NUTRITION MANAGEMENT GUIDE

ISA BROWN
COMMERCIAL LAYER

FOUNDERS OF FUTURE GENERATIONS

A Hendrix Genetics Company

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Introduction

Many years of genetic research have developed layers with excellent production traits like live ability, production and egg quality.

These highly favourable genetic characteristics can only be fully realized when the bird is provided with good management, which includes, but is not limited to, good quality feed, housing and proper management practice.

The purpose of this management guide is to help the producer to gain the best possible results for their investment. This will be achieved by providing conditions in which the layers can thrive. The information supplied in this publication is based on the analysis of extensive research and field results, produced over time and with many years of experience.

We do recognize that over time, many egg producers have developed their own management program, based on specific housing types, climate, feed, market conditions and other factors. These individual management techniques will also be the result of experience and many of these techniques will work for our layers as well.

Therefore do not hesitate to use your own experience in conjunction with the guidelines in this guide. And of course, do not hesitate to consult our distributors who will be happy to help in any way they can.

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Rearing period

Feeding during the rearing period

Energy Level
During the first few weeks of life, meat type chickens just like young pullets are incapable of regulating their energy intake according to the energy concentration of the diet. It takes weeks to develop the digestive tract. During the first 8-10 weeks, any increase in the energy level is accompanied by an increase in growth. When given the feed in a crumb form, young pullets are able to increase their feed intake.
The table below shows the influence of energy level and presentation method on the bodyweight of pullets at 5 weeks of age.

Presentation. Dietary Energy Level	Mash Bodyweight at 5 weeks	Crumbs Bodyweight at 5 Weeks
3100 kcal	375 g	412 g
2790 kcal	345 g	405 g

Newcombe (1985)

After 10 weeks of age, pullets correctly regulate their energy intake according to the energy level of the diet in both hot and temperate climates. Under consumption during that period is often the result of a poor grit size. The objective is to develop the pullet's ability to eat feed, so that it can increase its consumption by approximately 40% in the first few weeks of lay.
During the period 10 - 17 weeks, it is important to develop the digestive system by using diets with an energy concentration less than or equal to that of the layer's diet.

Protein Requirements
The amino acid requirements are to a large extent dependent on the feed conversion ratio and, therefore on age; that is why, when young the requirements expressed in mg of amino-acids per g of growth are the same as a broiler.

The table below shows the influence of amino acid content on the weight of pullets at 4 weeks

Ration	**100 %**	**90 %**
in % of the recommendations)		
Protein (%)	20	18
Digestible Lysine (%)	1.01	0.91
Digestible Methionine+Cystine (%)	0.76	0.69
Weight at 4 weeks (g)	**335**	**302**

Bougon 1997

Any delay in growth during the first few weeks will be reflected in a reduced bodyweight at 17 weeks and in later performance. It is, therefore, extremely important to use a starter diet for the first 4 or 5 weeks, which has an amino acid/protein ratio similar to that of the broiler.

Any amino acid deficiency will result in a reduction in growth rate and an increase in the FCR

Amino Acid content of diets (in % of the recommendations)	**100 %**	**90 %**
Bodyweight at 28 days (g)	**335**	**302**
Bodyweight at 118 days (g)	**1685**	**1630**
Feed consumption (g)	6951	6904
Feed conversion ratio	4.12	4.24

Bougon, 1997

In hot climates, the amino acids and minerals concentrations should be slightly higher than in temperate climates. That results in a reduction in the maintenance requirement, and, therefore in the feed conversion ratio.

Feed Presentation

Feed consumption is determined to a large extent by the form of presentation and the stage to which the digestive tract has developed. Presenting feed in crumb form makes it easier for the chicken to eat it, reduces the time taken in eating, and encourages growth. The energy cost of eating, thus saved, gives an improvement in feed conversion ratio.

Form of Dietary Presentation	**Mash**	**Crumbs**	**Difference**
Weight at 70 days (g)	984	1016	+ 32 g
Weight at 99 days (g)	1344	1405	+ 61 g
Weight at 123 days (g)	1589	1664	+ 75 g

Source: ISA/CNEVA, 1996

This benefit of feeding crumbs will only be obtained when the birds have access to good quality crumbs in the feeders. A poor quality crumb can lead to a build up in fine particles in the feeders and, therefore have the opposite effect to that sought.

From 0 to 4/5 weeks, we recommend using a crumbed diet, after which mash, with a good particle size, should be used.

It is, however, possible to use a granular feed later, where the grinding is coarser, or even as crumbs, if need be. However, we recommend using a mash diet from 12 weeks to avoid a risk of under consumption at the beginning of the sexual maturity if the change is made later.

The bird's appetite for feed depends to a large extent on its particle size. After 4 weeks, we recommend the following particle sizes:
Particles below 0.5 mm: 15 % maximum
Particles above 3.2 mm: 10 % maximum

At least 75 to 80 % of the particles should be between 0.5 and 3.2 mm. If this standard cannot be achieved, it is preferable to use a diet of good quality crumbs.

Development of the digestive system

The achievement of good growth and a rapid increase in feed consumption at start of lay depends on the chicken having a well-developed digestive system, especially a good strong gizzard.

Using feed of good particle size, giving grit during rearing and/or using limestone granules from 10 weeks will all contribute towards good gizzard development.

