Recommendations for energy and nutrients of layers: a critical review*)

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Introduction

The first monograph with recommended energy and nutrient requirements (as percentage or units per kg of diet, amounts required per hen daily) of poultry was published in 1944 by the US National Research Council (NRC). These standards were based on the substantial knowledge available at that time in North America on energy and nutrient requirements of laying hens and other poultry as well as contents (energy, nutrients) of feedstuffs used in poultry diets. The tables were updated in subsequent editions (9th edition published in 1994).

Europe followed in 1963, with recommendations for energy and nutrient requirements, published by the Agricultural Research Council (ARC) in the UK. In Germany, the Committee for the development of energy and nutrient standards published the first recommendations for energy and nutrient requirements of layers and broilers and for the concentration of energy and nutrients in rations in 1999, for fattening turkeys in 2004 (GfE).

As shown in table 1, several national research groups worked on this subject and published recommendations, and H. VOGT of the Poultry Research Center in Celle coordinated a project of the WPSA Working Group Poultry Nutrition to work out recommendations for Europe. Recommendations for minerals were published in 1981 and followed for macro-elements for growing and adult poultry in 1984 and 1985; recommendations for trace elements and vitamins were planned, but never published.

The American monographs on poultry nutrition cover energy and nutrient needs extensively. In his book „The Scientific Feeding of Chickens“, TITUS (1st edition 1941, 4th edition 1961) already lists relevant information on energy and nutrient content in poultry feed. SCOTT, NESHEIM and YOUNG treated energy and nutrient requirements in their book „Nutrition of the Chicken“ (1st edition 1969) in great scientific detail and depth. This tradition is continued in the 4th edition of „Scott`s Nutrition of the Chicken“, edited by LEESON and SUMMERS (2001). H. VOGT (1987) followed the factorial approach and contributed an extensive chapter on energy and nutrient requirements of poultry in „Geflügel“ (SCHOLTYSSEK).

Recommended energy and nutrient contents in whole rations and concentrates have also been published by companies specialized in feed additives (e.g. Evonik), by trade associations (e.g. AWT for amino acids and vitamins) and by primary poultry breeding companies (e.g. Lohmann Tierzucht).

The following discussion refers primarily to recommendations for laying hens published by scientific organisations (table 1) or authors of books. Recommendations are based on the daily nutritional needs of laying hens depending on age and current production, expressed in terms of contents in complete rations.

Scientific recommendations and safety margins

The requirements determined under experimental conditions are not always sufficient in practice, for various reasons listed in table 2, and the rations should be supplemented to provide necessary safety margins. How much to supplement cannot be derived from experimental results and needs experience and judgment on the part of the producer; excessive levels of nutrients may also be detrimental.

*) based on an invited paper, presented at the annual meeting of the German WPSA Branch, March 15-16, 2011, at the University of Hohenheim.

Table 1. Recommendations published by scientific organisations

Source	Country	Year	Recommendations for
Agricultural Research Council (ARC)	UK	1975	Chickens, turkeys, ducks, geese
Gesellschaft für Ernährungsphysiologie (GfE)	D	1999	Laying hens, broilers
		2004	Turkeys
Council of Agriculture Taiwan (CAT)	T	1991	Water fowl
Institut National de la Recherche Agronomique (INRA)	F	1981	All poultry species
National Research Council (NRC)	USA	1994	All poultry species
Normenkommission der Forschungskooperation TE	GDR	1983	Laying hens, Broiler breeders
Polish Academy of Sciences (PAN)	PL	2005	All poultry species
World Poultry Science Association (WPSA)	Europe	1984/85	Macro-elements for all poultry species

Table 2. Reasons for recommended additions/allowances to scientifically determined requirements (energy, nutrients)

