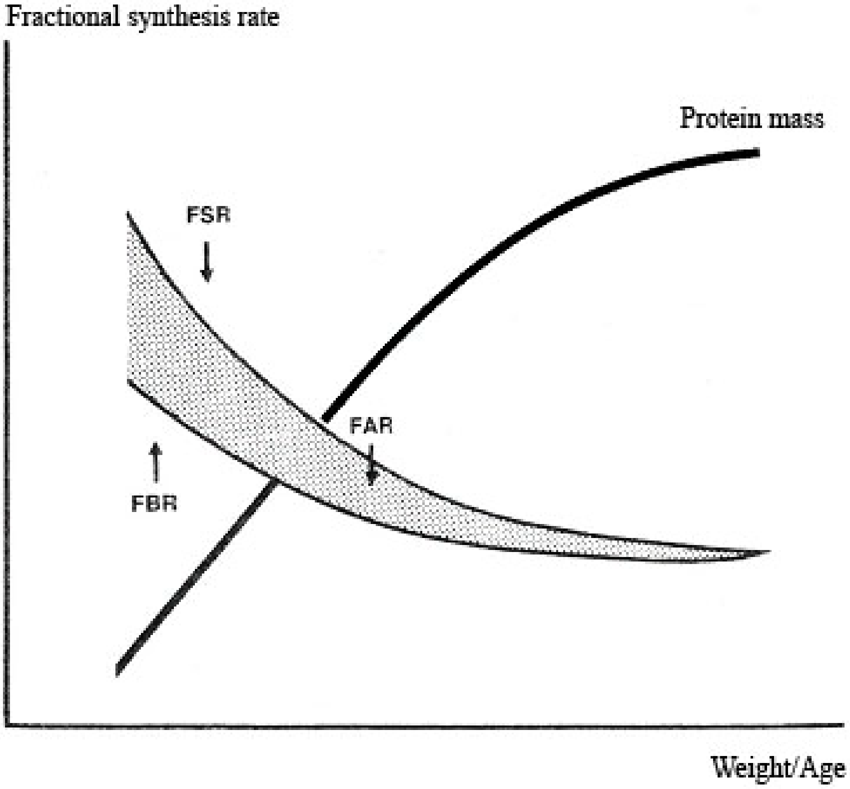

Fig. 1-1: Age-dependent development of the fractional synthesis rate of protein (FSR), of the fractional decomposition (FBR), of the fractional accretion rate (FAR), as well as the total protein accretion (WATERLOW et al., 1978)

JEROCH et al. (1999) formulated the following functions of a high protein turnover:

- basis for a rapid change of quantity (activity) of specific enzymes (adaptation ability),
- indispensable partial process in cell differentiation and growth. Both are possible only if the decomposition of old structures goes together with the formation of new ones,
- mobilization of proteins in the case of protein or energy deficiency (adaptation ability),
- limited proteolysis plays an important role in the post-translational conversion of the pre-stages into effective protein.
- The dimension of conversion processes is considerable. In the case of a pig of 90 kg live weight and a protein accretion of 69 g dry matter /day, 235 g protein are decomposed and 304g protein synthesized, i.e. in this case 4.4 times the quantity of the daily protein accretion is synthesized (BERGEN & MERKEL, 1991).

A high turnover rate of protein does not automatically mean a high N-excretion, because a considerable part of the amino acids and nucleic acids are re-utilized. According to CLAUS (1996a) the high muscle growth achieved by breeding is largely explicable by the fact that not only protein synthesis is raised by the body's own increased secretion of growth hormones, but the release of glucocorticoids is considerably reduced. With a low content of glucocorticoids the protein decomposition processes are blocked and N-retention is considerably improved (GOLDBERG et al., 1980; CLAUS & WEILER, 1994). However, it may be supposed that the breeding reduction of glucocorticoids is physiologically problematic, because these hormones are essential for cell differentiation and the functionality of tissues.

The importance of protein accretion for performance is illustrated in Table 1-4. with the example of the fattening pig. According to this, the difference in protein accretion (130 or 150 g/day) based on the same feed intake, has a different effect on daily weight gain, feed expenditure for the increase in live weight (feed conversion) and on muscle growth. From this relationship it becomes obvious that under the current economic pressure on production costs it seems useful to exploit the protein accretion of the animals in order to achieve a high growth performance, low feed expenditure and low nutritional losses.

Tab. 1-4: Importance of protein accretion for performance in fattening pig

Protein accretion (g/d)	**Fat content(g/d)**	**Daily weight gain (g/d)**	**Feed conversion (kg/kg)**	**Muscle growth (g/d)**
130	250	840	2.61	330
150	240	920	2.39	380
Body weight: 60 kg; Feed intake: 2.20 kg/d: 13.0 MJ ME/kg; MEm = 0.475 MJ/kg BW ^{0,75}; kpf = 0.7022 % xp in dFFS; 56 % of total body protein in muscle; 1 g CP corr. 2.55 g muscle growth				
Source: SUSENBETH, 2002				

In the growing period, N retention increases as the supply of limiting amino acids increases (HEGER et al., 2002). The dose-effect ratio, illustrated in Figure 1-2, can be subdivided into the nutrition-dependent phase, which is substantially linear, and the plateau phase, which is also influenced by the nutrient composition of the diet, in particular by the first limiting amino acid in the contribution to the ideal protein for the animal species and category (SUSENBETH et al., 1999; SUSENBETH, 2002).

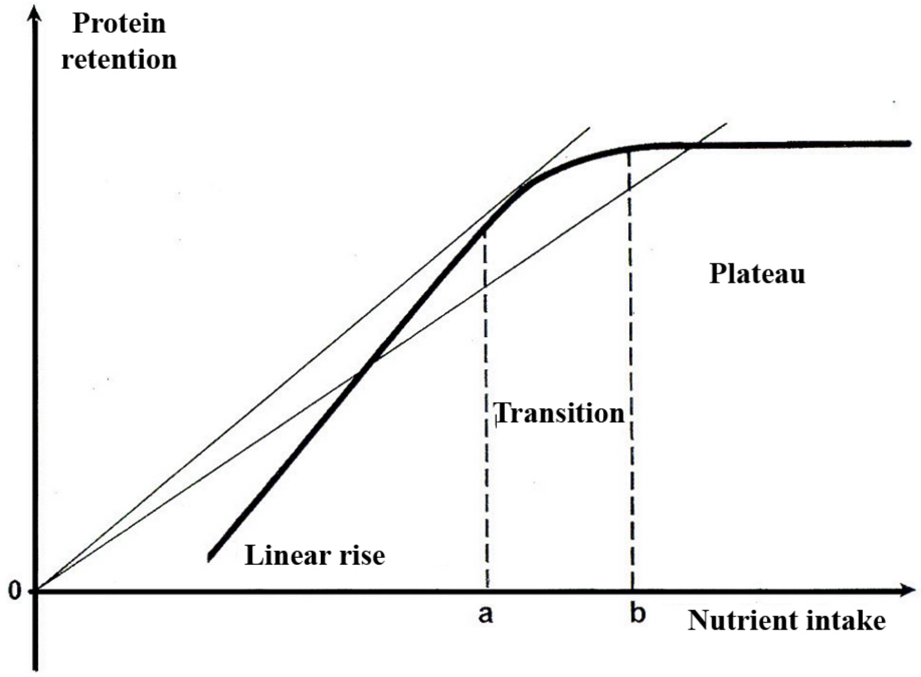

Fig. 1-2: Representation of nutritional effects on the protein accretion (SUSENBETH, 2002)

1.3.5 Conclusions

Protein accretion is the result of protein synthesis and decomposition rate; both are influenced by the genotype. Under conventional conditions, farmers intend to maximize protein accretion for economical reasons by using genotypes with a high growth capacity and by increasing the supply of limited amino acids by the way of increasing their concentration in the feed ration.

Due to the restricted availability of limited amino acids in organic livestock production protein accretion capacity is limited. To optimise the use of limited resources, the farmer is challenged to adapt the level of amino acid supply to the protein accretion capacity of the animals to a high degree as suboptimal supply reduces the performance while excess supply with amino acids cannot further increase performance.

Due to the high variation in availability, feed intake, digestibility and in utilization of amino acids between farms and the variation in protein accretion between genotypes there is need for the development of recommendations that are more closely related to the farm specific situation.

2 Protein sources in conventional and organic livestock production

In conventional livestock production, soybean meal (SBM) is used world wide as the most important protein source for monogastric animals. It contains a comparable high portion of essential amino acids which are easily digestible. In addition, there are high value proteins from the food industry, such as brewers yeast, potato protein and maize gluten. Animal protein sources such as fish or animal meal are no longer as important as in the past because of the ban on animal meal in feedstuffs. Grain legumes and extracted rapeseed meal are used in smaller quantities as protein agents in supplementation to SBM.

In organic systems, there are high aspirations to use home grown protein sources. Conventionally produced protein sources listed in paragraph C in the appendix of the EU Council-Regulation can only be used until the end of the transition period.

Factors such as amino acid availability, metabolisable energy content, fibre content, digestibility and type and quantity of anti-nutritive factors (ANF's) will influence the maximum inclusion rate of home grown protein sources. Thus a feed ingredient that has a low protein content or a deficit of one essential amino acid may be considered valuable if it has other useful attributes. As soybean meal from conventional cultivation is banned in organic agriculture, grain legumes represent the main protein source. However, if soybeans are grown organically, and instead of an extraction process with a chemical solvent, a physical process for the separation of the oil is used, soybean cake is of high importance also in organic agriculture. However, only inadequate tests on cake have so far been carried out.

2.1 Domestic protein sources in organic livestock production

Grain legumes are used worldwide both in human and animal as a major protein source. In temperate climates as it is the case in most European countries, it is possible to grow faba beans (*Vicia faba L.*), peas (*Pisum sativum L.*) and sweet lupins (*Lupinus spec.*). There are several varieties of grain legumes with distinct nutrient content. The mean crude protein content can vary, according to species and variety, between 258 and 440 g/kg DM, as table 2-1. shows. The crude protein proportions increase in the sequence peas, faba beans and lupins. Peas are among the poorest in protein and lupins the richest of the grain legumes. All have a relatively high lysine content but the concentration of sulphur containing amino acids and tryptophan are low.

Tab. 2-1: Crude nutrient content of grain legumes

Grain Legumes	Crude nutrients (kg DM)			
	Crude protein g	Ether Extract g	Crude fibre g	N-free extract fraction g
Faba beans	285	15	95	565
Feed peas	258	15	68	621
Yellow sweet lupins	440	70	145	295
White sweet lupins	362	116	132	365
Blue sweet lupins	339	72	157	332

Source: JEROCH et al., 1993, SUNDRUM et al., 2005b

Faba beans and peas have a larger N-free extract fraction (primarily based on starch) than lupins. The lysine content of faba beans is high but they are low in sulphur containing amino acids and linolenic acid. The latter is especially important in egg production.

With lupins the yellow sweet lupine (*Lupinus luteus*) reveals a clear higher crude protein (approx. 445 g/kg DM) than the white (390 g/kg DM) and blue lupine (339 g/kg DM). Sweet lupins have a similar crude protein content to that of full fat soya. The lysine content is high and the methionine + cystine content is moderate. The quality of sweet lupins as a feed ingredient is variable. Lupins, especially the white lupins, have a higher fat content than beans or peas. The proportions of saturated fats are relatively low at approx. 20 % (ABEL, 1996).

The grain legume protein consists up to 10 % - 20 % of albumins and up to 80 % - 90 % of globulins (ABEL, 1996). JEROCH et al. (1993) consider the protein of grain legumes to be more valuable than the grain protein because of the amino acid pattern. The pattern of single amino acids in the crude protein and the values calculated for the muscle protein of pigs are illustrated in table 2-2.

The starch content of grain legumes varies, depending on varieties, location and year of cultivation. In general, a distinction is necessary between starch-containing and non-starch-containing polysaccharides (NSP) (ABEL, 1996). The NSP content in faba beans and peas is about 20 % of the DM, while in lupins it is over 40 % of the DM (GDALA et al., 1995). The NSP are localized above all in the shells.

Crude protein of grain legumes shows a relatively high lysine content. It is highest in peas, followed by soybeans and faba beans, and lowest in lupins. The methionine content is low in all varieties. In order to cover the need for methionine, the portion of grain legumes in the feed ration is often very high, which usually leads to an excess in other amino acids.

Tab. 2-2: Amino acid content (g per 16 g N) in grain legumes compared with muscle protein of pigs

Amino acid	Muscle protein of pigs	Faba beans	Peas	Lupins	Soy bean meal
Lys.	8.5	6.3	7.0	4.4	6.2
Met.	2.5	0.8	1.0	0.7	1.7
Met+Cyst.	4.3	2.0	2.4	2.2	3.4

Source ABEL, 1996 JEROCH, 1988

According to ABEL (1996), the amino acid pattern of lupins is better suited to the requirements of fattening pigs than that of faba beans and peas. JEROCH et al. (1993) recommend combining legumes with other methionine-rich protein carriers. To GORDON (1999), peas seem to be the most promising potential feed ingredient for organic poultry rations. They can probably be incorporated in broiler diets at up to 250 to 300 g/kg and in layers diets at up to 150 to 200 g/kg. Some reports suggest that modest levels of sweet lupins (200 g/kg) might also replace soya in layers feeds. However, due to wide variation between lupins cultivars and in the treatment of raw materials, and therefore in their nutrient analysis, it is not possible to provide definitive universal recommendations. Thus the maximum inclusion rates suggested for lupins depend on the quality of the ingredient used. According to VAN BARNEVELD (1999), blue lupins can be included in pig diets at high levels without having negative effects on feed intake and growth performance. The maximum recommended inclusion levels were 200-250 g/kg diet for growers and 300-350 g/kg diet for finishers. Beans do not appear to be a good alternative protein source for use in organic poultry rations. This is because of the low concentration of sulphur amino acids and the presence of ANF's. Rapeseed produced from the double low (00) glucosinolate species may only be incorporated in poultry rations at small concentrations (no more than 100 g/kg in feeds for brown laying hens and 50 g/kg in brown broiler starter rations, possibly increasing to 80 g/kg in broiler finisher rations). This is because of egg taint problems and off flavours in poultry meat caused by the presence of ANF's in rapeseed.

2.2 Digestibility of grain legumes

Legumes are easily digested by monogastric animals despite the high crude fibre components in the grains. The digestibility of different grain legumes is shown in table 2-3. The apparent digestibility is about 70 % in poultry or up to 96 % in pigs (JEROCH et al., 1993). The energy content of legumes in grain legumes varies to a high degree. For poultry peas, followed by faba beans and yellow sweet lupins have the highest energy content.

Tab. 2-3: Crude protein digestibility of grain legumes

Animal variety	Faba beans (%)	Yellow sweet lupin (%)	White sweet lupin (%)	Peas (%)	Soybean meal (%)
Pig	80-85	89	96	88	85
Poultry	76-80	74	75-81	80-88	83

Source: JEROCH et al., 1993

2.3 Anti-nutritional factors (ANF)

Legume protein sources can only be fed to a limited extent due to the occurrence of anti-nutritional factors (ANF's). Plant breeding research has developed methods to select for lower levels of ANF's in legumes, but relevant legume crops still contain significant amounts of ANF's, which reduces the use of the legumes as a protein source.

Substances in grain legumes that have a performance-reducing effect on the animal metabolism are tannins, lectins, protease-inhibitors and pyrimids-glycosids. An overview of ANF in legume seeds is provided by HUISMANN et al. (1989), HEINZ et al. (1991); ABEL (1996) and GORDON (1999).

The tannin group (polyphenol substances) are hydrolizable in carbohydrates and phenol (HEINZ et al., 1991). They occur in the shells of faba beans and peas of the coloured-flower varieties more often than in the white-flower varieties. The tannins form, with proteins and carbohydrates, stable indigestible complexes in the digestion tract and block digestion enzymes (JEROCH et al., 1993; ABEL, 1996).

Lectins are proteins that easily combine with sugar components to form glycoproteids. This combination restricts the absorption capacity of villi in the intestine. Serious digestion and metabolism disorders may be the result (HEINZ et al., 1991). Lectins are in the cotyledons. Peas are lectin-richer than faba beans, and lupins are lectine-free (ABEL, 1996).

Protease-inhibitors are peptides that can form stable inactive compounds and so reduce the activity of trypsin and chymotrypsin. Consequently, the digestibility of the protein or the absorption of the amino acids are diminished. The inhibitors occur in the cotyledons of peas and the cotyledons and shells of faba beans; lupins contain only small quantities (JEROCH et al., 1993).

Vicin and convicin belong to the pyrimids-glycosids, which are relevant only in faba beans. They are degraded microbially in the digestion tract. The substances released may cause haemolysis and can affect both egg quality through blood patches in the egg and egg size (HEINZ et al., 1991; ABEL, 1996).

Lupin seeds contain alkaloids which have a bitter taste and negative effects on feed palatability. The content of alkaloids in blue lupin seed has ranged from 0.1 up to 2.6 g/kg DM (GDALA et al., 1996; CHRISTIANSEN et al., 1997, WASILEWKO & BURACZEWSKA, 1999). According to GODFREY et al. (1985), the feed intake of pigs is decreased when the alkaloids content of the diet exceeds 0.2 g/kg feed. Lupin seeds have also a high content of α-galactoside oligosaccharides which cannot be hydrolysed in the small intestine, due to the absence of the appropriate enzyme. Consequently they are fermented by gastrointestinal bacteria into carbon dioxide, hydrogen and methane. High levels of α-galactosides in a diet have had an adverse effect on the ileal digestibility of nutrients, including amino acids and can cause flatulence and diarrhoea in animals (SALGADO et al., 2002).

In addition to the influences of location and growth year there is a clear genetic influence on the content of anti-nutritional substances. These might be successfully reduced through breeding (JEROCH et al., 1993; ABEL, 1996). An overview of suggested maximum inclusion rates of home-grown feedstuffs is presented in the Annex (table A-1).

There are several technical treatment procedures to minimize the content of anti-nutritional factors in grain legumes: For instance, the shells with the largest share of trypsin inhibitors can be removed. Peeled seeds are also poorer in crude fibres and thus more easily digestible for poultry. Anti-nutritional substances can be deactivated by autoclaving, expanding, extruding, toasting or steam-pelleting. A practical process is the pelleting of feed using steam. The alkaloid content is reduced substantially by swelling the grains and washing them. Water-saving extraction processes have already been developed. However, due to the limited scale of organic livestock production, the large scale feed processors are still hesitant in developing separate organic production lines for this type of processing.

2.4 Protein supplement feedstuffs from organic production

The replacement of conventional by organically produced commercial feed is important in order to meet the protein requirements under organic conditions. Among organically produced feedstuffs are, in particular, various cakes (oil produce where the fat has been removed through physical pressure) and milk products. Ingredients of several protein-rich feedstuffs are presented in table 2-4. For the feed value the contents of digestible lysine and methionine are particularly decisive. There are high contents especially with soya expeller (toasted) and non-fat milk powder. The individual feedstuffs vary in respect of both essential amino acids and fat and energy contents. Every feedstuff shows specific advantages and disadvantages, which should be taken adequately into account in formulating the feed ration.

Soya products show a favourable amino acid pattern, which explains its success in conventional feedstuffs and is expected to provide an increasing use also in organic agriculture. Soya products basically have to be toasted, due to their high ANF content. The soya full bean, in comparison with extracted soybean meal, shows a very high fat content, which limits its possible use. Also with regard to cake special attention has to be paid to the fat content.

Sunflower cake is a suitable alternative protein source. Although it is deficient in lysine it is very rich in sulphur containing amino acids. Its inclusion rate in organic diets for laying hens may be limited less by its ANF's than by its moderate metabolisable energy.

Rape cake has a high crude protein content. The lysine and methionine contents are comparable to those of soybean meal. The metabolisable energy value of rapeseed is low. Its inclusion rate in poultry rations is limited by the presence of high concentrations of ANF's.

Linseed meal has a moderate crude protein content relative to soya but it is low in lysine and methionine. Linseed contains an array of ANF's. Problems with fishy taint and rancidity of poultry meat because of the content of unsaturated fatty acids occur at modest inclusion levels. However, its potential feeding value is enhanced by its ability to manipulate tissue and egg concentrations of linolenic acid.

Tab. 2-4: Contents and digestibility estimates for pigs of protein supplement feedstuffs in relation to conventional soybean meal (Sundrum & Rübesam, 2003)

	Soybean meal	Soya full-beans	Soya cake	Rape-seed cake	Sunflower cake	Flax cake	Non-fat milk powder	Whey powder (de-sugared)
DM	880	880	880	910	910	900	960	960
g CP	451	356	424	334	431	337	350	229
g EE	12	177	68	79	107	89	4	12
MJ ME	13.0	15.5	14.4	12.3	14.0	11.4	15.2	13.4
g Lys	26.8	21.8	25.9	17	11	11.9	25.9	16.7
g M+C	12.6	10.6	12	13.5	12.4	10.6	11.4	8.2
g Thr	17.2	14.1	16.5	13.4	11.5	11.7	14.8	13.0
g Trp	5.9	4.8	5.6	3.9	4.1	5.7	4.5	3.4

MJ ME = Mega Joule metabolizable energy, CP = Crude protein, EE = Crude fat, Lys = Lysine, M+C = Methionine + Cystine, Thr = Threonine, Try = Tryptophan, Source: Degussa (2002)

Non-fat milk and whey powder are characterized by their high digestibility. Therefore, they are a valuable component especially when feeding young stock. With sweet whey powder there is the risk that the high lactose content may cause problems with regard to storage and will not be properly digested in the small intestine. On the other hand, partially de-sugared whey powder is still useful. However, the possible uses of feedstuffs are not determined exclusively by the value-giving and anti-nutritional contents or taste. Determining factors in particular are the availability and price. But it may be assumed that increasing demand will lead to sustainable increased cultivation and processing of corresponding protein supplement feedstuffs.

3 Protein supply of poultry and pigs

3.1 Protein supply of broiler

Growth performance and protein accretion of broilers are affected by various factors. The most relevant causes of variation in farming practice are explained in more detail below.

3.1.1 Genotype

Since the mid-50s there has been a clear increase in the performance and protein accretion capacity of broilers due to breeding. This has led to considerable differences in the demands with regard to the supply with energy and nutrients between breeds and strains of then and now. Thus, the breeds common in earlier years (Sussex, Leghorn, Sussex-Leghorn and New Hampshire-Leghorn) needed an average of 59 to 61 days to reach a weight of 800 g and about 84 days to reach a live weight of 1300 g (MEHNER, 1962).

At the beginning of the 70s hybrids were bred from two or more line-crossings of White Cornish cocks (roosters) and White Rock hens. The males of those hybrids reached a live weight of about 1600 kg in 56 days, while the females gained about 1400 g in the same time period (JEROCH, 1972). In experiments with Lohmann broilers STROHSCHNEIDER (1981) was able to achieve an average weight of 1640 g within 42 days. With Lohmann broilers MAURUS (1987) even reached a living weight of nearly 3000 g within 56 days. The development of the age of broilers at the time of slaughter maturity (1500 g) in the course of the 20th century is represented in figure 3-1.