Between 3 and 10 weeks, we recommend that 3 g per pullet per week (particle size 2 to 3 mm) are offered. After 10 weeks this can be increased to 4 to 5 g (particle size 3 to 5 mm). It is also possible from 10 weeks onwards to use a diet 50 % of the calcium is supplied in carbonate form with a particle size of 2 - 4 mm.

Feed specifications during rearing period

Those requirements are based on the “European Amino acids Table” (WPSA, 1992) of raw materials composition and expressed as digestible amino acids by using the digestibility coefficients mentioned in the “Tables de composition et de valeur nutritive des matières premières destinées aux animaux d’élevage” (INRA editions 2002).

Between 18 & 24 °C	Diet	Starter	Grower	Pullet	Pre - lay
	Units	0 - 4 weeks	4 - 10 weeks	10 - 16 weeks	112 days to
		1 - 28 days	28 - 70 days	70 - 112 days	2 % lay
Metabolisable energy	kcal/kg	2950-2975	2850-2875	2750	2750
	MJ/kg	12.3-12.4	11.9-12.0	11.5	11.5
Crude protein	%	20.5	19	16	16,8
Methionine	%	0.52	0.45	0.33	0,40
Methionine + Cystine	%	0.86	0.76	0.60	0.67
Lysine	%	1.16	0.98	0.74	0.80
Threonine	%	0.78	0.66	0.50	0.56
Tryptophan	%	0.217	0.194	0.168	0.181
Digestible amino acids					
Dig. Methionine	%	0.48	0.41	0.30	0.38
Dig. Meth. + Cystine	%	0.78	0.66	0.53	0.60
Dig. Lysine	%	1.00	0.85	0.64	0.71
Dig. Threonine.	%	0.67	0.57	0.43	0.48
Dig. Tryptophan	%	0.186	0.166	0.145	0.155
Major minerals					
Calcium	%	1.05 - 1.10	0.90 - 1.10	0.90 - 1.00 (1)	2 - 2.10 (1)
Available Phosphorus	%	0.48	0.42	0.36	0.42
Chlorine minimum	%	0.15	0.15	0.14	0.14
Sodium minimum	%	0.16	0.16	0.15	0.15
	Diet	Starter	Grower	Pullet	Pre - lay
Above 24 ° C	Units	0 - 5 weeks	5 - 10 weeks	10 - 16 weeks	112 days to
		1 - 35 days	35 - 70 days	70 - 112 days	2 % lay
Metabolisable energy	kcal/kg	2950-2975	2850-2875	2750	2750
	MJ/kg	12.3-12.4	11.9-12.0	11.5	11.5
Crude protein	%	20.5	20.0	16.8	17.5
Methionine	%	0.52	0.47	0.35	0.42
Methionine + Cystine	%	0.86	0.80	0.63	0.70
Lysine	%	1.16	1.03	0.78	0.84
Threonine	%	0.78	0.69	0.53	0.59
Tryptophan	%	0.217	0.207	0.175	0.190
Digestible amino acids					
Dig. Methionine	%	0.48	0.43	0.32	0.40
Dig. Meth. + Cystine	%	0.78	0.69	0.56	0.63
Dig. Lysine	%	1.00	0.89	0.67	0.74
Dig. Threonine.	%	0.67	0.61	0.45	0.50
Dig. Tryptophan	%	0.195	0.175	0.152	0.163
Major minerals					
Calcium	%	1.05 - 1.10	0.95 - 1.10	0.95 - 1.05 (1)	2.1 - 2.2 (1)
Available Phosphorus	%	0.48	0.44	0.38	0.44
Chlorine minimum	%	0.16	0.16	0.15	0.15
Sodium minimum	%	0.17	0.17	0.16	0.16
(1) : To avoid falls in food consumption, 50% of the calcium should be supplied in granular form (diameter = 2 to 4 mm)					

Production period

Feeding program during the production period

Basic rules of our Feeding Program

Feeding the birds has to be simple, to reduce the risk of errors at varying levels in the manufacturing and delivery process. There are also additional reasons which are related to the birds directly. For example, birds are very sensitive to the feed presentation and the introduction of new raw materials, for this reason we recommend a limited number of feed changes.

Amino acids requirements depend of the productivity of the flocks and from the uniformity of the productivity. Our amino acids recommendations are based on an average productivity of 60 g per day. At 50 weeks, the egg mass produced is around 58 g. A lot of birds are able to produce more than 60g of egg mass over a period of 50 – 65 weeks. This is the reason why is difficult to reduce the amino acids levels after 50 weeks without affecting the productivity.

A deficiency in amino acids reduces in a first time egg weight and in a second time the persistency, around 4 or 5 weeks later.

Pre-lay Feed or Layer 1

Medullary bone is developed in long bone before the first ovulation. The total calcium contained in this medullary is around 1.5 to 2 grams. A pre-layer feed with a higher calcium level is needed to establish this bone reserve. It has to be used from approximately 16 weeks. Its characteristics are similar to the layer 1, but with a level of calcium of 2 – 2.2%.

Don't forget to use the Layer 1 before 2% lay. If the change is realized later, the earliest birds ingest around 1,8g of calcium and need to produce a shell with 2g of calcium. They will stop or reduce laying for some days and will produce eggs without shell. These birds will exhibit cage layer fatigue later and osteoporosis at end of lay.