Energy/nutrients	Reasons why safety additions/ allowances are necessary in practice	Margin added (%)
Metabolisable energy (AMEN)	Variable contents in feed components, Genetic differences in efficiency of conversion, Management conditions, temperature	5-10
Crude protein, Amino-acids	Variable contents in feed components, Differences in ileal (prececal) digestibility, damage of components during processing, antinutritive factors (ANF), differences in utilization, protein bound/ free amino acids	10-15
Macro-elements	Source, differences in digestibility and utilisation, antagonistic effects, age effects, ANF, structure	~10
Trace elements	Variable contents in feed components, form of binding, utilization of trace elements from feed and feed additives, variation in net demand, interactions among trace elements and with other feed components, ANF	10-20
Vitamins, essential fatty acids	Variable contents in feedstuffs, losses, environmental effects, feed effects, antagonists, availability, unspecific recommendation, increasing performance	20-100

Energy requirement and supply

Energy in poultry feed is expressed world-wide (in Germany since the early 1960s) in terms of apparent metabolisable energy, N-corrected (AME_N). Contents of components and complete diets and recommendations for daily intake are commonly expressed in kJ or MJ (occasionally still in kcal).

The energy requirement for laying hens in table 3 has been derived by the factorial method described by GfE (1999). The daily energy needs are the sum of requirements for maintenance and for production. The maintenance requirements are primarily determined by metabolic body mass of the hens. Additional factors are activity (more in barn and free range systems than in cages), ambient temperature, condition of feather cover and genotype.

The energy requirements for production are primarily determined daily egg mass output, body mass increase between sexual maturity and mature weight and regrowth of feathers. Table 3 shows the suggested energy demand from several published sources for layers with 1.8 and 2.2 kg body mass, producing 55 or 60 g egg mass per day.

All recommendations for laying hens in conventional cages, with the exception of the 1975 ARC figures, are in close agreement. The latter assume higher energy requirements for maintenance, which accounts for 60 % of total energy needs, while only 40 % are used for production.

The GfE recommendations assume 10 % and 15 % more maintenance energy for activity in barn egg and free range systems compared to cages, but so far insufficient experimental results are available to confirm these rough figures. Additional energy will also be needed for dissipation of body heat in case the house temperature exceeds the thermo-neutral optimum. This would be a frequent problem in subtropical and tropical regions, occasionally also during hot summers in moderate climate zones like central Europe and therefore justifies more research.

Additional energy is also needed if the ambient temperature drops below 15 °C. The GfE (1999) recommendations assume 7 kJ/kg $W^{0,75}$/d more energy for each °C lower temperature. Loss of feathers has to be compensated with more energy to maintain body temperature, especially in case of induced molting. More experimental results quantifying the actual effect of different degrees of feather loss on energy demand are needed.

Table 3. Recommendations for energy requirements of laying hens at peak production under conditions of thermo-neutral temperature

Source	Live weight kg	AMEN requirement	(MJ/hen/day)
		55 g daily egg mass	60 g daily egg mass
GfE (1999)	1.8	1.28[1]/1,35[2]/1,39[3]	1.33/1.40/1.44
	2.2	1.40/1,49/1,53	1.45/1.53/1.58
ARC (1975)	1.8	1.60	-[4]
	2.2	1.67	-
LEESON and SUMMERS (2001)	1.8	1.22	-
	2.2	1.38	-
NRC (1994)	1.8	1.31	-
	2.2	1.45	-
VOGT (1987)	1.8	1.31	1.35
	2.2	1.39	1.44

[1]cages; [2]barn; [3]free range; [4]no data

The recommendations for optimal energy supply (in AME_N/kg diet) are in reasonable agreement (table 4), with the exception of the ARC (1975) experts, who assumed that laying hens can adjust their daily energy intake by increased feed consumption, provided a minimum of 9.6 MJ/kg feed is assured. Although we agree that hens tend to adjust their feed intake to some degree on the basis of energy content, our own results suggest that 9.6 MJ/kg would be too low for today's highly efficient layers, who are unlikely to increase their feed intake accordingly.