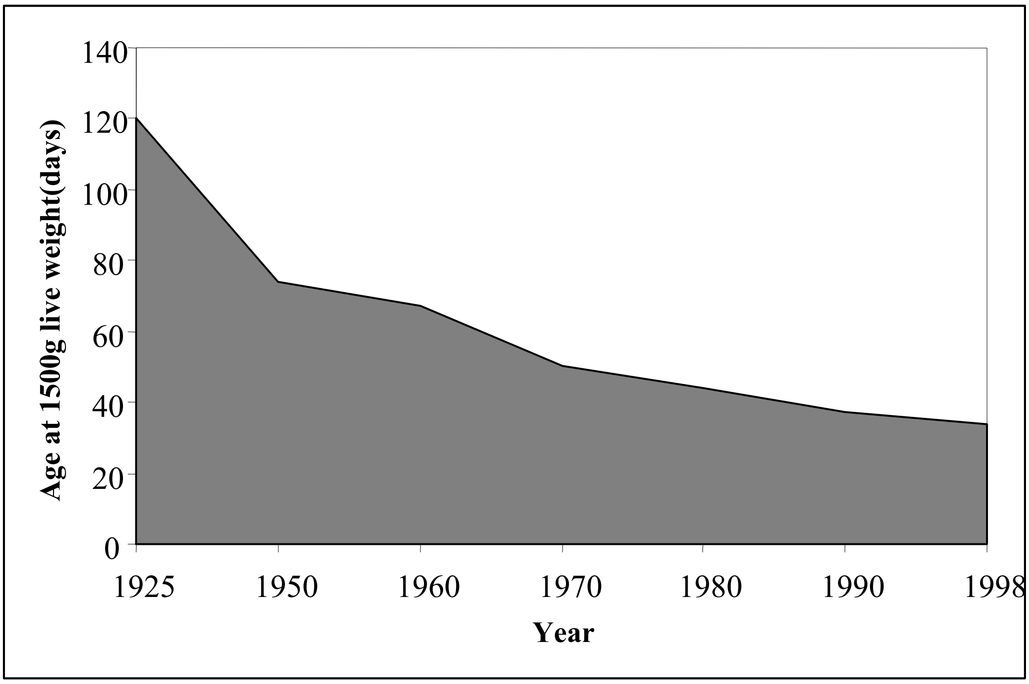

Fig. 3-1: Development of age of broiler with a live weight of 1500 g (ALBERS, 1998)

Within 27 years, from 1962 to 1989, the average live weight based on a fattening period of 56 days increased from 800 to 3000 g. As a result of the breeding progress fattening period and feed utilization were almost halved (HAVENSTEIN et al., 1994a,b). However, this was possible only because the nutrient content in the feed was simultaneously increased.

The development of body weight in laying hens, male and female broilers of conventional and slow growing strains (Label Rouge) are presented in figure 3-2. It can be concluded from the difference in the growth process that protein requirements are clearly reduced if slow growing strains like those in the label rouge programme are used compared to conventional strains. PETER et al. (1997a,b) examined the effects of various protein and energy contents in the diet on male Sasso-Label-broilers and concluded that, for an optimal fattening performance, protein content of 20% in the initial fattening diet are adequate. From the 6th week the protein content can even be reduced to 17.5%.

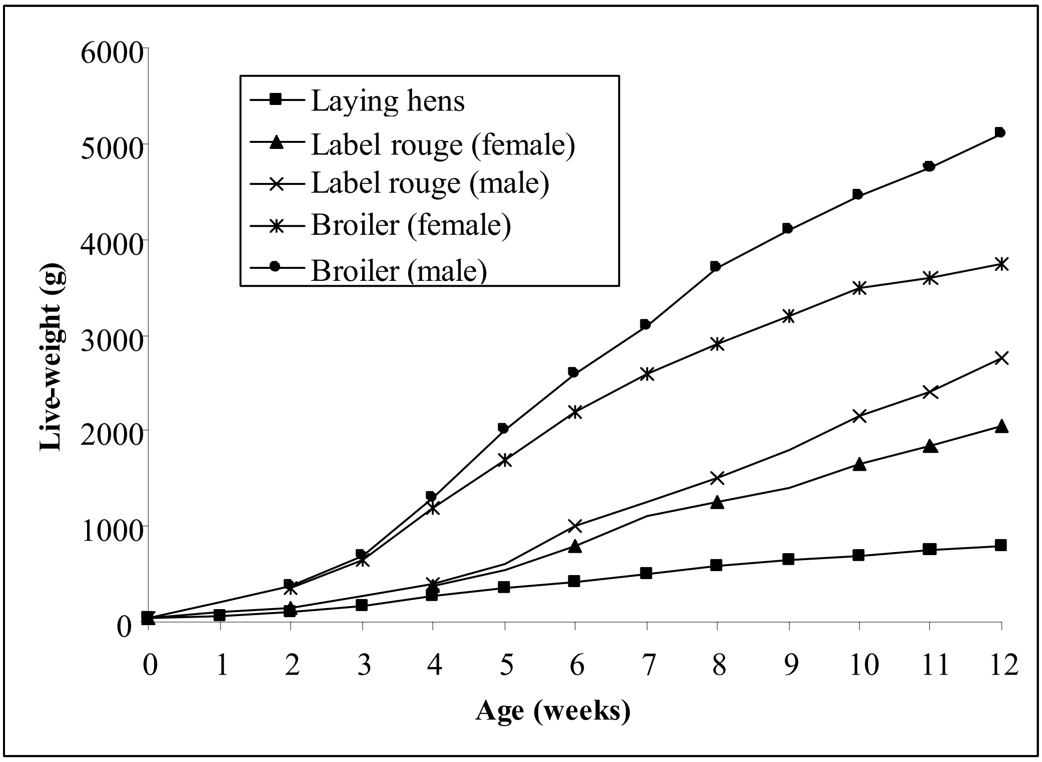

Fig. 3-2: Development of body weight in laying hens, male and female broilers and Label Rouge (EU-Report, 2000)

3.1.2 Sex, age, and live weight

Male animals have a genetically higher capacity for protein accretion than female (PEISKER, 1997; CHAMRUSPOLLERT et al., 2002). This is ascribed principally to the different hormone status of the sexes. The need for essential amino acids in male animals is higher than in females. Fig. 4-2 shows that the male animals after five to eight weeks of fattening period achieve a 15 % to 19 % higher live weight than the female ones (KIRCHGESSNER, 1997). The higher protein accretion of males is principally due to a higher feed intake (NRC 1994).

During the growth process there is, in addition to the increase of live weight, a specific change of organ proportions and, with it, also a change in the chemical composition of the organism. With increasing live weight the need for energy and nutrients to maintain and produce new tissue increases. The ratio between protein and fat content changes and with it the ratio between the requirements for amino acids and energy (MAURUS, 1987). Fig. 3-3 represents the net requirement of methionine and cystine by broilers for feathers, maintenance and animal body content during the fattening period.

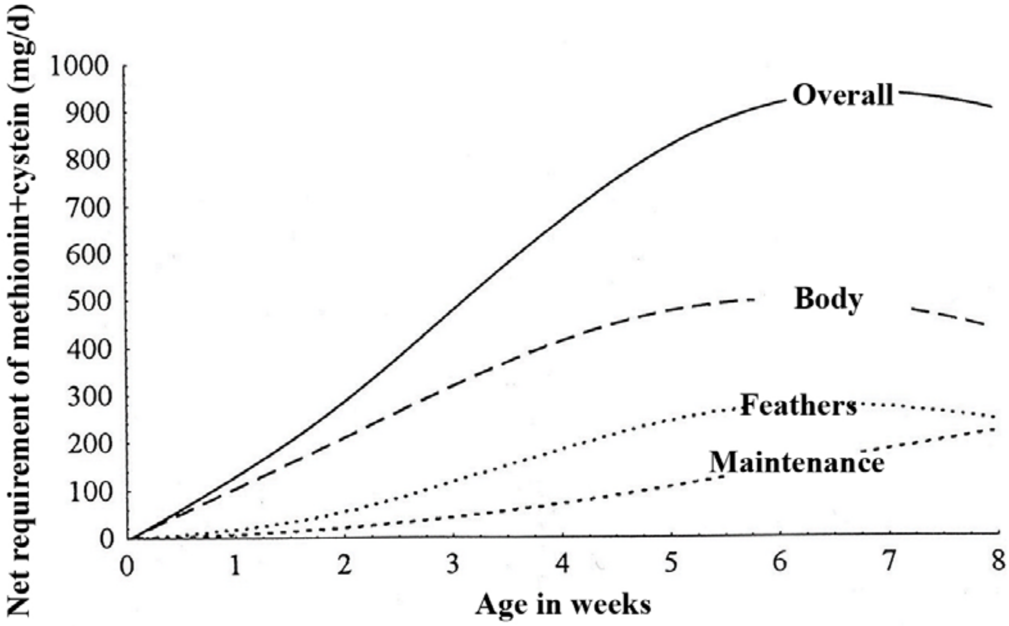

Fig. 3-3: Net requirement of methionine and cystine by male broilers in the fattening period (GfE, 1999).

In growing animals the amino acid requirement varies in the different stages of the development (Peisker, 1997). In the first third of the growth period, requirements in relation to essential amino acids are at the highest level, but decline with increasing age. In order to meet the requirements in the different stages, diets are usually adapted to three growth periods. In order to be able to estimate the energy and nutrient availability for the retention, knowledge of the potential for feed intake is very important. Feed intake is affected, among other things, by age, live weight, sex, environmental temperature, feed components and energy and protein content of the diet (Parr & Summers, 1991).

Lipstein et al. (1975) concluded from their investigations that deficiencies in essential amino acids can affect the feed intake in such a way that the animals take in feed until their need for amino acids is satisfied. Parr & Summers (1991), Chee & Polin (1978) und Schutte & Pack (1995) confirmed that broiler are able to compensate partially for a low content of essential amino acids in the diet by a higher feed intake. Because of the quicker growth process, male broilers take in more feed than females (see Figure 3-4).

3.1.3 Environmental influences

The utilization of energy and nutrients provided by feed is subjected not only to animal related but also to environmentally specific factors. The environmental conditions have an effect principally via a modification of the feed intake. Thus, as the stocking rate increases, the feed intake decreases (Scholtyssek, 1987; Bessei, 1993). High stocking rates favour the creation of high humidity and the formation of ammoniac (NH_3).

Also long-standing heat stress leads to growth depression (Bessei, 1993). Furthermore, feed intake and daily live weight gain can be increased via a light regime (Scholtyssek, 1987).

Fig. 3-4: Feed intake at 13.4 MJ ME/kg feed and feed utilization in the first weeks of male and female broilers (KIRCHGESSNER, 1997)

3.1.4 Supply with amino acids

The genetic origins of broilers currently used in intensive fattening have a high protein accretion capacity, which entails a high provision requirement of essential amino acids, which is not always estimated accurately. In table 3-1 a comparison between three different "ideal" amino acid profiles for broiler chicks is shown (PEISKER, 1997). In the case of methionine and tryptophan there are large differences between the recommendations of Rhone-Poulence-Animal Nutrition (RPAN, 1993) und National Research Council (NRC, 1994).

With high-performance strains the protein requirement can be covered not only with extracted soybean meal as protein source. In order to avoid performance depressions the rations are usually supplemented with synthetic methionine (DL-methionine). The optimal quantity of DL-methionine used is determined by the feedstuff components, the proportion of protein and energy content in the feed.

Tab. 3-1: Amino acids profile for broiler chicks

	IICP (1994) (digest. AS)	**RPAN (1993)** (total AS)	**NRC (1994)** (total AS)
Lysine	100	100	100
Methionine + Cystine	72	77	82
Methionine	36	47	46
Tryptophan	16	19	18

3.1.5 Protein supply in organic broiler production

In organic broiler production, the Council-Regulation (EEC No. 2092/91) prescribes a minimum age at slaughter of 81 days. This is derived from the EU Marketing Standard (EEC 1538/91) for poultry meat from "free range farming". The French brand "Label Rouge" is also based on this marketing standard.

Modern hybrid strains demonstrate a high growth potential that makes the animals suited for slaughter well below the Council-Regulation prescribed minimum age of 81 days. However, also slow growing strains fed with organic components reach their slaughter weight in 56 days, well before the minimum age at slaughter (DAMME, 2001). In general, the female animals display a lower growth intensity than the male ones and are more likely to be considered for use when available nutrients are limited.

In the case of broiler fattening it is possible to replace soybean meal with faba beans without reducing performance, if there is a corresponding balance of energy and methionine (JEROCH, 1988; HEINZ et al., 1991). RUBIO et al. (1990) found that replacing extracted soybean meal with faba beans means a higher feed consumption in the first four weeks and a corresponding increase in live weight.

Technical treatment procedures with faba beans (fine grinding, peeling and autoclaving) have a positive effect in broiler on feed utilization (ABEL, 1996). Thermal treatment processes can prevent the negative effect of tannins with a high pea proportion in the feed. VOGT et al. (1979a) have established that the usual pelleting for poultry feed as thermal treatment for peas is enough to destroy the anti-nutritive substances.

GALIK et al. (1994) have established that the complete replacement of soybean meal by rape-cake in broiler up to the end of the 7th week resulted in a lower body weight than when only 50 % of the feed was replaced. Feed utilization was equal in all groups. The use of rape-cake for broiler is recommended to be very suitable if it is started at the 4th week.

In a six-week broiler experiment in the use of 20 % sunflower meal in combination with brewers yeast was investigated as a natural source of lysine in broiler feed (TASKA, 1996). No significant differences in the final weight and in the feed utilization between control and test groups were established. The crude fibre content in the rations, which had risen above the recommended value to 7 %, had no detectable effects on the results.

According to DAMME (2000), the EU restrictions in relation to several conventional feed components produce a lack of essential amino acids in fattening fast growing broilers. As a consequence, the use of slowly growing broiler strains with a lower amino acid requirement will be necessary.

BELLOF & SCHMIDT (2005) investigated the effect of organic diets when using a slow growing strain (ISA J 257). The rations differed in the level of energy and essential amino acids. Feed intake in the different feeding groups ran conversely proportional to the energy level of the diets. The obtained performance and carcass yield reached a high level under the framework of organic production. The authors concluded that those rations enable a 100% organic feeding with an acceptable performance and with low animal losses. The feeding ration is presented together with other examples of organic feed rations in the annex (table A-2, A-3). Additionally, table A-12 in the Annex provides an estimation about the proportional demands for cereals, corn legumes and high protein feed in organic broiler production.

O'BRIEN et al. (2005) carried out a study which was conducted on a commercial organic broiler farm to assess the impact of feeding a one hundred percent organic feed ration compared to that of a commercially available eighty per cent organic feed ration by using two different genotypes (ISA 257 and Colourpac). In contrast to the previous assumption, the results revealed no overall health, growth, behaviour or welfare concerns or increases in production costs when comparing the two rations and the genotypes.

Concerning the current situation in organic broiler husbandry practice, there is little information available about feeding conditions. ZOLLITSCH et al. (2000) reported about the situation in Austria that intensive consultation activities have been successful. The farms usually fed commercial sole feed in the first few weeks which had an approximately unified protein content of 22%. In the final fattening there were clearly more heterogeneous conditions in the use of home grown feedstuffs. In a field study of 90 farms considerable differences in protein content were established. Mostly hybrids were kept with a genetically lower growth potential than conventional broilers.

3.1.6 Conclusion for organic broiler production

Concerning broiler production, growth performance, protein accretion, feed intake, and feed utilization are subject to considerable variation, which depends to a large extent on the genotype, sex and environmental conditions. A suboptimal level of limited amino acids in the feed ration can be partly compensated for by increased feed intake, especially when the energy content in the diet is reduced. Studies on organic broiler husbandry and brand programmes using slow-growing lines (slaughtered after 81 days) show that, with lower demands with regard to the performance, a clearly lower amino acid content in the feed is required. However, so far only few research work has been carried out to investigate the implications of organic framework conditions on broiler production and on the capacity of broiler strains to adapt to changes in the nutrient supply.

3.2 Protein supply of turkeys

3.2.1 Effect of genotype on growth and protein accretion

By using modern line-crossing, hybrid lines were bred in the past that were capable of high protein accretion and high growth rate. Turkeys are divided according to their weight and size between heavy, medium-weight and light turkeys. The heavy white broad-breasted hybrids are preferred for long fattening because of their optimal slaughter performance and rapid growth (SCHOLTYSSEK, 1987). Tab. 3-2 shows the development of the average increases between 1972 and 1995. These increase from 42 g/day to 125 g/day, i.e. about threefold.

Tab. 3-2: Effect of genetic development (1972 to 1995) on growth in turkeys

	1972	1981	1995
Varieties	Average varieties	Big 6	Big 6
Fattening period (weeks)	15	18	18
Live weight at slaughter (kg)	4.5	12.7	15.8
Average daily live weight gain (g)	42	101	125
Feed conversion 1:	2.83	2.76	2.66
Source	JEROCH, 1972	FRANKENPOHL, 2002	

With modern varieties (Big 6) the male turkeys today achieve a living weight of 18 to 21.5 kg within 20 to 22 weeks and the females 10.5 kg within 15 to 17 weeks (JEROCH & LEHMANN, 1998).

3.2.2 Sex and age

With growth types there is a considerable sex dimorphism that is most marked in the heavy turkeys (see Tab. 3-3) (WEGNER, 1987). The male turkeys show a stronger growth than the female ones. Because of the higher live weight, feed intake in male animals is higher than in females. On the other hand, feed conversion in females is higher than in males (JEROCH & LEHMANN, 1998). The breast meat accretion incl. the breast skin in males amounts to between 32.1 and 33.6 % of the living weight and in females between 30.1 and 31.6 % (FRANKENPOHL, 2002). Thus, the amino acid requirements of the sexes are quite different.

Tab. 3-3: Live weight in male and female turkeys depending on type and fattening stage

Type	**Fattening stage**	**♂ (kg)**	**♀ (kg)**
Heavy	Age	20 - 25	10 – 12
	20 or 16 weeks	15 - 16	8 – 9
Medium weight	Age	10 - 12	6 – 7
	18 or 14 weeks	8 - 19	5 – 6
Light	Age	7 - 8	5 – 6
	14 or 12 weeks	6 - 7	4 – 5

Source: WEGNER, 1987

3.2.3 Environmental factors

In turkey fattening light has a determining effect on feed intake and thus protein accretion, because light intensity and activity of the animals are closely correlated with each other (GÜNTHER, 2001). In particular, intermittent programmes with multiple changes between light and dark phases can have a positive effect on the growth of the animals.

In the first few weeks young turkeys require a high environment temperature (33 to 35 °C), which is normally achieved with warm rays at chick height. The temperature can be lowered each week by 2 to 3°C (WEGNER, 1987). The stall temperature has a determining effect on the weight development of turkeys. Thus, with higher environmental temperature, the feed intake can clearly fall (NIXEY, 2003).

3.2.4 Amino acid supply

Turkeys show a high growth rate that requires suitable amino acid supply. The fattening period depends on whether the type can be fattened light or heavy. In addition, sex is a determining factor. The male animals are fattened up to 24 weeks and approx. 20 kg, while the females can be kept up to 16 weeks and a weight of approximately 10 kg. It is common to separate the nutrient supply of turkeys in feed phases, which with females is divided into five stages and in males into 6 stages (NRC, 1994; GFE, 1999). Tab. 3-4 shows the feed recommendations of NRC (1994) and JEROCH & DÄNICKE (2002).

WALDROUP et al. (1997) are critical of the recommendations of the NRC (1994), because they are calculated with a computer model and not on the basis of feed trials. The authors have corrected the need for the performance criteria of live weight increase, feed conversion and maximum breast meat yield upwards. BOLING & FIRMANN (1997) also criticize the NRC recommendations, because the calculations are on the basis of the total amino acids in the ration and not on the basis of digestibility. They correct the recommendations downwards to 0.76 % digestible amino acids for optimal growth in female turkeys in the first four fattening weeks, which corresponds to a proportion of about 0.88 % of the total amino acids in the feed. JEROCH & DÄNICKE (2002) recommends shortening the programme of the feed phases in the 1st and 2nd fattening phases. Instead of 4-week intervals (NRC, 1994) they suggest, up to the age of 4 weeks, two-week and then three-week intervals.

Tab. 3-4: Recommendations on amino acid supply in fattening turkeys

Age (weeks)	**Crude protein (%)**	**Met (%)**	**Met + Cys (%)**	**Crude protein (%)**	**Met (%)**	**Met + Cys (%)**
1 + 2	28	0.55	1.05	28	0.58	1.05
3 + 4				26	0.52	1.01
5 – 8	26	0.45	0.95	23	0.48	0.90
9 – 12	22	0.40	0.80	21	0.43	0.81
13 – 16	19	0.35	0.65	19	0.38	0.69
17 – 20	16.5	0.25	0.55	15	0.27	0.58
> 20	14	0.25	0.45	15	0.24	0.45
Source	NRC, 1994			JEROCH & DÄNICKE, 2002		

An ideal protein model was drawn up by FIRMAN & BOLING (1998) and GRAMZOW (2001) on the basis of digestible amino acids. The ideal protein model is a satisfactory aid to keeping the right balance of amino acids, which exactly meets the needs of turkeys without excess or deficiency of amino acids This model has been tested on various turkey varieties. Between the sexes and strains there were no differences. The ratio of lysine and SAA changes in the course of the growth period depending on the composition of body tissue.

3.2.5 Compensatory growth

AUCKLAND & MORRIS (1971) studied the compensatory effects in turkeys as a reaction to limited crude protein content in the feed. Turkeys provided with 29 % and 22 % crude protein in the starting period (0 to 6th week) and 24 % respective and 20 % in the growth phase (6th to 10th week) achieved, after 20 weeks, the same live weight. From the 10th to the 20th week all animals were fed with a diet containing appropriate crude protein content. The turkeys in the different treatments consumed nearly the same feed quantity, but a 10 % less amount of crude protein.

3.2.6 Protein supply in organic turkey husbandry

The development of organic turkey fattening is still at the beginning. Providing turkeys with essential amino acids is particularly difficult in the initial period, because feed intake is low while the protein accretion capacity is high relative to the live weight. In this phase, the decisive factors are the expected performance level on the one hand and protein concentration and availability of essential amino acids in the diet on the other hand.

The Council-Regulation (EEC No. 2092/91) envisages for turkeys a minimum slaughter age of 140 days and the use of slow-growing strains. Due to the demand of the market for heavy turkey with about 20 kg live weight it is possible to use conventional strains in organic livestock farming for a fattening period of 140 days (20 kg in 20 weeks). While in organic broiler production slow-growing strains are essential to produce a marketable product in a minimum of 81 days without excess weight, it is no longer necessary to use slow-growing strains in organic turkey production because of the market for heavy turkey. As there is no clear definition of the term ‘slow growing’ and as production units are not controlled by the certification bodies with regard to the intensity of the growth process, the use of conventional strains in organic turkey production is expected to be the rule rather than the exception.

If high performance breeds or strains are used, protein supply for turkeys up to 8 weeks without supplementation of the diet with synthetic methionine to balance the demand for essential amino acids is difficult (RICHTER, 1996). DAMME (1998) compared bronze broad breast turkeys of the Kelly company with Big 6 turkeys under organic conditions and came to the conclusion that the Kelly turkeys were clearly more suited to organic feed conditions than Big 6 ones. RICHTER und STEINGASS (2001) replace extracted soybean meal with faba beans in the case of turkey fattening up to the 17th week. According to their results, a maximum of 10% faba beans should be used in the mixed feed for fattening turkeys up to the 35th day and thereafter a maximum of 15 %.