We think that the risk will be reduced by using a layer 1 instead of a pre-lay feed. However, if the limestone is in 2-4 mm particles form, it is possible to use the layer 1 at 16 weeks. The main reason for the use of pre-lay feed was the risk of under consumption when the limestone used was in powder form. *Don't forget to use the Layer 1 before 2% lay.*

Layer 1

Layer 1 has to be satisfying the amino acids requirements for growth and production at a moment where the feed consumption is lower. At start of lay feed consumption is lower because the birds have not yet reached their adult body weight. Growth is not completely finished by 28 weeks. With regard to protein, a requirement for growth is added to the requirement for production.

From a practical point of view, we have estimated that it is necessary to increase the concentration of amino acids by about 6 % during the 18-28 week period in relation to the feed consumption observed after 28 weeks.

This feed has to be used until the moment that the feed consumption is normal or an average egg size of 60-61g is obtained or around 26-28 weeks.

At the onset of lay, it is desirable to encourage feed consumption and quickly to obtain eggs of marketable size. For this, a feed enriched in fat allows to improve the presentation of diet which gives an increase in feed consumption. Oils rich in polyunsaturated fatty acids are responsible for a large increase in egg weight.

Layer 2

This feed has to be used from 26-28 weeks until 50 weeks or end of lay. If it is possible, it will be good to increase the limestone level at 50 weeks to reduce the percentage of seconds. Birds have daily requirements for amino-acids and minerals, consequently, the percentage of nutrients has to be defined according to the feed consumption observed. The feed consumption depends mainly of the energy requirement and of the temperature

Layer 3

Amino acids requirement: Taking into account persistency in lay, individual variability and egg weight, the requirement for amino acids does not fall throughout the laying period. In an economic context, it may be worth reducing the safety margins slightly. However, the best results, in terms of productivity and feed conversion ratio, are obtained, when one maintains the intake level of amino acids. Any deficiency of amino acids, no matter, which type of amino acid, shows up as a reduction in performance, of which 2/3 is due to a reduction in rate of lay and the remaining 1/3 is a decrease in mean egg weight. It is, therefore, not possible to reduce egg weight towards the end of lay by reducing the amino acid concentration without bringing about a reduction in rate of lay.

Persistency in lay has improved considerably (30 to 35 weeks above 90% lay). An analysis of the individual performance over the period 40-66 weeks shows that 66 % of the birds had performance above average. The 40 % best layers had laid 177 eggs in 182 days and /or 63.2 g of egg mass per day.

Productivity of a sample of 694 pullets hatched in 2001 during the period 40-66 weeks

Quintile	**Rate of lay**	**Egg Mass/day**
1st	98.2 %	65.0 g
2nd	96.3 %	61.4 g
3rd	94.1 %	59.1 g
4th	90.1 %	56.0 g
5th	76.6 %	47.8 g
Mean	91.0 %	57.8 g
% of pullets above the mean	**66.3 %**	**60.4 %**

Hendrix Genetics 2002

Egg weight: A reduction of the oil percentage and energy level is a way to get a stabilization of the egg weight.
Shell quality: Shell weight increases with age throughout lay. For that reason, we advise increasing the calcium concentration in the diet from 50 weeks of age.

Age of the control			Number of eggs controlled	Eggshell weight (g)
Shell Weight	**at 30 weeks**	**g**	**923**	**6,25**
Shell Weight	**at 42 weeks**	**g**	**909**	**6,39**
Shell Weight	**at 50 weeks**	**g**	**807**	**6,32**
Shell Weight	**at 60 weeks**	**g**	**732**	**6,51**

Hendrix Genetics 2006

Which energy level during the production period

Influence of the energy level on productivity

We studied the results of many experiments on the effect of the feed energy level on the production made during the last 15 years with white or brown strains. Main conclusions are the following.

Between 2400 and 3000 kcal, for an energy level reduction of 100 kcal, the energy consumption drops by an average of 1.2 % when the effect of diluting the feed is studied and by 1.4% when the reduction in fat levels is studied. The energy level of the feed has little effect on the number of eggs produced, and, in all cases, the differences are less than 1%. The egg weight reduces in accordance with the reduction in the feed energy level. The reduction can be estimated at about 0.5% or 0.3g for a variation of 100 kcal. The consumption rate, expressed in kcal per gram of egg produced, always improves with the dilution of the feed. The gain is about 0.8% for 100 kcal. This rate gain is a result of a reduction in body weight, an improvement in feather cover and an improvement in the digestibility of the feed. In many experiments the addition of fats seems to have a specific effect on the energy consumption due to an improvement in palatability and the physical form of the feed. When the feed is diluted, the reduction in consumption is particularly marked at the time of the change. Laying hens take several weeks to increase their level of consumption gradually.

Influence of the fiber level on productivity

Feed dilution forces hens to increase the volume and quantity of feed ingested and, therefore, to increase the feed consumption time. There is no longer any doubt that feed dilution brings about an improvement in plumage and a reduction in feather picking itself. This explains the mortality reduction observed in certain trials using diluted diets.

Comparison between feed in meal or pellet form shows that the consumption times are lower when the feed is in pellet or crumb form. This explains why feed in pellet form causes deterioration in plumage and increases feather picking.

