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INTRODUCTION

INTRODUCTION

Genetics has been considerable evoluated in recent years. However, feed and feeding techniques are the keys that allow to externalize the genetic potential of layers, in terms of productivity, egg quality, behaviour. We will split in this guide our recommendations per strain: Brown and White. They are applicable to commercials, as well as to parentals, if they are of irreproachable general quality (raw materials, factory, distribution...)

Today, faced with price volatility and variability of raw materials, different approaches can be considered for the formulation (use of co-products, enzymes ...) to provide essential nutrients to layers while maintaining a good presentation of the feed.

This guide to **informative vocation**, is a compilation of bibliographic data and "field experiences", tinged with the experience of our teams. Our recommendations for energy, protein, amino acids, minerals and vitamins are general indications about the optimal values. They can be affected by factors, environmental health, technical or otherwise, and in all cases, they must be interpreted and adjusted by a local nutritionist depending on observe performances.

⁽¹⁾ Note: The performance data contained in this document was obtained from results and experience from our own research flocks and flocks of our customers. In no way does the data contained in this document constitute a warranty or guarantee of the same performance under different conditions of nutrition, density or physical or biological environment. In particular (but without limitation of the foregoing), we do not grant any warranties regarding the fitness for purpose, performance, use, nature or quality of the flocks. NOVOGEN makes no representation as to the accuracy or completeness of the information contained in this document.



DIGESTIVE PHYSIOLOGY OF LAYERS

1. DIGESTIVE PHYSIOLOGY OF LAYERS

Because the digestive tract of poultry is shorter than those of other monogastric species, feed moves faster. The excretion of non-digestible particles starts three hours after ingestion and it takes eight hours of transit time to eliminate most of the undigestible fraction of the feed.

1.1. BEAK AND ORAL CAVITY

The beak is, before all else, an organ of prehension that hens use to obtain feed. It is composed of two jaws: the upper and lower mandibles. The oral cavity is lined with a mucous epithelium and is delimited by the tomia and the pharynx. Since limits with the pharynx are not easily specified anatomically (the combined cavity of mouth and pharynx is often referred to as the oropharynx). In the absence of lips and teeth, feed is not chewed and water is directly swallowed. The tong has no flexibility and can only move back and forth during meals and watering.

Even though saliva glands are well developed and saliva is secreted abundantly, very little enzymatic activity is observed in the mouth. Saliva wets the feed to make it easier to swallow and thus facilitate the passage towards the oesophagus.

1.2. OESOPHAGUS

With a length of 25 cm in the hen, this tube-like organ is located at the right of the trachea. The oesophagus carries food from the oral cavity to the proventriculus. Just before entering the thoracic cavity, it bulges and forms a diverticulum, called the crop, used for temporary feed storage. The whole length of the oesophagus is lined with a mucosa that presents accentuated longitudinal folds. The oesophagus also has very developed longitudinal internal muscles and is very dilatable.

1.3. CROP

The crop, a feed storage organ, is an out-pocketing of the oesophagus located at the base of the neck. In the hen, it has a very extensible ventral pouch whose lower part sticks to the neck skin and subcutaneous muscles. The crop's very thin wall contains smooth muscles that are not very developed but are rich in elastic fibers allowing the progressive release of food particles into the proventriculus. This is where feed is hydrated and pellets crumbled. When the lower parts of the digestive tubes are empty, the feed does not stay in the crop but moves directly to the proventriculus. Inversely, when the gizzard is full, feed is stored in the crop, notably during the nocturnal period.

1.4. PROVENTRICULUS

The proventriculus, also known as the glandular stomach, is a fusiform pouch (on average 3 cm long in the hen) whose mucosa is very rich in glands excreting mucous, hydrochloric acid, pepsinogen and lipases. It is the chemical stomach where digestion begins with protein hydrolysis and daily solubilization of 8 to 10 g of calcium carbonate. The feed just transits a few minutes in the proventriculus.

1.5. GIZZARD

The gizzard is the hen's largest organ (6 to 8 cm long, with a weight of approximately 50 g when empty and 100 g when full). It has a rounded shape and its cavity is saccular. It is made up of strong muscles. The bulk of the organ consists in two thick masses of muscle that insert on pearly white glistening tendinous centers on each side



DIGESTIVE PHYSIOLOGY OF LAYERS

of the gizzard. This mechanical stomach is very extensible and can grind coarse particles such as whole cereal grains. The lysis and minerals (calcium carbonate and phosphates) solubilization continues in the gizzard thanks to the hydrochloric acid produced in the proventriculus, ionize the electrolytes and destroy the tertiary structures of feed proteins. Similarly, pepsin, the unique gastric enzyme, cannot efficiently act in the light of the proventricule but will contribute to hydrolyse the proteins in the cavity of the gizzard. During the calcification period, the gizzard contracts at a rate of three contractions per minute to expel a calcium-rich solution.

1.6. SMALL INTESTINE

The small intestine is 1.20 m long and is divided into three parts. It is where most of the nutrient absorption occurs (85%):

- Duodenum: it starts at the pylorus then forms a large intestinal loop that surrounds the pancreas. Bypassing the gizzard, this loop constitutes the most ventral part of the intestine in the abdominal cavity. Three pancreatic ducts and two bile ducts enter the duodenum by a common papilla. The location of this papilla marks the end of the duodenum and the beginning of the jejunum.
- Jejunum: it is divided into two parts. The proximal part, called the Meckel's diverticulum (a vestige of the duct linking the embryonic digestive tube to the yolk sac) is the most important part. The distal part is called the supra-duodenal loop.
- Ileum: it is short and strait and of variable diameter and length.
- There are little differences between the jejunum and ileum which are similar in length and structure. Together, they represent the largest absorption surface area of the digestive tube thanks to the peristaltism and reverse peristaltism which mixes the chyme, thus favouring lipid hydrolysis and absorption. The intestinal juice contains mucus, electrolytes, and enzymes. The bile, secreted by the liver and discharged into the duodenum, holds bile salts and lipids. The pancreatic juice allows the hydrolysis of proteins, carbohydrates and lipids.

1.7. CECA

Poultry has a much-reduced colon and a very short rectum (7 cm). The ceca absorb some of the undigested feed and reabsorb water. A cecum is a blind pouch that opens into the intestinal tube at the ileorectal junction by an ileocecal valve. Although ceca contain an abundant bacterial flora, bacterial fermentation does not play a large part in nutrient absorption. Reverse peristaltism discharges the non-digested feed coming from the colon into the ceca, favouring liquids over solids. Faecal discharge occurs via the ceca five to eight times a day.

1.8. CLOACA

The cloaca is the terminal part of the intestine into which open the urogenital tracts. It divides into three chambers each separated by a transversal fold not readily defined :

- The coprodaeum is where excrements are collected. It is a terminal dilatation of the rectum. Faeces and urine accumulate in the coprodaeum before their discharge.
- The urodaeum is the middle part of the cloaca. It receives the urogenital tracts. The two ureters enter
 the urodaeum on either side of the dorsal midline. In females, the oviduct has an opening on the left
 dorsolateral wall. In males, the ductus deferens enter the urodaeum on the left and right dorsolateral
 walls.



DIGESTIVE PHYSIOLOGY OF LAYERS

• The proctodaeum comes from a depression of embryonic ectoderm and is opening to exterior by anus. In young bird, it is linked by a duct to the bursa of Fabricius. The cloaca opens to the exterior of the body by the cloacal orifice: a vertical slit closed by two horizontal lips.

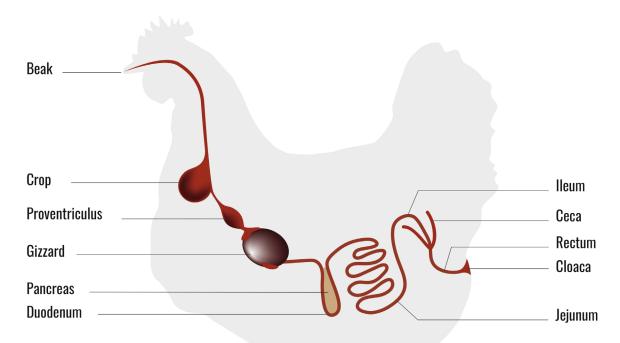


Figure 1: Hen's digestive system



2. ENERGY REQUIREMENTS

Energy is necessary for maintaining poultry's basic metabolic functions (the maintenance), body weight growth and egg production. It is supplied by dietary nutrients: fats, carbohydrates, and proteins... The "Metabolizable Energy" (ME) system is usually used to describe the energy content of poultry diets. ME is the difference between the gross amount of energy of a feed consumed and the gross amount of energy excreted in faeces, urine, and gaseous products. ME is therefore used to express the available energy content of a diet.

2.1. ENERGY EVALUATION

As illustrated in table 1 below, the ME values assigned to feed ingredients of the same name by different nutrient databases differ substantially. Geographical origin and plant variety may be the source of slight modifications in the composition of the raw materials which can lead to variation in ME values.

Table 1 : Value of o	corn, wheat ar	nd soya bean	meal showing	difference	s in ME values

Country – Table	Co	Corn		Wheat		Wheat Soya bean meal		meal 48%
	Kcal/kg	MJ/Kg	Kcal/kg	MJ/Kg	Kcal/kg	MJ/Kg		
Brazil – Rostagno (1)	3 381	14.15	3 046	12.74	2 302	9.63		
Europe – Janssen (2)	3 289	13.79	3 036	12.69	2 323	9.72		
France – INRA (3)	3 203	13.40	2 988	12.50	2 280	9.53		
Netherlands – CVB (4)	3 415	14.29	3 258	13.63	2 309	9.66		
USA – Feedstuffs (5)	3 390	14.18	3 210	13.43	2 458	10.28		

- (2) Rostagno, H.S. (ed). 2005. Brazilian tables for poultry and swine. Composition of feedstuffs and nutritional requirements. 2nd ed. Departemento de Zootecnia, Universidade Federal de Vicosa, Brazil.
- (3) Janssen, W.M.M.A. (ed). 1989. European table of energy values for poultry feedstuffs. 3rd ed. Spederholt Center for Poultry Research and Information Services, Beekbergen, the Netherlands.
- (4) Sauvant, D., J-M Perez, and G. Tran (eds). 2004. Tables de composition et de valeur nutritive des matières premières destinées aux animaux d'élevage. INRA 2^{nde} ed. INRA-AFZ, France.
- (5) Centraal Veevoederbureau (CVB). 2008. CVB Table booklet feeding of poultry. CVB-series no.45.
- (6) Feedstuffs 2008 Reference issue and buyers guide. Feedstuffs, September 10, 2008. Minnetonka, Minnesota, USA.

The main differences come from:

- The chosen method of measurement;
- The animal used as model (adult poultry versus growing chicks);
- The apparent ME and True ME (taking into account endogenous energy);
- The feed intake during trial;
- Anti-nutritionals factors;
- The correction with nitrogen balance;
- Poultry house temperature...

As a result, the calculated ME value of a given diet may vary substantially depending on which ME values were used for the individual feed ingredients. In theory, TME is more reliable. But practical estimation of Endogenous Energy is difficult (since it depends on various factors such as feed intake or type of feed...). In practice, AME is the more commonly used system in all continents.



Nitrogen retention introduces a deviation of the ME value, as it is very dependent on the physiological status (growth, production or maintenance), the nature of the feed or the feed intake level. Since the goal is to formulate a balanced feed for all physiological status, a correction for zero nitrogen retention has been used in most research works.

Each country, and even every nutritionist, has its own method to calculate the energy (the equations, and therefore the energies are sometimes very different for the same raw material), we will make recommendations in ranges to cover a maximum of possibilities. However, these values must be adjusted with a local nutritionist.

2.2. ENERGY REQUIREMENTS

The energy requirements of laying hens depend on the bodyweight, production, temperature, activity and feathering. We recommend the following formulas to determine their energy requirements :

Brown-egg hens in cages at 22°C

 $E = 130*W^{0,75} + 1.8*M + 3\Delta W$ from 18 to 35 weeks

 $E = 130^{\circ} W^{0.75} + 1.8^{\circ} M + 6\Delta W$ after 35 weeks

White-egg hens in cages at 22°C

 $E = 137* W^{0,75} + 1.8*M + 3\Delta W$ from 18 to 35 weeks

 $E = 137^* W^{0,75} + 1.8^*M + 6\Delta W$ after 35 weeks

With E : Energy required per day (kcal/day), W : live weight (kg), M : daily egg mass (g/day) and ΔW : daily weight gain (g/day).