Table 4. Recommendations for energy content of laying hen diets

Based on	Source	MJ AME_N/kg feed (88 % DM)
Scientific experiments	ARC (1975)	min. 9.6
	JEROCH AND DÄNICKE (2010)	approx.11.4
	LARBIER AND LECLERCQ (1994)	11.3-12.1
	LEESON AND SUMMERS (2005)	11.7-12.1
	NRC (1994)	approx.11.9
	PAN (2005)	11,1-11,7
	VOGT (1987)	11.0-11.5 (range 10.5-12.5).
Practical experience	Lohmann Tierzucht	11.4-11.6
	DLG Standards (1992)	10.4-11.4

Adequate energy supply at high ambient temperatures is always a challenge. With increasing temperature, laying hens reduce their daily feed intake and thereby energy and nutrient intake. In older literature it has been suggested to increase energy density at high temperature to compensate for reduced feed intake. At high temperature, when the daily intake is already low, the hens will reduce their intake less in response to increased energy concentration of feed, with the net effect of increased energy intake, as shown in table 5.

The energy concentration of layer diets can be increased by added fat or oil, which has the additional advantage of improved feed structure and reduced metabolic heat production compared to other feed components. While these relationships are commonly understood in commercial feed formulation today, it would be highly desirable to verify the rather old results with modern hybrid layers to quantify the effects and fine-tune recommendations.

Table 5. Effect of feed energy concentration (AMEN) on daily intake of feed and metabolisable energy at different temperatures[1]

Metabolisable Energy MJ/kg feed	18° C		30° C	
	Feed intake g/hen/day	Energy intake MJ/hen/day	Feed intake g/hen/day	Energy intake MJ/hen/day
11.95	127	1.52	107	1.28
12.79	118	1.50	104	1.34
13.58	112	1.52	102	1.38
14.42	106	1.52	101	1.46

[1] PAYNE (1967), quoted in LEESON and SUMMERS (2005)

Crude protein/ amino acid requirements and supply

The protein and amino acid (AA) requirements for laying hens have been the subject of extensive research in the past, based on the factorial method (GfE, 1999). Other estimates of requirements were derived from metabolic studies and performance trials.

As shown in table 6, the AA requirements published by GfE (1999) are in the range of other recommendations. With the exception of tryptophan, the NRC (1994) listed the lowest levels for all AA, while AWT (2000) advocates a higher lysine level than other sources. All figures refer to total amino acids.

Table 6. Daily requirements for crude protein and amino acids for a laying hen with 1.8 kg body mass and 60 g daily egg production

Reference	Crude protein g	Lys mg	Met mg	Met+Cys mg	Thr mg	Trp mg
GfE (1999)	19.8	729	363	635	520	169
LARBIER and LECLERCQ (1994)	17.7	731	342	-	572	177
LEESON and SUMMERS (2001)	17.0	700	370	640	630	150
NRC (1994)	15.0	690	300	580	470	160
VOGT (1987)	20.5	835	405	775	520	170
AWT (2000)	-	880	420	780	575	160

As an alternative to the factorial derivation of AA requirements, the calculations can also be based on the concept of ideal proteins, as described by GRAMZOW (2001) and others. With this approach, only the requirement for a reference amino acid, usually lysine has to be determined, either by the factorial method, in balance trials or in dose-effect feeding trials. Table 7 gives a summary of ideal AA profiles published by different authors; their effects were discussed recently by BREGENDAHL, (2009). From the known relationship to other AA, the requirements for all other AA can then be derived. Current recommendations of Lohmann Tierzucht follow LEMME (2009). Additional research is needed to generate input data in terms of standardized ileal digestibility (KLUTH and RODEHUTSCORD, 2009) to define the ideal AA profile and fine-tune the recommendations for modern laying hens.

Table 7. Ideal amino acid profiles derived by different authors for laying hens

Amino acid	NRC (1994)[2]	JAIS *et al.* (1995)[3]	GfE (1999)[4]	LEESON & SUMMERS (2005)[5]	ROSTAGNO (2005)[6]	BREGEN-DAHL (2009)[7]
Lysine[1]	100	100	100	100	100	100
Methionine	43	44	50	51	50	47
Met+Cystine	84	-	87	88	91	94
Threonine	68	74	72	80	66	77
Tryptophan	23	16	23	21	23	22
Arginine	101	82	91	103	100	<107
Isoleucine	94	76	91	79	83	79
Valine	101	64	100	89	90	93

[1] Lysine = 100% [2] based on total AA requirement [3] based on N-balance [4] based on factorial derivation of gross AA requirements [5] based on total AA requirement of layers at 32–45 weeks of age [6] based on requirements for digestible AA [7] based on requirements for true digestible AA for laying hens with maximal egg mass production at 28–34 weeks of age

When comparing the recommended CP and total AA levels between different sources in table 8, the corresponding feed energy content needs to be kept in mind. The GfE recommendations are based on the results of factorial method and were first calculated for 1 MJ AME_N and then for common energy levels. The levels listed by GfE and NRC (1994) are lower than those from other sources and take no safety limit into account.

