Supply of protein feed to young pigs and chickens in organic farming

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Summary

Supplying monogastric livestock with amino acids is a key challenge in animal husbandry. In organic farming, the challenges are even higher due to legislative restrictions on the use of high-quality protein feed and especially synthetic amino acids, the latter being common practice in conventional livestock production. For this reason, there are currently derogations that allow the use of non-organically produced protein feed to a limited extent. These exemptions have been increasingly restricted in recent years. Under current EU law, it is still permitted to mix non-organic protein feed into the diet of young poultry and pigs weighing less than 35 kg up to a proportion of 5% in feed (dry matter) from agricultural sources if there is a proven lack of availability of organically produced protein feed. Until this derogation expires in 2026, all EU member states are required to prepare an annual report on the use and availability of organically produced protein feed. In addition, it is crucial to know the amino acid requirements of the animals, which protein feeds are available to meet these requirements and the effects on animal welfare and health, if the supply of amino acids is insufficient. Amino acid requirement depends on genetics, age, performance (predisposition) and husbandry conditions (exercise, climate, immune system, etc.). It is therefore difficult to determine exact requirements for each animal. Intake and bioavailability of amino acids also depend on the feeding regimen (feed used, ratio to energy and other nutrients, etc.). There are numerous studies that show that the potential to supply pigs with 100% organic feed without negative effects on animal welfare and health under good husbandry conditions. An extended suckling period and an optimized rearing feed after weaning can be important factors. For chickens, the challenge is particularly great in the early rearing phase, as they place high demands on protein quality during this period, regardless of the direction of use.

Keywords: monogastrics, amino acids, animal welfare

Zusammenfassung

Die Versorgung von monogastrischen Nutztieren mit Aminosäuren ist eine zentrale Herausforderung in der Tierhaltung. Werden die Tiere unter den Bedingungen des Ökologischen Landbaus gehalten, wird die Versorgung durch Restriktionen bezüglich des Einsatzes hochwertiger Proteinfuttermittel und synthetischer Aminosäuren, die in der nicht-ökologischen Erzeugung üblicherweise eingesetzt werden, weiter erschwert. Aus diesem Grund gibt es derzeit Ausnahmegenehmigungen, die den Einsatz nicht-ökologisch erzeugter Proteinfuttermittel in einem geringen Umfang erlauben. Diese Ausnahmegenehmigungen wurden in den letzten Jahren immer weiter eingeschränkt. Derzeit ist es nach geltendem EU-Recht bei nachgewiesen fehlender Verfügbarkeit von Proteinfuttermitteln aus ökologischer Erzeugung noch erlaubt, in die Ration von Junggeflügel und Schweinen, die unter 35 kg wiegen, nicht-ökologische Proteinfuttermittel bis zu einem Anteil von 5 % einzumischen (bezogen auf die Trockensubstanz der Futtermittel landwirtschaftlichen Ursprungs). Bis zum Auslaufen dieser Ausnahmegenehmigung im Jahr 2026 wird jährlich von allen Mitgliedsstaaten der EU ein Bericht zum Einsatz bzw. der Verfügbarkeit von ökologisch erzeugten Proteinfuttermitteln erstellt. Zusätzlich ist es relevant, zu wissen, welcher Bedarf an Aminosäuren für die Tiere besteht, welche Proteinfuttermittel es zur Deckung dieses Bedarfes gibt und welche Effekte auf das Tierwohl inklusive der Tiergesundheit bei einer nicht ausreichenden (bedarfsgerechten) Versorgung mit Aminosäuren zu erwarten sind. In diesem Working Paper sind Informationen zu diesen Themen zusammengestellt. Der Bedarf an Aminosäuren ist abhängig von der Genetik, Alter, Leistung bzw. Leistungsveranlagung und Haltungsbedingungen (Bewegung, Klima, Immunsystem, u. a.). Es ist daher schwierig, exakte Bedarfsangaben für jedes Tier zu ermitteln. Die Aufnahme und Verfügbarkeit der Aminosäuren ist zudem abhängig vom Fütterungsregime (eingesetzte Futtermittel, Verhältnis zu Energie und anderen Nährstoffen, etc.). Es gibt zahlreiche Studien, die zeigen, dass die Versorgung von Schweinen mit 100%-Biofutter ohne negative Auswirkungen auf das Tierwohl unter guten Haltungsbedingungen möglich ist. Eine verlängerte Säugezeit und ein angepasstes Aufzuchtfutter nach dem Absetzen können wichtige Stellschrauben sein. Bei Hühnern ist die Herausforderung vor allem in der frühen Aufzuchtphase groß, da sie in diesem Zeitraum unabhängig von der Nutzungsrichtung hohe Ansprüche an die Proteinqualität stellen.

Schlüsselwörter: Monogatrier, Aminosäuren, Tierwohl

Background and questions

On 09th of December 2022, the BMEL contacted the Thünen Institute of Organic Farming and the Friedrich-Loeffler-Institut and requested a technical opinion on the subject of derogations for the feeding of conventional protein feedstuffs for young livestock in organic farming (poultry and pigs) on the basis of Article 53(4) of Regulation (EU) 2018/848 supplementing the opinion of 24th of March 2022 on the link between protein feedstuffs and animal welfare. The following questions arose:

1. What is the daily requirement for total protein and essential amino acids in young poultry and pigs based on different age ranges or body mass, if necessary, adapted to the type of production?
2. Which feedstuffs available in organic quality can be used to meet this demand?
3. What effects on animal welfare, animal health and performance (economic impact) can be expected in the respective age ranges if the required protein feed qualities are not available?
4. Since the derogations are only valid until the end of 2026 on the basis of Article 53(4) of Regulation (EU) 2018/848, it would be necessary to clarify the need for further action to ensure sufficient availability of the protein-feed qualities required for young animals from 2027. In addition to aspects of feeding, breeds, etc., possible impacts on the political aim to extend the proportion of organic farming to 30 % would also have to be taken into account.

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Preliminary remarks

In answering the specific questions, the following points are assumed:

- Poultry refers to chicken, which represent by far the largest proportion of poultry kept in organic farming.
- The rule in the EU Regulation 2018/848 that a maximum of 5% of the diet for young poultry may consist of non-organic protein feeds, provided that these are not available from organic production (Annex ll Part ll 1.9.4.2 c), does not define the term “young poultry”. In the further explanations, “young poultry” is defined as pullets up to the age of 18 weeks and broilers in the complete course of fattening.
- Piglets up to 35 kg are by definition rearing piglets, although rearing usually ends earlier. In studies, the term rearing piglets is often used synonymously for piglets during the entire rearing period (birth to 35 kg) and for piglets from weaning to rearing, but originally describes only the latter period. Up to weaning, we use the term "suckling piglets".
- Animals cover their needs for nitrogen and amino acids from the crude protein in the feed. The value of protein depends on its amino acid composition and availability (bioavailability, digestibility).

Daily requirement of total protein and essential amino acids for young poultry and pigs

It is assumed that the daily requirement for total protein and essential amino acids in organic production is identical to the requirement in conventional production when using the same genetics and targeting equal performance. In poultry, there is an increasing variety of genotypes with different characteristics that are better adapted to the conditions of organic farming. However, in organic pig production high-yielding genetics are utilized as bred and used in conventional production for decades. Due to the small scale of organic compared to conventional pig production, it does not seem foreseeable that selective breeding of suitable breeds will be carried out in the near future. Existing genetics and hybrids that are more robust to disease and have lower daily body mass gains may be better adapted, but are generally less uniform in their characteristics (size, gains, lean meat content, etc.), making their products much more difficult to distribute through the usual distribution channels and slaughterhouses.

For slow-growing genetics or breeds with reduced performance, the daily demand for total protein and amino acids, which is dependent on the performance of the animals, is reduced. This applies both to pigs and poultry. Increased requirements for energy and protein (i.e. amino acids) may occur for the required immune response when dealing with microorganisms (pathogens) and parasites, for greater freedom of movement, and for regulation of body temperature in outdoor climatic conditions. An important factor, in addition to the increased energy and protein requirements at low temperatures, is the tendency for longer or more intense heat waves in summer, which impairs feed intake. The use of covered free-range areas and roughage could also contribute to the protein and amino acid supply. Overall, energy and nutrient requirements for young animals are based on the respective requirements for maintenance, growth, exercise and thermoregulation as well as immune responses and can be determined accordingly. While in the past factorial derivation of requirements in animal nutrition has generally been carried out under controlled environmental conditions, the transfer of data to animals in organic husbandry with access to outdoor areas is accompanied by a certain degree of uncertainty. There is a need for research in order to ensure adequate care of livestock based on their nutritional requirements as legally anchored in the German Animal Welfare Act (Section 2, TSchG 2022) and German Animal Welfare Farming Regulation (Section 4, TSchNutztV 2021).

Varying amino acid levels of available feed components are usually included in the feed calculation and thus a diet balanced for amino acid requirement is produced, using a suitable combination of feedstuffs. While synthetic amino acids are available in conventional animal feeding to compensate for deficiencies and to reduce the total protein content in the feeds, their use is not permitted in organic animal feeding. In order to meet the demand for essential amino acids and to avoid insufficient supply, there may be an excess of total protein in organic feeding, which should be kept as low as possible due to the associated metabolic stress, the environmental effects of the elevated excretion of ammonia as well as the cost of protein feedstuffs.

In the subsequent sections we attempt an approximation of nutrient requirements and feeding recommendations for organically raised young poultry and swine. This approximation is mainly based on older literature written for conventional agriculture.

Poultry

Due to the paramount importance of chicken for organic poultry production compared to other poultry species, the protein and amino acid requirements of pullets and broilers are discussed in detail below. For a similarly detailed presentation of turkeys, geese, ducks and other poultry species, there is a lack of both data and own experimental experience within the author team, which could compensate for the missing data. Therefore, a presentation is omitted.

The protein requirement of chicken is primarily a requirement for amino acids. Both in the rearing of pullets and in the fattening of chicken, the amino acid methionine is first-limiting due to the formation of feathers. Based on the possibility of synthesizing cysteine from methionine, the sum of the two sulfur-containing amino acids methionine and cysteine have also to be considered. No specific values are available for the total protein and essential amino acid requirement of organically fed chicken to date. Therefore, the commonly used recommendations of the German Society of Nutrition Physiology from 1999 (GfE 1999), the more recent German reference book "Geflügelernährung" (Poultry Nutrition) by Jeroch et al. (2019) as well as the recommendations of the National Research Council (NRC 1994) of the USA serve as a basis for the requirement values. As can be seen from the publication dates of the former and latter publications, these are already older and refer to research results from the years before the respective publication date. Due to the continuing breeding efforts, it can be assumed that the requirements of contemporary chicken differ in detail. In practice, this uncertainty is countered by relying on the feeding recommendations of breeding companies, which are based on dose-response studies and aim at optimal animal performance, on the one hand, and by applying generous safety margins, on the other hand.