BELLOF (2002) carried out a trial in accordance with the Council-Regulation on female turkeys of the variety Big 6. The rations contained hemp cakes and were supplemented with casein or low fat milk powder. After 18 weeks the animals achieved a weight of 10 kg or a daily increase of 79 g. The author concluded that the essential amino acid requirements could be met by high-protein feedstuffs such as casein, or milk powder. Several feeding rations for turkeys on the base of 100 % organic feedstuffs for the use in slow growing strains are described in the Annex (table A-4.). Additionally, table A-13 in the Annex provides an estimation about the proportional demands for cereals, corn legumes and high protein feed in organic turkey production.

3.2.7 Conclusion for organic turkey production

In organic turkey production it is difficult to ensure the supply of essential amino acids, especially in the initial fattening phase, due to the high protein accretion capacity in relation to the live weight and a low feed intake potential. In the starting phase, growth and protein accretion react very sensitively to a suboptimal supply with essential amino acids. With increasing age the demand on amino acids clearly declines and turkeys are more able to compensate partially for suboptimal contents of amino acids in feed by increased feed intake. Male animals can better compensate for the deficiency in amino acids than female ones, because their feed intake is higher.

There have so far been very few studies on the effects of the inadequate supply with essential amino acids in organic turkey production using robust breeds or slow growing strains. However, husbandry and feeding of turkeys under organic conditions should be organized in such way that it is not accompanied by deteriorating health.

The use of conventional strains with a high genetic capacity for protein accretion is not in accordance the guidelines of organic animal husbandry. However, currently it seems to be common practice. There are only few data and experiences available concerning the use of slow growing strains. Contrary to broilers, the necessity for the use of slow-growing strains in organic turkey production is abolished due to the possibility to produce marketable products with a high slaughter weight.

3.3 Protein supply of laying hens

3.3.1 Factors affecting laying performance

3.3.1.1 Genotype

Laying performance has grown continuously in recent decades. At the same time, animal losses could be reduced drastically (see Tab. 3-5). The increase in performance is based partly on breeding progress and partly on the fact that the genetic performance capacity can be better exploited as a result of optimisation in feeding, husbandry and animal hygiene.

Tab. 3-5: Average performance in laying hens per animal and year

	1950	**1960**	**1970**	**1980**	**1990**
Laying performance (eggs)	170	210	240	280	300
Egg weight (g)	53	56	60	63	-
Feed conversion (g feed/100 g egg weight)	350	340	320	260	-
Mortality (%)	25	18	12	6	-
Source	SCHOLTYSSEK, 1987				PINGEL & JEROCH, 1995

With the laying hens used today there is no clear distinction between breeds and strains. One of the most important breeds is the white leghorn (single comb), within which the various strains make up the modern hybrid lines. They are distinguished by a low live weight, which results in a low requirement for maintenance. The laying performance of pure leghorns is between 220 and 240 white-shelled eggs per year, the leghorn crosses about 300 a year (PINGEL & JEROCH, 1995). Another important breed is the dark-red brown Rhode Island Red, which produces medium-heavy brown-shelled eggs. Besides these two main breeds there are others, such as New Hampshire, Plymouth Rock and Sussex that are important for the development of breeding strains.

The laying performance, which is usually between the 141st and 504th day (a period of 364 days), shows clear differences between the strains. With the increase of laying performance the requirements of energy and essential amino acids also increases.

LANGE (2002) reports on a laying performance test with four different brown-feathered strains and a white-feathered strain (LsL). On average the brown hens laid fewer eggs (306) than the LsL white ones (324). The same tendency could be observed in the egg weight, although all animals received the same feed. The amino acid pattern of the egg protein is genetically programmed and is not affected by the feed (JEROCH et al., 1993).

3.3.1.2 Age and live weight

The laying hens reach laying maturity aged about 20 to 24 weeks. The laying period is generally divided into three phases (see fig. 4-6). Phase 1 is from week 22 to week 34, phase 2 to the 53rd week and phase 3 to the end of the laying period, which normally lasts until the 65th week. After about 40 weeks the animals are fully grown and achieve the highest laying performance. This then decreases continuously, while the egg weight still increases slightly. Egg production in the laying period is shown in fig. 3-5.

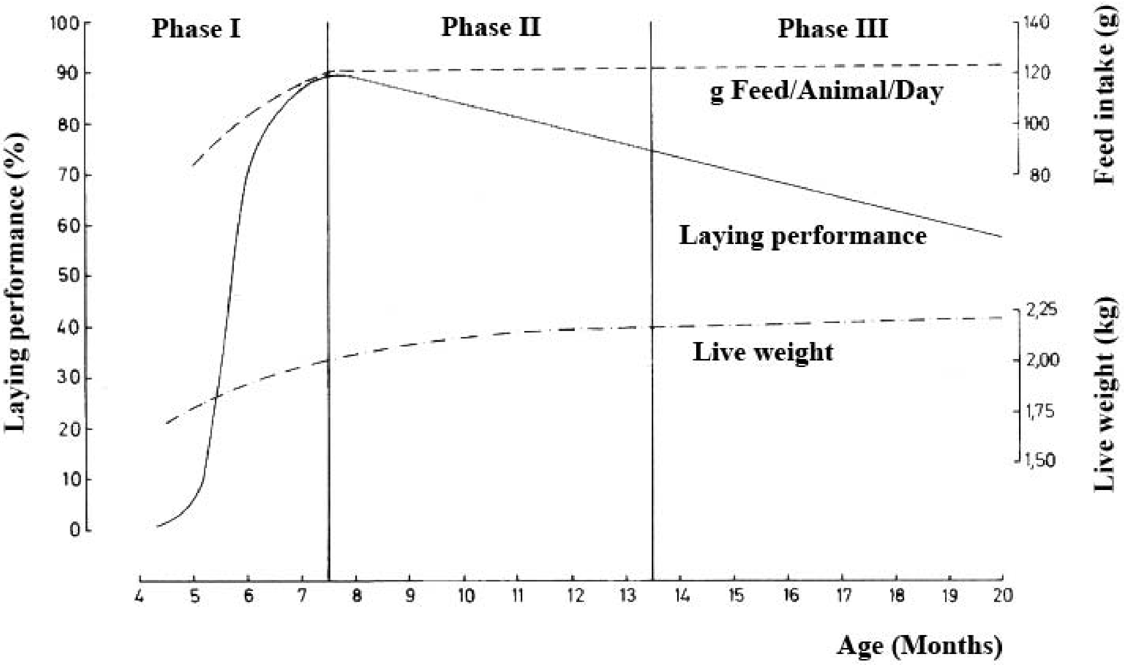

Fig. 3-5: Development of egg production, live weight and feed intake of laying hens (Light Laying Hybrids) during the laying period (KIRCHGESSNER, 1997)

In the first laying month the laying performance is about 10 % of the maximum, because the hens are still growing in this period. Then the laying performance increases in about 8 weeks to approx. 80% to 85 % and then continually decreases. The growth changes in this phase only slightly (JEROCH & DÄNICKE, 2002).

Hybrids with up to 20 kg egg weight a year (egg weight multiplied by egg number) achieve an enormous protein synthesis, more than 1 kg egg protein per kilogram of live weight (VOGT, 1987). KIRCHGESSNER (1997) has calculated that for an egg of 61 g weight approx. 157 g crude protein per kg DM in the feed are required. According to GFE (1999) an evaluation of the literature shows a great range with respect to crude protein need values from 15g to 21 g per hen per day. This range depends on the variation in the live weight and performance.

3.3.1.3 Environmental factors

Light has a strong effect on the performance of the laying hens in that it affects the hormonal control of the laying performance and regulates the feed intake. During the breeding the lighting is normally reduced up to the 20th week gradually to ten hours a day. From the 20th week and during the laying period the light is slowly increased to 17 hours a day and interrupted by periods of darkness. The light regime at the end of the laying phase is particularly effective in terms of the egg size and shell stability (SCHOLTYSSEK, 1987). In the breeding phase the light favours early maturity in that the feed intake is higher during long periods of light, which results in high egg production in the succeeding laying phase.

3.3.1.4 Amino acid supply

There are numerous studies on the amino acid requirement of laying hens at various ages and laying periods (NRC, 1994; GfE, 1999; Jeroch & Dänicke, 2002). With laying hens the criteria of laying performance and duration, egg weight, shell stability and live weight are significant. A chicken egg has an average weight of about 60 g. The largest proportion (58%) consists of egg white, the yolk amounting to approx. 32 % and the shell stability approx. 10 %. A medium egg of 60 g thus contains approx. 7.3 g protein. According to variety this content fluctuates and can be affected only to a limited extent by feed. The protein of chicken eggs has a high proportion of methionine and cystine. These amino acids are also required to a large extent in building feather protein (Kirchgessner, 1997).

The data on the total requirement of amino acids are formulated as gross amino acids or digestible amino acids. NRC (1994) specifies the gross amino acid requirement. The starting point of data presented in Tab. 3-6 is a 90 % laying performance. The requirement values for brown-shell eggs are approx. 10 % higher than for white-shell eggs. The principal reason for this is the higher live weight of the hens.

Tab. 3-6: Recommendations for the amino acid requirement in laying hens, depending on body weight

	Body weight					
	light	**medium**	**light**	**medium**	**medium**	**heavy**
Lys.	670	680	690	760	-	-
Met. + Cys.	580	595	580	645	595	615
Met.	330	335	300	330	335	350
Source	GfE, 1999		NRC, 1994		Jeroch, 2002	

The protein requirements of laying hens depend, among others, on laying performance, live weight, variety, age, feed components, the digestibility of the feed and environmental factors. Protein requirements of laying hens are higher for the best possible feed conversion than for maximum egg weight, and this in turn is higher than for maximum laying performance (Jensen et al., 1974; Schutte & van Weerden, 1978; Scholtyssek, 1987; Calderon & Jensen, 1990; Harms et al., 1998).

The methionine and SAA requirement of laying hens has been investigated in many studies on the basis of varying performance potential. The data vary to a high degree. While Jensen et al. (1974) report on values between 290g to 300 mg methionine per hen per day for optimal egg production, Schutte et al. (1994) recommend provision of 440 mg methionine per hen per day to achieve high performances.

Cherry & Siegel (1981) have studied the compensatory effect in feed consumption as a reaction to low contents of SAA. Three iso-caloric rations containing 15% crude protein and showing differences in methionine content were fed to young hens from two different genetic strains with different live weight. The effects on live weight, sexual maturity, egg production, egg size and egg quality were not significant. The conclusion was that young hens are able to compensate for a limited deficiency of SAA by increased feed intake.

3.3.2 Protein supply in organic laying hen husbandry

For organic laying hen production there are so far no systematically collected data on amino acid supply in practice based feedstuff analyses. In addition, there are only a few trials on the feeding of laying hens in the growing and laying period in organic agriculture. Living conditions of free range laying hens differ clearly from the conventional battery conditions. In particular, the increased energy requirement for movement and thermo-regulation in changing environmental conditions are obvious in alternative husbandry systems. The uncertainty with respect to the current feed consumption of a flock and possible depressions in feed consumption at high temperatures have a severely limiting effect on the optimisation of the diet formulation (ZOLLITSCH, 1996). Examples of 100% organic feed ration for laying hens are presented in the Annex (A-5).

VOGT et al. (1987) have been able to use tannin-poor varieties of faba beans up to 42 % in laying hen diets without affecting the performance and feed utilization of the hens. The taste of the eggs and the fertilization were not affected by the pea content in the feed, but there was a reduction in the stability of the egg shells.

ROTH-MAIER & KIRCHGESSNER (1995) fed laying hens with white lupins gradually up to 30 % in the ration without negative consequences, and reached the same performance as in the control group. The latter agreed with the results of PRINSLOO et al. (1992), which were able to establish, with a proportion of up to 30 % lupins in the ration, no significant effect on egg production, egg size, feed utilization and egg stability.

No difference in the number of eggs, however, a significant lower egg and live weight as well as a higher mortality was found by DAMME (2000) when feeding an organic (for details see also Table A-5 in the annex) in comparison to a conventional ration. The figures are presented in table 3-7 .

Tab. 3-7: Comparison between organic and conventional diets in relation to the layin performance (DAMME, 2000)

	Organic diet	Conventional diet	Difference
Number of eggs	291	292	- 1
Egg weight (g)	62,9	65,0	- 2,1
Mortality (%)	6,9	4,9	+ 2,0
Live weight, 72.week (g)	1970	2035	- 65

In studies of STROBEL et al. (2002) a conventional and an organically prescribed diet were fed for three laying periods. Both mixtures contained wheat, peas and triticale, but differed in the protein carriers. In the conventional diet extracted soybean meal, bone- and fish meal together with synthetic DL-methionine and L-lysine were used, in the organic one maize gluten, potato protein and brewers yeast. The rations were arranged iso-calorically. The methionine content in the conventional and organic variants were at the same level with 0.40, 0.32 and 0.36 % . These rations were fed to animals of six breeds: Lohmann Braun (LB), Lohmann Experimental (Lex), ISA, Tetra, Master hybrids (MH) and New Hampshire crossed with Maraus (RK). The feed intake in the treatments with organic diets up to the 20th week were on average 4,8 % lower than with the conventional diet. In the 20th week the LB breed fed on an organic diet achieved a live weight of 1 % more than the animals with conventional diets. Other breeds were on average 3.4% lighter with organic diets. Considered over the whole experimental period, LB achieved a 7.8 % higher feed intake and 12.3 % higher live weight and a higher feed conversion.

The largest difference in laying performance between the breeds was ± 3 %, apart from the ISA breed, where the laying performance was less (7,1 %). This can, among other things, be attributed to the highest egg weight. The egg weight with organic diets was on average about 2 % lower than with conventional diets. The feed consumption was generally lower with organic feed rations than with conventional ones. The feed expenditure was between 2.1 und 2.5 and in four breeds more favourable in the organic treatment.

Low energy rations have been suggested by DEERBERG et al. (2004) to increase the overall feed intake and therewith allowing the use of diets with a higher proportion of grain legumes without reducing the daily supply of essential amino acids.

ROSE et al. (2004) compared production and welfare traits of barn-housed hens fed either a 80 % organic feed formulation (including synthetic amino acids) as the control treatment and three alternative experimental diets. The control diet was a nutritionally complete diet (11.8 MJ/kg ME, 163 g protein /kg DM, 8.5 g/kg lysine and 7.0 g/kg methionine plus cystine) based on wheat, full fat soya, maize gluten meal, peas and limestone. It concluded 2.98 g/kg synthetic lysine and 1.58 g/kg of synthetic methionine. The first experimental diet used the same formulation as the 80 % control diet but without the two synthetic amino acids. The second experimental diet was a 100 % organic formulation based on wheat but included higher levels of full fat soya that resulted in the same energy, protein and lysine content as the control diet but contained less methionine and cystine (5.2 g/kg). The third experimental diet was a 100 % organic formulation based on maize, wheat feed, full fat soya and sun flower seed meal. The content of lysine and methionine plus cystine was the same as the control diet but had a higher protein (222g/kg) and a lower energy content (10.8MJ /kg. 1500 16-week old Hy-Line Brown pullets were fed one of the four diets.

Hens fed the 100 % organic high protein/low energy diet had a higher egg weight than the control diet. There were no differences in egg numbers ($p < 0.05$). In the second part of the laying period the birds fed the 100 % organic low methionine diet had a lower ($p < 0.01$) egg weight than the control treatment. No differences in bird weight and mortality in the flock were detected. There were no differences in feed intake between the birds fed any of the three experimental diets but these treatments had a 17 % higher feed intake than the control treatment. The 80 % diet minus synthetic amino acids led to less overall feather cover and the area under the tail was the particular site of feather loss. Those birds tended to make more aggressive pecks towards other birds in the pen. Feeding the 100 % organic diet led to a higher egg output compared to the hen in the control treatments. However, the higher feed intake and the much higher ingredient costs of the experimental diets clearly increased feed costs compared to the control diet. The margin of egg income over feed ingredient costs was halved in this treatment, whereas the margin of the low methionine 100 % diet (relatively lower ingredient costs) was reduced by two-thirds.

Preliminary data from Danish Agricultural Advisory Service (Hermansen, 2005) on layers indicated that the impact of 100 % organic feed (compared to 80 %) with a content of Meth + Cyst of 5.7 g/kg feed was a minor reduction in egg production (< 10 %) and a slightly higher feed intake, but no effect on plumage. This experiment included 4.500 layers on control treatment and 1.500 layers on 100 % organic feed and lasted until week 70 of age.

3.3.3 Conclusion for organic laying hens

In laying hens the laying phase from the 22nd to the 34th week is very critical with respect to essential amino acid supply. In this phase laying performance is very high and at the same time body weight is still increasing. An inadequate supply with essential amino acids has a negative effect on the performance in strains with a high genetic performance capacity.

The proportion of methionine to cystine is an important factor for the performance. The methionine proportion should not be below 50 % of the SAA. There is an interaction between energy and methionine, in that low methionine content increases the feed intake while a high energy supply reduces feed intake. The laying performance increases most intensively with a high methionine and low energy content in the feed.

Laying hens are able to compensate partially for a suboptimal supply with limited amino acids by an increased feed intake. However, a feed ration with a relatively high energy content limits feed intake.

There is need for further studies focussing on the possibilities for the use of specific strains that may be more adapted to a restricted availability of limiting AA.

Although some studies reveal that, in organic laying hen production, performances comparable with those of conventional husbandry can be achieved by using high-value protein sources, there is a need for further research work to investigate the possibilities on how to optimise the production of eggs under the organic framework conditions.

3.4 Protein supply of pigs

3.4.1 Lactating sows

3.4.1.1 Requirements in protein supply

Most studies on the effects of protein supply in lactating sows confine themselves to a comparison between feed rations with high, medium or low protein content (JOHNSTON et al., 1993, 1999; JONES & STAHLY, 1999a,b). In pig production amino acid requirements should be related both to dietary protein and to the relevant energy value of the feed. The formulation of need-oriented provision of AAs for lactating sows according to the factorial method is relatively difficult. On the one hand, it requires knowledge of the appropriate AA utilization for the various performances, and on the other hand the implementation of AAs is to be taken into account for reproduction (pregnancy, lactation), milk proteins, but also for lactose and milk fat via glycogenous AAs.

On the empirical investigation of the lactating sows' requirement of essential AAs comprehensive studies have been carried out by PAULICKS et al. (2002). In the feeding treatments the methionine/cystine contents in the feed varied between 2.1 and 8.4 g/kg feed, while the energy and other protein provision remained unchanged in all treatments. The milk yield of the sows showed a continuous increase, when the methionine/cystine content in the feed was raised from 2.1 to 6.3 g sulphur-containing amino-acids (hereinafter abbreviated to SAA) /kg feed and from this level of achieved a plateau. A parallel development was detected in the daily weight gain of the piglets. Fat and protein content and the AA pattern in the milk remained constant. As a result of various parameters, including the methionine and urine concentration in the blood, the authors conclude that there is a necessary minimum SAA content in the lactation feed of 6,5 g/kg feed. These results only partially confirm the feed recommendations so far for lactating sows. On the basis of 7.3 g of apparently ileal digestible lysine per kg feed (NRC, 1998) the authors calculate from their studies a lys : met : thr : val ratio of 1 : 0.8 : 0.95 : 0.8. This ratio does not agree either with the "ideal protein" ratios of 1 : 0.6 : 0.66 : 0.75 nor with the AA ratio in sow milk (1 : 0.49 : 0.59 : 0.66) (SCHNEIDER et al. (1992b) or in the young pig growth (1 : 0.47 : 0.59 : 0.66) (STAUDACHER et al., 1982) and highlights the problem of establishing general recommendations for protein supply.

3.4.1.2 Feeding-environment interaction

Apart from the AA content of feed mixtures there is a limiting factor in the feed intake for the protein supply of lactating sows (KOKETSU et al., 1996a, b). High environmental temperatures can lead to a clear reduction in feed intake (BLACK et al., 1993). Moreover, there are clear differences in the course of the individual feed intake and growth curves, which in individual life stages lead to differences in feed conversion (SCHULZE et al., 2001).

3.4.1.3 Protein provision in organic sow feeding

In organic sow feeding the crude protein supply is generally based on the provision with domestic grain legumes (RUBELOWSKI & SUNDRUM, 1999). Additionally, various cake products are suitable as protein feed supplement that provides essential AA (SUNDRUM & RÜBESAM, 2003). Examples for the use of possible feed components are given in the annex (table A-11) on the basis of specimen diets for lactating sows. Additionally, table A14 in the Annex provides an estimation about the proportional demands for cereals, corn legumes and high protein feed in organic sow production.

In organic pig production, roughage or silage must be added to the daily ration. Feeding roughage or silage during pregnancy provides the potential for an increase of feed intake in the succeeding suckling period. MATTE et al. (1994) have been able to establish a higher feed intake during the succeeding suckling period and an improved development of suckling pigs compared to a control treatment in sows fed roughage during pregnancy.

In data collected from 21 organic pig farms in Austria a suboptimal nutrient supply of lactating sows was found on many farms (ZOLLITSCH et al., 2000; WAGNER et al., 2001). Deficiencies were detected especially in relation to the energy supply and less in the protein supply. With respect to the SAA supply, most farms were found to be deficient. In general, there was clearly an inadequate feed management on farms of generally small structure.

According to FERNANDEZ (2005), the nutrient need of pregnant sows can be adequately met by a basal concentrate diet complemented with either clover-grass in summertime or ensilage in wintertime. Pregnant sows can satisfy more than half of their energy need by grazing or by intake of silage. In this conditions the protein supply exceeded the requirements.

3.4.2 Piglets

3.4.2.1 Protein provision requirements

In the literature, the recommendations for the nutrient supply of piglets weighing between 5 kg and 20 kg show a great variation (0.55 % to 0.82 %) with respect to the supply with methionine + cystine (GFE, 1987; NRC, 1998). According to CHUNG & BAKER (1992) different recommendations are partly based on the different energy and crude protein content of feed rations in the trials, the methionine-cystine ratio in the diets, the different analytical methods and the different AA availability of various feed components.

3.4.2.2 Feeding-environment interaction

Data from test stations revealed that feed intake of piglets show a large animal-specific variation (BRUININX et al., 2001). Thus, for the feed intake after birth it is decisive to what extent the piglets have been adapted to the intake of solid feed during the suckling period. A successful rearing of piglets is closely coupled with a good development of the digestion tract and enzyme activities, which is influenced significantly by the quality and digestibility of the feed components and by intake quantities (CERA et al., 1988; KELLY et al., 1990; COLE & SPRENT, 2001). Substrate-induced enzyme activity and morphological influence on the villus length in the small intestine underscore the importance of the feed components for feed conversion after weaning and as a main variation cause for the differences encountered in practice (PLUSKE et al., 1997).

In a review study by FERGUSON (1999) various influence variables are discussed which have an effect on growth potential via feed intake in farrows for market. A suboptimal feed ration in terms of AA composition causes the piglets to take in more feed, and therewith enables the piglets to compensate partially for the deficit in AA. The extent of the compensation was to a high degree influenced by the extent of the deficiency and by the temperatures in the husbandry environment. The author assumes that a large proportion of the feed utilization variation observed in practice can be attributed to differing diets and environmental temperatures.