Between 15 and 30°C, energy requirements vary inversely to ambient temperature: approximately 2 Kcal per kg of live weight, for a variation of 1°C, i.e. 1.4 g of feed per hen and per degree. Above 30°C and when thermoregulation becomes difficult, feed consumption decreases significantly.

❖ ALTERNATIVE SYSTEMS

Maintenance requirements for hens kept on the floor (with or without an imposed course), increase by 10% due to higher levels of activity and feed waste. The coefficients corresponding to maintenance requirements are therefore of 143 for brown-egg strains and 151 for white-egg strains.

2.3. ENERGY REGULATION

During the first ten weeks, pullets cannot regulate they energy intake according to the energy level of their diet. This is why any increase of the energy level results in a growth increase. We thus recommend the use of feed in crumble form during the first five weeks in order to increase consumption due to easier feed prehension, shorter feed consumption time and improvement of feed conversion ratio.

Table 2: Comparison of the influence of feed presentation on the body weight of pullets at 5 weeks of age

Energy level	Mash	Crumble
3100 Kcal	375 g	412 g
2790 Kcal	345 g	405 g

(1) Newcombe (1985)



After ten weeks of age, pullets correctly regulate their energy intake according to the energy level of the diet. The goal becomes then to develop the pullets' ability to eat feed, so that they can increase their consumption by 40% in the first few weeks of lay. During this period, it is important to develop their digestive system by using diets with an energy level equal or higher than the one of the layer's diet.

2.4. ENERGY LEVEL AND FEED DILUTION

Diluting the feed induces an increase in the volume and quantity of feed to ingest. Feed intake varies with the raw materials used and depends in particular on cellulose content. Feed dilution has an impact on :

- Production: limited impact of approximately 1%;
- Average egg weight: the reduction can be estimated at 0.4% for an energy level variation of 100 kcal / kg;
- Feed conversion ratio : when expressed in Kcal, the FCR improves by 0.8% when the energy level increases by 100 Kcal ;
- Digestibility: fibers improve the digestibility of the starch by enhancing gastro-intestinal reflux of bile salts as well as increasing the retention time in the gizzard;
- Liveability: Diluting the feed results in a feed intake increase both in volume and quantity, increasing therefore feed consumption times. This leads to a reduction of feather pecking and of mortality related to this behaviour. It has been demonstrated that pecking is inversely proportional to feed consumption time. A very low fiber level in the diet is connected to feather pecking. Indeed, hens try to satisfy a specific need for insoluble fiber (lignin), that enhances feed retention in the gizzard. That is why sometimes, layers seeking their fiber needs by consuming feathers.

Fiber is a nutritionally, chemically and physically heterogeneous material. This heterogeneous mix can be categorized into two major subclasses: soluble, viscous, fermentable fiber and insoluble, non-viscous, non-fermentable fiber. Differentiating between water-soluble and insoluble fiber components has helped elucidate the physiological effects of fiber (Newman et al., 1992). As the two subclasses have different roles in digestive / absorptive processes within the gastrointestinal tract (table below).



Table 3: Soluble versus insoluble fibers

Soluble fibers	Insoluble fibers
 Lowers intestinal passage rate Reduces digestion of fat, protein and starch Constitutes an energy source for monogastric animals Affects the viscosity of the digesta Is mainly made of fermentable parts Reduces faecal dry matter contents Binds nutrients (pectin) 	 Is a structuring fiber Accumulates in the gizzard. Regulates the passage of feed through the digestive tract Improves starch digestibility Increases intestinal passage rate Can only be poorly fermented Stimulates intestinal villi growth Does not constitute an energy source for young monogastric animals Increases faecal dry matter contents Orientation and development of the
	microbiota

For all high fiber diets, it is essential that animal growth remains in the range recommended for the given breed. With low ME diets, feed intakes are higher than those observed with higher ME diets (but the feed is often less expensive). Sufficient amounts of water shall also be available to allow the feed to swell in the digestive tube thus enhancing the feeling of satiety.

The use of diluted diets, especially in the growing stage, depends mainly on the availability and cost of raw materials. Some high fiber ingredients are not well known and their ME is not well defined while others increase the risk of contamination by mycotoxins concentrated in fibrous seed coatings (same situation with co-products of grain that focus mycotoxins).

2.5. ROLE OF FAT

Energy regulation is modified by the presence of fat in the diet which enhances feed presentation and palatability. It has been demonstrated that an increase in fat content enhances feed intake. Between 2,200 and 3,000 kcal, a 100 kcal increase in energy level leads to an increase in energy consumption of approximately 1.2% if it is obtained without addition of fat and of 1.4% when fat is added (Joly, 2005). At an equal energy level, the energy intake increases by 2.8% with the addition of 4% fat that improves the palatability and the presentation by gluing fines particles together.

Increasing the fat content in the diet does not seem to affect the number of eggs produced. However, egg weight increases significantly, especially at the beginning of the laying period. Oils rich in polyunsaturated fatty acids have a greater impact on egg weight increase.

Fat has several characteristics that make it especially useful in feed formulations :

- Fat is the concentrated source of energy. Fat has about 2.25 times more energy per unit of weight than carbohydrates.
- Energy from fat is generally more efficiently used (better assimilation) by poultry than energy from protein or carbohydrates, especially when storing fat in tissues.



- Fat has a relatively low heat increment, which means that less body heat (extra heat) is produced from digesting and metabolizing a calorie from fat than a calorie from protein or carbohydrates. This is especially beneficial when poultry is heat-stressed or in hot climate.
- Fat blends containing vegetable oils are a good source of linoleic acid and other essential fatty acids. If the linoleic acid content is marginal in some grain-based diets, there is a higher risk for producing eggs of smaller than normal size.
- Added fats and oils bind dust and increase the palatability of mash feed. However, one has to make sure that they are good in quality, stabilized to avoid oxidations and prevent rancidification. Be careful because sensibility at: heat, light, oxygen...
- Unsaturated oils and fats (solid at 35°C, such as palm oil for example) allow better gluing of fines and a better hold of pellets, thus improving the presentation of mash and pellet.

Polyunsaturated fatty acids (PUFA), and especially n-3 PUFA, omega 3, have beneficial effects on immunity and inflammatory diseases, but also on cell membrane integrity, immune competence, fertility and embryonic development. They are preferable where possible.

- Pullet feed: its energy level shall be superior or equal to the one of « layer feed », but its density shall be lower to promote consumption when hens enter the laying period.
- Layer feed: at the first stage of egg production, the goal is to promote feed consumption in order to rapidly obtain eggs of marketable size. It is thus recommended to use a diet rich in fat, with a minimum insoluble fiber (lignin) content. After the laying has begun, a diet richer in cellulose will protect the feathering and will decrease the risk of pecking. This strategy can be of particular interest for alternative poultry farming (free range, biologic...), especially when there is no litter on the course.

From a practical point of view, the effect of low density, high cellulose (insoluble fiber) raw materials may be balanced by the use of fats. Feed granulometry has also an effect on energy consumption. If the feed is too finely grounded, the energy consumption is reduced.

It thus appears that the three following factors must be controlled: feed presentation, fiber content and fat content. A balance between these three criteria must be sought to allow the expression of the genetic potential at a lower cost. Hens' feed consumption time depends on the volume ingested and density of diet. Feather pecking is inversely proportional to feed consumption time. For hens reared on the floor or in aviary, it is thus necessary to avoid very high-energy diets and to add a minimum amount of fiber. It is also recommended to add a minimum amount of litter over the course. **Energy regulation is not specific to a breed (white-egg layer, brown-egg layer or tinted-egg layer), but depends on the dilution methods used.**



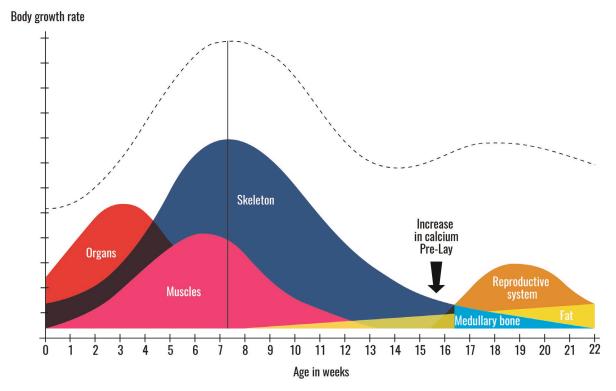
PROTEINS AND AMINO ACIDS REQUIREMENTS

3. PROTEINS AND AMINO ACIDS REQUIREMENTS

Proteins are structural components of tissues such as feathers and muscles. Poultry uses amino acids, the elementary components of proteins. A crude protein gives relatively little information on the composition in amino acids and/or their availability. Since poultry does not synthesize some amino acids or since the amounts produced are insufficient, these amino acids must be supplied by the feed.

Over the past thirty years, genetic progress in productivity and feed efficiency has led to a significant increase in amino acid requirements. Today, nutritionists agree to the expression of amino acid requirements in milligrams of amino acids per gram of egg produced. This allows them to make some adjustments according to the strains, production, feed intake.

The total amino acid requirement of a hen includes three components : a requirement for maintenance, a requirement for tissue protein accretion (the growth) and a requirement for egg production.



Schema: Corporal evolution of pullet growth according to the age

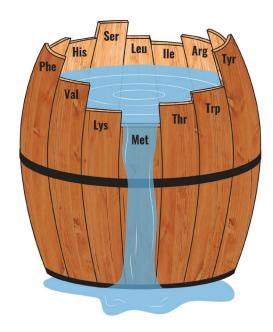
Forced by economical and environmental reasons, the ineluctable reduction in amino acid content implies a better knowledge in amino acid requirements. The "ideal" protein concept is defined by satisfying amino acid requirements. The formulation shall then be based on the content in limiting amino acids of the chosen raw materials and their digestibility. Formulating diets based on digestible amino acids has allowed the reduction of the safety margin. This method gives a better estimate of the bioavailability of amino acids in the feed. Modern diets should solely be based on digestible amino acids. Since this formulation process is more accurate, it generates more cost-efficient diets and can lower the environmental impact in comparison to a diet based on total amino acids or crude protein.

In any case, the formulation shall take into account the need to satisfy all the requirements in essential amino acids, notably in methionine (met), cystine (cys), lysine (lys), threonine (thr), tryptophan (trp), isoleucine (ile) and valine (val).



PROTEINS AND AMINO ACIDS REQUIREMENTS





The use more and more of synthetic amino acids has changed the balance in diet formulation this twenty last years.

- Isoleucine and valine are limiting factors when diet formulas are based on wheat or when meat products are excluded from the feed (Valine is now common in feed mills).
- Tryptophan is a limiting factor in formulas where the base consists of corn, soya bean meal or meat products.

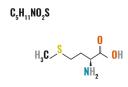
As soon as the methionine, lysine, isoleucine, valine and tryptophan requirements are satisfied, an addition of 300 mg of proteins per gram of egg produced shall satisfy the requirements for the other amino acids. Moreover, if the formulation takes correctly into account the isoleucine and valine requirements, it does not seem necessary to require a minimal constraint in protein (Joly, 2002).

3.1. METHIONINE REQUIREMENTS

When the requirements are expressed in milligrams per gram of egg produced, they are independent from the productivity level. However, when they are expressed in daily requirements, they are proportional to the productivity. Based on an economical optimum, the requirement is estimated to 7.56 (+/-0.37) mg of total methionine per gram of egg produced, i.e. 7.11 mg of digestible methionine, with a digestibility coefficient of 94%.

3.2. CYSTINE REQUIREMENTS

Since cystine is synthesized from methionine, its requirement is difficult to establish. Some authors are thus considering a requirement in methionine+cystine, whereas others decide to consider only the requirement in methionine if it appears to be independent from the cystine level of the feed. The cystine requirement seems to be lower than 4.5 mg per gram of egg produced.