GfE (1999) and NRC (1994) report total protein and amino acid requirements as gross requirements, i.e., the total sum of ingested amino acids including all losses that occur during digestion and intermediate utilization. Although GfE (1999) points out that prececal digestibility of amino acids is the best approximation to requirement coverage at the digestive level, due to methodological difficulties, requirements were not yet based on digestible amino acids at the time of publication. In neighboring countries such as the Netherlands (CVB 2018), feeding recommendations already refer to digestible amino acid levels due to extensive research efforts. Brazilian supply recommendations for poultry also give equations for broilers and layers to calculate the requirement of prececally digestible amino acids (Rostagno et al. 2011).

Pullet Rearing

The rearing phase of pullets covers the period from hatching to start of laying, which mostly occurs between the 18th and 20th week of life, depending on the genotype. As defined above, the period from hatching to 18 weeks of age is considered in the following explanations. The feeding regime during rearing is divided into at least two, but usually three or four, feeding phases to meet the changing requirements of the animals. Feed intake increases and thus the demand for crude protein and amino acids per kilogram of feed decreases, i.e. the demand for the amino acid concentration of the protein feeds decreases.

The goal of feeding during pullet rearing is not maximum growth, but healthy development and optimal physiological preparation for the laying period. Pullets are usually fed *ad libitum*, and in preparation for the laying period a high feed intake is desired. Since pullets already precisely adjust their feed intake to meet their energy requirements, the amino acid contents in relation to the energy content (per MJ AME_N) must also be considered in addition to the total amino acid requirement. The energy content of the feed can be varied within certain limits. This variation can be used to cover the requirement even with a lower amino acid concentration in the feed. Jeroch et al. (2019) summarized the data from several sources in the following recommendation on energy content:

- Week 1-6: 11.0 – 12.1 MJ AME_N kg^{-1} feed
- Week 7-12: 10.5 – 11.9 MJ AME_N kg^{-1} feed
- Week 13-18: 10.5 – 12.2 MJ AME_N kg^{-1} feed

The German Society of Nutritional Physiology (GfE 1999) has not yet published requirements for pullets. In the Dutch and Brazilian recommendations, the rearing phase is also not addressed. Instead, there is a note referring to the breeders of the respective breeds (Rostagno et al. 2011, CVB 2018). The National Research Council (NRC 1994), while noting a lack of work on pullet feeding, provides recommendations on the levels of total protein and the five major essential amino acids in complete diets for pullets, as well as data on feed consumption. Jeroch et al. (2019) also provide recommendations on amino acid contents based on kg of feed as well as on MJ AME_N, but data on feed consumption are lacking. Table 1 summarizes the recommendations on amino acid content based on MJ AME_N, as well as the recommendations derived from the above sources on the daily supply of total protein and the five major essential amino acids. It should be explicitly noted that the data in Table 1 are feeding recommendations, not factorially derived requirements.

Table 1: **Recommendations from Jeroch et al. (2019) and NRC (1994) for the supply of total protein (XP) and essential amino acids in the rearing of pullets, data in g day $^{-1}$ and in g MJ $^{-1}$ AME_N (modified)**

	Feeding recommendation [g Day^{-1}]								Amino acid content [g MJ $^{-1}$ AME_N]				
Age in weeks	XP	Lys	Met	Met+Cys	Thr	Trp	Feed consumption [g]	AME_N [MJ kg^{-1} feed]	Lys	Met	Met+Cys	Thr	Trp
Jeroch et al. 2019													
1-6	6.1	0.31	0.14	0.25	0.24	0.07	33	11.5	0.83	0.36	0.66	0.63	0.17
7-12	8.9	0.39	0.19	0.35	0.31	0.09	54	11.0	0.66	0.32	0.58	0.53	0.15
13-18	9.6	0.41	0.19	0.32	0.29	0.09	62	11.0	0.61	0.26	0.47	0.43	0.13
NRC 1994 (white depositor)													
1-6	5.9	0.28	0.10	0.20	0.22	0.06	33	11.9*	0.71	0.25	0.52	0.57	0.14
7-12	8.6	0.32	0.14	0.28	0.31	0.08	54	11.9*	0.50	0.21	0.44	0.48	0.12
13-18	9.3	0.28	0.12	0.26	0.23	0.07	62	12.1*	0.37	0.17	0.35	0.31	0.09

*NRC (1999) 2,850, 2,850 and 2,900 kcal, converted to MJ AME_N with a factor of 1 MJ = 239 kcal

Lys = lysine

Met = methionine

Cys = cysteine

Thr = threonine

To illustrate how pullets can be fed organically, Table shows the feeding regime from a pullet rearing in 2021 at the experimental farm of the Thünen Institute of Organic Farming. Except for the yeast mixture (1 % of the diet, necessary due to coordination with project partners from other EU countries), all components were derived from organic production.

Table 2: Composition (%) and calculated nutrients (g kg^{-1} feed as fed unless stated otherwise) of a pullet feeding regime from 2021 at the Thünen Institute of Organic Farming

	Week of life 1-3	Week of life 4-8	Week of life 9-16
Wheat	190	175	145
Corn	180	170	160
Triticale	70	100	120
Barley	60	70	100
Wheat bran			28
Soy cake	215	175	95
Rapeseed cake	50	64	75
Sunflower cake	50	65	75
Peas	85	100	140
Potato protein	50	32	20
Yeast mixture*	10	10	10
Mineral mixture	20	20	15
Monocalcium phosphate	9	6	
Calcium carbonate	11	12	15
Salt		1	2
Crude protein	213	197	161
Ether extract	48	48	44
Crude fiber	55	58	55
Lysine	12.2	10.9	8.3
Methionine	3.5	3.2	3.2
Met+Cys	6.8	6.3	4.9
Phosphorus	7.7	7.1	5.9
Calcium	10.3	10.2	9.4
Energy. MJ AME_N	11.7	11.7	11.7

*from conventional production, contains 418 g of crude protein, 28.5 g lysine, 6.5 g methionine kg^{-1}fresh mass

Broilers

In chicken fattening, requirement for total protein and amino acids is largely determined by the growth intensity. The growth intensity is limited by EU Regulation 2018/484 to the extent that either slow-growing breeds or genotypes must be used, or a minimum age of 81 days must be complied with at slaughter (Annex ll Part ll point 1.9.4.1). Which growth intensity is considered slow is to be defined by the individual EU Member States. In Germany, the “Federated State Working Group on Organic Farming” (Länderarbeitsgemeinschaft Ökologischer Landbau LÖK) defined at a meeting on the 24th of June 2009 that genotypes classified as slow-growing can reach a maximum of 80 % of the daily body mass gain of high-performing genotypes, such as Ross 308 or Cobb (LÖK 2009). Data are based on information on conventional farms from the current poultry yearbook. In “Faustzahlen für den Ökologischen Landbau” (KTBL, Bachinger et al. 2015, p. 583), published by the Association for Technology and Structures in Agriculture e.V., daily body mass gain of 38 g at a fattening duration of 63 days are mentioned as the average performance level. The specification of a fattening period of 63 days shows that the use of slow-growing genotypes according to the national definition is predominant in Germany. Currently, daily body mass gains of 50 (short fattening, 28-30 days) to 70 g (long fattening, 38-42 days) are reported in conventional broiler fattening, depending on the fattening duration (see Thobe et al. 2022). Thus, a slow-growing broiler is likely to have daily body mass gain of 40 to 56 g according to the current definition. However, if slower-growing genotypes such as old breeds or dual-purpose cockerels are fattened, growth intensity may be significantly lower.

Depending on the length of the fattening period, the feeding regime is divided into at least two, but usually three, feeding phases in order to meet the changing requirements of the birds and optimize litter quality (avoiding risk of foot pad lesions due to wet litter), but also to avoid unnecessary feed costs and nutrient surpluses.

In contrast to pullets, a factorial derivation of the requirements for total protein and amino acids is available for broilers. This is composed of the requirement for maintenance and the requirement for performance, i.e. feather formation and body protein accretion. The corresponding equations are presented in detail in GfE (1999). It has to be considered that these derivations of requirements are results of studies conducted with broilers commonly used in the years before the publication of the recommendations for energy and nutrient supply. The performance potential of conventional broilers has increased significantly since then, whereas organically kept broilers were not considered by GfE (1999). It is quite possible that differences exist between the broiler hybrids used at the time of demand derivation and modern organically kept broilers. In addition, the data of the GfE (1999) on protein and fat content are only given up to the 8^{th} week of life. For the time thereafter, the data of the 8^{th} week of life are used, although a deviating requirement may exist here. In the Netherlands, supply recommendations for fattening broilers with prececally digestible amino acids were issued in 2018; however, organic farming was not considered here either and the requirement does not change further after the 4th week of life according to this information (CVB 2018). An approach similar to that adopted in Brazilian supply recommendations (Rostagno et al. 2011), which allows calculation of amino acid requirements as a function of animal and environmental factors, could enable supply recommendations in Europe to be flexible to changes in environmental conditions and animal performance.

Therefore, we believe that the following calculations are to be considered as the best possible estimate at the moment. Table 3 shows requirements for total protein and the most important essential amino acids for broilers of different growth intensities used in organic farming, calculated according to the equations of GfE (1999). Since broilers, like pullets, can adjust their feed intake within certain limits to meet their energy requirements, the energy requirements of the animals as well as the resulting calculated amino acid density in g MJ^{-1} AME_N are also shown. Regarding the energy requirements of broilers, both GfE (1999) and Jeroch et al. (2019) point out that an addition should be made to the maintenance requirement when temperatures are outside the thermoneutral zone or there is an increased need for exercise. This is both the case in organic husbandry. Another challenge can occur due to warm seasons (long, hot summers) that represent a much more pressing issue, since it is difficult for poultry to maintain body temperature when high temperatures arise and high temperatures lead to a strong reduction of feed intake. However, due to the lack of study results in this context, the aforementioned sources do not provide an estimate of the magnitude of the addition. Therefore, Table 3 gives the energy demand without addition.