Apart from the composition of the diet, utilization of AAs offered by feed can be impaired by the presence of anti-nutritive factors, which can have a direct effect on the nutrient utilization or an indirect effect via metabolic disorders (WAREHAM et al., 1994).

WILLIAMS (1998) investigated the effect of animal health on the performance ability of piglets. The authors examined a higher feed intake, higher daily gain and lower feed expenditure per kg of increase in animals with better health. In addition, various levels of lysine supply were examined. Piglets of the group with poorer health, unlike the healthy ones, were unable to use increased lysine to the maximum level of supply. In order to compensate for the lower feed utilization the protein supply (measured by lysine content) would have to be raised, according to the estimate of the author, by 15%-25%.

3.4.2.3 Protein supply in organic feeding of piglets

The Council-Regulation (EEC-No. 2092/91) prescribes a suckling time of at least 40 days for piglets which may be almost two times the period in conventional production. The sow's milk is the best source to provide piglets with nutrients and essential AAs. In the suckling phase the provision is usually balanced. In addition to the various advantages of an extended suckling period for the well-being, piglets are better prepared to take in supplementary concentrate feed, because of the advanced development of the digestion tract. In different trials intake of supplementary feed during the suckling period was decisively influenced by the age of the pigs (APPLEBY et al., 1991; BOE, 1991). FRASER et al. (1994) were able to demonstrate a positive effect of the amount of supplementary feed intake before weaning on feed intake after weaning.

Provision status of piglets was examined on 21 farms in Austria (ZOLLITSCH et al., 2000). The contents in the feed ration in most of the small farms was sometimes clearly under the guideline values for balanced supply with AAs. On some farms an extended suckling period (up to 8 weeks) was practised.

The National Committee for Pig Production in Denmark (MARIBO, 2004) investigated the effect of 100 % organic feed for weaners compared with 80 % organic feed. In the 100 % diet organically produced skim milk powder (5 %) was included in the growth period (17-24 kg), but not from 25-40 kg where the diet consisted of 30 % barley, 12 % wheat, 15 %oats, 25 % soybean cake, 10 % rapeseed, 4 % soybeans, 0.5 % rapeseed oil and 3.5 % minerals and vitamins. 500 piglets were included on each treatment. The daily gain of the pigs fed with the 100 % organic ration were 676g per day and the daily feed intake was 1.44 kg. (versus 762 for the pigs fed with the 80 % organic diet and a daily feed intake of 1.65 kg per day). No differences in illness and mortality existed between groups. Mortality was on average 2.3 % and all piglets were treated at least once against diarrhoea.

According to SUNDRUM & RÜBESAM (2003), there are various feeding strategies to ensure an adequate supply with essential amino acids for piglets under the organic framework conditions. Examples of 100% organic feed ration for piglets as creep feed as well as feed rations before and after weaning are presented in the annex (A-7, A-8). However, data are missing on how far these strategies are implemented in practice.

3.4.3 Fattening pigs

3.4.3.1 Protein provision requirements

Breeding progress has led to considerable changes in chemical composition of fattening pigs. Because of the demands of the market the fat content in particular has been reduced considerably within the last decades in favour of the lean meat percentage. While the empty bodies of saleable pigs 20 years ago still had over 30% fat in the carcass, the values today are about 20% (DREISHING, 1998).

From the production point of view the fattening performance is characterised by the traits of daily live weight gain, fattening period and feed expenditure per kg of growth. For the slaughter performance the meat cuts, the muscle proportion and meat quality are most relevant. As protein accretion forms the basis of the recommendations for AA supply, the causes of variation are discussed in more detail.

3.4.3.2 Genotype

The capacity for protein accretion is determined principally by the genotype. Fig. 3-6 illustrates the daily protein accretion of various strains depending on the development of the live weight.

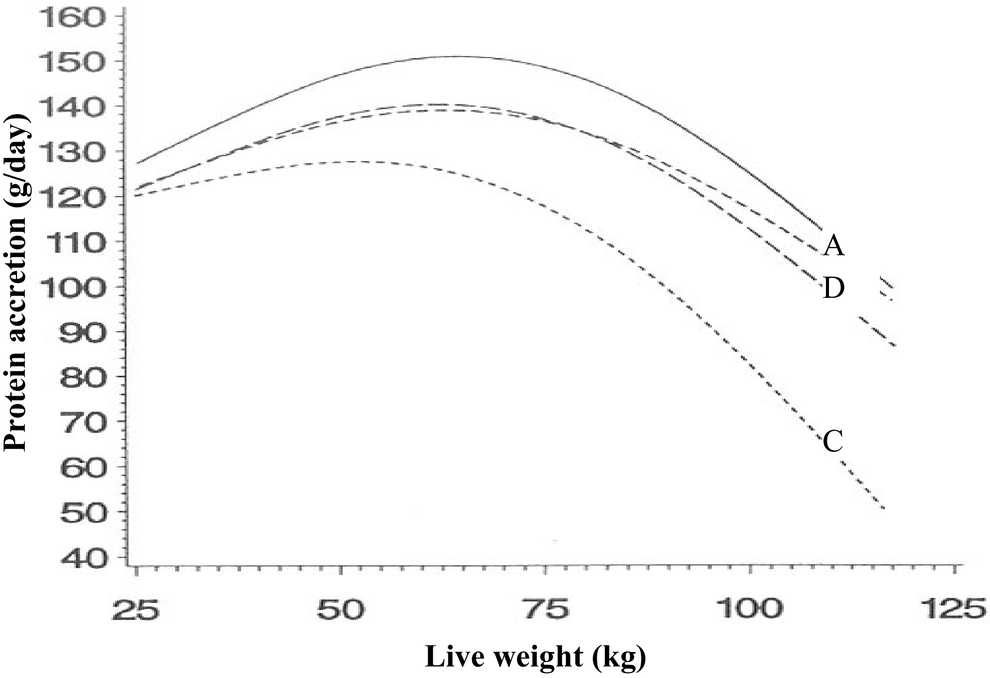

Fig. 3-6: Daily protein accretion potential of fattening pigs in 4 genotypes for a high (A), medium (C) to high (D) and an average (B) muscle growth (PALMER et al., 1993)

Meat-rich genotypes achieved clearly higher protein accretion over the entire fattening period than those with an average muscle growth. Differences between the genotypes are the result of differences in the total protein accretion over the fattening period and due to differences in the decrease of protein accretion after the maximum.

However, as studies of SUSENBETH et al. (1999) show, the dominant effect of the first-limiting AA for protein accretion cannot be affected by the properties of the animals. Through breeding for high meat content and low feed expenditure, the extent of the utilization of AAs for the protein accretion has not changed (SUSENBETH, 2002). The superiority of animals with a high genetic capacity for protein accretion becomes manifest only in combination with a very high protein supply. Differentiation of feed mixtures for animals of different genotypes on farms where only a medium feed intake can be achieved is not recommended by the author. Variations in determined values for digestibility in different pig farms also include inaccuracies in registration of feed intake and sampling of faeces, which is quite difficult in commercial farms.

3.4.3.3 Sex

With equal supply of energy and essential AAs the sexes show different accretion values for fat and protein. In a study of FULLER et al. (1995) boars showed the highest and castrated pigs the lowest protein accretion. The protein accretion of females was between those of boars and castrates. With fat accretion the ratios were reversed.

3.4.3.4 Age and live weight

The capacity for protein accretion is closely connected with the live weight and the age of the pigs. According to SCHINKEL & DE LANGE (1996) the highest protein accretion is reached at a live weight of about 50 to 90 kg. With sufficient essential AAs supply the accreted quantities of protein and fat depend on sufficient energy supply. If the protein accretion capacity is fully used, excess energy supply is accreted as fat.

3.4.3.5 Animal-environment interactions

Nutrient supply results from the quantity of feed intake and nutrient concentration in the diet. Influences of the living conditions on nutrient supply are principally effective via feed intake. Knowledge of actual nutrient supply is limited where the feed intake quantities are not known or only in rough approximation as daily intake of the group or sometimes only as an average feed intake over the total fattening period.

Studies of MORTENSEN (1986) show an increase in the feed intake of fattening pigs kept on partly slatted floors if the lying area is covered with straw. In a comparative study of 4 husbandry systems LYONS et al. (1995) established a significantly higher feed intake in pigs (27-90 kg LM) kept on straw than in pigs kept on slatted floors.

For a high variation in accretion between differing living conditions, differences in environmental temperature (BELLEGO et al., 2002), in stocking rate (EDMONDS et al., 1998) and in the general stress situations (WHITTEMORE et al., 1988; SCHINCKEL, 1994; Hyun et al., 1998b) are held responsible. In an investigation on 17 farms, ELBERS et al. (1989) found a considerable variation in the digestibility of organic matter (77 - 84% at a live weight of 35-

40 kg and 78-86% at a live weight of 65-70 kg). The variation between the farms was greater than within the farms.

Fattening pigs exposed to a high pressure of infectious agents, increased stress and suboptimal living conditions cannot fully use their genetic potential for protein accretion, even if they are offered an optimal feed ration *ad libitum* (SCHINCKEL & DE LANGE, 1996). In fig. 3-7 protein accretion gained under various living conditions but based on the same feed ration and the same genotype with a high genetic growth potential is illustrated by means of representative development curves over the fattening period. Under optimal living conditions (experimental farm) the highest growth rate and the best feed conversion was achieved in the 25 to 52 kg live weight range. On the three practical farms the protein accretion in pigs, despite the same genetics, deviated partly very clearly from the maximum genetic potential for protein accretion. Under poor living conditions only about 50% of the protein accretion achieved under optimal conditions was gained. The most important factors named by the authors were stocking rate, group size, hygiene management and health impairment.

Clear differences in the growth progress of pigs between various living conditions have also been established by HOLCK et al. (1998). Growth rates and protein accretion in growing pigs under practical conditions were about 30% lower than under optimised experimental conditions. By recording exactly the courses of growth and protein accretion on various farms, SCHINCKEL et al. (2002), despite the same genetics and feed strategy, established considerable differences. The authors attributed the differences partly to differing conditions in the rearing phase.

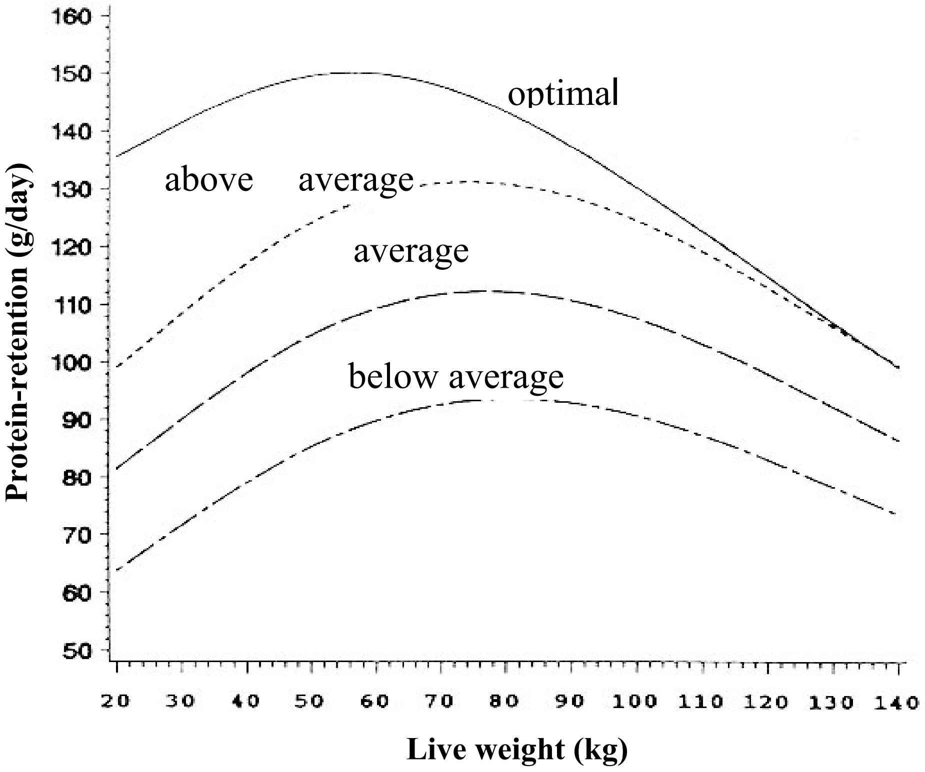

Fig. 3-7: Medium protein accretion in animals with a high genetic accretion potential under optimal husbandry conditions and on three farms (PALMER et al., 1993)

3.4.3.6 Energy supply

In general, it can be assumed that a linear relationship between protein accretion and energy supply exists as long as the energy intake is higher than the energy required for survival and lower than the energy estimated for maximum protein accretion (QUINIOU et al., 1995; SCHINCKEL & DE LANGE, 1996). However, this connection is confined mostly to the range below about 50 kg live weight. In the final fattening phase (> 50 kg live weight) the maximum genetic capacity for protein accretion is principally decisive (NOSSAMAN et al., 1991; WILLIAMS et al., 1994; NICKL & SUSENBETH, 1995). Accordingly, this leads to a different AA requirement, to which the AA-energy ratio has to be adjusted. According to SCHINCKEL & DE LANGE (1996) the quantity of energy and feed intake are the limiting factors for the extent of the protein accretion during the initial fattening period.

3.4.3.7 Compensatory growth

In various studies the possibilities of compensatory growth have been sounded out. DE GREFF et al. (1992) induced an AA provision in the initial fattening. It led to a compensatory growth in the final fattening, but the performances of "normally" provided animals in the total fattening period were not reached. However, the lysine provision as first-limiting AA amounted in the initial fattening only 6.6 g lysine/day, while the control group was provided with 22.5 g lysine/day.

CHIBA et al. (1999) examined the influence of a restrictive supply with essential AAs in the initial fattening (80% of the NRC-recommendations) compared with a feed ration highly enriched with essential AAs on performance and carcass quality. In the initial fattening period the appropriately provided animals showed the highest and most efficient growth and the least back fat thickness. Also in respect of the total fattening period the appropriately provided animals showed the highest growth rate. However, with respect to protein accretion, there was no significant difference between the treatments. At the same time those animals whose provision was restricted in the initial period showed a lower back fat thickness and a higher back muscle area. Further studies of the working group (CHIBA et al., 2002) tested the effect of a restrictive provision with essential AAs in the initial fattening compared with genotypes with a high and medium potential for protein accretion. The above-mentioned results were confirmed. However, the animals bred for high protein accretion in the initial fattening with restrictive provision showed a lower growth rate than the control group with average accretion potential. The authors conclude that the strains bred for high meat growth are less tolerant with respect to a suboptimal protein supply in the initial fattening.

Also FABIAN et al. (2002) found in their studies that a suboptimal supply of essential AA was fully compensated with regard to growth performance and carcass yield independently of the genotypes used. When feeding a restrictive amount of AA in the initial period, the authors determinded an improved feed conversion and a lower nitrogen excretion.

3.4.3.8 Feed intake

To increase the feed intake by improving the living environment and the management is the most relevant option when only those feedstuffs are available that contain a low portion of essential AAs. Thus, an increase in feed intake from 1.0 to 1.1 kg feed/day of a diet with 13.0 MJ ME and 50 g methionine per kg effects an improvement of the energy provision by 1.3 MJ

ME and an improvement of methionine provision by 5 g per animal and day. In this way it is easier to achieve a 10% better energy and methionine supply than by increasing the energy content and the concentration of methionine in the feed ration.

In general it is assumed that the feed intake is influenced primarily by live weight, sex, stocking rate and the stall climate conditions (NRC, 1986). SCHINCKEL (1994) examined differences in the order of 30 % between different genotypes in otherwise equal feed rations and living conditions. Crowding, group size and mixing are factors that markedly influence feed intake, conversion efficiency and growth rates (HYUN et al., 1998a,b; WELLOCK et al., 2003). Moreover, the feed intake is influenced by the condition of feed (particle size, crude fibre type and quantity, water binding capacity, anti-nutritive substances), the presence of pathogenic germs, and the physiological digestion capacity of the pigs (BLACK et al., 1986; EMMANS & KYRIAZAKIS, 1989). Pigs fed with voluminous, fibre-rich feed rations showed a higher stomach volume than pigs fed only on concentrate feed: the anatomical stomach volume is closely correlated with the long-term quantity of feed intake (DROCHNER, 1999).

3.4.4 Use of grain legumes in pig production

Digestibility of grain legumes in pigs can vary between and within the species and varieties in a wide range. The apparent ileal digestibility of the different amino acids is affected among others by the tannin content (JANSMANN et al., 1993). In faba beans anti-nutritive substances also affect the apparent digestibility of crude fibres.

In peas, protein and amino acid digestibility are reduced with increasing protease-inhibitors. Extruding leads to destruction of trypsine-inhibitors activities and increases the ileal digestibility of protein (AUMAITRE et al., 1992). According to GATEL & GRASJEAU (1990) winter varieties had a less favourable effect on the fattening performance due to their higher content of anti-nutritive substances than summer ones. It was not possible to completely balance the negative effect of the anti-nutritive factors by extruding. LEITGEB et al. (1994) investigated the use of peas in the various stages of the development and found no negative effects when proportions of 20 % peas in the feed ration were fed.

Lupins are important in pig-feed because of their high protein content and the relatively high fat content. In the past, the bitter parts (alkaloids) in lupins have been clearly reduced by plant breeding. However, small amount of alkaloids can still reduce feed intake. Depending on the various varieties, sweet lupins display total alkaloid contents from 0.01 to 0.1 %. An alkaloid content of 0.03 % in the feed mixture is considered acceptable (BELLOF & SIEGHART, 1996). In a trial conducted by ZETTL et al. (1995) extracted soybean meal and grain without amino acid supplement was replaced by 10% or 20 % lupins. With a proportion of 10 % lupins in the feed there were no visible effects on the fattening performance, whereas the use of 20 % reduced the daily live weight gain. With a proportion of 10% sweet lupins in the initial and 15% in the final fattening period BELLOF & SIEGHART (1996) found no negative effects on the fattening performance.

In various feed trials growth performance comparable to conventional production was achieved by using home-grown grain legumes, rapeseed cake or potato protein (SUNDRUM et al., 2000). Results showed that the protein provision of fattening pigs could be covered, albeit without maximum performance, principally by a combination of home-grown grain legumes, such as faba beans, peas and lupins, with only limited need to buy additional protein supplement feed. Excessive proportions of grain legumes in the feed ration could, however, clearly reduce the feed intake because of the slightly bitter taste. Examples of 100% organic feed ration for fattening pigs in the growing and finishing period are presented in the annex (A-9, A-10). Additionally, table A15 in the Annex provides an estimation about the proportional demands for cereals, corn legumes and high protein feed in the fattening period.

With respect to the implementation of the different feeding strategies in agricultural practice, surveys show that there is a considerable optimisation potential in organic pig production (WAGNER et al., 2000; SUNDRUM & EBKE, 2004). Many organic farms, especially those with a low flock size, for various reasons do not appear to be interested in increased performance of stalled animals. But practical examples show that solutions can be successfully implemented as a result of consultation measures (ZOLLITSCH et al., 2000).

3.4.5 Conclusion for organic pig production

In organic pig production possibilities to provide an adequate supply with essential AA are limited. Protein supply is primarily based on grain legumes which are characterised by a low percentage of essential amino acids, especially with regard to methionine.

Piglets have the highest demand for limited amino acids. Their requirements should be covered in order to prevent predisposition of diseases. Mismanagement, i.e. a huge discrepancy between nutrient requirements and supply, is the cause of different diseases, such as diarrhoea in piglets and reproductive disorders in sows and a suppression of the immune reaction. Furthermore, diarrhoea in piglets can be caused by ANF's from legumes. The exclusion of chemically solved soybean meal can be compensated for by other protein sources like skim milk powder, soybean cake or rape cake. In practice, options for producing the "ideal" baby pig diet are often constrained by the cost factor.

While the percentage of grain legumes is limited in the diet of piglets, there are many options for the use of grain legumes in the feeding ration of sows and fattening pigs. Multi-phase feeding and sex segregation is recommended in all cases. Furthermore, optimising the husbandry environment with related potential of a higher feed intake is an important option to make better use of the limited essential AA content in the available feed and to achieve a satisfactory performance and carcass yield. At least, the EC-Regulation still allows the use of non-organic bought-in feedstuffs. As the leading idea of organic agriculture is to establish a largely closed farm system and to restrict oneself in the use of means of production, the portion of non-organic feedstuffs should be reduced to a minimum extend needed to prevent deteriorating animal health and welfare.

There is need for further studies concerning the use of breeds or genotypes that are more adapted to the organic framework conditions and at the same time do not provoke negative side effects on carcass quality such as obesity.

The preferable use of home-grown feedstuffs and limitations in the choice of bought-in feedstuffs can be the cause of a huge variation in the composition of the diets and increase the demand of the analysis of the ingredients and calculation of the diet. The high variation in genotypes and housing conditions in organic farming in comparison to the more and more standardized conditions in conventional production impairs the predictability of the specific requirements and the rate of utilisation of the nutrient potential.

4 Effect of protein supply on traits of product and process quality

4.1 Effects of protein supply on product quality

4.1.1 Carcass composition of broilers

Because of the low fat content, poultry meat is regarded in general as healthy produce, which is partly reflected in increasing poultry meat consumption (WICKE et al., 2000). One of the determining factors in the composition of the carcass is the proportion of essential AAs in relation to the energy content in the feed ration. Studies of HUYGHEBAERT et al. (1994) showed that the meat : fat ratio is improved by increasing proportions of AAs. The carcass weight and the breast meat accretion react to an addition of methionine more strongly than to increased protein content. CHAMRUSPOLLERT (2002) showed that broilers were able to put on 15 to 20 g more breast meat, if the recommendations of NRC (1994) with respect to lysine and methionine supply are exceeded by 12% in the first and second fattening phases.

With reduced AA content and sufficient energy content in the feed mixture the feed intake rises in order to cover the AA requirement (KIRCHGESSNER et al., 1989; PARR & SUMMER, 1991). The energy excess is converted into fat. In order to counteract excessive fattening when providing a suboptimal supply of essential AAs adjustment of the energy provision is needed.

4.1.2 Carcass composition of turkeys

With respect to added value in the slaughter and processing, the breast meat of turkeys, with a proportion of about 35% of the slaughter weight, is very important. In Germany about 90% of turkey meat production is accounted for by heavy processing turkeys (WICKE et al., 2000). With increasing age, the live weight and carcass value rise in relation to the live weight. The proportions of the valuable breast parts and the abdominal fat increase with age and live weight, while the thigh proportion remains at about the same level (WALDROUP et al., 1997). The AA content has no significant effect on the total quantity of abdominal fat. In percentage terms to the carcass weight the abdominal fat decreases with increased SAA in the feed. The breast meat on the other hand increases with the rising AAs proportion in the ration.

4.1.3 Carcass composition of fattening pigs

The implications of the supply with amino acids on protein accretion and carcass composition of pigs has already been described in detail in chapters 1.3.4. Generally, a protein supply is recommended that is highly adapted to the demands of a carcass with a high lean meat percentage (NRC, 1998). Feed rations containing an unbalanced pattern of amino acids and a surplus in energy in relation to the protein accretion capacity are expected to lead to a carcass with a high fat content (CASTELL et al., 1994; KERR et al., 1995; CISNEROS et al., 1996).