PROTEINS AND AMINO ACIDS REQUIREMENTS

For the formulation, it is advised to introduce a minimal constraint for the group M+C of approximately 12.1 mg per gram of egg produced, with a digestibility coefficient of 94% for methionine and 84% for cystine.

3.3. LYSINE REQUIREMENTS

Mathematical model analysis does not provide a clear estimate of lysine requirements as the requirement is overestimated by 10%. However, a study conducted by P. Joly in 2008 led to an estimate for the lysine requirement of 15 mg per gram of egg produced, with a digestibility coefficient of 89%.

$$\begin{array}{c} \mathbf{C_6H_{14}N_2O_2} \\ \\ \mathbf{H_2N} & \begin{array}{c} \mathbf{NH_2} \\ \end{array} \\ \end{array} \\ \mathbf{O} \\ \end{array}$$

3.4. SUMMARY OF DIGESTIBLE AMINO ACID REQUIREMENTS

Table 4 : Summary of daily amino acid requirements

Digestible Amino Acids	Requirement in mg / day
Lysine	800
Methionine	430
Methionine + Cystine	690
Tryptophan	180
Arginine	990
Threonine	550
Valine	770
Isoleucine	720

3.5. CALCULATION OF REQUIREMENTS

During the formulation, it is important to make sure that all the amino acid requirements are satisfied according to the guidelines in effect. Several factors need to be taken into consideration: age of the animals, feed intake, energy level, and ambient temperature. The calculation is always based on the following formula:

(Daily amino acid requirements * 100) / Daily feed intake

For example, if the daily requirement for lysine is estimated to 800 mg / day and the average intake is 110 g, the following percentage of lysine will be calculated: (800 mg * 100) / 110 = 0.727% of digestible lysine in the feed.



4. CALCIUM APPETITE AND EGGSHELL QUALITY

Eggshell quality has become even more critical because of the lengthening of production cycles and the development of automatic egg collection systems. While substantial genetic progress has been achieved. However, diet and feeding techniques are the keys to the expression of this genetic progress. Eggshell quality and colour depend essentially on the hen's ability to use its dietary calcium during shell formation. A good calcium diet improves eggshell quality, colour, prevents bone demineralization (osteoporosis) and fractures.

4.1. CALCIFICATION AND SOURCES OF CALCIUM

Nowadays, the time taken to produce an egg is close to 24 hours. The ovulation occurs within 5 to 10 minutes following the previous oviposition. Calcification starts after albumen hydration and appearance of crystalline nuclei in the protein framework of the shell membrane. i.e. approximately 10 hours after the previous egg has been expelled. The calcification lasts about 12 hours and starts shortly before turning off the lights and this independently of the chosen lighting program. The calcification process is the following:

- At the very beginning of the calcification, the proventriculus secretes large amounts of hydrochloric acid in a continuous manner.
- The gizzard mixes the food and expels a calcium-rich solution that is immediately absorbed.
- Calcium binds to the Calbidin protein (a protein with a high affinity to calcium) to pass through the intestinal barrier.

Ovulation at 6h

Night

Rapid Calcification

Calcification

Time (80%)

Representation

Finter in Shell Gland at 11h

Calcification at 16h

Night

Rapid Calcification

Rapid Calcification

Rapid Calcification

Period

Schema: Course of calcification on a day

Radioactive calcium has been used to demonstrate that it only takes 30 minutes between the intake of calcium and the moment when it is found in the shell. Where the interest of 'fine' calcium, but also particulate calcium to maintain a constant deposit during the night.

Eggshell weight increases regularly of approximately 0.5 g per hour for the 12 hours of the calcification period. If during the calcification, calcium is not available in sufficient quantity in the digestive tract, eggshell quality will suffer.

There are two sources for the calcium used during the calcification: feed is the main source and the medullary bone is the secondary one. The calcium in the medullary bone is only mobilized if there is a deficiency in dietary calcium in the gizzard during the calcification. However, the medullary bone does not store enough calcium to fully compensate a calcium deficiency. Some studies have shown that reducing the dietary calcium supply by only 1% had an immediate negative effect on eggshell quality. Moreover, demanding calcium constantly from the



medullary bone results in osteoporosis, fractures, mortality and medium-term deterioration of eggshell quality through an exhaustion of animals (Nau et al, 2010, Science et technologie de l'œuf 116-117).

4.2. CALCIUM REQUIREMENTS

Since hens export approximately 2.2 g of calcium daily to build eggshell, it is vital that their diet provides a daily supply of this mineral: they shall eat approximately twice as much as what they use.

Calcium absorption occurs essentially during the 12 hours of the calcification. The absorption rate is then way above 70%. In the absence of calcification, the absorption rate can get down to 20%; calcium is then used to rebuild the medullary bone.

For this reason, the calcification depends on the amounts of calcium ingested at the end of the day and on the molecular size of the calcium. Using granular calcium carbonate of 2 to 4 mm allows an increase of calcium storage in the gizzard. The solubility of the carbonate was as important as the size of the particles (a common goal of solubility is between 60 and 80%). Because these particles dissolve more slowly, higher quantities of calcium are available towards the end of the night. Small size particles (less than 1 mm) are not well retained in the gizzard and are found partially in the faeces. This results in reduced quantities of absorbed calcium leading to a deterioration of eggshell quality.

- Brown egg hens: the intake of particulate carbonate must represent 60% of total intake. This
 corresponds to an incorporation of approximatively 65 kg of particulate calcium carbonate per tonne of
 feed. The remaining 40% must be supplied in pulverulent form to promote the reconstruction of the
 medullary bone.
- White egg hens: the intake of particulate carbonate must represent 50% of total intake and the
 remaining 50% must be supplied in pulverulent form. These hens tend to lay eggs later after the light is
 turned on, allowing them to more effectively use the pulverulent calcium from the feed ingested early in
 the morning.



Photo: Particulate calcium carbonate from 3 to 5 mm

Calcium carbonate, which is used in powder form as a whole, is responsible for a reduction in the quality of the eggshell and a decrease in consumption because it increases the fineness of grinding of the feeds. Supplying calcium carbonate solely in powder form results in a decrease of eggshell quality and a decrease in consumption because the grist is too fine. Inversely, the supply of granular calcium carbonate results in increasing calcium intake at the end of the day by promoting higher calcium consumption just before shell formation. The start of the calcification triggers a specific calcium appetite that drives the hen to eat high quantities of calcium. So, always available feed before extinction to satisfy this need.



Eggshell quality also depends on the solubility of the calcium. To achieve a good retention rate, low soluble calcium shall be used. When calcium solubility is too high or too low, shell quality is negatively impacted. However, hens that have not completed their calcification after the lights have been turned on need a very rapid supply of very soluble calcium. It is thus interesting to keep some calcium in powder form in the diet which should be available in sufficient quantity in the morning when lighting.

With increasing age and egg weight, it is sometimes necessary to increase the proportion of particulate limestone at 70/30 for the Browns and 60/40 for the Whites, to compensate a drop of shell quality.

❖ INFLUENCE OF AGE ON CALCIUM REQUIREMENTS

As the hens age, shell weight increases, the quantity of calcium deposits increases. It is thus important, at the end of the laying period, to adequately satisfy layer's calcium requirements by increasing the calcium content in the feed as soon as 45/50 weeks of age. At this age, more than 2.4 g (+/- 0.22 g) of calcium are deposited which corresponds to a theoretical daily requirement of 4.8 g. Our recommendations are therefore function to the age: 4.2 g before 45 weeks, 4.5 g from 45 to 70 weeks and 4.8 g beyond this age. Must be adjusted according to the solutiliby of carbonate and observed shell quality.

❖ FEED DISTRIBUTION AND LIGHTING SCHEDULES

Since the goal is to have sufficient quantities of calcium available throughout the calcification period, feeding times shall fit the hens' calcium requirements to obtain a good eggshell quality. Calcium intakes at the end of the day shall thus be encouraged by adapting the feeding times and by leaving the feeders empty in the middle of the day or end of the morning (never late in the day before the extinction or very early in the morning just after lighting).

When possible, hens ingest more than 50% of their ration during the 6 hours prior to lights out in order to satisfy their specific calcium appetite. A fraction of this calcium intake is stored in the crop.

Since hens do not eat during the night, shell quality depends on the quantity of calcium remaining in the digestive tract at the end of the day. A way to improve shell quality is to encourage hens into consuming calcium in the middle of the night with the use of flashing lights.

4.3. PHOSPHORUS REQUIREMENTS

During the calcification, a fraction of bone calcium is desorbed freeing calcium and phosphate ions into the bloodstream. Phosphate ions are then reabsorbed by the kidneys (a part only is recycled). Consequently, rebuilding bone calcium storage requires supplying phosphate. Phosphate requirements depend on the demand in calcium stored in the bones, on the form under which calcium is supplied in the diet, and on the type of feeding. Indeed, the use of granular calcium and adequate feeding times limit the use of bone calcium and thus reduce the loss of phosphorus in the urine. The need for phosphorus via the feed is then lower.

A shortage in phosphorus leads to a demineralization of the hen's skeleton which can over time cause fractures (cage layer fatigue), decrease egg production and increase mortality.

Phosphorus recommendations shall take into account the significant variations of raw material phosphorus content and quality as well as phytic phosphorus availability which for the most part is related to the presence of natural phytases or additives. There are several methods for expressing available phosphorus, in particular as a function of the basic reference which can vary. This criterion is essential because the digestibility of phosphates is not the same between a monocalcium (more assimilable) and a dicalcium dihydrate (about 75% against a monocalcium with reference base 100). A phosphate origin is never pure at 100%, it is always a mix between the different forms. Example with a monocalcium who can be constituted to : monocalcium 75% + dicalcium 15% + tricalcium 10% (undigestible). Today, some laboratories are able to analyse phosphates in order to characterize them better by fraction and thus to adjust in consequence the matrix value.



Adding phytases to the feed allows the increase of phytic phosphorus availability. Each phytase supplier has different recommendations in term of valorisation which can vary to 0.8 to 1.6 g of available phosphorus (more with extra-dosing). Phytases, whether natural or microbial origin, are easily degraded by heat, even though thermosresistant coatings are available today. This is to be taken into account in formulation and during the manufacturing process of the feed.

Excess of phosphorus tends to have a negative impact on shell quality. We recommend to reduce it in the end of lay to improve the eggshell quality.

It is thus recommended to:

- Use a pre-layer feed sufficiently rich in phosphorus to allow the development of the medullary bone which is made of a phosphocalcic frame.
- Take into account the form in which calcium is supplied. Phosphorus requirements are lower when the added granular calcium has a size comprised between 2 and 4 mm and has a low solubility.
- Maintain a sufficient safety margin at the beginning of the laying period to avoid any risk of deficiency (especially in breeders).

4.4. SODIUM AND CHLORINE REQUIREMENTS

A sodium deficiency will cause a general weakening of the body, pecking, cannibalism and a decrease in production. A deficiency in chlorine will lead to a reduction in consumption until the feed is totally rejected.

An over-consumption of water will lead to a deterioration in the quality of the droppings. In order to supply chlorine-free sodium, it is recommended to use in addition to the salt, sodium bicarbonate (or sulphate) with a preference for bicarbonate due to its positive effect on the electrolytic balance.

Sodium as well as chlorine requirements are estimated to 120 mg / day. To include a safety margin, it is recommended to add a daily supplement between 160 and 200 (Na) or 160 and 220 (Cl) mg / day are recommended. The maximum chlorine can be adjusted according to the moisture of the droppings (with a reduction if the droppings are too wet).



5. FEED PRESENTATION

5.1. IMPORTANCE OF GRANULOMETRY

Feed consumption results from a choice implying particle selection. Being grain eaters, poultry's consumption is related to feed presentation. Poultry preferably eats particles over mash, thus presenting finely ground feed may lead to reduced feed intake which in turn can generate deficiencies whereas a coarser grist or a diet in crumble or pellet form promotes feed consumption.

❖ FEED IN CRUMBLE FORM

The impact of feed presentation is well known in broilers. Pullets behave in the same manner. Indeed, it has been demonstrated that during the first weeks of age, giving a feed under crumble form improves growth by 10 to 32% according to the energy levels. In theory, presenting a diet in crumble or pellet form may contribute to better bacteriological quality and will lead to shorter feed consumption time with a lower chance of diet segregation compared to mash.