Table 3: **Recommendations of the GfE (1999) on the supply of energy, total protein and essential amino acids in chicken fattening using examples of different growth intensities, data on body mass and daily body mass gains (DMG) from the stated literature**

Age			Requirement [g Day^{-1}]						Amino acid content [g MJ $^{-1}$ AME$_N$]				
[weeks]	Body mass* [g]	AME$_N$ [MJ]	XP	Lys	Met	Met+Cys	Thr	Trp	Lys	Met	Met+Cys	Thr	Trp
Ötz Coffee, male (Baldinger and Günther 2020; Total DMG 24.3 g													
2	***114***	***0.19***	***2.8***	***0.14***	***0.05***	***0.10***	***0.09***	***0.02***	***0.74***	***0.26***	***0.53***	***0.47***	***0.11***
4	***347***	***0.45***	***6.3***	***0.30***	***0.11***	***0.24***	***0.22***	***0.05***	***0.67***	***0.24***	***0.53***	***0.49***	***0.11***
6	691	0.78	10.8	0.50	0.19	0.45	0.39	0.08	0.64	0.24	0.58	0.50	0.10
8	***1144***	***1.08***	***14.2***	***0.65***	***0.26***	***0.62***	***0.53***	***0.11***	***0.60***	***0.24***	***0.57***	***0.49***	***0.10***
10	***1624***	***1.32***	***16.7***	***0.77***	***0.32***	***0.74***	***0.64***	***0.13***	***0.58***	***0.24***	***0.56***	***0.48***	***0.10***
12	2126	1.48	17.5	0.80	0.34	0.79	0.69	0.14	0.54	0.23	0.53	0.47	0.09
18	3104	1.34	10.5	0.42	0.25	0.53	0.48	0.08	0.31	0.19	0.40	0.36	0.06
Hubbard JA 757, female (Höhne et al. 2022; Total DMG 35.0 g)													
2	***258***	***0.41***	***3.5***	***0.17***	***0.06***	***0.12***	***0.11***	***0.03***	***0.41***	***0.15***	***0.29***	***0.27***	***0.07***
4	566	0.63	8.3	0.39	0.15	0.33	0.29	0.06	0.62	0.24	0.52	0.46	0.10
6	***1121***	***1.20***	***15.9***	***0.74***	***0.29***	***0.68***	***0.59***	***0.13***	***0.62***	***0.24***	***0.57***	***0.49***	***0.11***
8	***1752***	***1.47***	***17.2***	***0.79***	***0.33***	***0.77***	***0.67***	***0.14***	***0.54***	***0.22***	***0.52***	***0.46***	***0.10***
10	2492	2.00	23.7	1.11	0.46	1.08	0.94	0.19	0.56	0.23	0.54	0.47	0.10
Hubbard JA 757, male (Höhne et al. 2022; DMG total 41.0 g)													
2	***259***	***0.42***	***3.6***	***0.18***	***0.07***	***0.12***	***0.12***	***0.03***	***0.43***	***0.17***	***0.29***	***0.29***	***0.07***
4	602	0.67	9.1	0.43	0.17	0.36	0.33	0.07	0.64	0.25	0.54	0.49	0.10
6	***1252***	***1.30***	***18.4***	***0.87***	***0.34***	***0.80***	***0.69***	***0.15***	***0.67***	***0.26***	***0.62***	***0.53***	***0.12***
8	***2009***	***1.60***	***20.5***	***0.96***	***0.39***	***0.92***	***0.88***	***0.17***	***0.60***	***0.24***	***0.58***	***0.55***	***0.11***
10	2911	2.19	28.3	1.35	0.56	1.31	1.13	0.24	0.62	0.26	0.60	0.52	0.11
Hubbard 957, mixed- sex (Schmidt and Bellof 2008; Total DMG 45.2 g)													
2	***248***	***0.45***	***7.3***	***0.39***	***0.14***	***0.26***	***0.25***	***0.06***	***0.87***	***0.31***	***0.58***	***0.56***	***0.13***
4	814	1.12	16.8	0.84	0.31	0.68	0.61	0.14	0.75	0.28	0.61	0.54	0.13
6	***1596***	***1.69***	***23.7***	***1.14***	***0.44***	***1.04***	***0.90***	***0.19***	***0.67***	***0.26***	***0.62***	***0.53***	***0.11***
8	2454	2.06	26.3	1.25	0.51	1.20	1.04	0.22	0.61	0.25	0.58	0.50	0.11
10	***3247***	***2.16***	***24.9***	***1.17***	***0.51***	***1.17***	***1.02***	***0.21***	***0.54***	***0.24***	***0.54***	***0.47***	***0.10***
12	3833	1.97	19.7	0.90	0.43	0.98	0.86	0.17	0.46	0.22	0.50	0.44	0.09

*In the absence of weighing data, the bold and italic printed values represent estimates based on weighing values at other times.

Table 3 presents daily requirements for total protein and essential amino acids in broilers and show a marked increase with increasing growth intensity (expressed as daily body mass gain, g d^{-1}, DMG). Table 4 shows recommendations of the GfE (1999) on amino acid density for comparison. Here it is again clear that the demand for protein quality of the feed decreases with increasing age. The comparison shows that the highest growth intensity shown in Table 3 (Hubbard 957, daily body mass gain 45.2 g) requires a similar amino acid density as given in the GfE (1999) recommendations for conventional broilers. The lower growth intensity of the other examples given in Table 3 requires a lower amino acid density.

Table 4: Recommendations of the GfE (1999) on amino acid density in g MJ^{-1} AME_N in broiler diets (min-max for mixed-sex)

Age, weeks	Lysine	Methionine	Met+Cys	Threonine	Tryptophan
1 – 2	0.87 – 0.89	0.31 – 0.32	0.58 – 0.59	0.57 – 0.58	0.13 – 0.14
3 – 5	0.79 – 0.81	0.29 – 0.30	0.61 – 0.62	0.56 – 0.57	0.13
6 – 8	0.64 – 0.70	0.25 – 0.27	0.59 – 0.64	0.51 – 0.56	0.11 – 0.12

Due to the regulation of feed intake according to energy requirements, the energy content of the feed can only be varied within certain limits. Jeroch et al. (2019) summarized information from several sources in the following recommendation on energy content in feed for slow-growing broilers:

- Week 1-4: 11.0 – 12.0 MJ AME_N kg^{-1} feed
- Week 5-8: 11.5 – 12.5 MJ AME_N kg^{-1} feed
- Week 9- end of fattening: 11.5 – 12.5 MJ AME_N kg^{-1} feed

How organic feeding of broiler chickens can look like in practice is shown in Tables 5-7, which represent the feeding regimes of the examples given in Table 2-3. Except for a few components indicated in the footnotes, all feed components were derived from organic production.

Table 5: Analyzed nutrients (g kg^{-1} feed as fed unless stated otherwise) of the feeding regime for the mixed-sex rearing of the dual-purpose genotype ÖTZ Coffee (Werner et al. 2023)

	Week of life 1-3	Week of life 4-7	Week of life 8-11*	Week of life 12-18
Crude protein	211	171	194	167
Ether extract	72	67	67	57
Crude fiber	63	71	53	68
Lysine	10.1	7.6	10.2	8.2
Methionine	3.9	3.1	3.4	2.9
Met+Cys	7.4	6.1	6.8	5.9
Phosphorus	10.7	6.2	9.7	6.3
Calcium	15.8	7.0	11.0	7.2
Energy, MJ AME_N	11.5	11.8	12.2	11.6
Feed consumption, g	21	64	102	115

* Feed contained corn gluten from conventional production

Table 6: **Composition (%) and analyzed nutrients (g kg^{-1} feed as fed unless stated otherwise) of the feeding regime for mixed-sex fattening of Hubbard JA 757 females and males (Höhne et al. 2022)**

	Week of life 1-4	Week of life 5-7	Week of life 8-10
Wheat	270	310	350
Corn	250		
Triticale		130	160
Soybean cake	200	180	135
Rapeseed cake		75	100
Sunflower cake	90	25	
Peas	50	200	200
Rice gluten	50	47	25
Alfalfa green meal	25		
Brewer's yeast*	25		
Mineral mixture	35	33	30
Crude protein	172	208	184
Lysine	9.2	10.7	9.8
Methionine	3.3	3.3	2.9
Met+Cys		7.2	6.6
Phosphorus	6.9	3.8	4.8
Calcium	9.2	7.9	7.5
Energy, MJ AME_N	9.9	12.4	12.6
Feed Consumption, g day^{-1}	.	89	145

*from conventional production; .in the starter phase, the feed intake could not be fully documented

Table 7: **Composition and analyzed nutrients of the feeding regime for the mixed-sex fattening of Hubbard 957 females and males (Schmidt and Bellof 2008), g kg $^{-1}$ feed as fed unless stated otherwise**

	Week of life 1-4	Week of life 5-8	Week of life 9-12
Wheat	80	111	134
Corn	260	310	450
Soybean cake	250	200	175
Sunflower cake	59	55	50
Linseed cake	120	95	90
Peas	100	100	
Corn gluten	75	60	30
Rapeseed oil	17.5	30	35
Mineral mixture	36.5	35	34
Limestone	2	1	1
Monocalcium phosphate		3	1
Crude protein	239	225	197
Ether extract	68	88	91
Crude fiber	65	59	56
Lysine	10.6	10.0	9.0
Methionine	3.8	3.7	3.3
Met+Cys	14.4	7.4	6.9
Phosphorus	8.5	6.8	5.6
Calcium	13	9.8	11
Energy, MJ AME_N	11.8	12.2	11.9
Feed Consumption, g day^{-1}	49	132	175

Pigs

Suckling piglets

Due to the statutory minimum suckling period of 40 days in organic piglet rearing, sow milk is, compared to the conventional suckling period of 28 days, the most important protein source for suckling piglets over a long period of time. Adequate intake of colostrum and milk is very important for the survival and growth of suckling piglets (Prunier et al. 2020). Colostrum is very rich in immunoglobulins and protein, and contains less fat and lactose compared to mature milk (Inoue and Tsukahara 2021). Within 24 h after birth, the content of immunoglobulins and protein decreases, whereas the content of lactose and fat increases continuously throughout lactation (Kecman et al. 2016) (Table 8).