In contrast, recent studies indicate that it is possible to produce carcasses under the framework conditions of organic farming that do not differ in the lean meat: fat ratio, the fat area and the back fat thickness compared to control diets although the AA patterns were unbalanced (SUNDRUM et al., 2000, 2005a). However, the area of *M. longissimus dorsi* and the lean meat percentage were reduced compared to the control treatment, which confirms the importance of the supply of essential AA for these traits described earlier by (HAHN et al., 1995; CISNEROS et al., 1996).

4.1.4 Traits antagonism in fattening poultry

In conventional fattening poultry intensive growth for economic reasons is the target in order to achieve the desired slaughter weight with less feed, and as quickly as possible. Negative correlations between fattening and reproduction performance have led to a division between paternal and maternal lines with differentiated selection programmes. The further the intensification, the more the negative relationships between fattening performance and stress stability become obvious (WICKE et al., 2000).

Intensive selection in fattening poultry for growth and meat accretion seems to have exceeded certain metabolic and anatomical-histological limits. According to STEPHAN (1993) it can be assumed that, as with Porcine Stress Syndrome (PSS) in pigs, there is also an Aviary Stress Syndrome with various manifestations such as poor quality meat in the sense of PSE and DFD meat, various forms of myopathia and transport death. As in PSE pigs, there is also a likelihood of a genetic defect in the ryanodine receptor (SANTE et al., 1995).

Histo-pathological changes in chickens and turkeys are evidence of the negative consequences of a one-sided selection for meat, especially with respect to the breast muscle proportion. If the carcass composition and the histo-chemical characteristics are collocated with meat quality, animals with high carcass weight, high breast muscle proportion and fibre hypertrohia are inclined to develop meat quality deficiencies (WICKE et al., 2000).

A further impairment of carcass quality in broilers and fattening turkeys occurs as a result of changes in the *Bursa praesternalis* (HAFEZ, 1996). They can lead to considerable reduction of carcass quality or even to rejection of the entire animal. The extent of the problem varies strongly depending on the management, stocking rate, litter quality and the type of bacterial germs involved. Mechanical-traumatic injuries from excessive sedentariness combined with low activity and high humidity of the litter are given as reasons for this (BESSEI, 1993). There is also a close connection with the side-effects of an high growth intensity (KAMYAB, 2001).

4.1.5 Traits antagonism in fattening pigs

The trade value of carcasses is determined principally by the lean meat proportion, slaughter weight and cuts composition on the basis of price labels. Increasing demand for lean meat over the last twenty has produced a situation where the back fat thickness in pigs has been reduced by over 50% and the proportion of muscle meat has risen correspondingly in many European countries during this period (ANDRESEN, 2000). These major changes are the result of a combination of progress in genetics and improved nutrient supply. Genetically, halothane and RN genes in particular are known for their negative influence on meat quality. If these main gene defects can be excluded, genetics, in the view of DE VRIES et al. (2000) and TRIBOUT & BIDANEL (2000), contributes only with a proportion of less than 30% to the total variation of meat quality criteria. Therefore, nutrient supply and environmental factors together with the hitherto imperfectly understood connection between genetics and environment are of high importance when improving meat quality (ANDRESEN, 2000).

With increase of meat condition achieved by more muscle meat and a strong reduction of overlay fat, the risk that meat deficiencies will appear increases (HARR, 1989; LENGERKEN, 1990). Meat research experts have been demanding for years that a muscle meat proportion of 55%, for reasons of meat quality, should not be exceeded (AUGUSTINI et al., 1981; SCHEPPER et al., 1983; HONIKEL, 1996; FISCHER, 2001).

The taste of meat is largely determined by criteria of tenderness, juiciness and flavour (CLAUS, 1996a). For all three criteria intramuscular fat content is decisive (KALLWEIT & BAULAIN, 1995). In particular, the genus criterion 'flavour' is linked to fat, because this serves partly as a carrier for fat-solvent flavour materials (AFFENTRANGER et al., 1996). The full flavour emerges only in the preparation as a result of chemical reactions between fat acids and other meat components. Low-fat muscle meat is almost taste-neutral. Only the finely distributed fat in the muscle, recognizable in higher contents as marbling, makes a taste differentiation between animal varieties possible (KALLWEIT & BAULAIN, 1995). The IMF content optimal for taste in the back muscle (muscle part with the lowest IMF content), is between 2.5 % and 3% (BEJERHOLM & BARTON-GADE; 1986; FERNANDEZ et al., 1999; Murray, 2002). Modern slaughter pigs currently show an average IMF content of only 1% (DOEDT, 1997; KÖHLER et al., 1999). As a result of the medium to high level of heritability of IMF content of $h^2 = 0.41$ (DE VRIES et al., 1994) to $h^2 = 0.50$ (HOVENIER et al., 1993) breeding would be possible. This has been done successfully in Switzerland for many years (SCHWÖRER et al., 2000).

However, an antagonistic relationship exists between lean meat percentage of the carcass and the IMF content (KÖHLER et al., 1999; DGfZ, 2001). A highly significant negative correlation between IMF content and lean meat of $r = -0.58$ was found by BAULAIN et al. (2000). According to DGfZ (2001), the antagonistic relationship is also the case for other farm animals. With a corresponding inclusion of the IMF in the breeding strategy, the meat proportion will consequently be reduced.

On the other hand, studies indicate that under the framework conditions of organic pig production using different combinations of grains legumes an increase of the intramuscular fat content (IMF) can be obtained by specific feeding regimes (SUNDRUM et al., 2000, 2005a).

Because breeding for high meat proportion in pigs leads to an increased formation of 'white fibres', extremely hypertrophied muscles are not only almost fat-free, but strikingly light. In a survey of DOEDT (1997) pigs with a high lean meat proportion produce more "PSE meat". 22% of the animals whose muscle meat proportion was over 58% were categorized as PSE-suspect or PSE meat because of the pH 90 value in the cutlet. The PSE proportion of animals with a muscle meat proportion between 50% and 52% was 13.5%.

In addition, a high proportion of ham in relation to the total carcass is negatively correlated with the appearance of “PSE” meat as a consequence of the related muscle hypertrophy (FEWSON et al., 1987; KALLWEIT, 1989). According to DOEDT (1997), the negative effect of the type shaping on meat composition is more strongly marked than the influence of the lean meat percentage. Both are closely connected with each other, as a higher lean meat percentage is to be expected with an increasing type shaping (GLODEK, 1980). A consideration of the ham form in the payment system thus leads, because of the antagonism to meat condition ($r = -0,26$), to an increase of meat condition deficiencies.

In addition to the meat condition the fat condition is also impaired by a high lean meat percentage. The fat tissue of pigs, especially the back fat, is an indispensable raw material for the production of most fresh, sausage and processed goods to achieve qualitative properties in terms of taste and firmness. The fat tissue used for these products has to satisfy high requirements. In particular, fat of a high consistency and high oxidation stability is necessary to produce high quality long-lasting products. The one-sided breeding and feeding for high-meat and low-fat animals leads to reduction of overlay fat, intramuscular fat (IMF), and a deterioration of the fat quality (LITTMANN, 1991). Among the most important quality defects are empty fat tissue (increased deposits of water), inadequate oxidation stability and insufficient fat consistency (SCHWÖRER et al., 1990; PRABUCKI et al., 1991). The results are production difficulties, a negative influence on product quality, reduced consistency and storage life together with difficulties in calculating product composition. Quality defects are attributed to both the receding total fat accretion and the composition of the accreted fat. The changes in carcass composition with increased meat proportion and lower fat overlay mean that animals with high lean meat percentage only seldom display good fat quality (SCHWÖRER et al., 1995).

4.1.6 Label programmes

Apart from organic livestock production only few label programmes have so far been developed that offer meat products of specific quality. Production of ‘Label’ broilers, which achieve a 12-week weight below 2 kg by using slow-growing varieties are well developed in France, but not in other European countries (WICKE et al., 2000). In the view of the authors label programmes of this sort can easily be accommodated in organic production.

The establishment of label programmes in the poultry sector has been associated with the breeding of suitable slow-growing broiler lines that meet certain quality requirements. In the ‘Label Rouge’ programme a minimum slaughter age of 81 days is prescribed. The ration composition in this fattening procedure is fixed in a quality programme and based principally on locally produced feed. This programme has existed since the 1960s and in recent years has clearly become more in demand. In 1996 over 80 million chickens were marketed under this label (GRASHORN, 2000). The label programme is based, like the corresponding data in the Council-Regulation on organic animal husbandry, on the marketing standard for poultry meat (EEC-No. 1538/91) to identify poultry from free range farms.

LEWIS et al. (1997) compared ‘Label Rouge’ (LR) chickens with table birds reared under intensive conditions (UK). ISA birds were grown to 83 days, and compared with Ross birds grown to 48 days. Whilst LR birds showed no mortality, intensive grown Ross birds had a mortality rate of 11.3 %. LR and UK broiler birds had similar carcass component weights, breast meat yields, and total meat yield, but LR birds had less meat on the frame, larger drumsticks and more meat on the wings.

FARMER et al. (1997) evaluated the effects of the genotypes ISA and Ross, diet, and age on eating quality. The most pronounced sensory differences between the two genotypes were in the appearance and texture of the cooked meat. In particular, scores for toughness were higher for breast meat from Ross than ISA birds, though the opposite effect was observed for the thigh meat. Odour and flavour intensity of breast meat increased with age. Breast meat of ‘Label rouge’ chickens showed lower scores for toughness but higher scores for odour and flavour. The results confirmed those of CULIOLI et al. (1990). Sensory tests carried out using all the thigh and breast muscles showed that while the 'label meat' had less juiciness, it was nevertheless preferred, since it was firmer and has a strong flavour. The studies of PETER et al. (1997b) showed a comparatively high intramuscular fat content in breast meat in the 'Label' broilers, which points to good sensory properties of the meat.

Relationships between physiological age and higher fattening final weight and product quality with respect to the proportion of valuable cuts, fat content, the sensory properties and grill losses in preparation are described in more detail by JORDANA, (1983), RISTIC et al. (1990), and CULIOLI et al. (1990).

SERRY (1990) has examined, by means of three feed variants with graded crude protein and energy contents in approx. the same protein : energy ratio, the effects of a restrictive nutrient condition for performance data and the body composition of male broilers. The author concluded from the results of the studies that different production goals require different recommendations for the nutrient supply. If the performance-oriented parameters of weight increase, fattening duration and feed utilization are followed as a priority, a high feed intensity (about 23% crude protein, 13.5 MJ ME/kg/DM) is recommended. But if a high animal health status, a good carcass quality and reduced depot fat formation are the prime targets, the resulting recommendation is a lower feed intensity (about 18% crude protein at 11 MJ ME/kg/DM).

In a study carried out by GRASHORN (2000) broilers were fattened conventionally under semi-extensive and extensive conditions. Appropriate strains were used for the three production processes and fattened over 35, 49 and 81 days, respectively. The meat from extensive production was more red, which the author attributes to the use of slow-growing strains. A clearly higher grill loss in the preparation of the meat from conventional production indicated the differences in the composition of muscle tissue of the various strains.

According to WICKE et al. (2000) there are market niches not only for broiler but also for turkey production. Recommended are free range fattening and organic production using bronze turkeys and black turkeys (e.g. Kelly), which are opening up the possibility of clear definable demarcation from conventional intensive fattening.

Concerning pork there is a huge range, stretched from traditional southern European label products (e.g. 'Pata negra') a cured product of high economic value from very extensive husbandry practices where genotype-environment interactions do result in measurable effects to pork from industrial units where pigs from high yielding genotypes are living under standardised housing and feeding conditions to maximize protein accretion.

Organic pig productions is something in between, clearly demarcated from the industrialised production chain but also not per se an extensive production. The housing conditions vary from outdoor pig production to indoor production and encompass huge differences between regions and seasons not only in relation to environmental conditions but especially in relation to nutrient supply and genotype. Nevertheless, the production is clearly defined by the EEC-Regulation on organic agriculture as the basic standard.

4.1.7 Conclusion in relation to product quality

The supply of limited amino acids is of high importance for the protein accretion and the muscle growth, therewith influencing the quantity of meat. Concerning meat composition and the sensorial quality of meat there is strong evidence for an antagonistic relationship between meat quantity and sensorial quality. Following the principle that feed is intended to ensure quality production rather than maximizing (Council-Regulation, annex I, paragraph 4.1), the restricted availability of limited amino acids in organic livestock production fits to the objective of a high sensorial quality of products, by preventing producers from focussing primarily on quantity traits. However, sensorial quality of meat does not occur automatically when extensifying the production process but needs special management skills to balance the various relevant factors in a comprehensive approach.

The antagonistic relationships between those traits that are relevant for a high sensorial quality like IMF and the production traits like lean meat percentage and muscle area leads to a simple but a crucial conclusion: aiming at a higher sensorial quality means a decreasing in the meatiness of the carcass, and a reduction in the payment of the carcass according to the current classification. If the objective of meat with high sensorial quality should be implemented, the products must be honoured by premium prices that cover not only the higher production costs in organic livestock but also the lower meat yield.

To justify premium prices towards the consumer needs the development of specific quality or label programmes. So far, possibilities for an improved sensorial quality of meat by the means of a reduction in productivity combined with the use of slow growing strains have already been realised in label programmes like “label rouge” for broiler. Very few quality programmes exist in relation to the production of turkey and pig meat. Further measures are needed to exhaust the potentials for the production of high sensorial quality within the organic framework conditions by improving advisory tools, control measures for ensuring high quality standards and last but not least by the development of marketing strategies to distribute the products to those consumers that are demanding high sensorial quality products and at the same time are willing to pay premium prices.

4.2 Effects of protein supply on animal health

4.2.1 Feed-conditioned health problems in fattening poultry

In the past feeding trials with broilers were aimed principally at determining the possibilities of increasing growth rate and feed utilization. There are scarcely any studies in which the tolerance of poultry in relation to protein imbalances with respect to parameters of animal health has tested been proofed.

In poultry feed intake is determined largely by energy supply. Furthermore, it is influenced by the environmental temperature and by individual factors. With low temperatures the feed intake rises, while with high temperatures feed intake, and thus energy and protein supply can become suboptimal. The high variation of feed intake between different flocks and individual animals makes it difficult to optimise the balance between protein and energy supply. This is especially true if the amino acid pattern in the feed ration displays an unfavourable ratio of essential to non-essential amino acids. Amino acids that cannot be utilized for protein synthesis are de-seeded by the organism (LABIER & LECLERCQ, 1994). This is an energy-consuming process and requires additional metabolic performance of liver and kidneys (TUCKER & WALKER, 1992).

In the breeding of broilers and turkeys the nutrient supply of the parent animals is usually drastically reduced through withdrawal of feed in order to counter an excessive live weight gain of the parent animals (EUROPEAN COMMISSION, 2000). With laying hens feed withdrawal is often practised in order to induce the onset of moulting. The hunger caused by this has effects on the metabolism process and behaviour of the animals.

Poultry is basically able to adapt physiologically in terms of metabolism to the different nutrient supplies according to the extent and length of feed withdrawal (KATANBAF et al., 1989; SAVORY et al., 1992).

However, according to the estimation of the working group of the European Commission (CEC, 2000) drastic feed restriction in the parent animals represents a major animal welfare problem, because it is difficult, especially from the behavioural physiological perspective, for the poultry to adjust to small amounts of feed. Poultry spends a large part of the daytime in activities closely connected with feed intake (DUNCAN & HUGHES, 1972). In various studies it was observed that feed withdrawal is associated with increased behavioural disorders, such as feather pecking and aggressive behaviour (AGGREY et al., 1990; SAVORY et al., 1992).

4.2.2 Health disorders in fattening poultry as a result of a high growth intensity

Fattening poultry has been bred for high growth rates and high protein accretion in the shortest time possible. There are numerous indications in the literature which confirm a relationship between the intensification of production and animal health problems. Deteriorating health usually has various causes, but can be influenced substantially by husbandry conditions as well as genetic dispositions in the animals (HAFEZ, 1999).

The most common clinical phenomena in fattening poultry, such as morphological deviations in the legs and locomotion disorders, are subsumed under the heading of "leg weakness" (HAFEZ, 1999). They are connected with damage to bones, tendons, skin, muscles and nerves. There are numerous indications that the skeleton is unable to adjust to the rapid course of growth and consequently suffers limb damage. As a result of the massive increase of breast musculature, the upper thighs are pressed outwards, which results in malfunction of the knee joints (OESTER et al., 1997). Increasing breast musculature leads to displacement of the body's centre of gravity (ABOURACHID, 1993; CORR, 1999), and in turn the various leg angles change and the lower thigh bones rotate and bend. Strain on the joints in some cases seriously impedes the movement ability of the animals (DUNCAN et al., 1991; MCGEOWN et al., 1999). In studies of KESTIN et al. (1992) 90% of broilers aged 7 weeks were diagnosed as having problems in walking. There is a strong genetic influence on the incidence of lameness in broilers (KESTIN et al., 1992; 1999).

According to studies carried out by MCGEWON et al. (1999) and DANBURRY et al. (2000) there is reason to suppose that the pathological changes and limited functions associated with the extremely rapid growth of fattening poultry involve severe pain.

An overview of the various negative side effects in intensive fattening of broilers is the subject of a report compiled by a working group commissioned by the EU Commission on keeping broilers under animal welfare conditions (CEC, 2000). The group concludes that the animal welfare problems of broiler husbandry can be explained principally as side effects of a one-side selection for growth and feed utilization. Health problems are especially due to damaged limbs, abdominal cavity dropsy and sudden death. In the view of the working group intensive broiler fattening with its high growth rates is not compatible with a satisfactory level of health. According to the report, no disadvantageous effects on animal health are to be expected from a reduced supply of nutrients, even if broilers do not thereby exhaust their growth potential. The working group expects that a reduced nutrient supply, especially at the beginning of the fattening phase, can be expected to have positive effects through a reduced growth process, and thereby reducing metabolic disorders and limb damage.

The effects of breeding on high growth rates on the animal health issue is also related to the mortality rate. Thus, in studies of PRIN & KOEHL (1998) broilers in intensive fattening phase showed a mortality rate of 1% a week, whereas "Label rouge" mast cocks showed a mortality rate 0.25% a week. With young hens GUERDER et al. (1998) detected a mortality rate of only 0.14% a week.

Sudden death syndrome (acute heart failure, heart attack) may be the cause of the death for 2-4 % of the male table birds in “good flocks”. These and other diseases related to fast growth are grouped under the term ”metabolic disorders” (JULIAN, 2004). Furthermore, there are several indications that stress to broilers with high growth rates makes these birds more sensitive to infectious diseases (YUNIS et al., 2000, LAMONT et al., 2003). KOENEN et al. (2002) concluded that the genetic and possibly nutritional changes have put fast growing broilers in a disadvantageous situation in terms of humoral immune function. QURESHI & HAVENSTEIN (1994) examined the influence of genetic selection and ration composition on the immunological defence capacity of broilers. The authors concluded that breeding for high growth performance has a negative influence on the adaptability of the immune system. MILLER et al. (1992) showed that broilers with low growth intensity had a clearly higher antibodies formation capacity than heavy broilers. They suppose that the reduced immunity caused by high growth intensity contributes to higher mortality rates.

Increasing limb disorders are observed in the intensive fattening of turkeys (ABOURACHID, 1993; BIRCHER et al., 1996; HIRT et al., 1996). In a study of HIRT et al. (1996)

of 4,894 cocks of the hybrid B.U.T. examined only 8.5% showed a normal leg position with normal locomotive ability. Most animals (83%) had slightly difficulty walking problems and 8.6% had severe difficulties or found it impossible to walk. 88% of the lower thigh bones of the animals were found to have a tibial dyschondroplasia.

In turkeys a genetic disposition towards leg weakness is described (NESTOR, 1984; CHEREL et al., 1991). According to HOCKING (1993), leg weaknesses are more common in heavy than in light lines. Extreme breeding for growth performance also means an increased risk of aorta rupture and consequently sudden death of individual turkeys. Apart from stocking density and a lot of noise in the pen, risk factors also include the way feed is offered and the ration is formulated (HAFEZ, 1999).

4.2.3 Feather pecking

Feather pecking as an activity directed at the feathers of similar breeds is widespread in commercial poultry production. In the literature there is general agreement that feather pecking is a behavioural disorder (BAUM, 1994) and that it is one of the main welfare problems in modern poultry keeping BESTMAN (2000).

The reasons for the appearance of feather pecking are extremely complex. They include environmental factors like absence of litter, poor litter quality, inadequate opportunities for movement, stocking density, light intensity, and climate as well as feed composition and deficiencies (AMBROSEN & PETERSEN 1997; BESTMAN & WAGENAAR, 2003). It is suggested that the common factor, which links these diverse factors, might be stress. Feather pecking is regarded as redirected pecking behaviour. The two most common hypotheses are that feather pecking is either linked to the behaviour of foraging (BLOKHUIS & ARKES, 1984) or of dust bathing (VESTERGAARD et al., 1993). In the literature, two types of feather pecking are described: gentle and severe feather pecking. Gentle feather pecking does not cause damage and is performed by most birds in a flock. Severe feather pecking is the behaviour that is responsible for the damage and is performed by only a small percentage (9% according to KEELING, 1994) of the birds in a group. The birds that perform the severe feather pecking behaviour in general are the most active birds, even when housed in cages individually. In a group, they move from one victim to another and try to pull out feathers. Often the feathers are eaten. Feather pecking is not an aggressive behaviour, because the victims do not react to feather pecking in the same way as to aggressive behaviour. Another difference is that aggressive pecks are directed to the head and neck region, while feather pecks are directed to the back, rump and belly (KEELING, 2000).

In poultry housing sufficient light intensity is necessary for normal behaviour of the animals. In experiments of MARTIN (1991) the behaviour of laying hens was investigated in pens with deep litter under 2 different light conditions. It was found that scratching and pecking activity in the litter is strongly increased under adequate light conditions compared to the low light illumination usually used in most housing systems. Under low light conditions behaviour activity decreases but feather pecking increases strongly. NICOL et al. (2001) showed that current substrate was of great importance and adult birds housed on shavings performed significantly more ground pecking and less feather pecking than birds on wire, regardless of previous experience.

Last but not least, the structure of feed and the contents of the feed mixture are important. Feed that is consumed too rapidly and easily satiates the animals stimulates feather pecking because of insufficiently exercised pecking behaviour (BESSEI, 1980; FRÖHLICH & OESTER, 1989). Thus, in laying hens feather pecking can be reduced by meal as distinct from pellet feed, because the feeding time with meal takes longer than pellet feeding (BESSEI, 1980). Feeding aspects of feather pecking were evaluated by LINDBERG & NICOL (1994) with the result that operant feeding was a potential method for preventing feather pecking in laying hens kept on deep litter. The data presented led to the conclusion that operant feeders should be combined with conventional feeders, and birds should be fed mash to decrease the risk of feather pecking. BAUM (1995), after comprehensive research and studies on feather pecking in laying hens, came to the conclusion that feather pecking is principally due to non-existent or limited possibilities of suitable feed intake. The causes are mainly not enough pecking in the feed intake process and the processing of feed using species-appropriate inheritance co-ordinations. HUBER-EICHER (2001) made studies with small groups and showed that feather pecking and foraging behaviour are related and that both behaviours are influenced by early access to litter substrate. In aviaries, under commercial conditions, early access to litter substrate has a significant effect on the development of feather pecking. In order to reduce feather pecking and to increase foraging behaviour, it is recommended that laying hen chicks raised in aviary systems should get access to litter from the first day of life.