Photo: fine crumble







This however assumes that:

- The production lines before and after the pelleting process are clean and well maintained (see chapter on feed hygiene);
- The feeding systems in operation and the raw materials used are providing poultry with pellets or crumbles of good quality at the feeder levels;
- Hardness and durability should not be tested only at the factory outlet, but also in the feeders at the end of the distribution system.

Very often, difficulties in obtaining good quality pellets and crumbles cause the following technical problems:

- Breakdown of crumbles/pellets in feed distribution systems (especially by chain, common in layers) and build-up of fine feed particles in the feeders;
- Shell quality issues related to difficulties in using granular limestone;
- Increased feather pecking caused by a short feed consumption time. Indeed, the coarser the feed is, the shorter the feed consumption time will be ;
- Increased competition for coarser particles leading to feeding heterogeneity if the space around the feeders is insufficient (over-density), or if the crumble quality is too low;
- Increased manufacturing costs.

The use of crumbles or pellets during the laying period requires :

- The control of light intensity to reduce the risks of feather pecking due to short feed consumption times;
- The implementation of an adequate feed distribution schedule to reduce the effects on eggshell quality related to the use of small calcium particle sizes (midnight lighting);
- More attention in Brown because they lay earlier which results in less use of the pulverulent calcium associated with a morning consumption of feed.

The two main physical qualities of crumble or pellet are:

- Hardness: It is a measure of how resistant the pellets are to breaking when a force is applied (scale from 1 to 10).
- Durability: It is a measure of how long the pellets will last without breaking apart despite sustaining mechanical impacts during transportation from the feed factory to the farm and distribution of the feed at the farm → resistance to abrasion and impacts (expressed in %).

❖ FEED IN MASH FORM

In the rearing stage, with the exception of the first three or five weeks when the diet should be provided as crumbles, the use of uniform and regular mash feed is preferred. However, we advise to use crumbled feed up until ten weeks of age when it is difficult to obtain a sufficient body weight at this age.

During the laying period, if the feed is presented in mash form, the feed consumption time will be longer. However, if feed consumption times become too long, it is important to switch to a coarser mash and/or to increase the density of the feed (via the choice of raw materials or the incorporation of oil/grease).





Photo: medium mash (2200 tr/min, fine grill),

Photo: coarse mash (1800 tr/min, big grill)



Mash quality is assessed by studying the size and uniformity of its particles. Good uniformity of particle size is essential because poultry prefers bigger particles. If the mash is heterogeneous, the dominant birds will quickly eat those bigger cereal particles, while the rest of the group will eat the finer particles. If the space around the feeders is insufficient, a heterogeneous batch is obtained during the growing period as well as during production.

Being grain eaters, poultry has a digestive tract designed to quickly ingest its feed ration. The ingested feed is then stored in the crop to be "hydrated" and "acidified" by lactic acid secretions before going through the proventriculus. In the proventriculus, hydrochloric acid, pepsin and mucus secretions are increased when the size of feed particle is large. In the gizzard, the feed is grinded, impregnated and pre-digested by the secretions from the proventriculus. The gizzard also regulates feed flow in and out of the lower digestive tract. The intestinal peristaltic motility slows down the feed flow, allows better absorption of the nutrients by the intestinal villi, and helps stabilizing the intestinal flora.

Too fine feed dietary particles will not allow the above-mentioned natural process to properly progress in good conditions. Effectively, small particles will not remain long enough in the crop and will not promote an adequate pre-digestion in the gizzard. This happens frequently when crumbles or pellets are made with a too fine mash. In this case, granulation is mostly chosen for thermal and health reasons and not because of its hardness and durability. It is thus recommended to use a coarse mash to produce pelleted feed.



In production, an adequate granulometry allows the increase of feed intake and egg production. Our recommendations are given below :

Particle diameter	Mash	Crumble
Inferior to 0.5 mm	5% max	5% max
From 0.5 to 1 mm	10%	10%
From 1 to 2 mm	35%	15%
From 2 to 3.2 mm	40%	30%
Superior to 3.2 mm	10% max	40% max

5.2. HOW TO OBTAIN THE RIGHT GRANULOMETRY

Obtaining the right granulometry depends on the two following factors :

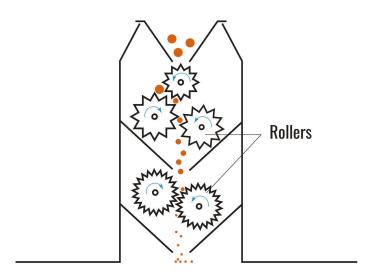
- Grinding technology used to manufacture the feed.
- Choice of raw materials and limits of their use depending on their presentation.

GRINDING TECHNOLOGY

Feed particle size depends mainly on the grinding method. Three types of grinders are available :

• **Grinders with fluted cylinders:** they are designed for heavy volume production. But they are more sensitive to deterioration by foreign bodies (stones, iron...), they use less energy and the feed produced has a more uniform particle size.

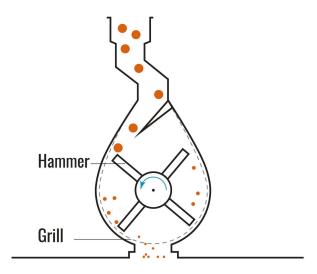
Schema: Principe of grinder with cylinders



• **Grinders with hammers**: they are more commonly used. Grinding is achieved both by contact between feed particles and the hammers and by the abrasive effect of the grills. Thus, the control of the grinding depends on the hammer peripheral speed, the grill mesh size, and the percentage of holes in the grill. Hammer peripheral speed is a combination of grinder diameter and rotation speed. For a given raw material, the higher the hammer speed is, the wider the distribution range of the feed particles will be.







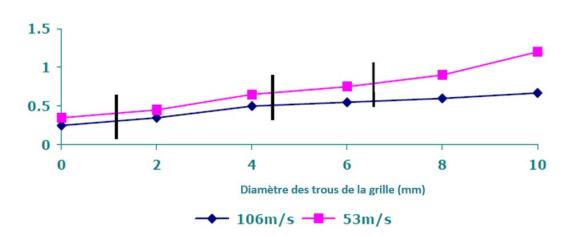
Example of calculation:

- Rotation speed = 1,500 RPM (Rotations Per Minute)
- Grinder diameter = 0.7 m
- Peripheral hammer speed = 0.7 x 3.14 x (1,500/60) = 55 m/s

If the grinder runs at 3,000 RPM, the peripheral speed is 110 m/s. 55 m/s is the most frequently used speed. Grinders with variable speed allow the adjustment of the speed to the raw materials and to the targeted feed particle sizes.

Figure 2: Influence of hammer speed on the grist size of corn







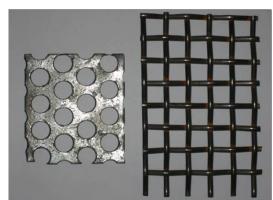


Figure 3: Grills with round mesh and grills with square mesh

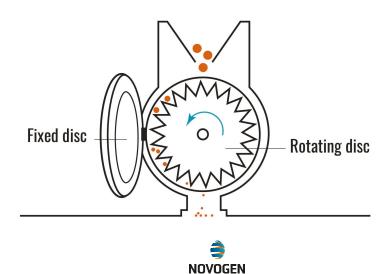
The two important criteria to take into account for grinder grills are mesh diameter (from 2 to 10 mm) and percentage of holes in the grill (from 27 to 52%). The higher these two values are, the higher the feed particle size and feed particle size distribution range will be.

Note that grills with square mesh screens have a higher proportion of holes as well as a lower wear rate. They also allow higher throughputs. Feed particle size and its distribution range must be regularly monitored. Excessive variation is a sign of hammer or grill wear. When hammers are worn, the distance between the hammer and the grill (normally 8 mm) is increased. The peripheral feed particle layer therefore becomes thicker and particle ejection is slowed down. The abrasive effect at grill level is increased. Grinder yield diminishes and more fine particles are produced. In the same manner, worn grills will tend to reject particles back to the grinder instead of letting them out. Hammers must be regularly monitored and changed.

Grinders with variable speed improve the uniformity of particle size and lower the amount of particles outside the desired range. Satisfying results are obtained when using grinders at a 55 m/s tangential speed along with large diameter mesh grills to reduce the production of fine particles and adding a post-grinding sifting step to exclude particles with a size above 3 mm.

Grinders with discs: A movable grinding disc rotates against a stationary disc and grips the product
to be grind. The compression force and the shear stress cause the desired grinding effects. The
progressive arrangement of the teeth of the grinding disc makes it possible to first carry out a first
crushing of the product and convey it by the centrifugal forces towards the outer zone of the discs
where the fine grinding takes place.

Schema: Principe of grinder with discs



It should be noted that the grinding technology, with equivalent particle size, does not matter! The main thing is not the equipment used but result of the grinding; either the particles size and their distribution.



Photo: Corn grinded with different particle sizes

CHOICE OF RAW MATERIALS

Here are our main recommendations for the use of raw materials :

- Incorporation of calcium carbonate in particulate form to 60 70% for browns; for whites the distribution must be 50 to 60% based on age.
- Limit the use of excessively pulverulent raw materials: the use is limited by the palatability of the feed and the intake levels observed in husbandry. A compromise must be found between the percentage of oil added to the feed and the use of pulverulent raw materials.
- Add vegetable oil or animal fat to help gluing finer particles and significantly improve feed palatability.
 The required percentage of added fat is a function of the percentage of fine particles present in the feed, as well as the manufacturing process (each feed mill/line of production is different).

In hot climates, a very coarse mash is better than a pellet both for price and palatability reasons. The use of this kind of feed allows for the addition of supplemental fat, if necessary.



Table 5: Laying hen & pullet major ingredients constraints (%)

		arter & rter		wer & lopper	Pre-La	y & Lay
	Min.	Max.	Min.	Max.	Min.	Max.
Corn	0	70	0	70	0	70
Sorghum	0	5	0	20	0	30*
Wheat	0	50	0	55	0	60*
Rye	0	10	0	20	0	20*
Barley	0	5	0	10	0	20*
Oats	0	2	0	6	0	6*
Wheat co-products	0	10	0	10	0	15*
Broken rice	0	15	0	15	0	20
Rice co-products	0	10	0	15	0	15
Soya bean meal	0	30	0	30	0	30
Full fat soya	0	10	0	10	0	10
Sunflower meal	0	8	0	15	0	25*
Cotton meal	0	2	0	4	0	5
Peanut meal	0	2	0	3	0	5
Dried Distillers Grains	0	3	0	10	0	15
Rapeseed meal 00	0	5	0	10	0	12
Fish meal	0	4	0	4	0	4
Vegetable oil (Satured)	0	1	0	2	0	3
Vegetable oil (Unsaturated)	0	2	0	3	0	4
Palm kernel cake	0	2	0	3	0	5
Oats hulls	0	0	0	4	0	5
Lucerne	0	1	0	2	0	3
Soya hulls	0	0	0	4	0	6
Sugar beet pulp	0	0	0	3	0	3
Molasse	0	2	0	2	0	2
Ca carbonate (granular)	0	0	0	2	4	10
Ca Carbonate (powder)	0	2	0	2	2	4

^{(1) *} these raw materials often require the simultaneous use of enzymes in order to maximize their values.

It is possible in some local contexts to exceed these maximums. The storage times of locally produced raw materials are generally shorter. That also means the knowledge of manufacturing process is facilitated in particular by more audit opportunities of these suppliers. The price is necessarily competitive, so, we can well characterize this R.M. with many analyses...



FEEDING PROGRAM AND DISTRIBUTION SCHEDULES

6. FEEDING PROGRAM AND DISTRIBUTION SCHEDULES

6.1. FEEDING DURING THE REARING PERIOD

To satisfy pullet requirements, we recommend four types of diets during the rearing period :

- A « starter » feed from 1 day to 5 weeks of age in the form of crumble. If body weights do not meet set goals, we recommend giving a starter feed for one more week (or using a specific Prestarter for the first week).
- A « grower » feed from 5 to 10 weeks of age in the form of coarse mash or crumble if the weights are too low.
- A « pullet » feed from 10 to 15 weeks of age in the form of coarse mash. Its energy level shall be superior or equal to the ones of the pre-lay and layer feeds to enhance feed intake at the beginning of the laying period. Be careful of too big differences of energy that can disturb the animals, especially at the entrance in lay.
- A « pre-lay » feed from 16 weeks of age to 2% lay in the form of coarse mash with carbonate particulate to exercise animals to consume it easily.