Table 8: Contents of fat, protein, lactose, dry matter and energy in colostrum, transitional milk and mature milk (according to Thiel et al. 2014)

	Colostrum			Transitional milk		Mature milk	
	Early	Middle	Late				
Time *post partum*	0 h	12 h	24 h	36 h	3d	17 d	SEM
Chemical composition² (g 100g⁻¹ OS)							
Lipid	5.1[c]	5.3[c]	6.9[ab]	9.1[a]	9,8[a]	8.2[b]	0.5
Protein	17.7[a]	12.2[b]	8.6[c]	7.3[cd]	6.1[d]	4.7[e]	0.5
Lactose	3.5[d]	4.0[c]	4.4[bc]	4.6[b]	4.8[ab]	5.1[a]	0.1
Dry matter	27.3[a]	22.4[b]	20.6[b]	21.4[b]	21.2[b]	18.9[c]	0.6
Energy (kJ 100g⁻¹)¹	260[d]	276[d]	346[c]	435[ab]	468[a]	409[b]	21

[1] in original substance (OS); The calculated energy derives from lactose and fat content (energy is not included in proteins because proteins in the colostrum (immunity) and milk (growth) play a different role and therefore are usually not oxidized to a large extent.)
[2] Values in rows without a common superscript differ significantly ($P < 0.05$)

In the further course of the suckling period, suckling piglets are introduced to solid feed in the form of creep feed or access to their dam's feed. These creep feeds should be optimized primarily with regard to palatability and digestibility in order to facilitate an easy transition to weaning and rearing. Usually, supplementary feeding is started at the latest from the 2nd week of life of the piglets, whereby the daily feed intake quantities are still negligible. Relevant amounts of suckling piglet supplementary feed were not found to be consumed until the fifth week of life (Schwediauer 2020, Bussemas and Weißmann 2015). The suckling piglet by-feed lays the foundation for the development of the gastrointestinal tract, which is relevant for the digestion and health of the animals for their whole life.

In the absence of nutrient supply recommendations for organically reared piglets, data of the German Society for Nutrition Physiology (GfE 2006) for a body mass between 5 and 10 kg and a daily body mass gain up to 300 g are assumed from this point on (Table 11). In view of the fact that suckling piglets feed primarily on sow's milk in their first phase of life, the adequate nutrient supply of the sow must be ensured at all times in order to meet demands of lactation. Table 9 shows two exemplary supplementary feeds for suckling piglets

Table 9: Components (%) and nutrient content of rations from Stalljohann (2006), supplying suckling piglets with complementary feed

	Stalljohann (2006)	
	Suckling piglets BIO	Suckling piglet POT
Components		
Barley	20.2	20.0
Wheat flakes	13.0	20.0
Oatmeal	12.0	19.5
Peas	10.0	5.0
Soybeans, toasted	10.0	10.0
Field beans (toasted)	20.0	10.0
Skimmed milk powder	10.0	6.0
Potato protein		5.0
Premix	1.5	1.5
Limestone	0.7	0.8
Monocalcium phosphate	0.5	0.7
Livestock salt	0.1	
Vegetable oil	2.0	1.5
Ingredients		
Crude protein (g kg^{-1})	197	201
Lysine (g kg^{-1})	11.7	11.9
Methionine (g kg^{-1})		
ME, MJ	14.3	14.5
g Lysin MJ^{-1} ME	0.8	0.8

<u>Rearing piglets after weaning</u>

The weaning period is critical because, in addition to the loss of the mother sow as social partner and her milk, the animals usually also experience regrouping in a new barn environment. Sudden changes of feed are therefore to be avoided during this phase. It is advisable to provide highly digestible feedstuffs.

The protein requirement of pigs is essentially an amino acid requirement. When using feed rations from conventional production, lysine is usually the first limiting amino acid. However, due to the increased use of lysine-rich grain legumes in organic farming, the sulfur-containing amino acids methionine and cysteine can also be limiting, in particular in legume-rich diets. Based on the level of crude protein digestible by the pigs, the prececal digestible (pcv) ratios of lysine, methionine and cysteine in feeds are crucial for meeting requirements. The ratio of pcv amino acids lysine to the sum of methionine and cysteine should be 1:0.53 (gross 1:0.6; Kamphues et al. 2014). Furthermore, the ratio to the energy content of the ration must be considered.

The total requirement for crude protein, amino acids and energy is composed of the respective requirements for maintenance and performance. The latter is largely dependent on the genetically determined protein accretion potential of the pigs. Daily body mass gains of rearing piglets are highly variable. Table 10 shows an overview of studies on the feeding of rearing piglets with diets consisting of 100% organic ingredients and the resulting performances.

Table 10: Overview of key data from piglet feeding studies using 100 % organic components and their resulting performance parameters (ranges of average results over several diets)

	Unit	Stalljohann (2006) Station	Baldinger et al. (2017) Station	Quander-Stoll et al. (2020a) Commercial organic farms	Quander-Stoll et al. (2020b)* Commercial organic farms
Number of animals	n	234	1509	> 1000	445
Weaning age	Days	49	48-50	42	46
Body mass at weaning	kg	14.8-15.7	15.2-15.6	11.0-11.4	10.5-11.5
Rearing age	Days	70	63	63	58
Body mass at rearing	kg	25.8-27.3	20.9-22.2	17.0-19.6	15.0-17.0
Feed intake	g Animal^{-1} day^{-1}				
Suckling piglets			61-82		134-152
Weaned piglets		950-990	522-641		557-676
Overall			245-298		
Body mass gain rearing	g day^{-1}				
Suckling piglets		251-259	295-362		230-280
Weaned piglets		526-556	317-450		300-380
Overall			291-368	258-407	

* Estimate values for body mass and gains from illustrations in the reference texts

As in poultry, there are no separately reported daily nutrient requirements for total protein and essential amino acids for pigs in organic farming. The recommendations published by the GfE in 2006 (GfE 2006) can be used as a basis for the adequate supply of pigs (summarized in Table 11).

Table 11: Recommendations of the GfE (2006) on the supply of prececally digestible (pcv) amino acids, pcv crude protein (g day^{-1}) and metabolizable energy (ME in MJ day^{-1}) in pigs (suckling piglets and rearing piglets) for expected performance in organic farming

Body mass (kg)	Daily gain (g)	pcv Lysin (g day^{-1})	pcv Methio-nine+Cysteine (g day^{-1})	pcv Threonin (g day^{-1})	pcv crude protein (g day^{-1})	ME (MJ day^{-1})
5	100	2.1	1.1	1.3	30	2.9
	200	4.0	2.1	2.5	58	4.1
	300	6.0	3.1	3.7	85	5.2
10	100	2.2	1.2	1.4		4.3
	200	4.1	2.2	2.6	59	5.5
	300	6.0	3.2	3.8	87	6.7
	400	8.0	4.1	4.9	114	7.9
15	300	6.1	3.3	3.9	88	8.0
	400	8.1	4.2	5	116	9.3
20	300	6.2	3.3	4	89	9.3
	400	8.1	4.3	5.1	117	10.6
	500	10.1	5.3	6.3	145	12.0
25	400	8.2	4.4	5.2	118	11.9
	500	10.1	5.3	6.4	146	13.4
	600	12.1	6.3	7.6	174	14.8
30	400	8.3	4.4	5.3		13.2
	500	10.2	5.4	6.5	148	14.7
	600	12.1	6.4	7.6	176	16.2

It should be noted that also in pigs the demand on the quality of the feed (density of prececally digestible essential amino acids) decreases with increasing age and is thus highest in the weaning piglet. The recommendations of the GfE (2006) on the supply of rearing piglets cover a body mass range of 5 – 30 kg and a daily body mass gain of 100 – 800 g. However, since the establishment of these recommendations is based on research results, most of which were obtained in the last century with deviating environmental conditions and performance potential, the values can only be considered as an approximation. The NRC recommendations (NRC 2012) cannot be easily compared in tabular form because they are based on average daily gains (based on pure muscle gain) of 325 g in a body mass range of 20 - 120 kg and cover much broader body mass or age ranges. Other supply recommendations are provided by INRAe (Institut national de recherche pour l'agriculture, l'alimentation et l'environnement, France) and CVB (Centraal Veevoeder Bureau, Netherlands). The CVB 2023 gives the requirement of prececally digestible amino acids as a function of the crude protein content of the diet for piglets at 5-6 weeks of age. The requirement of prececally digestible amino acids for fattening pigs was calculated with the tool "InraPorc" (INRA 2009), which, exactly like the Brazilian supply recommendations (Rostagno et al. 2011), uses equations related to environmental and animal parameters (CVB 2023). This tool could also be used to determine the requirements for breeds that differ from conventionally used breeds in terms of their characteristics and performance (Brossard et al. 2020).

Table 12 below shows various diets with which rearing piglets were supplied in different studies.

Table 12: Components (%) and nutrient content of rations from various studies for piglets

	Stalljohann (2006)[1]				Baldinger et al. (2017)[2]			Quander-Stoll et al. (2020b)[2]*			
Name	1	2	3	4	HID	MID	LID	Soy	Milk	LYS	POT
Components											
Barley	24.0	24.0	28.0	38.3	28.0	20.0	27.0	29.0	29.1	29.7	30.0
Wheat	24.5	24.5									
Triticale						27.5	30.0				
Oat								25.0	25.0	26.0	26.0
Lupins						10.0					
Wheat bran								2.4	2.9	5.1	3.8
Wheat flakes			22.0	22.0	22.0						
Peas	10.0					20.0	20.0	7.5	6.8	7.5	6.3
Beans	10.0				22.2		10.0	7.0	7.0	7.0	5.0
Soybeans, toasted	20.0	20.0	17.4	17.0	17.4						
Soy cake						14.3	4.8	13.4	10.5	9.5	5.6
Rapeseed cake							5.0	6.0	6.0		6.0
Sunflower cake										5.0	
Field beans (toasted)		20.0	22.0	10.0							
Whey powder						5.0					
Skimmed milk powder	7.0	7.0	6.0	4.0	6.0				3.0		
Potato protein				4.0							4.0
Lysine, fermented										0.2	
Premix	1.5	1.5	1.5	1.5	3.4	2.7	2.7				
Limestone	1.0	1.0	1.0	1.1							
Monocalcium phosphate	0.8	0.8	0.8	0.8							
Salt	0.3	0.3	0.3	0.3							
Vegetable oil	1.0	1.0	1.0	1.0	1.0	0.5	0.5				
Ingredients					in DM			in DM			
Protein (g kg^{-1})	192	196	196	197	205	201	177	187	185	174	178
Lysine (g kg^{-1})	11.1	11.1	10.9	11.1	11.9	11.3	10.0	10.1	10.0	9.9	9.4
Methionine (g kg^{-1})					3.0	2.6	2.4	2.3	2.5	2.1	2.5
ME, MJ	13.8	13.9	13.9	13.9	15.4	14.6	14.6	13.1	13.2	13.1	13.2
g Lysin MJ^{-1} ME	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.7