Bronze turkeys with meal feed take an average of 136 minutes a day for feed intake, but with pellets only 16 minutes (KRAUTWALD-JUNGHANNS, 2003). The author concludes that pellet feed alone does not occupy the animals enough.

Several authors see a connection between unbalanced nutrient supply and feather pecking (CURTIS & MARSH, 1993; AMBROSEN & PETERSEN, 1997; DÄNNER & BESSEI, 2002). AMBROSEN & PETERSEN (1997) studied the influence of the protein level in feed for signs of cannibalism and plumage quality. The trials were carried out with seven different laying hens and two different protein levels (11.1 and 19.3 % crude protein). The plumage and appearance of cannibalism were assessed after 45 and 65 weeks of life. The plumage improved with the addition of protein content in the feed. The mortality rate caused by cannibalism was influenced by the protein content in the ration and by genetic origin. Chickens whose feed ration was supplemented with methionine, in contrast to methionine-deficient rations showed a clearly improved plumage state and reduced feather pecking. The authors supposed that increased manifestation of cannibalism with low crude protein contents in the feed ration were to be attributed to a deficiency of amino-acids (lysine, methionine and threonine). However, the results are of low meaningfulness in relation to a general conclusion as the difference between the protein supply of the two diets was very high and the low protein diet clearly below the recommendations. In the study of DÄNNER & BESSEI (2002) the index value for assessing plumage (0 = without feather damage, 5 = almost without feathers) improved from 3.14 ± 0.36 at the lowest supply level with methionine to 2.32 ± 0.40 at the highest supply level. Even when a significant difference could be ascertained, still no causal connection could be proved with this by-result. Also with an optimised supply of methionine the laying hens were on average still quite a long way from intact plumage. According to KJAER & SOERENSEN (2002), the dietary level of methionine + cystine has only a minor effect on the pecking behaviour. (Composition of feed for the 16-43 week see annex table A-5). BIEDERMANN et al. (1993) were unable to detect any effect of crude protein content in the feed on plumage condition.

In view of a multi-factorial genesis the proof of a direct causal connection between deficient supply of amino acids and the appearance of feather pecking is difficult. Against a direct connection is the fact that behavioural disorder cannot be prevented by appropriate feed composition and additional supplement (HUGHES & DUNCAN, 1972; GREEN et al., 2000). On many farms feather pecking appears despite a feed ration highly enriched with methionine. Even after feather pecking animals have been transferred to an optimised husbandry environment, where there is no feather pecking from other animals, they still retain the behavioural disorder (BAUM, 1995). The author supposes that, as feather pecking appears, a false neuronal way has been built up, which remains despite the removal of the causes. This underscores the significance of the breeding phase for the potential manifestation of behavioural disorders in the adult phase. The genetic influence too plays a considerable role for pecking activities or aggressiveness in the population (BIEDERMANN 1993; PREISINGER 2000). PREISINGER (2000) reports that there are not only differences between strains, but also family differences in behaviour and in loss rate because of cannibalism. He recommends strict selection between the lines in order to reduce feather pecking and cannibalism.

4.2.4 Inadequate protein supply of lactating sows

In recent years litter size and milk production of breeding sows have increased substantially. A suboptimal supply with energy and essential amino acids increases the mobilization of fat and fat deposits and proteins from the body's own musculature. Inadequate supply of energy and essential amino acids can lead to considerable weight losses in the sows, decreased growth rates of piglets and impaired fertility (KING & DUNKIN, 1986; JONES & STAHLY 1999b). Weight losses are up to about 59% from protein, water and minerals and up to about 37% from fat (JONES & STAHLY, 1999a). First-lactating sows are more affected than multiparous sows (KUSINA et al., 1999; EISSEN et al., 2003).

NONN et al. (1996) investigated the effects of varying amounts of protein on reproductive performance, body weight and nitrogen excretion of 130 sows during 4 reproductive cycles. Treatment 1 consisted of excess protein and energy during the entire reproductive cycle, treatment 2 consisted of 2 different diets (excess protein) during gestation and another during lactation, and treatment 3 consisted of adequate protein and energy during gestation and a reduced-protein, amino acid-supplemented (L-lysine, DL-methionine and L-threonine) diet during lactation. No negative effects were observed with treatment 3. Treatment 1 caused several negative effects: sows had higher liveweight gain and body weight due to oversupply of energy, but problems with farrowing, stillborn piglets and piglet mortality due to overlaying. Moreover, reproductive cycle sows on treatment 1 reared 1.1 piglet more compared with sows on treatment III.

Increased feed intake in the suckling period can compensate partially for the loss of body weight and back fat. To reach a higher feed intake capacity during the suckling period the feed during pregnancy is important. According to JEROCH et al. (1999), pregnant sows need fibre-rich and hygienic high-grade feed. Crude fibre feed (up to 20% crude fibre) can be categorized as appropriate for pregnant sows, because it increases the feeling of satiation and promotes intestinal peristalsis. In sows fed with rations high in crude fibre during pregnancy MATTE et al. (1994) were able to detect higher feed intake during the following suckling period and an improved development of the piglets compared with a control treatment.

In organic pig husbandry the daily supply with roughage is set and thus offers the possibility of using it during pregnancy in a targeted way for increasing feed intake of concentrated during the lactation period and therewith compensate for feed components comparable low in the content of essential AA. The sows also take much more time for eating with roughage than is usual in conventional production with normal feed quantities of 2-3 kg concentrated feed in pregnancy (BROUNS et al., 1994; Meyer & Horügel, 2001).

According to WEBB (1995) feed intake is adversely affected by breeding for high a number of piglets and a high portion of lean meat. This involves a risk for breeding sows with regard to an energy deficit and a suboptimal supply with amino acids during the suckling period and can thereby impair the reproduction performance (KARSTEN et al., 2000; EISSEN et al., 2003).

4.2.5 Inadequate protein supply of piglets

Rearing healthy piglets is closely related to an undisturbed development of the digestion tract and the enzyme activities. Those are influenced to a high degree by the quality and the digestibility of feed components and by the quantities of feed intake (KELLY et al., 1990; COLE & SPRENT, 2001). The importance of feed intake before and after birth for the health of piglets has been adequately described in the literature and is summarized in the work of PLUSKE et al. (1997). The transition from suckling milk from the sow to the uptake of solid feed decides how the intestine villi after birth develop and to what extent the amino acids present in the feed can be used (NABUURS et al., 1993) or whether there is an increased risk of diarrhoea because of inadequate absorption in the intestine (KELLY et al., 1991; HAMPSON, 1994). On organic pig farms extended suckling periods ensure that the piglets in the first weeks of life are supplied with full value sows milk. To what degree the extended suckling period is used on organic farms in order to accustom the piglets to solid feed and thus to induce increased enzyme activity cannot be estimated at the moment due to a lack of data.

4.2.6 Inadequate protein supply of fattening pigs

The requirements of piglets after weaning and of growing pigs in relation to the supply of essential amino acids are directly correlated to the development of the protein accretion during the growth process (NRC, 1998). A supply with essential AA that is in correspondence with the protein accretion capacity will maximise muscle growth while a suboptimal supply is expected to reduce lean meat percentage without provoking harm to the animal. Surpluses in energy and in non-essential amino acids are used physiologically for fat deposition which does, however, not meet the expectations of the producer.

The high protein accretion capacity in pigs achieved by breeding can be explained to a large extent by the fact that not only does protein synthesis rise through increased formation of growth hormones, but also the release of glucocorticoids is considerably reduced CLAUS & WEILER (1994). Thus, the increase of meat quantity through breeding can be explained by changes in the underlying hormonal structure control mechanisms (CLAUS, 1996a). The significance of glucocorticoids for the differentiation of cells has been demonstrated for many cell types (DARDEVET et al., 1995). According to THOMPSON (1994), it may be objected to a further reduction of cortisol concentration that the degradation of protein is an important biological protection mechanism to separate out already defective or superannuated proteins. Because the maturity of chondrozytes, in particular in the area of the bone growth zones, is essentially dependent on cortisol (CLAUS & WEILER, 1996), the suspicion according to CLAUS (1996a) is justified that the "leg weakness syndrome" in pigs represents direct consequences of cortisol deficiency. In addition, increasing muscle mass with unchanged skeleton mass contributes mechanical disorders in the movement apparatus (REEDS et al., 1993; SIMONSEN, 1993). According to CLAUS (1996a) it must be asked whether the lowering of cortisol secretion due to breeding has not already led to physiological defects.

One-sided breeding for rapid growth and meat quantity performance makes osteochondrosis and stress myopathies in pigs more likely (BICKARDT, 1998). The accelerated protein accretion puts a strain on a young immature skeleton. The illness is determined by cartilage degeneration with epiphyseolyses and bone proliferative reactions. Pigs with high lean meat percentage and high growth rates showed poor assessment values in respect of carpal and tarsal joints (LUNDEHEIM, 1987; HUANG et al., 1995). According to RAUW et al. (1998), the characteristics antagonism between growth intensity and health impairment give rise to the supposition that the domestication of pigs has led to reduced ability to deal with environmentally determined stress.

4.2.3 Conclusion in relation to animal health

The general concern that nutritional imbalances encountered in practice might lead to deteriorating animal health and welfare are not justified. Several studies show that both poultry and pigs can compensate to a high degree for imbalanced feed rations without the onset of specific health problems. Nutrient imbalances with respect to the amino acids supply are, however, expected to lead to a reduced growth performance. The capacity of animals under natural conditions to adapt to the huge variation in feed supply still exists in domestic farm animals. However, young stock in the first week are more sensitive to an unbalanced nutrient supply. Under the organic framework conditions with a restricted availability of high quality protein, special attention should be paid to this group and non-organic feedstuffs allowed where organic feedstuffs of corresponding protein quality are not available.

There is reason to suppose that high yielding animals are more sensitive to suboptimal feed rations than slow growing strains or robust breeds. As organic livestock production is intended to adapt to the local conditions and should use slow growing strains, there is no need to allow non-organic feedstuffs for fattening animals and laying hens for the reasons of animal health and welfare.

In contrast , numerous studies show the negative side-effects of high growth rates and high yielding in conventional poultry and pig production on animal health and welfare. Allowing conventional feedstuffs to be fed in organic livestock production will further increase the intensification of production because under the current framework conditions there is no factor that can balance the economic pressure to reduce production costs increasing performance. The previous prescriptions for the use of slow growing strains inorganic poultry production obviously do not prevent the producers sufficiently from using high yielding breeds, either due to a lack a control or due to non-appropriate prescriptions as in the case of turkey. The comprehensive knowledge about the various interactions between increasing growth rates and health disorders or mortality rates leave no doubts that the intensification has already caused and will further increase the same problems in organic production as conventional production already shows to a very high degree. Thus, the uncontrolled use of non-organic feedstuffs is expected to have a damaging effect on the consumers expectations that organic products derive from healthy animals.

4.3 Effects of protein supply on environmental pollution

With respect to the efforts to reduce the emissions from livestock production various competing strategies exist with respect to effectiveness, practicability and sustainability (SUNDRUM, 2002). In conventional livestock production the emphasis lies on strategies to increase feed efficiency and to decrease nutrient excretion in relation to the quantity of products by using among others bought-in feedstuffs of high quality such as soybean meal and synthetic amino acids. In contrast, the system-orientated approach used in organic livestock production is based on the principle of avoidance. This implies that hazardous means of production will not be employed, and that nutrient input into farms will be drastically reduced by purposeful cutting back of resources.

Environmental damage caused by nutrient surpluses derived from livestock production and released into the environment are closely related to the nutrient flow within the farm system and the quantities of home-grown and bought-in feedstuffs. In this respect it is of central importance how nutrients imported on to the farm are used in a targeted and efficient way, and how it is dealt with the excess nitrogen given off from the feed. If the excess nitrogen in the commercial fertilizer can be caught and retained in the agricultural nutrient cycle, the environmental effects are relatively low. If the nutrients are discharged from the cycle and emitted into the environment, this can mean correspondingly high environmental damage (IFEU, 2002).

4.3.1 Feeding adapted to the requirements

The supply of amino acids and the conversion of them by the animals have a considerable effect on the possible extent of N release through animal husbandry. N losses are caused mainly by

- the urea in the excrement of mammals,
- the uric acid and urea in the excrement of the poultry.

In the mammals' urine nitrogen is up to 80 % urea or fixed to other easily degradable organic compounds. In contrast, nitrogen in the faeces escapes less easily, because it is contained in the undigested protein or in the bacterial protein and their nucleic acids. Excess feed protein is degraded in the animal and the surplus in nitrogen is excreted to a high degree as urea with the urine or as uric acid. A reduction of surplus protein through the formulation of diets that are closely related to the requirements minimizes N excretion with the urine and lowers the potential of ammonia emission .

A characteristic of a need-oriented feeding strategy in monogastric animals is the adaptation of essential AA content in the feed ration to age, the various growth and performance stages and the specific performance level of the animals. The supply recommendations worked out by various organizations here offer an important orientation. Table 16 gives an overview of the reduction potential in adapted feeding systems.

Through a nutrient adapted feeding the potential for ammonia emissions in animal husbandry can be reduced considerably via lowering N excretion. The IPPC (2003) has estimated the potential for reducing crude protein content in poultry feed at 10 to 20g crude protein/kg feed and for pigs at 20 to 30g crude protein/kg feed.

Tab. 4-1: Mean N excretion of pigs and poultry in standard and N adapted feeding systems

	Standard feeding system	N-adapted feeding system
Sows and piglets		
kg N/sow and year		
with 20 piglets with 28 kg LM	**38.0**	**33.0**
Fattening pigs		
kg N/place and year		
700 g daily live weight gain	**12.3**	**10.1**
800 g daily live weight gain	**14.0**	**11.6**
Egg production		
kg N/100 hen places and year	**78.0**	**75.0**
Young hen breeding		
kg N/100 breeding places and year	**28.5**	**24.4**
Broiler (short mast)		
kg N/100 places and year	**28.0**	**23.5**
Turkey fattening (Ø ♀♂)		
kg N/100 places and year	**152**	**141**

Source: AID, 2003

To what degree those potentials for the reduction of N excretion are implemented in practice can not be judged at the present moment due to a lack of sound data. However, surveys show that in practice often an extra charge is supplemented in order to be on the safe side and to counter potential performance losses (BRINKER et al., 1994; HOFFMANN et al., 2000).

The reduction percentages through N adapted feeding vary according to animal species, performance stage and level, and starting situation. In order to reduce the N excretion the crude protein content of the mixed feed for poultry and pigs has to be reduced in accordance with the energy concentrations. This can be achieved in particular by supplementing the feed mixture with synthetic essential amino acids. However, according to the EC-Regulation on organic livestock production the use of synthetic essential amino acids is forbidden. Thus, organic livestock production is left without this tool for the reduction of nutrient losses. Whether there are other options in organic livestock production will be discussed below.

4.3.2 Nutrient losses in poultry production

With regard to the total potential of nutrient emission from livestock production poultry husbandry plays only a subordinate role compared with cattle and pig husbandry (GRONAUER, 2002). Thus, ammonia emissions from poultry husbandry is only about 5 % (BMU, 1996). But this does not mean that high concentrations of animals may not be responsible for local environmental damage.

An excess protein content in the feed ration leads to a disproportionate increase in nitrogen excretion (KIRCHGESSNER & KREUZER, 1990). A reduction of the N input can be achieved by the use of both high value protein carriers and supplementation with synthetic amino-acids. Because the requirements of amino acids change during the fattening period, a phase feeding is recommended and generally a standard measure in poultry production. Reduction of the protein content in the feed ration for broilers from 22% to 18% is able to lower the N content in the emissions from 53.2 to 38.9 g N/kg TM (ELLWINGER & SVENSON, 1996). According to studies of ABEL et al. (1991) and HAMID et al. (1997) a reduction of N excretion by 20% to 30% could be achieved by reducing the crude protein content and supplementing the feed mixture with industrial amino acids without performance losses. According to NIEß, (1997) this effective measure is not actually used in practice, because it has an undesirable side-effect increase in fat deposition in the carcass of broilers.

Also in laying hens the crude protein content in the feed ration could be lowered by the use of synthetic amino acids and thereby N excretion drastically reduced (SCHOLTYSSEK et al., 1991; JAMROZ et al., 1996). In the composition of the nitrogen fragments in fresh poultry excrement there are only slight differences between broilers, fattening turkeys and laying hens (PRIESMANN et al., 1990). 40%-70% of the total nitrogen consists of uric acid, 4%-12% of urea and up to 4%-20 % of ammonium, the remainder organically fixed nitrogen.

Most of the uric acid is degraded by means of aerobic bacteria, which are able to form the enzyme uricasis, to urea, and urea subsequently via ureasis to ammonium (GROOT KOERKAMP, 1994). The enzymatic degradation processes are linked to the presence of water and are dependent on temperature. An important measure to reduce emissions consequently begins with a premature drying of the poultry excrement, which together with the measures of pH reduction, lowering of temperature, and withdrawal of water in the litter is able to prevent the degradation of uric acid (PRIESMANN et al., 1990; GROOT KOERKAMP & ELZING, 1996).

The various influence factors on the formation and evaporation of ammonia from poultry excrement are characterized by the nitrogen composition and its degradation (GROOT KOERKAMP, 1994). The emission rate of nitrogen quantities depends especially on the dry mass, the temperature, the carbon-nitrogen ratio, the pH value, the concentration differentials to the ambient air and the availability of oxygen (FLÜGGE, 1994). Correspondingly the storage time of the litter in the pen, treatment of excrement and litter, litter quantities and mucking out interval and the husbandry systems have a determining effect on emission potential (DÖHLER et al., 2002; GRONAUER, 2002).

In organic poultry production the use of grain legumes in the feed ration and the ban of industrial amino acids often are the reason for a higher crude protein content in the diet compared to conventional diets (see tables in Annex A-2, A-3 and A-4). This consequently leads to higher proportion of N-excretion per product unit. On the other hand, the prescription for the use of home-grown feedstuffs in the first place, the restrictions with respect to bought-in feedstuffs and the lower stocking density in organic poultry production is expected to result in a clearly lower nutrient input into the farm and in lower surpluses in relation to nutrient balance sheets on the farm level (ANDERSSON, 2004; KRATZ et al., 2004).

4.3.3 Nutrient losses in pig production

In pig husbandry there are four principal strategies of feeding measures to reduce nutrient losses (FLACHOWSKY, 1993; HOEGEN et al., 1996; CANH et al., 1998):

- reduction of the protein content in the feed ration and thus the N input per animal through a corresponding choice of protein carriers, differentiated feeding according to living mass and performance (phase feeding) and supplementing with industrial amino-acids,

- increase of the animals' performance because the N emissions will thereby be lowered in terms of kg per growth increase or per piglet, if the farm conditions remain equal,
- displacement of nitrogen emission from the urine into excrement by raising the biologically fermentable substance in the ration of nitrogen in the hind gut through microbes.
- reduction of the pH-value in the urine and in faeces and therewith reduce the pH-value in the slurry by a targeted selection of feed components.

Reduction of N input

A reduction of N input per animal is possible, especially by means of multi-phase feeding. The greater the use of nutrient-graduated feed mixtures, the higher the reduction potential with regard to nitrogen excretion. Substantial savings can thus be achieved if the phase feeding is accompanied by a simultaneous reduction of protein content (HOEGEN et al., 1996; KAISER et al., 1998). This can be achieved by the use of high value protein carriers (e.g. milk protein, potato protein and gluten protein) and/or by targeted feed supplement with industrial amino acids (lysine, methionine, threonine). Studies of KAISER et al. (1998) showed that reduction of crude protein content in the fattening ration from 16.5% to 13.5%, in combination with a suitable supplement of essential amino acids and a multi-phase feeding, could result in a reduction of nitrogen excretion by 20% to 22%. Analogous reductions can be obtained in sows by the means of a two-phase feeding (ROTH, 1990).

Increased performance

With pigs the N emission per husbandry unit increases with an increase in performance in terms of number of piglets or daily live weight gain, because quantity and quality requirements in relation to the crude protein supply increase. At the same time, however, the crude protein utilization increases with higher performance and the need of crude protein for protein accretion decreases relatively, because the requirements for maintenance declines proportionally with higher performance (FLACHOWSKY, 2001). The potential for the reduction in N excretion increases as the proportion of the requirements for maintenance in relation to the total N turnover decreases. This is true especially for breeding sows. In contrast, this relationship plays a subordinate role with fattening pigs and has hardly any effect on the quantity of nitrogen in the slurry in a further increase of performance intensity (KIRCHGESSNER et al., 1993). It should be noted, however, that with the same stocking density and an increasing performances the amount of nitrogen per hectare increases.

Displacement of N emission from urine to faeces

With a medium N intake of 6.1 kg (240 kg feed x 16% XP) during the fattening phase (20 to 100 kg living mass) about 33% (2.0 kg N) are retained in the body and 2.9 kg N are excreted via urine N and 1.2 kg via faeces N (ROTH, 1990). The ratio of urine N to faeces N is not a fixed variable, but is subject to large variations and thus corresponding possible influences. It is determined (a) by the crude protein quantity and the proportions of limiting amino acids in relation to the protein accretion and (b) by the activities of micro-organisms in the colon which are to be influenced by the feed ration.

With an increase of the crude fibre and bacterially fermentable substance (BFS) in the feed ration microbial growth in the hind gut and the amount of organically bound nitrogen in the faeces can be markedly increased (BOULDUAN & JUNG 1990; KIRCHGESSNER et al. 1991; KREUZER et al. 1998). Bacterially fermentable substance is the part of feedstuffs exclusively digestible by the microbes in the colon. It can be calculated from the crude material fractions of the digestible N-free extract (NfE) plus digestible crude fibres minus starch minus sugar (DROCHNER, 1984). The N excretion is thus displaced from the urine to the faeces, with a clear reduction in the quantity of easily emissible urea nitrogen. The nitrogen excreted with the faeces is compared to nitrogen in the urine to a high degree fixed in the bacterial protein and clearly more resistant against degradation than urine nitrogen (CANH et al., 1998). Urine nitrogen consists of large quantities of urea, which is split quickly by the enzyme ureasis into NH_4^+, which is transformed according to pH value into volatile NH_3. In contrast nitrogen in faeces consists of water-soluble nitrogen only up to 10%.

To what extent nitrogen is emitted during storage depends to a high degree on the ratio of urea N to faeces N. By feeding roughage and straw meal to breeding sows a fall of the urea nitrogen in relation to the slurry nitrogen from 85% to 50% was found with increasing intake of BFS-rich feeds (KIRCHGESSNER et al., 1993). Feeding fattening pigs a high proportion of sugar-beet chips under laboratory conditions led to a reduction of ammonia emissions from the liquid manure by 38% compared with conventional grain mixture (CANH et al., 1998). However, the increase of the proportion of BFS in the diet goes along with a decline of the energy digestibility and a reduction of the slaughter yield (KREUZER et al., 1994).