The animals must be weighted weekly in order to follow the growth at best and adapt (move forward or back) the transitions between feeds to reach the standard weight at 16 weeks. Never forget to calculate the homogeneity during weighing because the distribution of weights is also an important indicator of the good progress of a flock growth. The weight is not the only criterion to control, it also requires a well-developed digestive tract because a pullet should increase by about 30 to 50% its consumption in a few weeks as soon she will lay. A well-developed crop and gizzard are essentials for a good entrance in lay. A simple and widespread technic is the addition of insoluble fibers in pullet feeds.

After 10 weeks, it is also possible to distribute crumble feed, but we must ensure that the crumble is well presented. In any case, if the crumble is badly presented, it is better to distribute a coarse mash.

These different types of feed are characterized by a lowering of energy and protein levels. Since poultry is very sensitive to presentation and introduction of new raw materials, it is possible in order to facilitate dietary transitions to give out a diet corresponding to the mix of the two feeds for a few days. This transition phase may prevent under-consumption related to stress or adaptation periods.

6.2. FEEDING DURING THE PRODUCTION PERIOD

In production buildings, dietary programs can be divided into 4 or 5 parts:

- A « pre-lay » feed given out from 16 weeks of age to 2% lay. The main characteristic of this diet is its higher levels of calcium and phosphorus, necessary to build bone calcium reserves. If pre-lay feed is given in brooder-houses, it is advised to keep the same feed supplier for the production building to limit the stress caused by a change of presentation and formulation.
- A "layer 1" feed from 2% lay to 28 weeks of age. With this diet, richer in proteins and amino-acids, this allows to satisfy the production and the growth during the first weeks of lay. It is recommended to give out this feed up until feed consumption becomes stable and egg weight reaches 60/61 g. The amino-acid content of this feed shall be higher by approximately 7% than the one before the peak, because animals end their growth (weight gain of about 20% between the entrance in lay and the peak). A late diet switch, after 2% lay, can cause osteoporosis for the most precocious hens. To limit under-



FEEDING PROGRAM AND DISTRIBUTION SCHEDULES

consumption risks, we recommend the use of at least 1 to 1.5% oil to improve feed palatability and to promote a rapid increase in consumption and so on egg weight.

- A "layer 2" feed from 28 to 45 weeks of age. The composition of this diet depends on consumption levels to correctly satisfy hen requirements in proteins and energy.
- A "layer 3" feed from 45 to 70 weeks of age. This diet is characterized by an increase in calcium levels
 to compensate the deterioration of the calcification process with age. Since the persistency in lay has
 significantly improved over the past few years, it is difficult to reduce amino-acid levels without
 impacting production. However, it is possible to slightly lower the energy level, and in particular oil
 percentage, to stabilize egg weight.
- A "layer 4" après 70 weeks, to maintain a good persistency: with an increase in calcium, a decrease in phosphorus and energy level (with oil, to always master the egg weight).

6.3. DISTRIBUTION SCHEDULES

During the three first weeks, chicks shall have a permanent access to the feed in order to favour the start. From four weeks of age and up until 2% lay, all the feed distributions shall take place during the last four hours of the day. The last feed distribution shall occur right before the lights are turned off to allow pullets to eat the rest right when lights are turned on again. Finer particles will be eaten more easily in the morning. The amount of feed given will be adjusted so that the feeders are empty in the middle of the day. This is particularly important during hot weather periods (summer or hot climates).

During the laying period, the distribution schedules shall take into account behaviour of the hens:

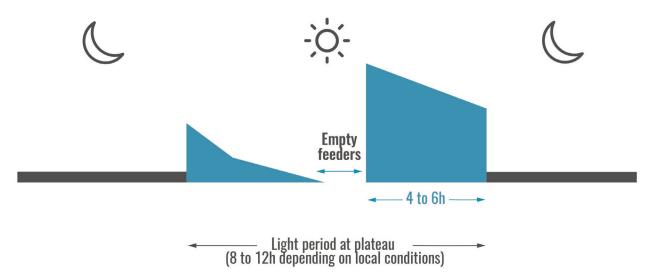
- More than 50 % of the feed is eaten spontaneously during the five-six last hours of the day.
- Too many occurrences of feed distribution increase competition between hens, result in deterioration if
 feed is presented in crumble form and create flock heterogeneity due to hen's preference for larger
 particles. This is why, we advise to carry out a minimum number of feed distributions.
- The number of distributions will be determined by feed density, feeding conditions, manual or mechanical distribution, and storage capacity of trolleys and feed hoppers.

Accumulation of fines particles leading to under-consumption shall be avoided. It is therefore recommended that the feeders remain empty for two to three hours (for the Brown strains) in the middle of the day to avoid under-consumption and increase feed intake at the end of the day. This does not qualify as a dietary restriction since hens adapt to the situation. The goal is ensuring that hens ingest the maximum of feed in the shortest time possible. For White strains, the empty feeder must be shorter, between 1 and 2 hours maximum.



FEEDING PROGRAM AND DISTRIBUTION SCHEDULES

Schema: Amount of feed consumed according to the time on a day (in end of rearing)



PRINCIPLES TO APPLY

Here are a few examples of distribution schedules :

- **Two distributions**: two-third of the feed will be given out approximately five to six hours before turning off the lights and the remaining third during the two to three hours after turning on the lights.
- Three distributions: the first distribution will occur five to six hours before lights off, the second approximately three hours before turning off the lights, and the third will occur during the two to three hours after turning on the lights.
- **Four distributions**: same schedule as for the three-distribution schedule with the addition of a fourth distribution during the night lighting period.
- **Five distributions**: the fifth distribution will occur approximately one hour after the first morning distribution.

To increase feed and calcium intake just before or during shell formation, feed shall be given out at the end of the day (and in the middle of the night, if it's necessary).

The morning distribution time shall be defined so as to obtain empty feeder in the middle of the day. In addition, not giving out feed during laying hours results in cleaner eggs, as to avoid egg laying on the floor in alternative system. These schedules should always be adapted to production system.

When the feed is distributed by a trolley, he shall be immediately returned to the end of the battery. This helps avoiding competition for large particles.

When using line/chain feeding systems, it is preferable to carry out feed distribution in the dark or to have rapid feed distribution systems to avoid any selective sorting.



7. NUTRITIONNAL RECOMMENDATIONS

Some important points:

- All our recommendations are made with a quality protein. That means with a good availability and digestibility of Amino Acids (A.A.). Any quality degradation (see raw materials chapter) must result in a proportional decrease in the A.A. matrix value in order to avoid any deficiency that would limit the genetic potential of the animals.
- Any anti-nutritional factors that may alter the bioavailability of A.A. must be controlled, taken into account in terms of risk and managed accordingly.
- There are many methods of defining available phosphorus, in particular because of the basic reference which may be different (monocalcium, anhydrous dicalcium, monosodium...). It is therefore necessary to adjust locally according to the field results.
- These recommendations are given for an average temperature in husbandry between 20 and 22°C, an optimal breeding and material.
- It is recommended, whenever possible, to formulate feeds in A.A-ratios, on the basis of lysine in order to avoid any imbalance (causing a greater need and losses due mainly to competition between A.A.).

	Pullets	Laying hens
Dig. Lysine	100	100
Dig. Methionine	48 / 50	52 / 58
Dig. Methionine+Cystine	76 / 80	85 / 90
Dig. Tryptophan	19 / 20	20 / 22
Dig. Threonine	68 / 74	66 / 74

These ratios are indicated by ranges, they are adjusted according to the observed field performances and the desired production objectives (typically feather, egg weight, etc.).

 Attention to the cumulative potential enzymatic valuations on A.A., protein and energy (see chapter enzymes).

We recommend **a minimum total fibers** for all their positive effects on the digestion and behaviour of the animals. For cage farms, 3.5% is the minimum. These levels need to be increased and adjusted for alternative production systems.



7.1. NUTRITIONAL RECOMMENDATIONS FOR REARING PERIOD FOR THE NOVOGEN BROWN AND WHITE

Table 6: Nutritional recommendations for the rearing period

	Starter	Grower	Pullet / Developer	Pre-Lay
	0 - 5 weeks	6 - 10 weeks	11 - 15 weeks	16 weeks to 2%
	Crumble	Crumble or Mash	Coarse Mash	Coarse Mash
EM Kcal / Kg	2900 - 3000	2800 - 2900	2700 - 2800 (1)	2700 - 2750 (1)
EM Kcal / lb	1316 - 1362	1270 - 1316	1225 - 1270	1225 - 1247
% Crude protein	20.0 - 21.0	18.0 - 19.0	16.0 - 17.0	16.0 - 17.0
% Crude fiber	-	2.5 - 5.0	5.0 - 6.5	3.5 - 5.5
% Crude fat	3.5 - 5.5	3.0 - 4.5	2.5 - 4.0	2.5 - 4.5
% Tot. Lysine	1.12	0.97	0.75	0.81
% Tot. Methionine	0.51	0.45	0.35	0.41
% Tot. Methio + Cystine	0.86	0.76	0.67	0.70
% Tot. Tryptophan	0.22	0.20	0.17	0.19
% Tot. Threonine	0.77	0.67	0.57	0.59
% Dig. Lysine	1.00	0.86	0.67	0.72
% Dig. Methionine	0.48	0.42	0.33	0.37
% Dig. Meth & Cystine	0.76	0.67	0.58	0.62
% Dig. Tryptophan	0.19	0.17	0.15	0.16
% Dig. Threonine	0.68	0.58	0.48	0.50
% Calcium	1.00 - 1.10	1.00 - 1.10	0.95 - 1.05	2.20 - 2.50
% Available Phosphorus	0.45 - 0.50	0.40 - 0.45	0.37 - 0.40	0.42 - 0.45
% Sodium	0.17 - 0.20	0.16 - 0.18	0.16 - 0.18	0.16 - 0.18
% Chlorine	0.16 - 0.20	0.16 - 0.20	0.16 - 0.20	0.16 - 0.22
% Potassium	0.70 - 0.80	0.65 - 0.80	0.60 - 0.80	0.60 - 0.80

⁽¹⁾ The energy level of the pullet feed 11 - 15 weeks and pre-lay should be equal to that of the laying feed at the beginning of lay.



⁽²⁾ In hot climates, it is recommended to increase amino acid levels by 5% in order to compensate for lower consumption.

7.2. FROM 2% OF LAY TO 28 WEEKS FOR THE NOVOGEN BROW

Table 7: Nutritional recommendations from 2% of production to 28 weeks

	Layer 1					
Ingested quantity (g/d)	Need g/ bird / day	100 (1)	105 (1)	110 (1)	115 (1)	120 (1)
% Crude protein	19.5	19.5	18.6	17.8	17.0	16.3
% Crude fiber	-			3.5 - 6.0		
% Crude fat	-			2.5 - 5.5		
% Tot. Lysine	-	0.96	0.91	0.87	0.83	0.80
% Tot. Methionine	-	0.49	0.47	0.45	0.43	0.41
% Tot. Methio + Cystine	-	0.82	0.78	0.75	0.71	0.68
% Tot. Tryptophan	-	0.22	0.21	0.20	0.19	0.18
% Tot. Threonine	-	0.69	0.66	0.63	0.60	0.58
% Tot. Isoleucine	-	0.85	0.81	0.77	0.74	0.71
% Tot. Valine	-	0.90	0.86	0.82	0.78	0.75
% Dig. Lysine	0.85	0.85	0.81	0.77	0.74	0.71
% Dig. Methionine	0.46	0.46	0.44	0.42	0.40	0.38
% Dig. Meth & Cystine	0.73	0.74	0.70	0.67	0.64	0.61
% Dig. Tryptophan	0.19	0.19	0.18	0.17	0.16	0.16
% Dig. Threonine	0.59	0.59	0.56	0.54	0.51	0.49
% Dig. Isoleucine	0.77	0.77	0.73	0.70	0.67	0.64
% Dig. Valine	0.82	0.82	0.78	0.74	0.71	0.68
% Calcium	4.20	4.20	4.00	3.80	3.65	3.50
% Available Phosphorus	0.42	0.42	0.40	0.38	0.37	0.35
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16
% Chlorine Max.	0.22	0.22	0.22	0.22	0.21	0.20
% Linoleic acid (Min.)	-	1.30	1.25	1.20	1.15	1.10

⁽¹⁾ The consumption levels listed above correspond to the usual observed consumption after 25 weeks.