Even though most researchers are in agreement over establishing a relationship between consumption time and feather picking, some very recent studies show a specific requirement

for insoluble fiber. Indeed, it appears that there is a specific requirement for insoluble fiber. The absence of insoluble fibers in the feed is responsible for the consumption of feathers and their presence in the gizzard, even when hens are housed in individual cages. Some studies make it possible to conclude that insoluble fibers do have an effect on the quality of plumage and on mortality. The specific size of the fibers, mainly lignin, would seem to be important.

We have noted that countries using sunflower meal in quite significant quantities have lower mortalities than those of countries that do not use it, whether using cages or floor systems. Very positive effects were observed after the introduction of sunflower meal to feed for free-range hens.

Effect of granulometry

Feed consumption is highly dependant upon granulometry. Chickens have a marked preference for grains. They are easy to pick up and do not lead to beaks becoming clogged. A hen will always tend to leave fine particles. We (ISA, 1999) carried out the following trial: a commercial feed, of good particle size, was re-milled through a finer screen. The feeds were distributed from 19 weeks of age.

Influence of feed granulometry on performance of laying hens between 23 and 51 weeks

Particle size	**Standard**	**Fine**	**Difference in %**
< 0.5 mm	9 %	31 %	
> 3.2 mm	10 %	0 %	
0.5 to 3.2 mm	81 %	69 %	
> 1.6 mm	65 %	21 %	
Laying, %	93.9	90.7	- 3.4
Egg weight, g	63.3	62.7	- 0.9
Egg mass, g/d	59.41	56.85	- 4.3
Consumption, g/d	118.1	114.2	- 3.4
Consumption Index	1.989	2.008	+ 0.9
Weight at 33 wks (g)	1.930	1.883	

ISA, 1999

Feed consumption is reduced by about 4 g when the feed is finely ground. This leads to a reduction of egg mass produced.
Distribution of fine feed is equivalent to rationing for hens. In this experiment, the laying rate proves to be affected more than the egg weight. Sometimes in other experiments, the reverse is observed.

Conclusion

Energy regulation is not specific to a breed, white egg layers or brown egg layers, but depends on the dilution methods used. The feed density (gm per litre) seems to be the limiting factor in ingestion regulation. The presence of insoluble fibre appears to be essential. It increases gizzard size, improves starch digestibility and limits feather picking by reducing the need to ingest feathers.

Conversely, the addition of fats brings about an improvement in feed palatability and thus an increase in energy ingestion in proportions which can be very significant. Increase in egg weight is only one result of this. These effects are dependent upon the quantity and type of fats added.

From a practical point of view, the effect of low density, high cellulose (insoluble fibre) raw materials may be balanced by the use of fats. The feed presentation also has an effect on energy consumption. Too fine feed presentation causes a reduction in energy consumption.

It thus appears that the 3 following factors must be controlled: the physical form of the feed, the cellulose content and the oil content. A balance between these 3 criteria must be sought in order to make possible the expression of genetic potential at a lower cost.

Principal applications and recommendations

At the onset of laying, it is desirable to encourage feed consumption and quickly to obtain eggs of marketable size. For this, a feed enriched in fat (1.5 to 2.5 %) and incorporating a minimum of insoluble fiber is recommended. After the onset of laying, a slightly lower energy level, richer in cellulose, will allow a good energy efficiency to be obtained (expressed in kcal) and plumage to be maintained. This strategy could be particularly beneficial for alternative production (free range, organic…), especially in the absence of ground litter.

From the practical point of view, the effect of raw materials which are rich in cellulose (insoluble fiber) and of low density can be compensated by the use of fat. Feed granulometry also affects energy consumption. Particles which are too fine lead to a reduction in consumption.

Amino acids requirements for commercial layers

Genetic progress and nutritional consequences

Just as for the other species, genetic progress has a considerable influence on dietary amino acid concentrations. Over the last 30 years, production to a constant age has increased by more than 40 %, while feed consumption has been reduced by about 10 %. An important consequence of this genetic progress has been a change in the daily amino acid requirements. It has also called into question the practice of phase feeding, since productivity remains high over longer and longer periods. The best units nowadays have daily egg outputs of over 60g/bird right up to 52 weeks of age.

The implication of genetic change in deciding amino acid levels is, therefore, considerable. It can be approached in the following way:

Feed conversion ratio over the period 30-50 weeks:

1971:	2.87	g of feed / g of egg
1981:	2.36	g of feed / g of egg
2005:	1.95 (-17%)	g of feed / g of egg

Classically, daily nutrient requirements have been expressed in mg / day. While this type of expression may be very easy for the formulator to use, it does not allow for genetic progress, nor for genotypic differences. Those genotypes, which produce large eggs, have larger daily requirements than those, which produce small eggs.

Most Researchers agree to the expression of nutrient requirements in mg of amino acids per gram of eggs produced. This method enables us to tackle the « requirement » starting from numerous experimental data sources. It is more precise. The synthesis that we have carried out according to this method shows it to be an excellent way of determining requirements.

Ideal protein and amino acids requirements

The concept of ideal proteins is a means of expressing the requirements for amino acids as a percentage of the requirement for LYS. There is a limited interest in applying this concept to layers. It implies that a balance between the different amino acids is necessary for optimizing requirements. That would suggest that high protein or amino acid levels would have a negative effect on performance.