Environmental effects of organic pig production

In organic animal husbandry the possibilities for the adaptation of the feed ration to the specific requirements by means of principal use of self-produced feed (e.g. grain legumes as crude protein source) and avoiding synthetic amino acids are considerably limited. From a traditional point of view organic guidelines are opposed to environmentally compatible commercial animal husbandry.

However, the organic farmer has other possibilities and strategies to reduce nutrient emissions. In the first place, the input of nutrients into the farm unit is clearly reduced due to the non-use of mineral fertiliser and restrictions in the amount of bought-in feedstuffs (SUNDRUM, 2002). Model calculations of HERMANSEN and KRISTENSEN (1998) showed that mixed farm systems including cattle and pigs, as intended in organic agriculture, provide a potential for a clear higher nutrient efficiency and an improved balance sheet compared to specialised farms because interactions between plant cultivation and livestock production can be better optimised.

Because a daily provision with roughage is prescribed in organic pig farming, the impact of nitrogen fixation in the faeces becomes quite important through increasing the proportions of bacterially fermentable substances (BFS) in the feed ration. BFS containing feeds can easily be included in the rations of pregnant breeding sows and fattening pigs in the finishing phase, as these animals can take up relevant quantities of roughage without substantial impairment of performance. However, there is still a considerable need for optimisation of this strategy in agricultural practice.

4.3.4 Conclusions in relation to environmental impacts

The complex interactions between the different groups of substances, the constantly varying environment in which animals are reared, and the considerable fluctuation found in the quantities of substances in cirulation mean that any quantification of the emissions emanating from animal husbandry must of necessity be only very approximate. Any assessment of the efficiency of individual measures or specific rearing systems can only be of limited scope, and the resulting data can scarcely be considered valid, if the farm context is left out of consideration.

Reduction in nitrogen excretion is often set equal with a reduction in nitrogen emission. This is only true in those cases where the excess nitrogen in the commercial fertilizer can be caught and retained in the agricultural nutrient cycle. If the nutrients are, however, discharged from the cycle and emitted into the environment, this can mean correspondingly high environmental damage.

The possibilities for reducing nutrient losses by specific feeding and other procedural measures are clearly limited in organic livestock production in comparison to conventional livestock production practices. On the other hand, at farm level, the quantities of substances in circulation, due to the drastic restrictions on nutrient imports and a system-orientated reorganisation of the farm, have sunk to a clearly lower level than on comparative conventional farms.

The system-oriented approach offers the prerequisite for a high degree of effectiveness in the application of internal and external farm resources, and is thus an economical and sustainable method for the creation of animal products. At the same time, however, it also involves drops in productive performance and animal-related productivity.

In organic animal husbandry it is also of high importance that because of the drastic reduction of nutrient imports into the farm there is an economic reason to implement emission-reducing measures for the farmer. The limited availability of fertilizers means that every reduction of nutrient losses is equivalent to an increase of yield and income-effective fertilizer availability. This aspect marks a major difference in the motivation of farmers in implementing environmental measures between conventional and organic farming.

The potential of organic animal husbandry with respect to reducing environmental damage is the result of the specific organization of the farm and becomes tangible only in the total context. With the goal of a largely closed farming system environmental damage is clearly reduced. At the same time it circumvents the problem of shifting consumption of resources and environmental damage in feed production and transport as well as the bringing of excess quantities of liquid manure to other feed producing regions.

EU regulations have created a system in organic animal husbandry that contains important conditions for environmentally compatible production. The conscious creation of resource scarcity with simultaneous banning of risk-laden production means a major restructuring of the farm in order to be able to employ the most efficient nutrient use possible with leguminous nitrogen resources, self-produced fertilizers and limited nutrient additives via commercial feed. Therefore, organic farming cannot be assessed only on the grounds of individual process technology measures, but as a systems approach only in the farming context.

4.4 Production costs

Concerning the production costs in organic livestock production, a huge variation exists between countries, regions and farms due to the very different conditions, especially in the availability of nutrients, in housing conditions and labour time needed to run the various animal husbandry systems. It can be assumed that every farm has its own optimum with respect to marginal utility for the use of specific production means.

However, independently of the specific farm situation, costs for feedstuffs and feed conversion rates always play a major role in relation to the total production costs. In the literature there are only few data available on feed costs and the total production costs in organic livestock production. In the following, some examples are given to provide examples with regard to the main differences between conventional and organic production of monogastric animals especially in relation to the feed costs. Although the data are incomplete and not representative, the information may be worth taking into account when discussing the whole production chain and the consequences of a restricted availability of feedstuffs with a high protein quality.

4.4.1 Broilers

In general, rapid-growing broiler strains are used in conventional broiler production for a short fattening period of approximately 35 days. In contrast, the EC-Regulations of organic broiler production prescribe the use of slow-growing strains. The minimum age at slaughter should be 81 days. Additionally, the use of self-produced feed, a low stocking density and outdoor run areas is preferred. Thus, clearly lower daily live weight gains and poorer feed utilization can be expected.

While a conventional fattening broiler strain reached an average live weight of 2750 g in 56 days, slow growing strains gained only about 1998g or 1806g within the same time period (Ristic & Damme, 2002). In conventional broiler production, extra expenditure to improve profitability is subject to marginal utility. The use of feedstuffs in broiler mast is primarily dependent on their price (Pack & Schutte, 1995). If the higher feed costs, the higher investment costs for the housing conditions, and the higher expenditure of labour, compared with conventional production, are taken into account, the production costs of organic broiler are clearly over those of conventional production. According to GRASHORN (2000), organic production means higher production costs in the range of 20% to 40%.

4.4.2 Laying hens

In organic farming chicken and pullets have to be kept and fed organically from day 1 and have to derive from an organic farm. The consistent implementation of the EC regulation is reflected in the price for pullets. On-farm evaluations showed, that the proportion of feed costs in the total production costs of organic eggs is on average about 50% (INGENSAND & HÖRNING, 1999; INGENSAND, 2002). Details about the average feed consumption vary between less than 120 g and more than 160 g per hen and day (STROBEL ET AL., 1998; STAACK ET AL., 1999).

4.4.3 Pig production

According to Kempkens (2003), feed costs have the largest impact on the producer price. As a consequence, organically produced pork was about 60 % more expensive than conventionally produced pork, mainly because of the clearly higher feed costs. Due to the antagonistic relationship between lean meat percentage and relevant traits for a high sensorial quality, a quality oriented production is expected to further increase the production costs (Affentranger et al., 1996). In studies of Acosta et al. (2005), where the production of a high sensorial quality of pork was intended, production costs of organically fed pigs were markedly higher than those of conventionally fed pigs, conditioned by higher feeding costs (up to 32%) and by lower price quotations for the carcasses.

4.4.4 Future development of the market

Examples from Denmark and The Netherlands show that in livestock production integrated production and quality assurance will become more important in the near future. The reasons for the hitherto poor success in marketing rigorous integrated quality assurance systems are, according to Schweinsteiger (2001), connected with the extremely sharp competition as a result of massive economic pressure and the fact that the need for such systems is still not appreciated. Even if many farms producing meat and sausages are ISO certified, have worked out a HACCP concept, audit pre-delivery, all these measures align themselves to the processing processes, but not to the production and the finished products processes. In addition, trade in fresh meat is cut-throat, and in an environment characterized by price marketing quality questions are asked, but never scrutinized or tested. Spiller (2001) sees the significance of the quality factor threatened by the price-aggressive strategy of the retail trade. In the opinion of the author, brands are a way out of pure price competition, which would allow a company or producer group some leeway for a policy of quality.

In view of the lack of knowledge and experience on the farm level on how to improve quality, organic livestock production could play a pioneer role to sound out the territory for meat production which is not based on the lowest costs, but on aspects of product and process quality. According to Zeddies (1994), the change in animal husbandry to adopt more quality and consumer oriented husbandry methods is not a question of cost, but a question of compensating for the additional costs on the farms and a question of the effects in international competition and protecting domestic production.

5 Explanations concerning the system-oriented approach

From the perspective of conventional production, animal nutrition is the most relevant key to increasing productivity and to decreasing production costs. In contrast, the EC-Regulation on organic livestock production limits the availability of feedstuffs with high quality protein and thereby reduces the potentials for increasing productivity and to decreasing production costs. Due to a restricted availability of limiting amino acids (AA) under the framework of organic farming, it is clearly more difficult to formulate diets that accurately meet the requirements of the animals than in conventional production. As a consequence, the welfare of animals in organic farming might be under great risk. Further problems are expected in relation to meat quality due to low levels of limiting amino acids and environmental pollution due to unbalanced feed rations. As a solution to all these concerns, the extension of the derogation for the allowance of non-organic feedstuffs and even the use of synthetic amino acids is often recommended. In the following, pro and contra arguments are discussed and related to the system approach of organic livestock production.

5.1 Differences in objectives

From the perspective of conventional animal nutrition, the formulation of diets should primarily intend to meet the specific requirements of specific animal strains with the supply of adequate nutrients in order to produce ‘as cost-effectively as possible’. High quality feedstuffs such as soybean meal and synthetic amino acids are seen as very important protein sources and essential for conventional production goals. Adopting this point of view, it is difficult to understand why these tools should not be used in organic agriculture. However, the line of argument is often characterised by reducing the issue to a single question and by ignoring the context in which the organic production takes place.

From an organic perspective, the question of protein sources is part of the system approach and has to be solved in relation to other objectives and limitations within the system. As a consequence, the objective to meet the requirements of the animals for high growth performance as accurately as possible does not have the first priority but is subordinated to system-related and quality-related objectives.

To discuss the existing problems with protein supply in organic livestock production, it is essential to understand the system approach and the quality-related objectives in organic agriculture. Furthermore it is important to take into account:

- different breeding goals and variation in requirements due to different breeds and strains,
- implications of high live weight gains for animal health and welfare,
- implications of a high productivity on the sensorial quality of products of animal origin,
- the importance of home-grown feedstuffs within the farm-cycle.

The principles of organic livestock farming have been established to develop a concept against the implications of an exceeding intensification in agriculture and in livestock production. However, criticism from the traditional perspective puts the finger into an open wound of organic livestock production. There is no doubt that the restrictions in the availability of amino acids represent a challenge in relation to the welfare issue. The questions, however, arose:

- whether the derogation to allow non-organic protein sources is a system-related solution,
- whether there are alternatives to solve the problem,
- what are the consequences in relation to the leading idea and features of organic agriculture if there are further exceptions to the rule to ban synthetically produced and non-organic production tools.

5.2 Main objectives of organic livestock production

The principal objectives of organic livestock farming are to sustain animals in good health, to realise high animal welfare standards, to establish an environmentally friendly production and to produce products of high quality, and provide a reasonable sources of income for those that work on farms. By striving for high process and product qualities, organic livestock farming meets the demands of an increasing number of consumers for alternatives to conventional products.

There are conflicts of aims between the quality-related objectives and objectives concerning the productivity, the aim being that organic produce should be achieved in the most economic manner possible to benefit the widest section of society. However, it is not the objective of organic agriculture to reduce costs in the first place and to maximise the productivity but to ensure quality production (section 4.1 in the annex of the Council Regulation, EC-No. 2092/91). Quality production includes the quality of the product as well as the quality of the production process. While a reduction in the productivity is (with some exceptions) not possible under the current conditions of the conventional food market, organic farmers try to achieve a degree of independence from the permanent practical constraints within the present industrial agricultural system. There would be no difference between the conventional and organic production and products if the concept of organic agriculture does not have fundamental effects on the productivity, on the reorganisation of the farm and the price of the products. Single measures within organic systems can only be understood if the whole system has been understood.

5.3 Supply with AA that meets the requirements

Concerning the requirements of animals in relation to limiting amino acids, it is often ignored that the requirements are primarily a function of the growth performance that is expected from the animals by the farmer or by the poultry and pig industry under current conditions. High quality feedstuffs and synthetic amino acids are an essential production tool to meet the continual increasing demands of poultry and pigs in intensified production systems as a consequence of the steadily increase in the genetic performance capacities by breeding efforts. The claim for the allowance to use non-organic feedstuffs for the use in organic livestock production resulted from the lack of availability of organic feed material when the sector was much smaller, but could also be seen as complying with the request to introduce maximization of performance analogue to the conventional production.

A possibly way to reduce the gap between requirements and supply is not only to improve the supply but to decrease the requirements by using breeds or strains and by developing production systems that are suitable to the potential nutrient capacity of the farm unit. This is exactly what the organic farmer is supposed to do.

According to the EC-Regulation, in the choice of breeds or strains, account must be taken of the capacity of animals to adapt to local conditions, their vitality, and their resistance to disease. In addition, breeds or strains of animals should be selected to avoid specific diseases or health problems associated with some breeds or strains in intensive production systems (EC-Regulation, Annex I, paragraph 3.1).

Within the conventional agricultural system, farmers are forced to reduce the production costs by increasing the performance of the animals. In the past, the implications of the intensification on animal health have been of minor relevance. There seems to be no possibility to change the implications of the system other than to change the system as a whole. The organic livestock production does this successfully in crop production by restricting specific and banning synthetic production tools identified as being risky. The allowance of non-organic feedstuffs in organic as a derogation contradicts the principles and main objectives of organic agriculture. As long as those tools are cheaper than organic tools, it can be expected that they will be used by organic farmers that are under the same or even higher pressure with regard to production costs.

There seems to be no practical possibility to limit the pressure on the performance other then by limiting the available feed resources. To allow non-organic feedstuffs and even the use of synthetic AA would be like allowing the sole dominance of productivity crossing to enter into organic agriculture. If those restrictions are lost, it can be expected that there will be no relevant difference concerning health status between organic and conventional poultry production.

For the concept of organic livestock production, the ban of non-organic feedstuffs and synthetic amino acids is analogue to the ban of mineral nitrogen in plant cultivation. In both cases, the nitrogen source is most relevant for the level of performance, the implications on the organisation within the organic farm system, and the consequences that have to be faced due to exceeding performances on quality traits.

5.4 Restricted availability of amino acids in organic poultry production

Home-grown corn legumes (faba beans, peas and lupins) are the main home-grown protein source in organic livestock production. Although home-grown legumes are characterised by a high crude protein content, the portion of limiting amino acids and their digestibility are low compared to soya beans. Grain legumes contain anti-nutritional factors, which restrict the maximum inclusion rate. On the other hand, most of the anti-nutritional factors can be destroyed by heat or other measures. Additionally, within the last years plant breeders have been successful to reduce anti-nutritional factors drastically (esp. in the case of lupins).

The high requirements of poultry in relation to limiting amino acids make it necessary to supplement the diet with protein sources of high quality, i.e. with a high portions of limiting amino acids like soybean cake, maize gluten, brewers yeast and skim milk powder, in which the lactose content has been decreased by technical measures. The availability of such components is a function of the demand. There is still a problem concerning the high demands for starter diets at the beginning of the fattening period (week 0 to 4). Concerning the price of organic ingredients of high quality it has to be taken into account that the amounts needed are very small and the price will be of minor relevance in relation to the whole fattening period.

5.5 Restricted availability of amino acids in organic pig production

Organic pig farming requires increased efforts of the management in order to ensure appropriate supply with amino acids according to the specific requirements of the pigs. The preferable use of home-grown feedstuffs and limitations in the choice of bought-in feedstuffs can cause huge variation in the composition of the diets and increase the demand of analysis of the ingredients and calculation of the diet. The high variation in breeds and housing conditions in organic farming in comparison to the more and more standardized conditions in conventional production impairs the predictability of the specific requirements and the rate of utilisation of the nutrient potential (e.g. digestibility).

The framework of organic agriculture provides sufficient possibilities for an adequate availability of limiting amino acids. The exclusion of synthetic amino acids and chemically dissolved soybean meal can be compensated for by other protein sources such as soybean cake, rapeseed cake or and skim milk powder from organic origin.

Piglets have the highest demand for limiting amino acids. Their requirements should be covered in order to prevent predisposition of diseases, especially for diarrhoea. Farmers have a considerable responsibility for safeguarding the welfare of the newly weaned piglet by constructing diets which will not stress the physiology of the immature gut and therefore compromise health. Mismanagement, i.e. a huge discrepancy between nutrient requirements and supply is the cause of different diseases, e.g. diarrhoea in piglets and reproductive disorders in sows and a suppression of the immune reaction. In practice, options for producing the “ideal” diet for piglets are often constrained by costs and the farmer has to explore alternative strategies that will maintain piglets in satisfactory health.

6 General conclusions

- Organic agriculture is a land based system, avoiding the use of specific inputs, and with the priority to produce products of high quality rather than maximizing production. To deal with limiting resources is a main feature of organic farming. Thus, organic and conventional production of non-ruminants are characterised by completely different system approaches with different objectives, management priorities, and framework conditions. General conclusions derived from research under the framework of conventional production do not have the same relevance and meaningfulness when transferred to the organic production system and vice versa.
- Examples of feed rations based on 100 % organic feedstuffs indicate that, in general, it is possible to formulate diets without the use of non-organic feedstuffs. However, the preferable use of home-grown feedstuffs and limitations in the choice of bought-in feedstuffs can be the cause of a huge variation in the composition of the diets.
- Due to the restricted availability of limiting amino acids in organic poultry and pig production protein accretion capacity is lower in organic compared to conventional production. The farmers are challenged to optimise the use of these resources, as suboptimal supply reduces performance, while excess supply with AA cannot further increase it. The following measures are at the organic farmer's disposal:
  - use of slow growing strains and thereby reducing nutrient requirements of the farm animals in the different stages of development (An example is given by the ‘label roughe’ programme for broiler production. However, the use of slow growing strains is not well developed in other species and needs further research especially to prevent negative side effects on carcass quality such as obesity);
  - implementation of multiple phase feeding to adapt the supply more closely to the requirements during the growth development in the various stages of life and thereby improve economical use of with high quality protein feedstuffs;
  - implementation of sexually divided housing to adapt the supply more closely to the different requirements of the genders;
  - increase of feed intake by optimisation of the feeding and housing conditions or by reducing the energy content of the diet (esp. in poultry), thereby providing possibilities to increase the use of home-grown feedstuffs;
  - use of compensatory growth effects in relation to the suitability of the genotypes, thereby reducing the demand for high protein feedstuffs;
  - purchase of protein sources like rapeseed cake, soybean cake, or skim milk powder of organic origin to compensate for deficits in limiting AA supply, esp. in the diet of animals in the first weeks of life.
- Because of the huge variation in the composition of diets it is of high importance that the single components of home-grown feedstuffs are analysed regularly, at least with regard to the crude nutrients, and that the formulation of the feed ration is calculated beforehand. To provide a diet according to the specific requirements of the animals is an important but not the only objective in organic livestock production. The nutrient requirements of the animals have to be considered in detail and balances with other goals (such as farm based production) within the system.

- It is necessary to develop feeding strategies that are closely related to the farm specific situation due to a huge variation in relation to the availability of high quality feedstuffs between regions, in relation to the digestibility and utilization of amino acids between the various feedstuffs, and in relation to the capacity of protein accretion and feed intake between genotypes and farm specific housing and feeding conditions.
- According to the principles of organic agriculture, the various possibilities of the management to compensate for a limiting availability of high quality feedstuffs should be given first priority. Although the compensatory measures are expected to increase the production costs, this can not be a prime argument when the principle of 100% organic diets is discussed.
- The supply with limiting amino acids is of high importance for protein accretion in poultry and pigs, thereby influencing the lean meat proportion. However, there is evidence for antagonistic relationships between traits of meat quantity and sensorial quality. A lower intensity in growth performance provides the potential for a higher sensorial quality of meat. Following the principle that *feed is intended to ensure quality production rather than maximizing production* (EC-Regulation, annex I, paragraph 4.1), the restricted availability of limiting amino acids in organic livestock production fits the objective of a high sensorial quality of products, by preventing producers from focussing primarily on quantity traits. However, sensorial quality of meat does not occur automatically when extensifying the production process but needs special management skills to balance the various relevant factors in a comprehensive approach. Therefore, organic farming can not per se claim to produce high sensorial quality products but has the potential to do so.
- The risk of diseases and welfare problems in organic livestock production due to suboptimal nutrient supply are restricted to the animal's first weeks of life and can be handled by a proper management. From the animal health and welfare point of view, organic farming should be, however, protected towards the undesirable side effects of an intensified meat production by setting limits with respect to the intensification process.
- As the availability of limiting AA is the most relevant precondition for a high protein accretion, the limitation in the availability of high protein feed seems to be a suitable tool to restrict intensification. It is likely that this approach may be more successful in achieving this goal than the current prescription in the EC-Regulation for the use of slow growing strains. Previous reports in different countries gave reason to assume that this requirement is implemented only to a low extend. In contrast, the only loosely restricted use of non-organic feedstuffs as current is likely to expected to had have a damaging effect on animal health and welfare and on the confidence of those consumers who expect that organic products of animal's origin derive from healthy animals.
- Concerning environmentally friendly production, organic farming generally includes a higher excretion of nutrients per product compared to conventional production due to more unbalanced feed rations especially in relation to the protein supply. However, on the farm level nutrient input into the farm and nutrient losses from the farm into the environment can be clearly reduced compared to the high nutrient inputs in conventional production. Thus, organic livestock production can claim to be an environmentally friendly production method determined by the system.

- Productions costs in organic livestock production are clearly higher compared to conventionally production, mainly because of the higher costs for organic feed and the differences in housing conditions. As conventional production of pigs and poultry has a long history of cutting production costs including through the use of high protein feed as an external resource, organic production can not compete with conventional production with respect to the production costs.
- Organic livestock production could play a pioneer role to further development of animal production systems that are not based on lowest costs, but on aspects of product and process quality. The main question is, whether all the additional production costs at the farm level can be compensated for through price premiums and how a separate production chain and a quality assurance programme can be established to ensure a high level of quality for the consumer.

7 Preliminary recommendations

- Based on a review of the present literature and on the potentials and possibilities for compensation within the framework conditions of organic farming it is possible and recommendable to avoid feed and protein sources of non-organic origin in the production of organic poultry and pigs without compromising animal health and welfare.
- To prevent any harm to the animals that might be caused by unbalanced feed rations, the implementation of an animal health precaution plan, including the prescription to analyse and calculate feed rations especially for very young animals, should be integrated in the EC-Regulation. Derogations for the use on non-organic feedstuffs should be restricted to young animals in the first weeks of life.
- A nearly complete ban of non-organic feedstuffs as supplementary protein sources is suited to limit the intensification of this sector, to redirect organic poultry and pig production from a quantity related to a quality oriented production process and to provide a clear distinction between organic and conventional production. This is expected to improve the confidence of the consumers and aid the further development of a separate market.
- There is need to redefine the term ‘slow growing strains' to ensure that the genetic capacity of protein accretion is better adapted to the reduced availability of high protein feedstuffs in organic farming. Instead of demanding only a minimum age at slaughter, growing intensity (a maximum in daily weight gain) should be taken into account, especially in the case of turkeys.
- While organic framework conditions provide good preconditions for an environmentally friendly production, they do not automatically lead to a high level of animal health and welfare and high sensorial quality of meat products. Strategies should be developed on how measures to increase the sensorial quality of the products and the process quality in relation to animal health and welfare can be included in the organic certitfication process.