For this period, we recommend to increase by 7% protein and amino acids to take into account both the needs of growth in addition to production needs and secondly, to take account of lower consumption observed during the beginning of this period.



7.3. FROM 28 TO 45 WEEKS FOR THE NOVOGEN BROWN

Table 8 : Nutritional recommendations from 28 to 45 weeks

	Layer 2							
Ingested quantity (g/d)	Need g/ bird / day	100	105	110	115	120		
% Crude protein	18.5	18.5	17.6	16.8	16.1	15.4		
% Crude fiber	-	3.5 - 6.5						
% Crude fat	-	2.0 - 4.5						
% Tot. Lysine	-	0.90	0.86	0.82	0.78	0.75		
% Tot. Methionine	-	0.46	0.44	0.42	0.40	0.38		
% Tot. Methio + Cystine	-	0.77	0.73	0.70	0.67	0.64		
% Tot. Tryptophan	-	0.21	0.20	0.19	0.18	0.18		
% Tot. Threonine	-	0.64	0.61	0.58	0.56	0.53		
% Tot. Isoleucine	-	0.79	0.75	0.72	0.69	0.66		
% Tot. Valine	-	0.85	0.81	0.77	0.74	0.71		
% Dig. Lysine	0.80	0.80	0.76	0.73	0.70	0.67		
% Dig. Methionine	0.43	0.43	0.41	0.39	0.37	0.36		
% Dig. Meth & Cystine	0.69	0.69	0.66	0.63	0.60	0.58		
% Dig. Tryptophan	0.18	0.18	0.17	0.16	0.16	0.15		
% Dig. Threonine	0.55	0.55	0.52	0.50	0.48	0.46		
% Dig. Isoleucine	0.72	0.72	0.69	0.66	0.63	0.60		
% Dig. Valine	0.77	0.77	0.73	0.70	0.67	0.64		
% Calcium	4.20	4.20	4.00	3.80	3.65	3.50		
_			0.38	0.36		0.33		
% Available Phosphorus	0.40	0.40			0.35			
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16		
% Chlorine Max.	0.24	0.24	0.24	0.24	0.23	0.22		
% Linoleic acid (Min.)	-	1.30	1.25	1.20	1.15	1.10		



7.4. FROM 45 TO 70 WEEKS FOR THE NOVOGEN BROWN

Table 9: Nutritional recommendations from 45 to 70 weeks

	Layer 3							
Ingested quantity (g/d)	Need g/ bird / day	100	105	110	115	120		
% Crude protein	18.0	18.0	17.2	16.4	15.7	15.0		
% Crude fiber	-	- 3.5 - 7.0						
% Crude fat	-	1.5 - 3.5						
% Tot. Lysine	-	0.90	0.86	0.82	0.78	0.75		
% Tot. Methionine	-	0.46	0.44	0.42	0.40	0.38		
% Tot. Methio + Cystine	-	0.77	0.73	0.70	0.67	0.64		
% Tot. Tryptophan	-	0.21	0.20	0.19	0.18	0.18		
% Tot. Threonine	-	0.64	0.61	0.58	0.56	0.53		
% Tot. Isoleucine	-	0.79	0.75	0.72	0.69	0.66		
% Tot. Valine	-	0.85	0.81	0.77	0.74	0.71		
% Dig. Lysine	0.80	0.80	0.76	0.73	0.70	0.67		
% Dig. Methionine	0.43	0.43	0.41	0.39	0.37	0.36		
% Dig. Meth & Cystine	0.69	0.69	0.66	0.63	0.60	0.58		
% Dig. Tryptophan	0.18	0.18	0.17	0.16	0.16	0.15		
% Dig. Threonine	0.55	0.55	0.52	0.50	0.48	0.46		
% Dig. Isoleucine	0.72	0.72	0.69	0.66	0.63	0.60		
% Dig. Valine	0.77	0.77	0.73	0.70	0.67	0.64		
			l					
% Calcium	4.50	4.50	4.30	4.10	3.90	3.75		
% Available Phosphorus	0.38	0.38	0.36	0.34	0.33	0.32		
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16		
% Chlorine Max.	0.24	0.24	0.24	0.24	0.23	0.22		
% Linoleic acid (Min.)	-	1.20	1.15	1.10	1.05	1.00		



7.5. FROM 70 WEEKS TO THE DEPLETION FOR THE NOVOGEN BROWN

Table 10: Nutritional recommendations from 70 weeks to the depletion

	Layer 4						
Ingested quantity (g/d)	Need g/ bird / day	100	105	110	115	120	
% Crude protein	17.5	17.5	16.7	15.9	15.2	14.6	
% Crude fiber	-	3.5 - 7.0					
% Crude fat	-	1.5 - 3.0					
% Tot. Lysine	-	0.90	0.86	0.82	0.78	0.75	
% Tot. Methionine	-	0.46	0.44	0.42	0.40	0.38	
% Tot. Methio + Cystine	-	0.77	0.73	0.70	0.67	0.64	
% Tot. Tryptophan	-	0.21	0.20	0.19	0.18	0.18	
% Tot. Threonine	-	0.64	0.61	0.58	0.56	0.53	
% Tot. Isoleucine	-	0.79	0.75	0.72	0.69	0.66	
% Tot. Valine	-	0.85	0.81	0.77	0.74	0.71	
% Dig. Lysine	0.80	0.80	0.76	0.73	0.70	0.67	
% Dig. Methionine	0.43	0.43	0.41	0.39	0.37	0.36	
% Dig. Meth & Cystine	0.69	0.69	0.66	0.63	0.60	0.58	
% Dig. Tryptophan	0.18	0.18	0.17	0.16	0.16	0.15	
% Dig. Threonine	0.55	0.55	0.52	0.50	0.48	0.46	
% Dig. Isoleucine	0.72	0.72	0.69	0.66	0.63	0.60	
% Dig. Valine	0.77	0.77	0.73	0.70	0.67	0.64	
% Calcium	4.80	4.80	4.60	4.40	4.20	4.00	
% Available Phosphorus	0.36	0.36	0.34	0.33	0.31	0.30	
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16	
% Chlorine Max.	0.25	0.25	0.25	0.24	0.23	0.22	
% Linoleic acid (Min.)	-	1.20	1.15	1.10	1.05	1.00	



7.6. FROM 2% OF LAY TO 28 WEEKS FOR THE NOVOGEN WHITE

Table 8bis: Nutritional recommendations from 2% of production to 28 weeks

	Layer 1							
Ingested quantity (g/d)	Need g/ bird / day	100 (1)	105 (1)	110 <i>(1)</i>	115 <i>(1)</i>	120 (1)		
% Crude protein	19.0	19.0	18.1	17.3	16.5	15.8		
% Crude fiber	-	3.5 - 6.0						
% Crude fat	-			2.5 - 5.5				
% Tot. Lysine	-	0.94	0.89	0.85	0.81	0.78		
% Tot. Methionine	-	0.49	0.47	0.45	0.43	0.41		
% Tot. Methio + Cystine	-	0.82	0.78	0.75	0.71	0.68		
% Tot. Tryptophan	-	0.22	0.21	0.20	0.19	0.18		
% Tot. Threonine	-	0.69	0.66	0.63	0.60	0.58		
% Tot. Isoleucine	-	0.85	0.81	0.77	0.74	0.71		
% Tot. Valine	-	0.90	0.86	0.82	0.78	0.75		
% Dig. Lysine	0.83	0.83	0.79	0.75	0.72	0.69		
% Dig. Methionine	0.46	0.46	0.44	0.42	0.40	0.38		
% Dig. Meth & Cystine	0.73	0.74	0.70	0.67	0.64	0.61		
% Dig. Tryptophan	0.19	0.19	0.18	0.17	0.16	0.16		
% Dig. Threonine	0.59	0.59	0.56	0.54	0.51	0.49		
% Dig. Isoleucine	0.77	0.77	0.73	0.70	0.67	0.64		
% Dig. Valine	0.82	0.82	0.78	0.74	0.71	0.68		
% Calcium	4.20	4.20	4.00	3.80	3.65	3.50		
% Available Phosphorus	0.42	0.42	0.40	0.38	0.37	0.35		
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16		
% Chlorine Max.	0.22	0.22	0.22	0.22	0.21	0.20		
% Linoleic acid (Min.)	-	1.30	1.25	1.20	1.15	1.10		

⁽¹⁾ The consumption levels listed above correspond to the usual observed consumption after 25 weeks.

For this period, we recommend to increase by 7% protein and amino acids to take into account both the needs of growth in addition to production needs and secondly, to take account of lower consumption observed during the beginning of this period.



7.7. FROM 28 TO 45 WEEKS FOR THE NOVOGEN WHITE

Table 8bis: Nutritional recommendations from 28 to 45 weeks

	Layer 2							
Ingested quantity (g/d)	Need g/ bird / day	100	105	110	115	120		
% Crude protein	18.0	18.0	17.2	16.4	15.7	15.0		
% Crude fiber	-			3.5 - 6.5				
% Crude fat	-			2.0 - 4.5				
% Tot. Lysine	-	0.88	0.84	0.80	0.76	0.73		
% Tot. Methionine	-	0.46	0.44	0.42	0.40	0.38		
% Tot. Methio + Cystine	-	0.77	0.73	0.70	0.67	0.64		
% Tot. Tryptophan	-	0.21	0.20	0.19	0.18	0.18		
% Tot. Threonine	-	0.64	0.61	0.58	0.56	0.53		
% Tot. Isoleucine	-	0.79	0.75	0.72	0.69	0.66		
% Tot. Valine	-	0.85	0.81	0.77	0.74	0.71		
% Dig. Lysine	0.78	0.78	0.74	0.71	0.68	0.65		
% Dig. Methionine	0.43	0.43	0.41	0.39	0.37	0.36		
% Dig. Meth & Cystine	0.69	0.69	0.66	0.63	0.60	0.58		
% Dig. Tryptophan	0.18	0.18	0.17	0.16	0.16	0.15		
% Dig. Threonine	0.55	0.55	0.52	0.50	0.48	0.46		
% Dig. Isoleucine	0.72	0.72	0.69	0.66	0.63	0.60		
% Dig. Valine	0.77	0.77	0.73	0.70	0.67	0.64		
% Calcium	4.20	4.20	4.00	3.80	3.65	3.50		
% Available Phosphorus	0.40	0.40	0.38	0.36	0.35	0.33		
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16		
% Chlorine Max.	0.24	0.24	0.24	0.24	0.23	0.22		
% Linoleic acid (Min.)	-	1.30	1.25	1.20	1.15	1.10		



7.8. FROM 45 TO 70 WEEKS FOR THE NOVOGEN WHITE

Table 9bis: Nutritional recommendations from 45 to 70 weeks

	Layer 3							
Ingested quantity (g/d)	Need g/ bird / day	100	105	110	115	120		
% Crude protein	17.5	17.5	16.7	15.9	15.2	14.6		
% Crude fiber	- 3.5 - 7.0							
% Crude fat	-			1.5 - 3.5				
% Tot. Lysine	-	0.90	0.86	0.82	0.78	0.75		
% Tot. Methionine	-	0.46	0.44	0.42	0.40	0.38		
% Tot. Methio + Cystine	-	0.77	0.73	0.70	0.67	0.64		
% Tot. Tryptophan	-	0.21	0.20	0.19	0.18	0.18		
% Tot. Threonine	-	0.64	0.61	0.58	0.56	0.53		
% Tot. Isoleucine	-	0.79	0.75	0.72	0.69	0.66		
% Tot. Valine	-	0.85	0.81	0.77	0.74	0.71		
			ı					
% Dig. Lysine	0.80	0.80	0.76	0.73	0.70	0.67		
% Dig. Methionine	0.43	0.43	0.41	0.39	0.37	0.36		
% Dig. Meth & Cystine	0.69	0.69	0.66	0.63	0.60	0.58		
% Dig. Tryptophan	0.18	0.18	0.17	0.16	0.16	0.15		
% Dig. Threonine	0.55	0.55	0.52	0.50	0.48	0.46		
% Dig. Isoleucine	0.72	0.72	0.69	0.66	0.63	0.60		
% Dig. Valine	0.77	0.77	0.73	0.70	0.67	0.64		
% Calcium	4.50	4.50	4.30	4.10	3.90	3.75		
% Available Phosphorus	0.38	0.38	0.36	0.34	0.33	0.32		
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16		
% Chlorine Max.	0.24	0.24	0.24	0.24	0.23	0.22		
% Linoleic acid (Min.)	-	1.20	1.15	1.10	1.05	1.00		