In fact the formulator should make a point of satisfying the requirement for the following amino acids: MET - CYS - LYS - THR - TRP - ISO and VAL. This is only valid for diets and raw materials in common usage.

Those requirements, which need to be defined by comparison with reference tables, have been expressed from NRC (1994) table of raw materials composition. These results have been expressed as digestible amino acids by using the digestibility coefficients mentioned in the RPAN 1993 tables. Giving the expression in the digestible form has reduced the variability of the results observed.

Recommendations for amino acids expressed in total or digestible and ideal proteins established for a production of 59.5 egg mass per day.

Limiting amino acids	Ideal protein based on NRC 1994	Requirements in mg per g based on NRC table 1994		Daily Requirements based on NRC table 1994	
		Dig. AA	Total AA	Dig. AA	Total AA
LYS	100	13.50	15,25	810	900
MET	54	7.2	7,6	430	455
MET + CYS	85	11.45	13.0	690	770
TRY	22	3.00	3.5	180	208
ILE	83	11.5	13.0	690	775
VAL	93	12.6	14.2	760	840
THR	70	9.4	11.0	565	655

Feed formulation

Digestible Amino Acids: Bird requirements and formulation of diets should be made in terms of digestible amino acids. By formulating in digestible Amino Acids we are better able to satisfy the requirements of the birds, to reduce the necessary safety margins and assess the raw materials according to their true biological value. Formulation according to total amino acids leads to the same nutritional value being given to all raw materials irrespective of their digestibility. That leads naturally to increasing the safety margins in order to guarantee fully meeting the requirements of the birds.

Protein Requirements: When diets are formulated by taking into account the need to satisfy the requirement for each of the 7 essential amino acids, it doesn't seem to be necessary to introduce a minimal constraint for protein. The requirements for the limiting amino acids are generally enough. On the other hand, if all the essential amino acids are not taken into account when formulating, it is necessary to use a constraint for minimum protein, so as to reduce the risk of a deficiency.

Limiting factors: The experience acquired during the last decades in the feeding of layers, especially the use of synthetic lysine, has enabled us to assert that ISOLEUCINE and VALINE are becoming the limiting factors in layers feeds when meat products are excluded from the feed or when they are used in formulae based on wheat.

TRYPTOPHAN is the limiting factor in formulae, where the base consists of maize, soybean meal and meat products.
THREONINE and still less ARGININE do not appear to be limiting in the diets used nowadays. These last two amino acids need to be studied still further.
When the requirements for ISO, VAL and TRY are covered, the requirements for the other essential and non-essential amino acids are always satisfied when 300 mg of protein per gram of egg is supplied. When the feed formula takes into account the requirements ISOLEUCINE and VALINE, it is not necessary to impose a constraint for a minimum protein level.

Feed consumption and formulation: The amino acid concentration of the diets, therefore, depends on:
the potential of egg mass produced, which itself determines the daily requirements the daily feed consumption which determines the amino acid concentration the feed efficiency at peak of production given the amino acid concentration in dividing the requirement expressed

Amino acids recommendations for commercial layers

Formulation of layer's diets can be carried out by introducing ISOLEUCINE and VALINE as nutritional constraints replacing protein as a constraint. If this is not possible, we give hereafter some indications for a minimum of protein for feed containing or not Meat and Bone Meal (MBM).
(1) From a practical point of view, we estimate that it is necessary to increase the concentration of amino acids by about 6 % during the 18-28 weeks period in relation to the feed consumption observed after 28 weeks. Total or digestible amino acids levels are established for a production of 59.5 g egg mass per day.

Average feed intake observed after 28 wks in g / day		105	110	115	120	125
		FROM 2 % LAY TO 28 WEEKS OLD (1)				
Protein w/o MBM	%	(18.2-18.7)	(17.7-18.2)	(17.2-17.6)	(16.7-17.2)	(16.2-16.7)
Protein with MBM	%	(19.5-20.0)	(18.9-19.4)	(18.2-18.8)	(17.9-18.4)	(17.4-17.9)
Total amino acids % :						
Lysine		0,91	0,87	0,83	0,80	0,77
Methionine		0,46	0,44	0,42	0,41	0,39
Methionine + Cystine		0,77	0,74	0,71	0,68	0,65
Tryoptophan		0,210	0,200	0,192	0,184	0,176
Threonine		0,66	0,63	0,60	0,58	0,56
Isoleucine		0,80	0,77	0,73	0,70	0,67
Valine		0,86	0,82	0,79	0,76	0,73
Digestible amino acids % :						
Lysine		0,81	0,78	0,74	0,71	0,68
Methionine		0,44	0,42	0,40	0,38	0,37
Methionine + Cystine		0,70	0,66	0,64	0,61	0,59
Tryoptophan		0,182	0,173	0,166	0,159	0,153
Threonine		0,57	0,54	0,52	0,49	0,47
Isoleucine		0,73	0,70	0,67	0,64	0,61
Valine		0,78	0,75	0,71	0,68	0,66
		FROM 28 WEEKS TO THE END OF LAY				
Protein w/o MBM	%	(17.4-17.9)	(16.9-17.4)	(16.4-16.9)	(15.9-16.4)	(15.4-15.9)
Protein with MBM	%	(18.7-19.2)	(18.1-18.6)	(17.6-18.1)	(17.1-17.6)	(16.6-17.1)
Total amino acids % :						
Lysine		0,86	0,82	0,79	0,75	0,72
Methionine		0,44	0,42	0,40	0,38	0,37
Methionine + Cystine		0,73	0,70	0,63	0,64	0,61
Tryoptophan		0,198	0,189	0,181	0,173	0,166
Threonine		0,62	0,60	0,57	0,55	0,52
Isoleucine		0,76	0,72	0,69	0,66	0,64
Valine		0,81	0,78	0,74	0,71	0,68
Digestible amino acids % :						
Lysine		0,77	0,73	0,70	0,67	0,64
Methionine		0,41	0,40	0,38	0,36	0,35
Methionine + Cystine		0,66	0,63	0,60	0,58	0,55
Tryoptophan		0,170	0,162	0,155	0,148	0,142
Threonine		0,53	0,51	0,49	0,47	0,45
Isoleucine		0,69	0,66	0,63	0,60	0,58
Valine		0,74	0,70	0,67	0,65	0,62