For application in practice, about 10 % higher levels should be used (e.g. 6.9 g instead of 6.3 g lysine/kg feed with 11.4 MJ AME_N/kg). Results of a recent trial (HALLE *et al.*, 2005) comparing recommended GfE levels with 15 % higher or lower AA levels are shown in table 9. In this trial, higher concentrations did not improve performance, but lower levels of lysine and methionine had significant negative effects on egg output and feed conversion ratio.

In the past, recommendations were usually expressed in terms of total amino acids. More recently, AWT (2000) and Evonik-Degussa GmbH (LEMME, 2009) suggested to focus on true digestible AA for layers, which differs from the concept of standardized prececal (ileal) digestible amino acids (KLUTH and RODEHUTSCORD, 2009).

Table 8. Recommendations for crude protein and amino acid contents of complete layer feed (88 % DM) during early laying month and peak production

Source	Age or current production	CP g/kg	g/kg					AME_N MJ/kg
			Lys	Met	Met + Cys	Thr	Tryp	
GfE (1999)	60 g egg mass/day	161	6.3	3.1	5.5	4.5	1.5	11.4
ARC (1975)	90 % rate of lay	-	7.5	3.5	4.7	3.6	1.7	-
LEESON & SUMMERS (2005)	18-32 weeks of age	190	8.2	4.3	7.1	6.6	1.7	12.2
NRC (1994)	90 % rate of lay	147	6.7	2.9	5.7	4.6	1.6	11.9
PAN (2005)	>85 % rate of lay white hens	165-175	8.0	3.5	6.8	5.4	1.6	11.5-11.7
	>85 % rate of lay brown hens	155-160	7.2	3.4	6.3	5.1	1.7	11.3-11.5
AWT (2000)	-[1]	160	8.0	3.8	7.1	5.2	1.5	11.9

[1]not specified

Macro-elements requirement and supply

The requirements for macro-elements have been determined with the factorial method, like for energy, crude protein and essential amino acids (GfE, 1999). To calculate adequate phosphorus requirement is difficult, because the digestibility of phytate-P from plants and phytase concentration in plants vary considerably.

The requirement recommendations for this element are currently expressed in terms of available P (aP) or non-phytate-P (NPP), but this is not satisfactory (GfE 1999 und 2004); a new system is suggested, based on “usable” phosphorus.

Table 10 shows requirements derived by WPSA (1985) and GfE (1999), based on factorial calculations. Differences in the Ca recommendations result from the assumed utilization: GfE assumed 55 % (at peak production), WPSA 50 % (on average), and modern phase feeding assumes only 40 % toward the end of the laying period.

Table 9. Effects of reduced vs. increased lysine or/and methionine levels compared to GfE (1999) standards with phase feeding of commercial laying hens (Lohmann LSL-Classic)[1,2]

Experimental feed formulation	Feed g/hen/d	Prod. %	Egg mass g/d	Feed conversion	Body weight[3]
GfE standard	116	88	54	2,22	1919
GfE standard - 15 % Lys	108	82	47	2,32	1719
GfE standard - 15 % Met	113	85	51	2,26	1835
GfE standard - 15 % Lys+Met	102	73	42	2,46	1720
GfE standard + 15 % Lys	117	88	55	2,16	1919
GfE standard + 15 % Met	116	86	53	2,27	1941
GfE standard + 15 % Lys+Met	117	87	54	2,20	2025

[1] HALLE *et al.* (2005);
[2] layer mash based on maize, barley, wheat bran, wheat gluten, peas and soya oil, supplemented with lysine, methionine, minerals and vitamins; 11.4 AME_N/kg feed;
[3] final body weight at end of test, after 52 weeks of production.