7.9. FROM 70 TO 85 WEEKS FOR THE NOVOGEN WHITE

<u>Table 10bis: Nutritional recommendations from 70 to 85 weeks</u>

	Layer 4							
Ingested quantity (g/d)	Need g/ bird / day	100	105	110	115	120		
% Crude protein	17.0	17.0	16.2	15.5	14.8	14.2		
% Crude fiber	-			3.5 - 7.0				
% Crude fat	-			1.5 - 3.0				
% Tot. Lysine	-	0.91	0.87	0.83	0.79	0.76		
% Tot. Methionine	-	0.46	0.44	0.42	0.40	0.38		
% Tot. Methio + Cystine	-	0.77	0.73	0.70	0.67	0.64		
% Tot. Tryptophan	-	0.21	0.20	0.19	0.18	0.18		
% Tot. Threonine	-	0.64	0.61	0.58	0.56	0.53		
% Tot. Isoleucine	-	0.79	0.75	0.72	0.69	0.66		
% Tot. Valine	-	0.85	0.81	0.77	0.74	0.71		
% Dig. Lysine	0.81	0.81	0.77	0.74	0.71	0.68		
% Dig. Methionine	0.43	0.43	0.41	0.39	0.37	0.36		
% Dig. Meth & Cystine	0.69	0.69	0.66	0.63	0.60	0.58		
% Dig. Tryptophan	0.18	0.18	0.17	0.16	0.16	0.15		
% Dig. Threonine	0.55	0.55	0.52	0.50	0.48	0.46		
% Dig. Isoleucine	0.72	0.72	0.69	0.66	0.63	0.60		
% Dig. Valine	0.77	0.77	0.73	0.70	0.67	0.64		
% Calcium	4.80	4.80	4.60	4.40	4.20	4.00		
% Available Phosphorus	0.36	0.36	0.34	0.33	0.31	0.30		
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16		
% Chlorine Max.	0.25	0.25	0.25	0.24	0.23	0.22		
% Linoleic acid (Min.)	-	1.20	1.15	1.10	1.05	1.00		



7.10. FROM 85 WEEKS TO THE DEPLETION FOR THE NOVOGEN WHITE

Table 11: Nutritional recommendations from 85 weeks to the depletion

	Layer 5							
Ingested quantity (g/d)	Need g/ bird / day	100	105	110	115	120		
% Crude protein	16.75	16.75	16.0	15.2	14.6	14.0		
% Crude fiber	-			3.5 - 7.0				
% Crude fat	-			1.0 - 2.5				
% Tot. Lysine	-	0.91	0.87	0.83	0.79	0.76		
% Tot. Methionine	-	0.46	0.44	0.42	0.40	0.38		
% Tot. Methio + Cystine	-	0.77	0.73	0.70	0.67	0.64		
% Tot. Tryptophan	-	0.21	0.20	0.19	0.18	0.18		
% Tot. Threonine	-	0.64	0.61	0.58	0.56	0.53		
% Tot. Isoleucine	-	0.79	0.75	0.72	0.69	0.66		
% Tot. Valine	-	0.85	0.81	0.77	0.74	0.71		
% Dig. Lysine	0.81	0.81	0.77	0.74	0.71	0.68		
% Dig. Methionine	0.43	0.43	0.41	0.39	0.37	0.36		
% Dig. Meth & Cystine	0.69	0.69	0.66	0.63	0.60	0.58		
% Dig. Tryptophan	0.18	0.18	0.17	0.16	0.16	0.15		
% Dig. Threonine	0.55	0.55	0.52	0.50	0.48	0.46		
% Dig. Isoleucine	0.72	0.72	0.69	0.66	0.63	0.60		
% Dig. Valine	0.77	0.77	0.73	0.70	0.67	0.64		
% Calcium	5.00	5.00	4.80	4.60	4.40	4.20		
% Available Phosphorus	0.34	0.34	0.32	0.31	0.30	0.28		
% Sodium Min.	0.16	0.16	0.16	0.16	0.16	0.16		
% Chlorine Max.	0.25	0.25	0.25	0.24	0.23	0.22		
% Linoleic acid (Min.)	-	1.20	1.15	1.10	1.05	1.00		



> FEEDING IN HOT CLIMATES

8. FEEDING IN HOT CLIMATES

One of the first consequence of elevated temperatures in layers' facilities result in performance losses (growth, lay, liveability, eggshell quality...) which in turn can have a significant economic impact. It is thus imperative to adapt the management of these facilities to reduce the impact of heat. When temperatures rise, it becomes more difficult to remove animal heat. The hens' thermoregulation mechanisms kick in and a decrease in feed intake is observed.

8.1. MECHANISM OF THERMOREGULATION

Heat loss can occur via two mechanisms:

- Direct exchange with external environment (air, litter, radiation).
- Water evaporation in the respiratory tract (the main way).

Thermal exchanges depend on both ambient temperature and animal body temperature, they decrease when the external temperature rises. Cardiac and respiratory rhythms, regulated by body heat, intensify to facilitate water loss through the respiratory tract, thus allowing the animals to lose more heat (at the rate of 0.6 kcal for 1 g of water evaporated). This explains the very high consumption of water in hot climates.

Thermoregulation is rendered more difficult in very humid environments when relative humidity is superior to 75%, the animals can no longer remove heat by evaporation.

As body temperature rises, feed intake stops immediately. This results in a decrease in performances and growth. If conditions worsen, increased body temperature can lead to the animal's death.

25 % Evaporation

75 % Conduction Convection Radiation

20 % Conduction Convection Radiation

Schema: Thermoregulation in normal conditions and in case of heat stress

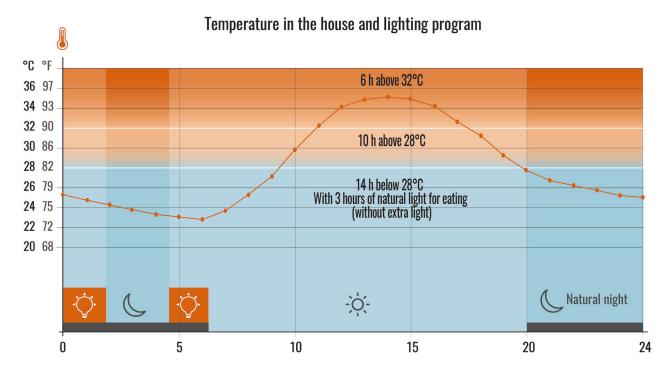
8.2. IMPACTS ON THE PERFORMANCES

- Reduced growth starting from 24°C; close to zero growth beyond 28°C.
- Reduced feed conversion ratio up to 28°C (lower maintenance), increased FCR beyond 28°C.
- Between 24 and 28°C, egg weight is reduced by 0.4% per °C; beyond 28°C, egg weight is reduced by 0.8% per °C.
- Reduced laying rate beyond 30°C; under 30°C, the first impact of increased temperature is egg weight reduction.



FEEDING IN HOT CLIMATES

Schema: Curve of temperature of a layer's house in hot conditions



- In blue on the diagram above, temperature range +/- optimal for animals (this temperature is not fixed, it is to be defined according to production objectives against production cost).
- In orange (28-32°C), temperature range with an initiation of performances degradation against optimum zone.
- In orange/red (> 32 ° C), a sharp drop in food consumption that can go up to a stop during these high temperatures.

It is important to have a presence of the feed in the coolest hours (blue zone) in order to ensure a good feed consumption and thus a good level of production. The addition of light must also be done in the coolest hours of the day: early in the morning or even with a flash during the night.

8.3. HOW TO REDUCE THE IMPACT OF HIGH TEMPERATURES

It is possible to maintain the performances by facilitating heat loss and/or dispensing the feed when the temperature is cooler to limit digestion during the warmest hours.

ADAPTING LIGHTING PROGRAMS AND FEEDING TECHNIQUES

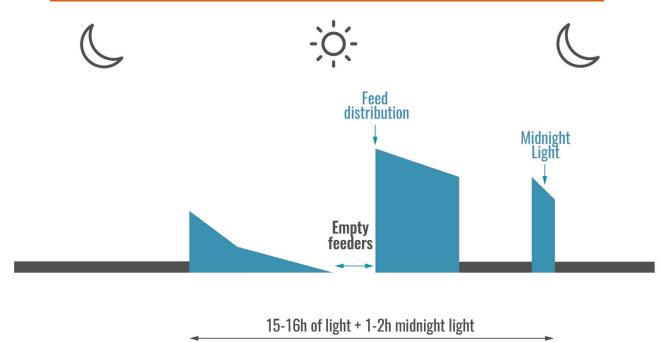
Since the impact of high temperatures can be reduced by making sure the feeding takes place during the coolest part of the day, it is recommended to :

- Lit the facility early in the morning (avoid at the evening if the temperature is not fallen enough).
- Provide a period of 1.5 to 2 hours of light in the middle of the night.
- Have an adequate granulometry (80% of the particles between 0.5 and 3.2 mm).



FEEDING IN HOT CLIMATES

Schema: Amount of feed consumed according to the time on a day, with midnight light



Because the actual act of feeding uses approximately 25% of the maintenance requirements, providing a feed with an adequate granulometry is essential to reduce the energy required to eat the feed. It is thus strongly recommended to use granular calcium carbonate (2 to 4 mm) and to add oil at a level comprised between 1 and 3% minimum to glue fines particles together and improve feed palatability. Feeders must be empty by the end of the morning to avoid any digestion during the warmest hours.

Any feed not eaten in the evening will be ingested more easily in the morning (or during the night). When lights are turned on, the hens' digestive track is empty and they will eat fine particles more easily. The first distribution of feed shall occur approximately two to three hours after lights are turned on, when the temperature is the coolest to avoid any digestion during the warmest hours. The feed shall be distributed approximately four hours before turning off the lights. Hens will be able to eat if the temperature is acceptable. However, the hens should have sufficient amounts feed during the night lighting period and during the hours after turning on the lights.

The distribution schedule and the quantity given will be determined based on the time at which the feeders are empty. It is recommended to make sure that the feeders are not empty in the hours after turning on the lights to avoid any risks of restriction.

If the hens do not eat enough food despite these techniques, it is possible to feed them crumble instead of mash.

As a reminder, it is not possible to compensate production losses due to high temperature by increasing energy levels and even more so after six weeks of age when the feathering is well developed and extra-heat loss is reduced.

❖ INCREASING HEAT LOSS BY DISPENSING COLD WATER

In hot climates, a hen can consume up 300 ml of water per day; it is necessary to maintain a difference of 15°C between ambient temperature and drinking water temperature, it helps reduce by more than 2% the quantity of heat to be removed. It is thus essential to find solutions to constantly provide hens with cold water (shaded water cistern and painted in white, underground water pipes...).

NOVOGEN

> FEEDING IN HOT CLIMATES

Soluble aspirin has an antipyretic activity and can be given at a concentration of 0.3 g per liter of water to stimulate water consumption. Moreover, vitamin C, at a concentration of 1 g per liter of water has also a positive effect on feed and water consumption. Sodium bicarbonate between 0.5 and 1 g per liter of water will also push the animals to drink in case of high temperature.

❖ REDUCING AMBIANT TEMPERATURE VIA OTHER TECHNIQUES

The buildings shall be properly insulated to prevent temperature increase due to sunlight exposure.

A surface superior to 500 cm² per animal should be allocated to facilitate extra heat removal (as a reminder, European regulations impose a minimum surface of 750 cm² per animal). Californian cages are preferable to standard battery units. They create less obstruction to air circulation and hens can get their heads out of their cage.