Those requirements are based on the “European Amino acids Table” (WPSA, 1992) of raw materials composition and expressed as digestible amino acids by using the digestibility coefficients mentioned in the “Tables de composition et de valeur nutritive des matières premières destinées aux animaux d’élevage” (INRA editions 2002).

Calcium nutrition and particles size

Year after year, improvements in productivity are brought about by reducing the time taken to produce an egg. Nowadays, the time taken to produce the egg is close to 24 hours which enables us to achieve very high rates of production with eggs being laid early in the morning.
Calcification of the eggshell takes about 12 hours being completed on average 2h - 2 h 30 min. before oviposition. Eggshell quality depends to a large extent on the quantity of calcium available in the digestive tract during the night and the form in which calcium carbonate is supplied play determining roles in deciding shell quality.
Some differences exit between white and brown layers for a program of 16 hours of light:

In Average (hours after lights on)	White Layers	Brown Layers
Beginning of large calcium deposit	15h30 (+/- 2hrs)	12h30 (+/- 2hrs)
End of calcium deposit	3h30 (+/- 2hrs)	0h30 (+/- 2hrs)

Calcification of the shell is mainly realised during the night. A high percentage of brown birds stop calcification at lights on or just after while white layers finished their shell after lights on.

Calcium absorption
During shell formation the bird uses the calcium contained in the digestive tract, it is dissolved by abundant secretion of Hydrochloric acid. Regular gizzard contractions allow delivering calcium through intestine. When the quantity of calcium is insufficient, the bone reserves are used (the calcium is deposited and the phosphorus eliminated by the kidneys). It has been demonstrated many times that birds which are forced to use their bone reserves produce eggs of poorer shell quality. Sauveur (1988) said "the eggshells are thicker when the part played by the bones is small". Calcium deposition is slow during the first 5 hours after enter in the shell gland. After that and for approximately 10 hours, the rate of shell deposition is rapid and linear. Calcium absorption varies from approximately 30% to over 70% between periods without calcification and period of shell formation. For this reason, all increase in the quantity of calcium available at the end of the night lead to an improvement in shell quality.

Importance of large limestone particle size
Large size of calcium and retention: Large sizes of limestone (over 2 mm) are retained in the digestive tract and dissolved slowly during the shell formation providing a more regular release of calcium.

The influence of particle size on the « in vitro » and « in vivo » solubility of calcium and its retention in the gizzard 5 hours after food withdrawal

Diameter of limestone particles average size (mm)	Solubility (%)					
	In vitro		In vivo		Retention in the gizzard (g)	
	A	B	A	B	A	B
3.3 – 4.7	29.8	36.3	84.8	82.5	15.4	3.4
2.0 – 2.8	45.8	54.8	79.0	84.0	11.8	4.3
1.0 – 2.0	49.3	57.7	77.8	74.4	5.5	4.7
0.5 – 0.8	63.1	67.6	76.5	69.4	0.7	1.6

A = low solubility sample B = high solubility sample Zhang et al (1997)

Relation between particle size and calcium retention for a consumption of 3.75 g calcium

Size	Particles			
of	Rejected in the	Stored in the gizzard	Calcium retained	
particles	faeces	After 24 hours	g	%
0.5 to.8 mm	44 %	0	1.94	52
2 to 5 mm	16 %	10 %	2.40	64

Rao and Roland (1989)

Large size of calcium and shell quality: The availability of calcium at the end of the night period is improved in using a coarse calcium source with a low solubility. In using a low solubility coarse limestone, the quantity of calcium available during the beginning of shell formation is reduced and improved at the end of the night.

The most important parameter is the solubility, lower is solubility and better will be the shell quality. Chen and Coon (1990) found a very high coefficient of regression between Shell Index and solubility. Coarse limestone with a high solubility is not able to optimize the shell quality.
There is no advantage to use oyster shell if the limestone size and solubility are correct.