Table 10. Requirement of macro-elements (g/hen/day) for different body weight and egg mass production

Source	Live wt. kg	Egg mass g/day	Ca	Non-Phytine-P	Mg	Na	Cl
GfE (1999)	1.8	55	3.65	0.35	0.047	0.11	0.15
		60	3.95	0.37	0.050	0.12	0.16
	2.2	55	3.65	0.37	0.048	0.12	0.15
		60	3.95	0.39	0.051	0.13	0.16
WPSA (1985)	1.8	55	4.15-4.80[1]	0.30	0.048	0.13	0.15
		60	4.50-5.20[1]	0.32	0.050	0.14	0.16
	2.3	55	4.20-4.83[1]	0.33	0.048	0.14	0.16
		60	4.55-5.25[1]	0.34	0.052	0.15	0.17

[1] last part of laying period

The recommendations for the contents of macro-elements in complete layer rations summarized in table 11 are based on the results of factorial experiments or trials focused on the response to increasing dosage of given elements. LEESON and SUMMERS (2005) present recommendations for specified hen age, energy content of feed and daily feed intake. The rather high Ca levels quoted by these authors are partly explained by the high energy level of typical feed formulation in the USA, with corresponding lower feed intake.

The NRC (1994) recommendations vary with feed intake, while PAN (2005) take strain of layer and rate of lay into account in addition to feed intake. In agreement with WPSA (1984) recommendations, both sources recommend increased Ca levels as the hens get older.

Table 11. Recommendations for macro-element contents in layer mash (88 % TS) during early laying months and peak production

Source	Ca	NPP	aP	Mg	Na	Cl	MJ AME_N/kg
GfE (1999)[1]	33.5	3.1	-	0.42	1.05	1.15	11.4
LEESON & SUMMERS (2005)[2]	42.0	-	4.0	-	1.6	-	12.0
NRC (1994)[3]	32.5	2.45	-	0.5	1.5	1.3	11.85
PAN (2005)[4]	35.0	-	3.7	0.5	1.5	1.6	11.3-11.5
WPSA (1984)[5]	36-426	3.0	-	0.4	1.3	1.2	11.25

[1] 1.8 kg live weight/hen, 60 g egg mass/day; 232-45 weeks of age;
[3] light strain of layer, 90% rate of lay, 100 g feed intake/day;
[4] brown-egg strain, > 85% rate of lay
[3-5] light strain of layer, 60 g egg mass/day; [6]toward end of laying period

The recommended levels for phosphorus appear excessive and are probably due to the uncertainties discussed above. In a recent trial, KOZLOWSKI and JEROCH (2011) demonstrated that much lower levels of non-phytate-P are adequate, provided the feed contains sufficient phytase (table 12). As an added benefit, the hens would excrete less P.

Table 12. Effect of added phytase on egg production, feed efficiency and shell strength (Lohmann Brown layers, 21-40 weeks of age) [1, 2]

Non-phytate-P g/kg feed	Added Phytase FTU/kg	Feed intake g/day	Rate of lay %	Egg weight g	FCR kg feed/ kg egg	Live wt. g	Shell strength N
2,5[2]	-	125	94.1[a]	62.1	2.16[a]	1997[a]	35.8
1,3	-	128	90.6[b]	61.0	2.33[b]	1820[b]	32.8
1,3	250	127	94.6[a]	61.5	2.20[a]	1922[a]	35.2

[1] KOZLOWSKI and JEROCH (2011); [2] 44 hens in single cages per treatment group [3] NRC-Norm (1994)

Supply with trace elements

The most important trace elements in layer rations are iron, copper, zink, manganese, iodine and selenium. No recommendations based on the factorial method have been published (reasons discussed by GfE, 1999). The recommended levels are exclusively derived from dose-effect feeding trials and show considerable variation (table 13).

With the exception of Fe, the NRC values are probably too low under commercial conditions. The GfE (1999) advocates levels of trace elements „which are optimal for the most productive and most efficient individual layers under commercial conditions”. Some authors recommend higher levels in breeder rations than in layer feed, but GfE considers the recommendations adequate for parent stock as well. The scientific support for such claims is, however, limited and perhaps outdated.