[1] After weaning up to day 70

[2] For suckling piglets as complementary feed and after weaning up to day 46-50

*Other components: Premix, limestone, monocalcium phosphate, salt, vegetable oil, apple cider vinegar, molasses

HID = high intensity, MID = medium intensity, LID = low intensity,

Lys = fermentatively produced lysine used, POT = potato protein used

While the diets of Baldinger et al. (2017) and Quander-Stoll et al. (2020b) were presented to suckling piglets and continued after weaning until the end of rearing (~ 20 kg body mass), the diets of Stalljohann (2006) were offered to animals only after weaning up to a body mass of ~ 26 kg. The diets are chosen as illustrations only as there are many other ways to design a diet for piglets. Grain products usually cover more than 50% of the diet. In addition, legume seeds such as peas, beans and soybeans, as well as oil cakes from soybean, rapeseed and sunflower seeds are used. To add concentrated amino acids, skim milk powder, whey powder and potato protein were used. The Swiss research team Quander-Stoll et al. (2020a, b) also used a fermentatively produced lysine (VitaLys®), although it is not currently available on the market and not approved in organic farming. They observed increased diarrhea in the rations without potato protein and signs of threonine deficiency in the ration with added lysine. When using individual amino acids, the next limiting amino acid (in pigs: methionine+cysteine, threonine, and tryptophan) needs to be taken into account always. Nevertheless, the use of fermentatively produced amino acids could improve monogastric feeding in organic farming. All diets can possibly be fed as 100% organic feed if the individual components are available in organic quality.

Uncertainties

In summary, there are **no scientifically proven requirements for total protein and essential amino acids** of organically reared young chicken and pigs and nutrient requirements established for conventional sector can only be transferred with a considerable degree of uncertainty. Moreover, the factorial requirement derivations made in the conventional sector were conducted under controlled environmental conditions, whereas organically raised chickens and pigs have access to outdoor exercise and their nutrient requirements are influenced by the associated outdoor climatic stimuli - affecting various systems such as the immune system, thermoregulation - as well as marked increased locomotion. Therefore, the feeding recommendations given in this chapter represent the best possible estimates under the given conditions. The nutritional requirements of pigs in conventional agriculture are also outdated in Germany and require revision and are to be used with caution in this context.

Thus, it is imperative to establish updated nutrient requirements for poultry and pigs that are adapted to animal husbandry in organic farming in accordance with state-of-the-art scientific methodology, otherwise a direct conflict with the Animal Welfare Act and the Animal Welfare Livestock Ordinance will arise. Against the background of the expansion of organic farming to 30%, this becomes even more pressing.

Feedstuffs to meet requirements (organically produced)

The use of various feed materials contributes to covering the requirement for crude protein and amino acids. The currently valid feed legislation at national and European level must be adhered to upon use. All feedstuffs can be found in the catalog for feedstuffs (https://www.feedmaterialsregister.eu/). Regulation 2018/848 lays down that feed originating in plants, algae, animals or yeast must be organically produced (part ll, 1.4.1.i). The use of GMOs, ionizing radiation, synthetic amino acids and chemical solvents is not permitted. Non-ecological feed of microbial origin shall be authorized in accordance with Article 24. In addition, 30% of the feed must originate on the farm or another farm in the region. Many feeds can also be found in the positive list for feed materials. This list includes feedstuffs which have been examined for their safety with regard to the raw materials, processing aids and manufacturing processes used, as well as their feed value by a German standards committee, and which are considered suitable for use in farm animal nutrition (Normenkommission der Einzelfuttermittel 2023).

When considering feedstuffs in terms of their role in covering amino acid requirements, both the amount used (proportion in rations) and the amount of crude protein and amino acids as well as their prececal digestibility are important. Very young animals in particular have high demands concerning feed quality.

Feed grains are the basis for a needs-based supply of monogastric animals and, by being used in high quantities, contribute to the amino acid requirement. High-quality cereal feed meals usually have increased crude protein content, but have a limited storage life.

Regionally producible **native grain legumes**, such as field beans, field peas, lupins or vetches are protein-rich components that can make up to 10% of the crop rotation and therefore contribute significantly to meeting protein requirements. It should be noted that these seeds are often rich in lysine but poor in methionine and cysteine, so additional feeds rich in methionine and cysteine are needed. In addition, use limits must be considered due to the presence of various antinutritional ingredients (ANF).

Soybeans have a very high protein content with a lot of lysine, but also methionine and cysteine. The degree of grinding and the correct procedure of toasting are to be considered for feeding. The scope of cultivation of the self-tolerant plants is increasing, mainly due to the fact that breeding is taking place, which allows cultivation even in colder regions with fewer hours of sunshine. Over the medium term, this makes soybeans a regional source of protein. Since soybeans contain large amounts of oil, they are classified as both grain legumes and oil crops.

Press cakes from soybeans, rapeseed, sunflower or other oilseeds and -fruits should have the lowest possible residual oil contents, as these lead to high energy and comparatively lower crude protein and amino acid contents and limit the storage life of the cakes. In addition, high oil contents with consequently high contents of polyenoic acids (polyunsaturated fatty acids) have an effect on animal products. Pork fat becomes softer and more sensitive to oxidation; fat becomes rancid more quickly and the keeping quality of sausage products (esp. raw sausage) is reduced. The nutritive quality of the oilcakes also depends on how much heat they have been treated with, since high temperatures during processing limit the digestibility of the amino acids.

Typically, protein residues from potatoes or cereals obtained during starch production are used to balance a ration. **Potato protein** is rich in lysine as well as the sulfur-containing amino acids methionine and cysteine. **Corn, rice and wheat gluten** contain large amounts of methionine and cysteine. However, demand for organic starch, on which production of potato protein and gluten protein depends, is low, so that these high-protein components are only available in organic quality to a limited extent.

Products from green plant parts often require elaborate processing, but can be protein-rich feed based on plants not used in human nutrition. Examples are green meal, leaf mass of legumes (Messinger et al. 2021; Pleger et al. 2021), silages (Wüstholz 2017, Bikker et al. 2014) or extracts from sugar beet leaves, legumes or grass (Brugger et al. 2016; Stødkilde et al. 2018).

Various **algae and aquatic plants** (microalgae, macroalgae (seaweed), duckweed) can also contribute to the amino acid supply (Øverland et al. 2019, Gatrell et al. 2014). Microalgae and macroalgae are protein sources that could play a larger role in the future (Costa et al. 2020).

Furthermore, there are different **animal products** with high protein content and an amino acid profile interesting for monogastric animals:

Various **dairy products** that are a by-product of food manufacturing can be used, especially in the feeding of piglets. These include whey and skim milk powders. These are nutritionally valuable and can replace potato protein in suckling and rearing pigs.

Non-marketable **eggs** (broken eggs, small eggs) or whole egg powder are high-quality protein sources that are actually intended for human nutrition, but can certainly be used in the feeding of chicks.

The use of some **insects** and **earthworms** in livestock feed has become acceptable. These can contribute to protein supply (Ding et al. 2019, Bahadori et al. 2017, Rothstein 2018, Maurer et al. 2015), but further research and development is needed for sustainable production. Initial results on the use of biowaste and food production byproducts are available (including Eggink et al. 2022).

Fishmeal can be used in rearing as a protein feed. Mollusk and shellfish meal can also be used. The availability is usually regional and depends on existing water bodies.

The use of **slaughterhouse by-products**, such as bone meal or meat meal, is logistically challenging and is not implemented in organic farming.

Other feeds with high crude protein contents are **brewer's grains, stillage or yeast**.

In the case of **residues from food processing**, the food retail trade or out-of-house catering, a high variability of the ingredients can be assumed. Furthermore, continuous availability is often not given and logistics is still a challenge to be solved. When using animal products and leftovers from food processing, an increased risk of inputs from the environment (long-term chemicals, pathogens, microplastics, etc.) must be taken into account.

A selection of common feeds and of feeds that are being researched for the protein supply of monogastric animals can be found in the following Table 13. In addition to the contents of crude protein, lysine, methionine and cysteine, possible disadvantages of the feeds and limits of use are listed, as far as data are available. Gentle treatment of the feeds (toasting, fermentation, ensiling, germination, hydrolysis, expansion, etc.) can improve the digestibility of the crude protein and amino acids. Optimal treatment methods must be selected for the feed in question.

Uncertainties

Variations in the ingredients of feedstuffs are generally high, but can be particularly strong in the case of certain feedstuffs (such as fish meal or food residues). For this reason, feed analyses are recommended for all feeds. With variation in ingredient levels, amino acid digestibility may also show variation. High-quality protein feeds (high levels of highly digestible essential amino acids, such as methionine and cysteine) should be used, especially for very young animals (chicks). Limits of use in the diet depend on various factors and cannot be clearly defined (guideline values from various sources are given here). If the quality is good (digestibility, amino acid composition, other components in the mixture), higher amounts of the individual feeds can certainly be used.