Av. Screen size (mm)	Shell index mg / cm²	Shell weight g	Specific gravity	Shell thickness µm
3.36	**75.6**	**5.27**	**1.0837**	**302**
2.38	**74.3**	**5.21**	**1.0839**	**290**
1.68	**74.0**	**5.23**	**1.0828**	**296**
1.02	**73.7**	**5.16**	**1.0825**	**294**
0.50	**73.0**	**5.05**	**1.0821**	**286**
0.15	**70.9**	**4.97**	**1.0802**	**280**

Chen and Coon (1990)

Importance of soluble form of calcium
At "lights-on", those birds, which have not completed calcification should have access to powdered calcium, which is very rapidly dissolved and absorbed. It takes no more than 30 minutes between the intake of calcium and the moment where calcium is incorporated into the shell. Koreleski et al, 2003, studied which percentage of coarse particles of limestone has to be used with brown birds. The best result is observed with 60% of large particles.

The effect of the percentage of limestone in particles of 2 to 4mm on the shell characteristics

Percentage of large particles used	Egg shell breaking strength N	Shell weight g	Shell Index mg per cm²	Shell thickness µm
0	33.6a	5.70	78.3	365
20	35.4ab	5.80	78.9	365
40	38.0d	5.75	79.7	368
60	38.2d	5.88	80.8	374
80	36.9cd	5.70	79.1	364
100	36.1bc	5.89	81.4	370

Koreleski (2003)

Recommendations
white layers: They finished their eggshell after lights on, consequently 50% of the calcium have to be in particles of 2 to 4 mm and 50% in a powder form.
brown layers: Around 40% of birds have finished their eggshell at lights on, consequently 65% of the calcium have to be in particles of 2 to 4 mm and 35% in a powder form.

Mineral and oil level recommendations

(1): When coarse limestone is supplied as particles of 2 to 4 mm, it is possible to use these values.
(2): We advise using these values when the calcium is supplied in powder form.
(3): Vegetable oil rich in unsaturated fatty acid improve egg weight, according to the requirement of the market and the appetence a level of 2 to 3% is required. To avoid egg size becoming too large at the end of lay, we advise reducing the quantity of vegetable oil being used.

DAILY REQUIREMENT	*From 17 to 28 WEEKS*	*From 28 to 50 WEEKS*	*From after 50 WEEKS*
Available phosphorus (1) mg	*400*	*380*	*340*
Available phosphorus (2) mg	*440*	*420*	*380*
Total Calcium g	*3.9 – 4.1*	*4.1 – 4.3*	*4.3 – 4.6*
White birds: Coarse Calcium (2 to 4mm) g	*2.0*	*2.1*	*2.2*
Brown birds: Coarse Calcium (2 to 4mm) g	*2.6*	*2.7*	*2.9*
Sodium minimum mg	*180*	*180*	*180*
Chlorine mini-maxi mg	*170 - 260*	*170 - 260*	*170 - 260*
Oil Mini-maxi (3) %	*2 - 3*	*1 - 2*	*0.5 – 1.5*
Fibre	A minimum of coarse fibre or lignin is required to prevent feather pecking and improve the feed digestibility		

Average feed intake observed after 28 weeks in g / day	*105*	*110*	*115*	*120*	*125*
	FROM 2 % LAY TO 28 WEEKS OLD				
Available phosphorus (1) %	0.41	0.39	0.37	0.35	0.34
Available phosphorus (2) %	0.45	0.43	0.41	0.39	0.37
Total Calcium %	3.9 - 4.1	3.8 – 4.0	3.6 - 3.8	3.4 – 3.6	3.3 – 3.5
Sodium minimum %	0.18	0.17	0.16	0.16	0.15
Chlorine mini-maxi %	0.17 - 0.26	0.16 - 0.25	0.16 - 0.24	0.15 - 0.23	0.15 - 0.22
	FROM 28 WEEKS TO 50 WEEKS				
Available phosphorus (1) %	0.36	0.34	0.33	0.32	0.31
Available phosphorus (2) %	0.40	0.38	0.37	0.35	0.34
Total Calcium %	3.9 - 4.1	3.7 - 3.9	3.6 - 3.8	3.4 - 3.6	3.3 - 3.5
Sodium minimum %	0.17	0.16	0.16	0.15	0.14
Chlorine mini-maxi %	0.16 - 0.25	0.16 - 0.24	0.15 - 0.23	0.14 - 0.22	0.14 - 0.21
	FROM 50 WEEKS TO THE END OF LAY				
Available phosphorus (1) %	0.32	0.30	0.29	0.28	0.27
Available phosphorus (2) %	0.36	0.34	0.33	0.32	0.30
Total Calcium %	4.1 – 4.3	3.9 – 4.1	3.8 – 4.0	3.6 – 3.8	3.5 – 3.7
Sodium minimum %	0.17	0.16	0.16	0.15	0.14
Chlorine mini-maxi %	0.16 - 0.25	0.16 - 0.24	0.15 - 0.23	0.14 - 0.22	0.14 - 0.21

Feed presentation for commercial layers

Importance of the feed particle size
Mixing difficulties, inappropriate particle size and separation problems have been resolved by milling the raw materials relatively fine.

However, diets, which are too finely ground, often seriously reduce feed intake. Low consumption has been avoided by using diets presented as crumbs or pellets. In effect, the ease of eating and the reduction in feeding time, due to pelleting, leads to an increase in the number of feeds taken by the birds and in their growth. This effect is observed in both laying hens and broiler chickens.

Birds are grain eaters and their feed consumption depends on feed presentation.