Table 13. Recommended levels of trace elements in layer rations (mg/kg feed with 88 % DM and normal AME_N)

Source	Fe	Cu	Zn	Mn	I	Se
GfE (1999)[1]	88	6	44	44	0.44	0.13
ARC (1975)	-	-	50[2]-60[3]	30-50	0-0.2	-
LARBIER & LECLERCQ (1994)[4]	60	10	50	40	0.3	0.1
LEESON & SUMMERS (2005)[5]	30	5	50	60	1.0	0.3
NRC (1994)	44[6]-59[7]	-	34-44	20	.034-0.1	0.06
PAN (2005)	40-45	5-8	50-60	60-80	0.7-1.0	0.15

[1] layers [2] layers in production; [3] parent stock in production; [4] layers and parent stock in production; [5] layers in production;
[6] layers in production; [7] parent stock in production

Additions of trace elements in feed supplements follow recommendations. However, in designing feed supplements, the trace elements contained in components are often ignored, and this may lead to overconsumption and excessive levels in excreta. Questions regarding the use of organic vs. inorganic compounds of trace elements have recently been discussed e.g. by SCHENKEL (2008). It has been demonstrated that some organic compounds of trace elements (especially Se) have a higher bio-availability than inorganic compounds in poultry as well. This means that lower levels in daily intake can reduce levels in excreta without sacrificing productivity and health. Experimental results for organic compounds of Zn-, Mn- and Cu are still inconclusive (review of literature, ref. SIMON, 2011). Additional experiments, especially with laying hens, are necessary in this area.

Feed formulations for the production of designer eggs generally contain much higher concentrations of specific trace elements than recommended for normal functioning and egg production.

Supply with vitamins

Balanced poultry feed requires feed additives for most vitamins. A factorial determination of requirements is impossible for the same reason as for trace elements: lack of detailed information about basic data. The GfE and NRC recommendations shown in table 14 are based on dose-response feeding experiments. In some experiments, the effects of different dosage were not only related to egg production, but also to contents in liver and egg yolk as well as biochemical parameters.

It should be pointed out that the recommendations in table 14 are based on feeding experiments many years ago, when the rate of production was much lower and feed conversion ratio (FCR) higher (table 15). As demonstrated in table 16, the vitamin A intake per unit egg mass is reduced by about one third due to higher production, if the feed formulation follows the NRC recommendations (2930 IE/kg feed). According to LEESON (2007), the NRC figures are not adequate for today's highly efficient layers. The GfE recommendations should be updated, based on recent experimental evidence and with necessary safety margins.

Other authors recommend much higher vitamin levels than NRC (1994) and GfE (1999), especially for fat soluble vitamins. Relationships between increased vitamin intake and benefits of "designer eggs" for human health or benefits for the immune system of laying hens will not be covered here.

In feed formulation, vitamins contained in components are usually ignored. This is justified for vitamins A, D3 und B12 because today's commercial rations contain only plant components, which may contain only low concentrations of ß-carotine. Other vitamins are contained in sufficient, sometimes even excessive, concentration in feed components. The recommendations of WHITEHEAD (1998) take the contents of B vitamins in components into account.

Table 14. Recommendations for vitamin contents and additives per kg all mash layer feed with 88 % DM and normal AME_N content

Vitamin[1]	GfE (1999)	NRC (1994)	Other sources[2]	Recommended for feed additives[3]
Vitamin A	4000	2930	8000 - 11000	7000 - 12000
Vitamin D_3	400	295	1600 - 3500	2000 - 3500
Vitamin E_2	5-9	5	10 -50	7.5 – 30 (150–240)
Vitamin K_3	0.5	0.5	1 - 3	1 - 4
Vitamin B_1	1.5	0.7	1 - 2	0 - 3
Vitamin B_2	2.5	2.5	4 - 5	0 - 9
Vitamin B_6	2.5	2.5	1 - 3	0 - 6
Vitamin B_{12}	0.01	0.004	0.01 – 0.02	0.005 – 0.25
Niazin	19	10	20 - 40	5 - 80
Pantothenic acid	4.9	2	5 - 10	4 - 18
Folic acid	0.5	0.25	0.4 - 1	0 - 2
Biotin	0.1	0.1	0.1	0 – 0.3
Choline	500	1050	200 - 500	0 - 600