Table 13: Crude protein, methionine and cysteine content (gross values) of selected feedstuffs as well as relevant disadvantages in the feeding of monogas triers (variability of contents is high and individual values do not reflect this– in practice deviations are expected)

Feeds	Crude protein in g kg^{-1} T	Lysine in g kg^{-1} T	Methionine in g kg^{-1} T	Cysteine in g kg^{-1} T	Disadvantages/ANF	Operating limits* in %	Source
Cereals							
Wheat	89 – 154	2.9 – 4.1	1.3 – 2.8	2.0 – 3.9	- NSP - Gluten	Poultry: 20 (-30)	1
Barley	74 – 118	2.9 – 4.4	1.2 – 2.0	1.5 – 2.5	- NSP - Trypsin inhibitors - Tannins	Poultry: 20	1
Oat	87 – 129	3.6 – 5.7	1.4 – 2.3	2.6 – 4.0	- High crude fiber content - NSP	Poultry: 20	1
Triticale	70 – 131	2.9 – 4.9	1.1 – 2.3	1.6 – 3.2	- Ergot - NSP	Mast poultry: 20 Young hens: 30	1
Rye	61 – 125	2.9 – 4.7	1.1 – 2.5	1.5 – 3.5	- Ergot - NSP	Mast poultry: 5 Young hens: 10	1
Spelt	126	3.2	2.1	2.8	-		3
Corn, grains	105	3.0	2.1	2.1	-	Poultry: 30	3
Milocorn	92	2.1	1.6	1.7	- Tannins	Poultry: 20 (tannin arm 30)	6
Grain legumes							
Field bean	257 – 335	16.8 – 21.2	1.7 – 2.7	1.8 – 3.6	- Tannins - Pyrimidine glucosides	Piglets: 5 Young birds: 25 (15 for flowering varieties)	1
Field pea	147 – 252	12.1 – 21.9	1.7 – 2.6	2.5 – 4.2	- Tannins - Oligosaccharides	Piglets: 10 Chicken Poultry:30 (flowering varieties 20) Turkeys: 15	1
Blue lupin	235 – 384	13.2 – 19.0	1.7 – 2.6	3.4 – 6.1	- NSP - Alkaloids	Piglets: 5 Poultry: 15	1
Yellow lupins	430	23.0	3.5	10.0	- Phytic acid - Glucosides	Piglets: 5 Poultry: 15	3,6
White lupins	370	17.5	2.6	5.0	- Protease inhibitors - Tannins	Piglets: 5 Poultry: 15	3,6
Vetch	343	21.5	2.4	3.5	- Cyanoalanine toxins - Pyrimidine glucosides - Tannins	Broiler: 5	9
Soybean	400	24.5	5.4	6.0	- High fat content - Trypsin inhibitors - Phytic acid	Piglets: 10	3,4,6

*Not formulated for all animal species, variable depending on ingredients; **calculated with conversion factor 4.3 instead of 6.25

1 Witten et al. 2020; 2 Staudacher 2009; 3 DLG feed value tables pigs 2014; 4 Heinze 2011; 5 Lindermayer et al. 2009; 6 Jeroch et al. 2013; 7 Messinger et al. 2022; 8 Pleger et al. 2021; 9 Höhne et al. 2022; 10 Stødkilde et al. 2018; 11 Spinola et al. 2022; 12 Costa 2020; 13 Ding et al. 2019; 14 Kluess 2023; 156 Bahadori et al. 2017; 16 Cremers 2002

Continuation of Table 13

Feeds	Crude protein in g kg^{-1} T	Lysine in g kg^{-1} T	Methionine in g kg^{-1} T	Cysteine in g kg^{-1} T	Disadvantages/ANF	Operating limits* in %	Source
Oil press cake							
Soy cake	455	27.0	6.8	10.0	- High fat content, polyenoic acids	30	3
Rapeseed cake	366	19.0	7.0	8.0	- High fat content, polyenoic acids - High crude fiber content - Sinapin - Glucosinolates - Phytic acid - Tannins	Piglets: 5 Young hens: 7,5 Broiler: 10 Fattening turkeys lt;15	3,4,6
Sunflower cake	450	9.0	5.0	4.0	- High fat content, polyenoic acids - High crude fiber content	Piglets: 5 Poultry: 15	3,6
Linseed cake	370	13.8	6.7	6.6	- High fat content, polyenoic acids - Cyanogenic glucosides - Linatin - Phytic acid - Protease inhibitors - NSP	Piglets: 5	3,6
Sesame cake Cotton cake Peanut cake	455	14.0	10.0	7.5	- High fat content, polyenoic acids - Non-regional, Salmonella, Mycotoxins - Cotton seed: Gossypol	Piglets: 15	
Products from the whole plant							
Green meal	165 – 188	7.0 – 8.9	2.1 – 2.5	1.5 – 2.0	- High drying costs - High crude fiber content	Piglets: 4 Laying hens: 5 Poultry rearing: 10	3,6
Fine legume leaves (Lucerne)	224 – 298	10.9-17.4	3.7-5.0	2.2 – 3.9	- Saponins - High crude fiber content	Piglets: 20 Poultry: 15	7,8
Plant extract	335-485	21.8-27.1	5.9-7.9	2.9-3.5	- highly variable depending on the source material - Cost-intensive		10
Microalgae (*Arthrospira platensis*)	260 – 756	12.7	6.7	2.1	- Cell wall digestion required for improved digesti-bility - High variability of ingredients		11
Macro algae (e.g. *Porphyra* sp.)	241 – 440	18.6	6.7	4.9	- High variability of ingredients - Digestibility tests necessary		12

*Not formulated for all animal species, variable depending on ingredients; **calculated with conversion factor 4.3 instead of 6.25

1 Witten et al. 2020; 2 Staudacher 2009; 3 DLG feed value tables pigs 2014; 4 Heinze 2011; 5 Lindermayer et al. 2009; 6 Jeroch et al. 2013; 7 Messinger et al. 2022; 8 Pleger et al. 2021; 9 Höhne et al. 2022; 10 Stødkilde et al. 2018; 11 Spinola et al. 2022; 12 Costa 2020; 13 Ding et al. 2019; 14 Kluess 2023; 156 Bahadori et al. 2017; 16 Cremers 2002

Continuation of Table 13

Feeds	Crude protein in g kg^{-1} T	Lysine in g kg^{-1} T	Methionine in g kg^{-1} T	Cysteine in g kg^{-1} T	Disadvantages/ANF	Operating limits* in %	Source
Animal products							
Whey powder	119 – 155	12.0	2.1	3.7	- Competition with human nutrition - Cost-intensive, gentle drying - Fresh whey regional - Poultry: Lactose restricts	Pig: 20 (fresh 2 %) Poultry lt;3	3,4
Skimmed milk powder	314 – 365	23.5 – 28.0	7.5 – 9.0	3.0 – 3.1	- Competition with human nutrition - Cost-intensive, gentle drying - Poultry: Lactose restricts	Piglets: 20 Growing Gefl.: 4 Laying hens: 5	3,4,6
Whole milk powder	270	21.0	7.4	2.9	- Competition with human nutrition - Cost-intensive, gentle drying - Poultry: Lactose restricts		3
Egg powder	460	35.0	17.0	12.5	- Competition with human nutrition - Cost-intensive		3
Feather meal	803 – 900	20.9 – 23.5	5.6 – 6.3	40.1 – 45.0	- Availability/costs Disease transmission	Poultry: & 5	3,5,6
Blood meal/blood plasma	940	83.0	11.0	12.0	- Availability/costs - Transmission of disease	Piglets: 3	3
Mealworms: Larvae (*Tenebrio molitor*)	491	27.0	6.0		- Availability/costs		13
Mealworms: Adult (T*enebrio molitor*)	653	29	8		- Availability/costs		13
Soldier fly larvae (*Hermetia illucens*)	409.8**	30.9	20.1		- Availability/costs		14
Crickets (*Acheta domesticus*)	673	36	9		- Availability/costs		13
Earthworms (*Ironia foetida*)	657	44.4	12.0	9.5	- Availability/costs		15
Fishmeal (lt;8 % fat) also Fish juice, crabs, shrimp, mussels, starfish	630 – 760	47.0 – 54.0	18.0 – 20.0	6.0 – 7.0	- Variation of ingredients - Sustainability - Competition with human nutrition - Cost-intensive, gentle processing important - Effect on the taste of the products - Polyenic acids - Trimethylamine, histamine, gizzerosin	Piglets: 5-8 Brown layer: 2 Laying hens: 8 to 4 weeks, then 10	3,4
Meat bone meal	432 – 686	17.1 – 43.4	4.49 – 11.1	1.6 – 8.4	- Risk of transmission of diseases - Variable digestibility - Availability/costs		16

*Not formulated for all animal species, variable depending on ingredients; **calculated with conversion factor 4.3 instead of 6.25

1 Witten et al. 2020; 2 Staudacher 2009; 3 DLG feed value tables pigs 2014; 4 Heinze 2011; 5 Lindermayer et al. 2009; 6 Jeroch et al. 2013; 7 Messinger et al. 2022; 8 Pleger et al. 2021; 9 Höhne et al. 2022; 10 Stødkilde et al. 2018; 11 Spinola et al. 2022; 12 Costa 2020; 13 Ding et al. 2019; 14 Kluess 2023; 156 Bahadori et al. 2017; 16 Cremers 2002

Continuation of Table 13

Feeds	Crude protein in g kg^{-1} T	Lysine in g kg^{-1} T	Methionine in g kg^{-1} T	Cysteine in g kg^{-1} T	Disadvantages/ANF	Operating limits* in %	Source
Other feedingstuffs							
Residues from food processing, retail, gastro	variable				- Unclear composition depending on origin - Only vegetarian products can be used - Availability variable	variable	
Potato protein	740 – 753	58.5	16.7	10,5	- Costs - Availability (by-product of starch production) - Gentle drying required	Piglets: 15 Poultry: 15	3,4,6
Corn gluten	608 – 623	10.0	14.5	10,4	- Costs - Availability (by-product of starch production)	Piglets: 10	6
Cereal and rice gluten					- Costs - Availability (by-product of starch production)		6
Malt germs, dried	295	11.0	3.2	3,0	- High crude fiber content - Gentle heating - Mycotoxins	Piglets: 4	3,10
Brewer´s grains, dried	256	9.5	5.5	5,4	- High fiber content	Piglets: 5	
Dried Distillers Grains with Solubles (DDGS)	300 – 382	7.7 – 8.4	5.5 – 5.7	5.4 – 6.9	- High drying costs - High levels of NSP, Na and Cl - Low digestibility	Piglets: 0 Chickens for fattening: 5 Young hens: 15	2,3,4
Yeasts	347 – 494	26.9– 35.0	5.5 – 6.8	2.3 – 4.3	- Availability	Piglets: 5 Poultry: 10	3,4,6
Bacterial protein/ Microorganisms	686	41.1	17.2		- Availability - Admission	Poultry: 8	6

*Not formulated for all animal species, variable depending on ingredients; **calculated with conversion factor 4.3 instead of 6.25

1 Witten et al. 2020; 2 Staudacher 2009; 3 DLG feed value tables pigs 2014; 4 Heinze 2011; 5 Lindermayer et al. 2009; 6 Jeroch et al. 2013; 7 Messinger et al. 2022; 8 Pleger et al. 2021; 9 Höhne et al. 2022; 10 Stødkilde et al. 2018; 11 Spinola et al. 2022; 12 Costa 2020; 13 Ding et al. 2019; 14 Kluess 2023; 156 Bahadori et al. 2017; 16 Cremers 2002

Effects of a deficiency of total protein and amino acids on welfare, health and performance of the animals

According to the Animal Welfare Act (§ 2, S. 1 No. 1 TierSchG), animals must be adequately fed according to their species and needs. The Animal Welfare Farming Ordinance (§ 4, S. 1 No. 4 TierSchNutztV) also stipulates that the daily supply of all farmed animals with feed and water in sufficient quantity and quality must be ensured according to their needs.