8 Summary

The preferable use of home-grown and limitations in the use of non-organic feedstuffs considerably reduce the availability of high quality protein in the nutrition of monogastric animals and restrict the possibilities for the adaptation of the protein supply to the specific requirements. The objective of the report was to discuss and assess by meta-analysis of the literature whether these restrictions can be compensated for by other measures that are in accordance with the leading ideas of organic agriculture without jeopardizing other objectives. Therefore, it was of special interest to evaluate whether nutritional imbalances encountered in practice might lead to deteriorating product quality, animal health and welfare or the environmental impact of production. The report encompasses the production of broilers, turkeys, laying hens and pigs and provides the following results:

Due to the restricted availability of feedstuffs with a high content of limiting amino acids in the feeding of organic poultry and pig production, growth rates and protein accretion are clearly lower in organic compared to conventional production. Different measures are at the farmer's disposal to optimise the use of limiting resources and to adapt the supply of limiting amino acids to the growth process in the various stages. However, those measures are mainly characterised by increased efforts, for example in terms of time input and expenditures. Thus, organic farmers are in no way competitive with the productivity in conventional livestock production.

Concerning product quality, reduced growth rates are an important precondition for high sensorial quality of meat from monogastric animals due to antagonistic relationships between traits related to performance and those related to sensorial quality. Thus, the lower growth rates in organic farming are a good starting point for high sensorial quality. However, sensorial quality of meat does not occur automatically when extensifying the production process but needs special management skills to balance the various relevant factors in a comprehensive approach. Therefore, organic farming can not per se claim to produce high sensorial quality products but has the potential to do so if appropriate management is put into place.

Concerning animal health and welfare problems in relation to nutritional imbalances, there is sound proof that, apart from the animal’s first weeks of life, both poultry and pigs can compensate to a high degree for imbalanced feed rations without the onset of specific health and welfare problems. However, strains with a high genetic yield capacity seem to be more sensitive to suboptimal feed rations than slow growing strains or robust breeds. In organic farming, various measures are to the disposal of the farmer to prevent any harm deriving from nutritional imbalances. On the other hand, in numerous studies the undesirable side effects of breeding for high protein accretion are described, especially in poultry production. Meanwhile pathological findings and diseases in intensified production systems have reached an alarming extent. While the risks for the occurrence of diseases and welfare problems in organic livestock production due to suboptimal nutrient provision by the farmer are comparably low and can be handled by a proper management, intensification of meat production provokes a system-related increase in undesirable side effects.

From the animal health and welfare point of view, organic farming should be protected against the undesirable side effects of an intensified animal production by setting limits within the standards with respect to the intensification of livestock production. As the availability of high quality protein is the most relevant precondition for a high protein accretion (and thus intensification), the limitation in the availability of high protein feed seems to be a highly suited tool to restrict intensification. On the other hand, the prescription for the use of slow growing strains in the EC-Regulation seemed to have failed to provide the expected results, possibly due to the absence of clear guidelines as to which strains fall into this category and resulting difficulties in considering this in the inspection process. Under such conditions, the uncontrolled use of non-organic feedstuffs would be expected to lead to an unwanted intensification of organic systems with its damaging effects on animal health and welfare and on the confidence of consumers who expect that organic products of animal origin derive from healthy animals.

Concerning the environmental impact of organic farming, a higher excretion of nutrients per unit of product compared to conventional production has been found, due to more unbalanced feed rations. However, on the farm level nutrient input into the farm and nutrient losses from the farm into the environment are clearly reduced compared to the high nutrient inputs in conventional production. Thus, organic livestock production can claim to be an environmentally friendly production method determined by the system.

While conventional production is intended to produce as cost-effectively as possible it is a characteristic feature of organic livestock production to use primarily the resources within the farm system. Due to different objectives, management priorities and framework conditions, organic and conventional livestock production are characterised by completely different system approaches. Thus, general conclusions derived from conventional production do not have the same meaningfulness in organic livestock production and vice versa.

While organic framework conditions provide good preconditions for an environmentally friendly production, they do not automatically lead to a high level of animal health as well as high sensorial quality of meat products. In the EC-Regulation on organic livestock production, measures should be implemented that are not solely focussed on the certification of the implementation of the EC-Regulations, but certify directly that specific traits of product and process quality have been achieved.

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Annex

A-1: Some published suggested maximum inclusion rates of various vegetable protein sources (g/kg) (Gordon, 1999)

	Broiler feeds	Layers feeds	References
Peas	250-300 Starter 50, finisher 100	150-200, 300 for better egg taste 100 100 300 200	UNIP-ITCF (1995) Leeson & Summers (1997) Larbier & Leclercq (1994) Castanon & Perez-Lanzac (1990) Igbasan & Guenter (1997b)
Lupins	50 Starter 80, finisher 100	100 150 200	McDonald *et al.,* (1995) Leeson & Summers (1997) Castanon & Perez-Lanzac (1990)
Beans	300	100	Larbier & Leclercq (1992) Jansman *et al,* , (1993)
Sunflower	Starter 80, finisher 100	100 150	McDonald *et al.,*, (1995) Leeson & Summers (1997)
Rapeseed	50 100 (double 00 varieties) Starter 50, finisher 80	100 (double 00 varieties, white layers only)	McDonald *et al.,* (1995) van Kempen & Jansman (1994) Leeson & Summers (1997)

A-2: Examples of 100% organic feed ration for broiler (starter period) (1. - 4. week)

	Ingredients	**I**[1]	**II**[1]	**III**[2]	**IV**[2]	**V**[3]	**VI**[3]	**Average**
Cereals	**Wheat**	18	14	40	40.5	13	25	
	Wheat bran						2.5	
	Barley	10	14					
	Oat		7.5					
	Maize	21	18	18	18	15	15	
	Portion in the diet	**49**	**53.5**	**58**	**58.5**	**28**	**42.5**	**48**
Pulses	**Faba beans**							
	Peas	10	12	8.5	14		12.6	
	Lupini							
	Portion in the diet	**10**	**12**	**8.5**	**14**	**0**	**12.6**	**10**
High protein fees	**Soya bean**	10				35	35	
	Soya cake	13	15			26.5		
	Maize gluten	2		7				
	Linseed cake	5	7					
	Sunflower cake	6	9	9	11	5	5	
	Fish powder				10			
	Portion in the diet	**36**	**31**	**27**	**21**	**66.5**	**40**	**37**
Additives	**Minerals**	3.7	3.5	3.5	3.5	3.5	3.9	
	Oil	1		3	3	2	1	
	Portion in the diet	**5**	**3.5**	**6.5**	**6.5**	**5.5**	**4.9**	**5**
Components	**Energy MJME**	12	11	12.5	12.5	12.1	12.2	
	Crude protein			21.3	17.5	27.2	21.9	
	Lysin g	10.2	9.4	9.9	9.2	14.3	11.5	
	Methionin g	3.7	3.4	4.4	3.8	4	4.1	

1 Bellof & Schmidt, 2005 2 Damme, 2001 3 Damme, 2005

A-3: Examples of 100% organic feed ration for broiler (fattening period)

	Ingredients	I[1]	II[1]	III[1]	IV[1]	V[2]	VI[2]	VII[3]	VIII[3]	Average
Cereals	**Wheat**	21	23	21	20	20	30	18.5	32.7	
	Wheat bran								3	
	Barley	11.2	15.2	14	20					
	Oat			9.3	10.3					
	Maize	19	21	19	18	33.5	40	10	10	
	Portion in the diet	**51.2**	**59.2**	**63.3**	**68.3**	**53.5**	**70**	**28.5**	**45.7**	**55**
Pulses	**Faba beans**									
	Peas	14	14	12	12	17	10		15	
	Lupini									
	Portion in the diet	**14**	**14**	**12**	**12**	**17**	**10**	**0**	**15**	**12**
High protein feed	**Soya bean**	15	12					35	28.5	
	Soya cake			12	10			25.3		
	Potatoe protein					6	6			
	Maize gluten	2				8				
	Linseed cake	5	4	4	3					
	Sunflower cake	7	5	5	3	10	8.5	5	5	
	Portion in the diet	**29**	**21**	**21**	**16**	**24**	**14.5**	**65.3**	**33.5**	**28**
Addi-tives	**Minerals**	3.8	3.8	3.7	3.7	2.5	2.5	3.5	3.85	
	Oil	2	2			3	3	2.75	2	
	Portion in the diet	**5.8**	**5.8**	**3.7**	**3.7**	**5.5**	**5.5**	**6.3**	**5.85**	**5**
Componet s	**Energy MJME**	12.4	12.4	11.2	11.2	12.8	12.8	12.3	12.3	
	Crude protein					20.5	15.6	27.8	21	
	Lysin	7.2	6.5	7.2	6.5	9.3	7.8	14.5	10.5	
	Methionin	2.7	2.4	2.7	2.4	4.2	4.2	3.9	3.9	

1 Bellof & Schmidt, 2005; 2 Damme, 2001; 3 Damme, 2005

A-4: Examples of 100% organic feed ration for turkey

	Ingredients	I 0-5[1]	II 6-9 [1]	III 10-13[1]	IV 14-17[1]	Average
Cereals	**Wheat**	30	35	46.5	53	
	Tritticale					
	Portion in the diet	**30**	**35**	**46.5**	**53**	**41**
Pulses	**Faba beans**	10	10	5	5	
	Peas	37.6	32.8	27.8	22.9	
	Lupini					
	Portion in the diet	**47.6**	**42.8**	**32.8**	**27.9**	**38**
High protein feed	**Soya bean**					
	Soya cake					
	Potato protein	13.5	12.5	11	9	
	Maize gluten	3	3	3	3	
	Brewer's yeast	2	2	2	2	
	Portion in the diet	**18.5**	**17.5**	**16**	**14**	**16**
Additives	**Minerals**	3.4	3.2	3.2	2.6	
	Oil	0.5	1.5	1.5	2.5	
	Portion in the diet	**3.9**	**4.7**	**4.7**	**5.1**	**5**
Components	**Energy MJME**	11.8	12.1	12.3	12.6	
	Crude protein	27.4	26.1	24	22	
	Lysin	17.3	16	13.9	12.2	
	Methionin	4.5	4.3	4.1	3.7	
	Methionin + cystin	9	8.7	8.2	7.6	

1 Richter, 1996

A-5: Examples of 100% organic feed ration for laying hens

	Ingredients	I[1]	II[2]	III[2]	IV[3]	V[3]	VI[4]	Average
Cereals	**Wheat**	35	49	47.7	29.3	28.3	39.4	
	Triticale						16	
	Barley	5			7.5	7.5		
	Oat	10			5	5		
	Portion in the diet	**50**	**49**	**47.7**	**41.8**	**40.8**	**55.4**	**48**
Pulses	**Faba beans**	6		10				
	Peas	15	23	15	44	43	12.5	
	Lupins							
	Portion in the diet	**21**	**23**	**25**	**44**	**43**	**12.5**	**28**
High protein feed	**Potatoe protein**						4.5	
	Maize gluten	12	10.6	9.9			9.8	
	Dried grass meal	3	5	5	2	4	5	
	Linseed cake						1	
	Whey powder	2						
	Portion in the diet	**17**	**15.6**	**14.9**	**2**	**4**	**20.3**	**12**
Additives	**Minerals**	10	10.4	10.4	10.2	10.2	10.2	
	Oil	2	2	2	2	2	1.6	
	Portion in the diet	**12**	**12.4**	**12.4**	**12.2**	**12.2**	**11.8**	**12**
Components	**Energy MJME**	11	11.3	11.2			11.2	
	Crude protein	18	18.6	18.8	15	15.4	19.6	
	Lysin g	7.5	7	7	8.1	8.1	7.9	
	Methionin g	2.8					3.5	
	Methionin+Cystin g		6.5	6.4	4.2	8.2	6.8	

1 Deerberg, 2004   2 Zollitsch & Baumung, 2004   3 Kjaer&Sørensen, 2002   4 Stroebel et al., 2002

A-6: Examples of 100% organic feed ration in case of pullets and chicken (STROBEL et al., 2002)

	Ingredients	Pullets	Chicken
Cereals	**Wheat**	36.4	57. 2
	Triticale	15	10
	Barley		
	Oat	16	
	Maize		
	Portion in the diet	**67.4**	**67.2**
Pulses	**Faba beans**		
	Peas	12	10
	Lupins		
	Portion in the diet	**12**	**10**
High protein feed	**Soya bean**		
	Soya cake		
	Potatoe protein	2	9.8
	Maize gluten	8	4.9
	Dried grass meal	5	
	Colza cake		
	Linseed cake	1	1
	Sunflower cake		
	Brwers yeast	1	2.5
	Whey powder		
	Portion in the diet	**17**	**18.2**
Additives	**Minerals**	3.3	3.9
	Oil	0.3	0.7
	Portion in the diet	**3.6**	**4.6**
Components	**Energy MJME**	11.4	12.2
	Crude protein	17.6	19.7
	Lysin g	7	9.1
	Methionin g	3.2	3.6
	Methionin + Cystin g	6.5	7.1

A-7: Examples of 100% organic feed ration in case of creep feed for piglets

	Ingredients	I [1]	II [1]	III [2]	IV [3]	Average
Cereals	**Wheat**	25	24	33	25	
	Wheat bran	9	5			
	Barley			18.5	25	
	Oat	25	25		6	
	Maize		5			
	Tritticale					
	Portion in the diet	**59**	**59**	**51.5**	**56**	**56**
Pulses	**Faba beans**					
	Peas			15	24	
	Lupins	8	8			
	Portion in the diet	**8**	**8**	**15**	**24**	**14**
High protein feed	**Potatoe protein**				8	
	Soya cake	15	15	15		
	Maize gluten					
	Brewer’s yeast					
	Dried grass meal					
	Colza cake					
	Linseed cake		5			
	Sunflower cake					
	Whey powder	5	5			
	Skim milk powder	10	5	15	9	
	Portion in the diet	**30**	**30**	**30**	**17**	**27**
Addi-tives	**Minerals**	3	3	3	3	
	Oil			0.5		
	Portion in the diet	**3**	**3**	**3.5**	**3**	**3**
Components	**Energy MJME**	13.4	13.4	13.4	13.1	
	Crude protein	19.5	19.4	20.1	18	
	Lysin g	11.2	10.2	10.3	11.7	
	Methionin g			3.2		
	Methionin + Cystin g	6.3	6.3	6.2		
	Threonin g			6.9		

1 Sundrum & Rübesam, 2003; 2 Lindermayer & Probstmeier, 2005 3 Lindermayer, 2000

A-8: Examples of 100% organic feed ration for piglets before and after weaning

	Ingredients	I[1]	II[1]	III[2]	IV[2]	V[3]	VI[4]	VII[4]	Average
Cereals	**Wheat**	25	24	33	33	34	35	45	
	Wheat bran	9	5						
	Barley			15.5	18	20	37	40	
	Oat	25	25						
	Maize		5						
	Tritticale								
	Portion in the diet	**59**	**59**	**48.5**	**51**	**54**	**72**	**85**	**61**
Pulses	**Faba beans**	8	8						
	Peas			15	15	18	15		
	Lupins								
	Portion in the diet	**8**	**8**	**15**	**15**	**18**	**15**	**0**	**11**
High protein feed	**Potatoe protein**						10	12	
	Soya cake	15	15	27	15	15			
	Linseed cake		5						
	Whey powder	5	5						
	Skim milk powder	10	5	5	15	10			
	Portion in the diet	**30**	**30**	**32**	**30**	**25**	**10**	**12**	**25**
Addi-tives	**Minerals**	3	3	3	3	3	3	3	
	Oil			1.5	1				
	Portion in the diet	**3**	**3**	**4.5**	**4**	**3**	**3**	**3**	**3**
Components	**Energy MJME**	13.4	13.4	13.6	13.5	13.3	13	13	
	Crude protein	19.5	19.4	20.9	19.9	19.1	19	19	
	Lysin g	11.2	10.2	11.3	11.4	10.1	11	10.5	
	Methionin g			3	3.5	2.8			
	Methionin + cystin	6.3	6.3	6.7	7.2	6.2			
	Threonin g			7.2	7.1	6.9			

1 Sundrum & Rübesam, 2003; 2 Lindermayer & Probstmeier, 2005; 3 LFL, 2005 4 Lindermayer, 2000

A-9: Examples of 100% organic feed ration in case of fattening pigs (growing period)

	Ingredients	I[1]	II[1]	III[1]	IV[2]	V[2]	VI[2]	Average
Cereals	**Wheat**	20	45	5	46	45	48	
	Wheat bran							
	Barley	28	2	62				
	Oat				18	15	19	
	Maize							
	Tritticale							
	Portion in the diet	**48**	**47**	**67**	**64**	**60**	**67**	**59**
Pulses	**Faba beans**		30	20				
	Peas	25						
	Lupins	22	18		12	12	12	
	Portion in the diet	**47**	**48**	**20**	**12**	**12**	**12**	**25**
High protein feed	**Soy bean oil meal**				19.5	10.3		
	Potato protein			8			3.3	
	Maize gluten							
	Brewer's yeast							
	Dried grass meal							
	Colza cake					15	15	
	Linseed cake							
	Sunflower cake							
	Whey powder							
	Skim milk powder							
	Portion in the diet	**0**	**0**	**8**	**19.5**	**15.3**	**18.3**	**12**
Addi-tives	**Minerals**	3	3	3	3.5	2.8	2.8	
	Oil	2	2	2	1			
	Portion in the diet	**5**	**5**	**5**	**4.5**	**2.8**	**2.8**	**4**
Components	**Energy MJME**	13	13		12.9	12.7	13.1	
	Crude protein	19.2	20.1		19	18.7	18.9	
	Lysin g	9.7	9.7		9.2	8.9	9.9	
	Methionin g				2.3	2.5	2.5	
	Methionin + Cystin g	5.2	5.3		5.6	6	6	
	Threonin g				6.3	6.4	7.1	
	Tryptophan g				2.1	2.1	2.1	

1 Sundrum et al., 2000; 2 Bellof et al., 1997

A-10: Examples of 100% organic feed ration for fattening pigs (finishing period)

	Ingredients	I[1]	II[1]	III[1]	IV[2]	V[2]	Average
Cereals	**Wheat**	24	40	11	47	44	
	Wheat bran						
	Barley	38	22	62			
	Oat				22.8	19.3	
	Portion in the diet	**62**	**62**	**73**	**69.8**	**63.3**	**66**
Pulses	**Faba beans**		14	16			
	Peas	14					
	Lupins	19	19		15	15	
	Portion in the diet	**33**	**33**	**16**	**15**	**15**	**22**
High protein feed	**Soy bean oil meal**				12.3		
	Potato protein			6			
	Colza cake					20	
	Whey powder						
	Skim milk powder						
	Portion in the diet	**0**	**0**	**6**	**12.3**	**20**	**8**
Additives	**Minerals**	3	3	3	2	1.75	
	Oil	2	2	2	1		
	Portion in the diet	**5**	**5**	**5**	**3**	**1.75**	**4**
Components	**Energy MJME**	13	13	13	13.04	13.0	
	Crude protein	17.1	17.8	16.2	18	17.7	
	Lysin g	7.9	7.9	8.8	8.1	8.6	
	Methionin g				2.3	2.5	
	Methionin + Cystin g	5.1	5.1	5.7	5.2	6	
	Threonin g				5.6	6.3	
	Tryptophan g				6.2	6.6	

1 Sundrum et al., 2000 2 Bellof et al., 1997

A-11: Examples of 100% organic feed ration for lactating sows

	Ingredients	I[1]	II[1]	III[1]	IV[1]	V[2]	Average
Cereals	**Wheat**		58	30	30	50	
	Wheat bran						
	Barley	63.5				21.5	
	Tritticale			22	22		
	Portion in the diet	**63.5**	**58**	**52**	**52**	**71.5**	**59**
Pulses	**Faba beans**				18		
	Peas		20	18		20	
	Lupini	10		15	15		
	Portion in the diet	**10**	**20**	**33**	**33**	**20**	**23**
High protein feed	**Soya bean**		18			5	
	Soya cake	20					
	Colza cake				9		
	Linseed cake			9			
	Portion in the diet	**20**	**18**	**9**	**9**	**5**	**13**
Addi.-tives	**Minerals**	4	4	4	4	3.5	
	Oil	2.5		2	2		
	Portion in the diet	**6.5**	**4**	**6**	**6**	**3.**	**5**
Components	**Energy MJME**	13.1	13.6	13.3	13.2	13	
	Crude protein	17	16.4	16.5	17.4	17	
	Lysin g	9.2	8.4	7.6	8.5	9	
	Methionin+Cystin g	5.3	5.2	5.3	5.1		

1 Sundrum & Rübesam, 2003; 2 Lindermayer, 2000

A-12: Demand of nutrient supply in broiler production.

Percentages are taken from tables A-2 and A-3. Data of feed intake (Kamphues et al., 1999).

Broiler	Starting (28 days)		Fattening period (53 days)		Demand per broiler	
	%	kg	%	kg	kg	%
Total	**100**	**1.0**	**100**	**4.8**	**5.8**	**100**
Cereals	48	0.48	55	2.64	**3.1**	**53.8**
Pulses	10	0.10	12	0.58	**0.7**	**11.7**
High protein feed	37	0.37	28	1.34	**1.7**	**29.5**
Additives	5	0.05	5	0.24	**0.3**	**5**

A-13: Demand of nutrient supply in turkey production

Percentages are taken from table A-4. Data of feed intake (Kamphues et al., 1999).

Age in weeks										
	0-5		6-9		10-13		14-17		Total Turkey	
	%	kg	%	kg	%	kg	%	kg	kg	%
Total	**100**	**1**	**100**	**4**	**100**	**18**	**100**	**30**	**55**	**100**
Cereals	30	0.30	35	1.4	46.5	8.4	53	15.9	**27**	**49**
Pulses	47.6	0.48	42.8	1.71	32.8	5.9	27.9	8.37	**17**	**30**
High protein feed	18.5	0.18	17.5	0.7	16	2.88	14	4.2	**8**	**15**
Additives	3.9	0.04	4.7	0.19	4.7	0.9	5.1	1.53	**3**	**6**

A-14: Demand of nutrient supply in laying hens:
Percentages are taken from table A-6. Data of feed intake (Kamphues et al., 1999).

Sows	Laying hens	
	%	kg
Total	100	6.4
Cereals	48	3.0
Grain legumes	28	1.8
High protein feed	12	0.8
Additives	12	0.8

A-15: Demand of nutrient supply in sow production
Percentages are taken from table A-11. Data of feed intake (BURGSTALLER, 1991).

Sows	Lactating period (40 days)	
	%	kg
Total	100	240
Cereals	59	142
Grain legumes	23	55
High protein feed	13	31
Additives	5	12

A-16: Demand of nutrient supply in fattening pig production
Percentages are taken from tables A-7, A-8, A-9 and A-10. Data of feed intake (BURGSTALLER, 1991).

	Creep feed		Piglets		Growing period		Finishing period		Total fattening period	
	%	**kg**	**%**	**kg**	**%**	**kg**	**%**	**kg**	**kg**	**%**
Total	**100**	**4**	**100**	**40**	**100**	**96**	**100**	**160**	**300**	**100**
Cereals	56	2.24	61	24.4	59	56.6	66	105.6	**188.9**	**63.0**
Pulses	14	0.56	11	4.4	25	24	22	35.2	**64.2**	**21.4**
High protein feed	27	1.08	25	10	12	11.5	8	12.8	**35.4**	**11.8**
Additives	3	0.12	3	1.2	4	3.8	4	6.4	**11.6**	**3.9**