1 vitamin E in mg or IE, all other vitamins in mg,
2 PAN (2005), LARBIER & LECLERCQ (1994), LEESON & SUMMERS (2005),
3 WHITEHEAD (1998), AWT (2001), DSM (2001, 2006)

Table 15. Development of egg production and feed efficiency in German random sample tests (conventional cages)

Parameter	White-egg strains		Brown-egg strains	
	1970/1971[1]	2002/2004[2]	1970/1971[1]	2002/2004[2]
Age at 50 % Prod., days	170	154	177	146
Egg number per HH	244	319	199	317
Average egg weight, g	60.3	64.3	62.4	66.2
Total HH egg mass, kg	14.7	20.5	11.8	21,0
FCR, kg feed/ kg EM	2.93	1.94	3.29	1.96
Live wt. at 504 days, g	2030	1847	2420	2204
Mortality, %	8.9	4.0	19.1	5.6

[1] FLOCK (1972); [2] Geflügeljahrbuch (2008)

Table 16. Comparison of vitamin A intake of laying hens if the same NRC (1994) standards were used in 1970/71 and 2002/04

Years of production	Egg number/hen housed	Vitamin A intake in IE	
		per 100 g EM	per 65 g egg
1970/1971	244	86 (100)	56
2002/2004	319	57 (66)	37

Summary and Conclusions

The above review of current recommendations for optimal layer nutrition leads to the following conclusions and demands for future research:

- The change from conventional cages to barn and free range management requires reliable estimates of additional energy needs for exercise, degree of feather cover and deviations from thermo-neutral temperature.
- Differences between hens (between and within strains) in their ability to adjust daily feed intake to variable temperature and energy content of feed should be analyzed with suitably structured data.
- Recommendations for amino acid contents in layer rations and daily intake should be developed for prececal (ileal) digestible AA. This requires analysis of digestibility of components under standardized conditions (KLUTH and RODEHUTSCORD, 2009) and derivation of recommendations on the same basis.
- The efforts to develop a new system to assess the availability of phosphorus should be intensified to improve the utilization of this limited resource and reduce waste in emissions.
- The recommendations for trace elements should be verified with focus on bio-availability from various sources, especially chelated compounds.
- Research to determine the optimal supply of vitamins, especially fat soluble vitamins, should include not only commercial hybrid layers, but also parent stock.

Zusammenfassung:

Versorgungsempfehlungen für Energie und Nährstoffe bei Legehennen kritisch hinterfragt

Der vorliegende Übersichtsartikel analysiert kritisch Versorgungsempfehlungen (Bedarf, Futtergehalte) für Umsetzbare Energie und Nährstoffe (Rohprotein, Aminosäuren, Mengen- und Spurenelemente, Vitamine) von Legehennen. Dabei werden vor allem die Empfehlungen der Gesellschaft für Ernährungsphysiologie, internationaler wissenschaftlicher Gremien (u.a. National Research Council, Polnische Akademie der Wissenschaften, World Poultry Science Association), Monografien zur Geflügelernährung (u.a. Leeson und Summers, 2005) sowie ausgewählte neuere Veröffentlichungen zur Thematik herangezogen. Es werden Schwachstellen aufgezeigt und daraus Hinweise für wissenschaftliche Aufgabenstellungen abgeleitet. Hierzu zählen insbesondere: Objektivere Einschätzung des zusätzlichen Energiebedarfs für Bewegungsaktivitäten, unterschiedliche Befiederung und für Umgebungstemperaturen unterhalb als auch oberhalb des thermoneutralen Bereiches, Futterverzehrsverhalten in Abhängigkeit vom Energiegehalt der Futtermischung in verschiedenen Bereichen der Umgebungstemperatur, AS-Versorgungsempfehlungen auf der Basis der standardisierten praeceacal verdaulichen Aminosäuren, neues Phosphorbewertungssystem, Bioverfügbarkeit der Spurenlemente aus organischen Verbindungen, Versorgungsempfehlungen mit fettlöslichen Vitaminen für Hochleistungshennen und begründete Sicherheitszuschläge.

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