Therefore, a protein (or amino acid) deficient supply is basically unacceptable. In general, but especially in organic farming, the identification of the nutrient requirements of the animals is a major challenge and has not yet been clearly resolved, as already shown in Chapter 1.

It should be noted that the feeding of farm animals is complex and that not only the amount of essential amino acids, but also the ratio to each other amino acid as well as to the energy content of the diet can have an impact on animal welfare. In addition, there are several other factors influencing the diet. These include nutrient digestibility, as well as the levels of crude fiber, non-starch polysaccharides (NSP), and antinutritional factors (ANF), which have already been listed as influencing factors in Chapter 2. Animal genetics can also influence their protein utilization and effects of lower protein supply (Hogberg and Zimmerman 1978; Brandt et al. 2010; Barea et al. 2011).

The term “animal welfare” describes the condition of an animal in terms of its needs and well-being. Animal welfare is understood as a multidimensional concept, whereby its various aspects can be assigned to three superordinate dimensions: animal health (basic health and functioning), the expression of natural behaviors (natural living), and emotional states (affective states) (Fraser et al. 1997).

A review of some of the known negative effects of protein and amino acid deficiencies follows in this chapter.

Poultry

A review of the available literature revealed that studies on the impact of protein deficiency in poultry focus mainly on economically relevant effects such as performance parameters (laying performance, growth rate) and feeding efficiency.

However, protein deficiency in productive poultry also leads to general signs of malnutrition, including slowed growth as well as reduced vitality and resistance to disease (NRC 1994). Due to the role of methionine in feather formation, deficiencies in feather or plumage quality are also evident. Feathers put on after the first molt are sometimes not changed until the animal is removed from the flock (turkeys for fattening, laying hens). Thus, deficiencies in feather or plumage quality provoked by nutritional deficiencies in the rearing phase may remain until the end of the productive phase. Since feathers are predominantly composed of the structural protein keratin, for the synthesis of which the amino acids methionine and cysteine are necessary, an adequate supply of these amino acids (essential in the case of methionine) is crucial for the functionality of the plumage, especially during feather formation (van Emous and Krimpen, 2019). Feathering may also potentially provide information on the severity of a deficiency situation. If lesions are set as a result of insufficient feathering due to mechanical action, these can serve as entry ports for pathogenic germs and promote an infection event (Naundrup Thøfner et al. 2019). A deficient supply of, for example, the sulfur-containing amino acids methionine and cysteine and the resulting feathering deficiencies and loss of function can therefore be classified as detrimental to animal welfare and, possibly, as relevant to animal welfare, because according to §2 TierSchG, whoever keeps, looks after or has to look after an animal must feed, care for and house the animal in a manner appropriate to its species and needs.

Laying hens/pullets

As we are not aware of any studies on the effect of protein and amino acid deficiency in pullets, the following section refers to laying hens.

In a study in eight European countries, Bestman et al. (2017) detected a correlation between increasing plumage damage and decreasing protein content in the diet as well as lack of access to outdoor runs in brown laying hens (n = 82 flocks). In this context, free range access and often higher total protein levels in organic laying hen rations can be considered positive.

In laying hen husbandry, feather pecking and cannibalism represent relevant animal welfare problems that are associated with pain and, in the worst case, death for the affected animals. The occurrence of these behavioral disorders is multifactorial, and is influenced by genetic, husbandry, and management factors in addition to feeding. Studies show an increased incidence of feather pecking and cannibalism with unbalanced feeding (Neal 1956, Siren 1963), which can be attributed to an increased search for the missing nutrients. A generally low level of protein intake was associated with increased incidence of feather pecking as early as 1947 by Schaible et al. and later by Ambrosen and Petersen (1997). In a review article, Kjaer and Bessei (2013) list other papers that consistently report negative effects of a lack of protein or individual amino acids on the incidence of feather pecking and cannibalism. However, the authors also point out the influence of other feed ingredients such as minerals, crude fiber and the highly relevant aspect of feed structure. The influence of the feed on feather pecking and cannibalism is therefore not limited to its protein content or the supply of individual amino acids alone.

In a study, dual-purpose hens (Lohmann Dual) showed less feather pecking than the higher-performance laying hybrid Lohmann Braun+ (Giersberg et al. 2019). This is interesting in that dual-purpose hens of other origins chose a lower methionine to energy ratio than a laying hybrid kept as a control when fed a choice diet in a study by Baldinger and Bussemas (2021b). Thus, the amino acid content of a diet cannot be considered independent of the performance level of the laying hens.

Based on existing literature, a negative effect of protein deficiency or amino acid imbalances on animal welfare of high-performance laying hens can be assumed, as this increases the risk of an occurrence of feather pecking and cannibalism. There are no detailed studies on this issue in the rearing of hens. It should be noted, however, that feather pecking and cannibalism can occur even with adequate feeding and that their occurrence is also caused by the feed structure, for example. The use of lower-performing (dual-purpose) hens may be an additional option for action to prevent the behavior.

Broilers

Wilhelmsson et al. (2019) compared a low crude protein content (14.5%) with a high crude protein content (17.0%) in the diet of slow-growing and fast-growing broiler chickens and concluded that feeding had little influence on the animal welfare parameters recorded using the Welfare Quality Protocol during a 10-week rearing period. However, other studies clearly show an influence of feeding on performance and animal health.

Broilers (Ross) fed a diet with a low crude protein content without additional amino acid supplementation used the outdoor run more and showed a higher frequency of foraging behavior compared to broilers with additional amino acid supplementation. The mortality rate (mainly due to leg weakness) was higher in the supplemented group (Eriksson et al. 2010). There is some indication that broiler chickens with access to the outdoors, as is common in organic farming, use this as a source of feed and can thus compensate for a lower amino acid intake.

Studies on the role of methionine in broiler chickens focus almost exclusively on performance and animal health. Due to the widespread use of synthetic amino acids in conventional chicken fattening, these studies often only consider the level of methionine use beyond the recommended requirements. In an older paper on methionine supply to broiler chickens, undersupply resulted in a clustered occurrence of footpad lesions (Chavez and Kratzer 1974). More recent studies show fewer footpad lesions with lower protein levels in the diet, but only with adequate supply of essential amino acids (review article by Greenhalg et al. 2020). Two studies on the effect of methionine deficiency on broiler chicken health consistently showed negative effects on the animals' immune defenses, including a negative effect on intestinal mucosa and its resistance (Ruan 2018) and humoral immunity (Zhang and Guo 2008). In broiler chickens, methionine and lysine supply also affects concentrations of lymphocytes and heterophilic granulocytes in the bloodstream, which play an important role in the immune response (Bouyeh 2012). There is also evidence that in broiler chickens, selection for growth-related traits may result in an impaired immune response. Broilers of fast-growing lines exhibited significantly higher mortality under field conditions than a comparison group with lower growth dynamics. Growth rate and mortality rate were significantly correlated (Yunis et al. 2000, 2002). Ask et al. (2006) also found a high mortality rate in fast-growing broiler lines after experimental Escherichia coli infection on the seventh day of life, whereas no losses occurred in animals of a slow-growing line. Against this background, it is obvious that it is necessary to use all factors that strengthen the defense capability and immune competence in poultry, for which, among other things, an adequate methionine supply is to be regarded as elementary.

The considerable influence of the growth intensity of broiler chickens on the amino acid requirement must be taken into account. For example, studies on slow-growing dual-purpose chickens with correspondingly lower methionine requirements showed high animal welfare (Baldinger and Bussemas 2021a) as well as low mortality and good health even when fed high proportions of regionally produced field beans (Nolte et al. 2020). However, undersupply of methionine can also cause amino acid imbalances in slow-growing broiler lines and lead to growth depression, impair feed conversion, and reduce free sulfur-containing amino acid concentrations in blood plasma (Leclercq et al. 1993; Rostagno et al. 1995). Leclercq et al. (1993) concluded that slow-growing broilers have an overall high requirement for sulfur-containing amino acids in the feed due to their lower feed intake and increased feathering. A supply in line with requirements must be ensured for slow-growing lines in the same way as for fast-growing lines.

In summary, it can be cautiously concluded that malnutrition caused by protein or methionine deficiency with correspondingly reduced vitality in broiler chicken can be relevant to animal welfare, depending on the extent of the deficiency. The use of slow-growing origins, which in principle have a lower daily amino acid requirement (exceptions due to environmental conditions, pathogens, etc. have been described in the text) represents an option for action in case of shortage of protein components and is recommended for organic farming due to the "protein gap".

Pigs

Suckling piglets

In organic farming, at least 40 days of suckling are mandatory and until weaning, suckling piglets are largely dependent on sow milk (Schwediauer et al. 2020, Bussemas and Weißmann 2015). Studies on the effects of a protein-reduced feeding regime on suckling piglets are not available. In addition, very little is known about amino acid metabolism in suckling piglets (Flynn et al. 2000).

However, piglet nutrition is closely linked to the sow and the adequate protein supply to the sow during pregnancy and lactation has a significant influence on the pre- and postnatal development of the piglets. Providing sows with first-limiting amino acids is not problematic in organic farming, but protein-reduced feeding, e.g., due to inadequately planned diets, can have negative effects. In studies with significantly reduced protein levels in diets for pregnant sows, reduced placental and fetal weights (Schoknecht et al. 1994) and consequently lower birth body masses of piglets were reported depending on the duration and timing of the treatment (Pond et al. 1992). Low birth body masses increase the risk of suckling piglet losses (Edwards 2002). In addition, significant protein deficiency during gestation can affect body mass of pigs up to slaughter (offspring from conventional sows fed 0.5% rather than 13% protein throughout gestation; Schoknecht et al. 1993).

In sows kept outdoors under organic conditions, a reduced protein feeding during pregnancy was compensated by the additional *ad libitum* supply of grass-clover silage thus avoiding negative effects on the number of piglets born, their birth and weaning body mass. However, during the suckling period, the reduced protein feeding of sows resulted in lower milk yield from the 20th day of lactation and loss of more than one kilogram of body fat per day from the 5th to the 20th day of lactation compared to control sows (Eskildsen et al. 2020). In an experiment by Álvarez-Rodríguez et al. (2017), reduced-protein feeding of lactating sows also resulted in a reduction in milk yield during the 36-day suckling period and in reduced body weight gain of piglets compared to piglets of control sows; however, sows did not exhibit loss of backfat or body mass.