Pelleted or crumbled diets for layers
In theory, presenting a diet in crumb or pellet form will give higher feed consumption. That presupposes that the feeding systems in operation and the raw materials used are providing the laying hen with a good quality pellet or crumb.

Very often, the difficulties in obtaining a good quality crumb are responsible for under consumption and some technical problems because of:

- the breaking down of the crumb in the feed distribution system
- the build up of fine feed particles in the feeders
- more shell quality problem related to the difficulties to use a granular limestone
- more feather pecking due to a shorter feeding time
- the increased cost of manufacture.

To develop a good digestive system it is necessary to have coarsely milled feed. With the intention of keeping good shell quality one can:

- use granular limestone if the diameter of the diet is adapted
- add some of the limestone after pelleting
- distribute 3 to 4 g per bird of granular limestone (2 to 4mm) in the poultry house each afternoon.

Mash diets of good texture
During rearing, with the exception of the first 4 or 5 weeks, when the diet should be crumbs, a good particle size will allow good growth and the development of a robust digestive system.

During the laying period, a good textured diet will allow the birds to increase their feed consumption, their production and their growth.

The table below shows the results of Summers and Leeson (1979) when they were comparing a fine mash with a diet 60 % cracked maize and whole barley grains.

		Cracked Maize + Whole Barley	Fine Mash
Consumption	(g/day)	114.5	102.0
Rate of lay	(%)	86.9	85.1
Egg weight	(g)	59.6	56.8

In hot climates, a good textured feed can reduce the under consumption experienced in summer.

That's why, we advise having at least 75 to 80 % of the particles between 0.5 and 3.2 mm. This type of diet is in fact easier and cheaper to produce, because the rate of output from the grinder is increased.
particle sizes less than 0.5 mm : 15 % maximum
particle sizes above 3.2 mm : 10 % maximum

These recommendations also apply to the rearing diets after the age of 4 or 5 weeks. The attractiveness of the diet improves markedly if the fine particles are sticking together. That can be achieved by the addition of 1.5 to 2.5 % vegetable oil.

The choice of raw materials
One should avoid raw materials, which are too dusty, and not grind ingredients, which don't need grinding.

When the diet does not contain meat meal 60 to 70% of the calcium carbonate should be supplied as granules of 2 - 4 mm diameter. When meat meal is included the proportion in granular form should be increased to 80%.

The phosphates should be supplied as micro-granules.

The technique of grinding
A good textured mash can be obtained by observing the following rules.

The speed at the periphery of the hammers should be 50 to 55 m/sec. This speed corresponds to about 1500 rpm for a grinder of 65 cm diameter.
We recommend using grill mesh screens in preference to those with round perforations. They have a higher proportion of spaces and allow higher throughputs.
The hole diameters should be the following: for wire screens = 8 mm minimum, for screens with round perforations: 8 mm minimum, 10 mm maximum.

It also depends on the raw materials being used. Using worn hammers gives an increase in the percentage of fine particles and reduces the output of the grinder.

We advise milling only those raw materials, which need it. The texture of the ground materials should be checked at least twice a week.

Suggested premix composition for commercial layers

FOR COMMERCIAL LAYERS		REARING PERIOD		LAYING PERIOD
		0 6 10 weeks	10 wks - 2 % Lay	
Added trace elements mg per kg of diet				
Manganese (Mn)	ppm	60	60	70
Zinc (Zn)	ppm	60	60	60
Iron (Fe)	ppm	60	60	60
Iodine (I)	ppm	1	1	1
Copper (Cu)	ppm	8	6	8
Selenium (Se)	ppm	0.25	0.25	0.25
Cobalt (Co)	ppm	0.25	0.15	0.15
Added vitamins per kg of diet in IU or mg				
Vitamin A	IU	13.000	10.000	10.000
Vitamin D3	IU	3.000	2.000	2.500
Vitamin E	mg	25	25	20
Vitamin K3	mg	3	3	3
Vitamin B1 (Thiamine)	mg	2	2	2
Vitamin B2 (Riboflavin)	mg	5	5	5
Vitamin B6 (Pyridoxine)	mg	5	5	5
Vitamin B12	mg	0.02	0.01	0.015
Nicotinic Acid (Niacin)	mg	60	40	40
Pantothenic acid	mg	15	12	12
Folic Acid	mg	0.75	0.75	0.75
Biotin	mg	0.2	0.1	0.05
Vitamin C in hot climate or during summer time	mg			100
Total Choline requirement per kg of diet (raw materials included) mg				
Choline	*mg/kg*	*1600*	*1400*	*1400*
Choline	*mg/day*	*-*	*-*	*160*
Add antioxidant				

Mixing

Trace elements and vitamins should be correctly mixed before being added to the raw materials. Premixes have to be mixed at a minimum level of 3 kg per tonne. Improper mixing or handling can be checked by dosing Manganese as a tracer.

Toxicity of some minerals

Maximum admissible levels for different minerals could be estimated as followed:

Potassium	2000 ppm	Magnesium	5000 ppm
Sodium	5000 ppm	Chlorine	5000 ppm
Iron	500 ppm	Manganese	1000 ppm
Zinc	2000 ppm	Copper	300-500 ppm
Selenium	10 ppm	Iodine	300-500 ppm
Vanadium	10 ppm due to contamination from rock phosphates		