In order to provide piglets with a sufficient supply of protein and amino acids it is very important that the sow is fed according to her performance. This is also essential in view of the prolonged suckling periods in organic farming. Depending on the intensity and duration of the decreased supply with essential amino acids the sow initially mobilizes body reserves for milk production during the suckling period. The above-average loss of backfat and body mass can lead to lower reproductive performance in the following pregnancy and lactation, as well as to more empty days between weaning and the estrus interval (Quesnel et al. 2014). However, a serious undersupply of suckling piglets with amino acids and the resulting animal welfare impairments are only to be expected in the case of long-lasting periods of extreme amino acid deficiency.

Rearing piglets after weaning

Rearing piglets are dependent on solid feed as a source of protein. In order to ensure a good transition to solid feed at weaning, it is crucial to provide supplementary feed to the suckling piglets as early as possible. This reduces weaning stress and, in particular, weaning diarrhea caused by the change in feed. Basically, there are very few studies on effects of protein supply on animal welfare and animal health in organically reared piglets. Most studies were conducted with fattening pigs and predominantly only production parameters were investigated.

The protein contents of organic feed diets are often formulated above the requirement in order to cover the supply of the first-limiting amino acids lysine, methionine and cysteine even with protein feeds that are medium to inferior in terms of contents of digestible limiting amino acids. However, the high protein content may increase the risk of post-weaning diarrhea (review articles by Jha et al. 2016, Rist et al. 2013).

In general, both too high and too low protein levels impair welfare, health, and robustness of pigs (Kobek-Kjeldager et al. 2022), including bone formation (Kornegay et al. 1994; conventional management). Pigs aged 9 to 14 weeks fed a protein-reduced diet (122 g crude protein kg^{-1}) showed increased activity behavior (standing, walking, digging in straw), compared with the group fed a higher-protein diet (240 g crude protein kg^{-1}), indicating that nutritional needs and food imbalances increase exploratory behavior.

Protein reduction can also affect the immune system of pigs (van der Meer et al. 2016). Infections with pathogens activate the immune system, which can lead to changes in nutrient requirements, especially regarding amino acids (van der Meer et al. 2017). Various studies show that stimulation of the immune system results in an increased demand for the amino acid tryptophan (Le Floc'h et al. 2008, Melchior et al. 2004). This is due on the one hand to the formation of acute phase proteins in the liver, which play a role in the innate immune response, and on the other hand to cytokine-induced degradation of tryptophan (messengers of the innate immune system; Le Floc'h et al. 2012).

Adapted feeding therefore has a positive effect on animal health and welfare. It should be noted that various feeding strategies can be used and that the housing environment contributes considerably. In a trial with three increasingly extensive rations (more home-grown components, less protein, higher fiber content), the number of medical treatments and losses did not differ significantly (they were generally low; Baldinger et al. 2017). According to this study, feeding rearing piglets a diet moderately below current supply recommendations (GfE 2006) in protein content (177 g crude protein per kg with 10.0 g lysine and 2.4 g methionine) would under optimal housing and management conditions (long suckling period > 42 days, high care and health status) only result in lower daily body mass gain. Under the conditions mentioned, no negative consequences on animal health are to be expected (Baldinger et al. 2017). Moreover, the effects of moderately protein-reduced feeding during rearing on body mass gain are reversible and can be compensated for at a later stage (Pond et al. 1980).

Biological performance and economic effects of protein deficiency

In principle, the biological performance of piglets reared under organic farming conditions is ultimately based on a large number of individual farm management decisions. These include parameters such as feeding intensity, share of purchased feed, use of derogations, accepted animal health level, capacity of the factor "labor", or animal genetics, to name but a few. This results in different levels of performance that do not influence animal welfare and do not have to correlate with economic success. For example, a farm that focuses on using its own inputs, slow growth, and differentiable product quality may be more economically successful through different marketing efforts than a farm with high biological performance and marketing in food retail markets. However, even under comparable marketing conditions, the conscious decision to raise piglets more extensively can be economically successful. For example, Baldinger et al. (2017) compared three different diets for piglets during a seven-week suckling period to the end of rearing at 63 days (approximately 21 kg live weight, see Table 9). Three feeding strategies with decreasing energy and nutrient levels were compared:

- An intensive strategy consisting of a high-quality purchased piglet starter, balanced according to the recommendations of the Society for Nutrition Physiology (GfE 2006) and without regard to the regional availability of the individual components,
- a medium-intensity strategy consisting of a piglet rearing feed such as farms with milling and mixing facilities can produce themselves using mainly regional feed components plus the purchase of a protein supplement,
- and an extensive strategy using a diet for lactating sows also for their offspring, primarily consisting of home-grown (on the farm) components, which additionally minimizes the on-farm logistical effort in feeding and feed component as well as feed stock management.

The intensive feeding regimen was formulated to meet requirements completely, the intermediate feeding regimen was formulated to partially meet needs, and the extensive feeding regimen was formulated to not meet needs of piglets (see Table 11).

As a result, significantly higher daily body mass gains could be determined for the piglets fed in the intensive and medium intensity compared to the extensively fed piglets. As the intensity increased, each animal took one day longer to reach the comparative weight of 20 kg. Concentrate utilization was best in the intensive group, but was not significantly different from the extensive group considering the body mass difference. The strategies did not differ with respect to animal health and animal loss parameters. The concentrate cost to produce a 20 kg piglet was 51% of the cost of the most intensive diet for the medium concentrate diet, and 42% of the cost of the most intensive diet for the extensive concentrate diet. Under the conditions prevailing in Baldinger et al. (2017), biological performance increased slightly and costs decreased significantly with increasing concentrate feed intensity. In another experiment, protein sources close to the farm were also fed without decreasing performance (Partanen et al. 2006).

In general, no "standard performance" can be given for piglets raised under organic farming conditions, even when using the same or similar genetics. This is due to the large variety of different management decisions, such as genotype selection, weaning age, feeding and housing conditions, generally causing larger variability. Table 9 and Table 14 show the variation in biological performance in four projects. As far as possible, mean values of selected raw data were calculated and presented. Here, for example, a range of over 100% for feed intake (with all caution regarding data quality) and over 30% for daily body mass gain is shown. This makes it difficult to obtain a uniform statement on the economic effects of a sufficient protein supply.

Table 14: Averages of selected results from BÖLN or similar projects regarding piglet rearing

Project	Inulin[1]	Piglet feeding strategies[2]	Grain legumes[3]				PigFeed[4]
Operation	Haus Düsse	Trenthorst/ Wulmenau	Haus Düsse	Practice A	Practice B	Practice C	Thalheim/Wel s
Suckling period (d)	40	49	43				43
Duration of rearing (d)	28	14	29	28	21	28	28
Body mass weaning (kg)	11.0	15.3	12.7	10.1	14.7	11.4	12.9
Final boy mass (kg)	21.8	20.6	26.9	19.8	22.6	23.9	23.0
Feed intake (g FM Tier d^{-1})	727	725	870	477	698	405	727
Body mass gain during the experimental period/rearing period (g animal $^{-1}$ d^{-1})	388	380	485	348	376	448	361

[1] Stalljohann and Patzelt (2010); [2] Bussemas and Weißmann (2015); [3] Kempkens et al. (2015); [4] Minihuber et al. (2018)

Both daily body mass gain and feed conversion (gain per kg feed) of piglets was improved with feed higher in protein content (Millet et al. 2006; Sørensen et al. 2009; Johannsen et al. 2023). Due to the relationship with the immune system discussed above, reduced amino acid supply leads to a deterioration in feed conversion under higher disease pressure compared to high sanitary conditions (van der Meer et al. 2016). A distinct protein deficiency that extends over the entire gestation period can have negative effects on the body mass development of piglets up to slaughter (offspring of conventional sows fed 0.5 % instead of 13 % protein throughout gestation). However, a short-term protein deficiency at any time of the pregnancy of the sow does not affect the body mass development of the offspring (Schoknecht et al. 1993).

Since the effects of protein content in the ration of organic pigs depend on many factors, a protein supply meeting the animal's demand is required in the interests of animal welfare, animal health and economic stability. For this purpose, the derivation of their nutritional requirements and the characterization of feed with regard to their energy, protein and amino acid content as well as their prececal digestibility is of enormous importance.

Uncertainties

Lacking actual nutrient requirements of organically reared pigs impedes a proper definition and quantification of nutrient undersupply. Environment and management of animal husbandry have a huge impact whereby feeding regime is but one part of a multifactorial affair.

Further need for action

to ensure sufficient availability of the required protein-feed qualities for young poultry and pigs from 2027 onwards. In addition to aspects of feeding, breeds, etc., possible impacts on the policy orientation of extending the proportion of organic agriculture to 30 % also have to be taken into account.

It transpired clearly during our work on the questions, that data are insufficient in many areas. The most important point is that there are no reliable nutrient requirements, and thus no indications of an expected shortage can be made. There is an urgent need for action here. In addition to environmental and animal-related factors, factors of diet formulation (feed components, energy content, antinutritional ingredients/antagonists, digestibility, etc.) also have an influence on protein and amino acid requirements. There is a large number of available feeds, most of which, however, entail limits of use for nutritional reasons, for reasons of availability, or often also for reasons of price worthiness, and whose ingredient contents can vary considerably.

Predominantly, animals with the same performance potential are used as are common in conventional animal husbandry. However, the animals have more time to develop their biological performance potential. Furthermore, current legal changes should be considered. Male chicks, which are not culled after hatching, exhibit a poor feed conversion ratio and thus compete with other non-ruminants for protein and amino acids. One trend is to use animals with lower biological performance (i.e. dual purpose and slow-growing breeds) which consequently have a lower nutrient demand. Deficiency symptoms are reported less frequently in these animals. This may also be influenced by the husbandry system, as the animals find additional feed through roughage, in a green outdoor area, and in the bedding material. Because of the lower targeted performance, feeds with a lower amino acid density can be used. In this case, poorer feed conversion occurs compared to conventional husbandry or to high-performing genotypes fed to maximum performance. This results in a lower daily or total requirement for high protein components. This area needs to be looked at by market analysts and economists, also because the consumers decide which products (lean meat content, etc.) are produced.

In order to quantify an "amino acid gap", a very differentiated approach is necessary as well. The quality of the feed (amino acid density and digestibility) plays a major role, especially for very young animals (primarily chicks and suckling piglets). The extent to which the expansion of organic farming to 30% will have an impact on the supply options for our livestock cannot yet be estimated with the available data. The extent to which the various sectors expand and which products are in demand will also play a role. An economic consideration of the question, which specific effects different feeding strategies can have now and in the future and which feeds are used due to their quality and price worthiness, could provide further information.

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