When hens are reared on the floor, it is recommended to add perches to limit floor density.

Fans can also be used to control air circulation speed and thus to increase heat losses between the animal and ambient air. However, air circulation speed has to be reduced during the night to prevent excessive feed consumption. The following parameters shall be taken into account when setting up the speed: temperature, humidity, ages of the animals, feathering.

Pad cooling and fogging systems are also good alternative solutions to decrease ambient temperature.



9. TRACE-ELEMENTS AND VITAMINS

9.1. TRACE-ELEMENTS

The determination of trace mineral requirements has been a secondary concern in poultry nutrition and has suffered from a lack of recent research into the fundamental aspects of nutrient availability and animal requirements in comparison to other nutrients. In view of the key role that many trace minerals have in the development of essential tissues and maintenance of animal health, this deficit may lead to production and health problems.

As an example, deficiencies of the trace minerals Selenium (Se), Zinc (Zn), and Manganese (Mn) have been linked to impaired reproductive performance in male and female farm animals (Smith and Akinbamijo, 2000). Research has also shown that inorganic and/or organic zinc increase levels of zinc in the bone and increase bone weight (Kidd et al., 1992). In general, almost all minerals play a role in ensuring optimum immunity. In general terms, minerals act as cofactors of different enzyme systems or as component of hormonal systems responsible for maintaining the integrity of the cellular and humoral defence mechanisms.

Over the last 50 years, trace element nutrition research has led to the development of more bio-available organic minerals, several of which have been approved for use in poultry. These include trace metals derived from chelates (Cu, Fe, Mn, Zn) and organic Se often from strain-specific yeasts. These organic forms help to reduce releases and accumulation in the environment. They can be particularly interesting for the parental flocks.

Table 12: Summary of trace-elements impacts in PS, their reproductive performances and progeny

	Reproductive performances	Juvenile growth of progeny	Juvenile liveability of progeny	Immune function	Skeleton development
Manganese	Х				X
Zinc	Х	Х	Х	Х	Х
Copper	Х				
Selenium	Х	Х	Х	Х	

Although those minerals bound to organic compounds have been available to the industry for some years, their adoption in commercial practice has been slow and frequently limited to the breeding (due to the high cost).

Conventional levels of trace minerals supplementation are recommended below (to adjust to meet local regulations may be more restrictive):

Table 12bis: Added trace minerals recommendations

		Parental	Commercial
Manganese, Mn	ppm	90	70
Zinc, Zn	ppm	90	60
Iron, Fe	ppm	60	50
Copper, Cu	ppm	10	8
Selenium, Se	ppm	0.30 – 0.35	0.20 – 0.25
lodine, I	ppm	2	1



9.2. ADDED VITAMINS

Vitamins are essential micro-nutriments, occupying a central role in most metabolic processes. They are required for optimum health and normal physiological functions such as growth, development, maintenance and reproduction.

Grossly underfeeding vitamins is not commonly seen in commercial practice. It is more likely to encounter marginal deficiencies caused either by low supplementation, sources of questionable quality, availability, poor conservation conditions and dominant breeders consuming less than the average calculated feed intake.

A marked deficiency of any one vitamin is known to result in negative responses in parent egg production: fertility, hatchability and offspring performance. With a marginal vitamin supply, the progeny will not exhibit classical deficiency syndromes but they will not necessarily perform to their genetic potential. This is why we recommend safe levels higher in parental vs commercial.

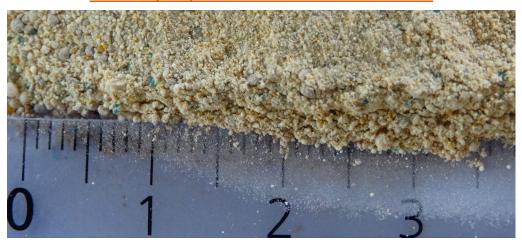


Photo: Layer's premix with vitamins & trace-elements

VITAMIN REQUIREMENTS

Requirements for vitamins are usually cover by adding all vitamins as synthetic sources (there are however, a few natural sources). Regular feed ingredients such as corn, wheat and soya bean meal, all contain natural sources of vitamins and in some situations, could theoretically contain enough to meet the animals' needs (example: choline if the feed is in mash). However, the concentration of vitamins will vary in feed ingredients because of crop location, fertilizer usage, plant genetics, plant disease, weather and storage. Harvesting conditions often play a major role in the vitamin content of many feedstuffs. Vitamin content of corn is drastically reduced when harvest months are not conducive to full ripening. In addition to this inherent variability is the effect that factors such as natural plant toxins and mycotoxins can have on vitamin availability.

Given these constraints, it is perhaps not too surprising that regular feed ingredients are not relied on to necessary and sufficient level of vitamins. Consequently, our vitamin premix recommendations are designed to supply all the vitamins the animal requires.

It is quite difficult to determine the vitamin needs. Research takes a long time to complete and is very expensive. The most recent official public vitamin requirements are from the US NRC (1994). These may be viewed as absolute requirements to prevent clinical deficiencies. In practical nutrition of breeders, the objective is not only to prevent signs of vitamin deficiency but also to support optimum health and ensure good egg production, hatchability and early chick vitality.



There is also extensive variation in vitamin recommendations according to environment effects (Ward, 1993), such as growing conditions and management, disease, diet considerations and strain. Higher levels can be recommended when the flock conditions are challenging: high stocking density and/or severe internal and external microbial challenges.

Our recommendations ensure the optimum delivery of vitamins to the animals and the developing embryo. With these extra levels of vitamins in the feed, there should be no need to use supplemental vitamins in the water. Except in situations due to environmental conditions, disease/parasite stress, low feed intake or enteritis, this rule should be broken.

Table 13: Added vitamins recommendation per kg for Parental & Commercial

		Standa	rd feed	Heat trea	ated feed
		Wheat based	Corn based	Wheat based	Corn based
Vitamin A (1)	IU	10 000	10 000	12 000	12 000
Vitamin D3 (1)	IU	3 000	3 000	3 200	3 200
Vitamin E	IU	50 - 100	50 - 100	60 - 100	60 - 100
Vitamin K3	Mg	3,0	3,0	5,0	5,0
Thiamine B1	Mg	2,5	2,5	3,0	3,0
Riboflavin B2	Mg	10	10	10	10
Pantothenate	Mg	12	14	14	16
Niacin	Mg	45	45	45	45
Pyridoxine B6	Mg	4,5	4,0	5,5	5,0
Vitamin B12	Mg	0,03	0,03	0,03	0,03
Folic acid	Mg	2,0	2,0	2,5	2,5
Biotin	Mg	0,30	0,25	0,30	0,25
Choline	Mg	300	500	300	500
Betaine	Mg	100	125	100	125

⁽¹⁾ To adjust depending on the local regulations may be more restrictive.

Notes: These recommendations could be used from day old to the end of the laying period. However, it is possible to reduce the level of the premix in vitamins from 10 to 20% during the growing stage (especially in the end of the rearing period) and in commercial flock of 20 to 30% in production according to environmental conditions and the observed performances.

❖ LOSS IN POTENCY OF VITAMINS

Another reason for higher vitamin fortifications relative to published data requirements is the loss in potency that occur between feed manufacture and consumption by the bird. The sensitivity of different vitamins to outdoor conditions varies widely (table 14). But as a generalization, it can be stated that the major causes of loss of vitamin potency are storage time, storage temperature, and storage humidity of the premix before mixing and of the feed after mixing. The galenic of vitamins can also play an important role, some sources being coated, protected by a matrix (often lipid) for the purpose of releasing at the appropriate time.



Table 14: Sensitivity of vitamins to environmental conditions

	Temperature	Oxygen	Humidity	Light	pH 3 – 5	pH 6 – 7,5
Α	XX	XXX	Х	XX	XX	0
D3	X	XX	Х	Х	X	0
E	X	Х	Х	Χ	0	XX
К3	XX	Х	XXX	X	XXX	0
B1	Х	Х	Х	Х	0	XX
B2	0	0	Х	XX	0	0
B6	XX	0	Х	Χ	X	0
B12	XX	Х	XX	X	0	0
Pantothenate	Х	0	Х	0	0	0
Niacin	0	0	0	0	Х	0
Biotin	Х	0	0	Х	Х	0
Folic acid	XX	0	Χ	XX	XX	Х
Choline	X	0	0	Х	X	Х
Betaine	0	0	0	Х	0	Х
C (1)	XX	XX	XX	X	0	X

⁽¹⁾ Vitamin C interesting in case of thermal stress to boost feed consumption.

(2) O Stable X Sensitive XX Highly sensitive XXX Extremely sensitive

Another major loss of vitamins occurs if they are premixed with minerals and Choline Chloride, stored for any length of time prior to incorporation in feed. Trace elements are aggressive against vitamins, if possible, it is necessary to divide the intake into two premixes (especially if the transport/storage is long). Other factors involved in the mixing of the premix and the feed may also cause a loss of activity: some vitamins are acidic, while others are deteriorated in an acid environment. Vitamin manufacturers can provide information on factors that may affect the activity of their vitamin products. Armed with this knowledge coupled with the conditions that can be anticipated in the field, it is possible to predict what levels of security are necessary to guarantee performances.

It is also important not to forget an essential factor having an effect on the stability of vitamins. Indeed, in many cases today, the feed undergoes a heat treatment (heat treatment of feed in the form of mash and/or pellet) during which vitamin degradation can be observed under the combination of the effects of temperature, pressure and humidity (in this case, favour a suitable galenic). As with all enzymes, it is advisable to perform a covering test to evaluate the impact of the manufacturing process on the final feed.



❖ EGG ENRICHMENTS

The egg is a very stable environment, its purpose being to provide all the nutrients needed for the development of a young chick. Without going into details, it is possible to enrich the egg in various constituents:

Vitamins

All vitamins can be increased but with varying degrees of success, because the transfer rates in the egg are very different. Vitamins D and E are those with the best transfer of feed to the egg. However, it is necessary to respect the maximum permitted levels of vitamins in feed by certain regulations (European, American...).

• Trace-elements

It is possible to enrich the eggs with trace elements such as Selenium or Iodine. But since environmental regulations are increasingly restrictive on releases, the possibilities are now very minimal.

Pigments

It is common in countries to consume eggs with yellows, more or less coloured according to local habits. It is entirely possible, thanks to the raw materials, to enrich the feed with xanthophylls in order to obtain the desired colour of the yolk.

LIVER PROTECTOR

Longer production cycles and increased performances enhance the use of hepato-protectors in regular cure, usually every 5 or 6 weeks. These special premixes are rich in elements helping to detoxify the liver as: choline, betaine, sorbitol, group B vitamins, and sometimes also some plant extracts. The goal is to improve the performance of this key and essential organ which is enormously stressed in the laying hen. The efficacy of the hepato-protector is optimal when used in preventive mode, before the onset of the first clinical signs in the farm. Their use can start from 25 to 30 weeks of age in order to preserve the capacities of laying at the end of production.

This investment is almost systematically profitable over the long term (it is all the truer in parental).



Many feed ingredients are suitable for feeding to layers. Supply, price and quality will usually determine the choice. Most countries are limited in the choice of basic ingredients, few have a wide choice. Raw materials should be of good quality with predictable and uniform nutritional value across all consignments. The quality of a feed material is determined by the nutrient composition of the material and how efficiently they can be digested and released for absorption and utilization in the bird.

Nutritionists continuously make choices over the margin of safety as they construct the feed formula, especially for poultry breeders of high value. This margin of safety can be increased or decreased according to several factors. The **rigorous quality-assurance** scheme for assessing nutrient content and the resulting uniformity of nutritional values across batches of all raw materials must be taken into consideration when building a margin of safety into a feed formula.

Ingredients must also be free of contamination by chemical residues, microbial toxins, heavy metals and pathogens. They should be as fresh as possible and should be stored under good conditions. Storage facilities must be protected from contamination by insects, rodents and in particular, wild birds; all of which are potential vectors of disease. It is common in many countries for these aspects of the production process to be monitored and managed within a scheme such as HACCP (Hazard Analysis Critical Control Point).

For breeders, we recommend to increase the control pressure and select raw materials with the best quality.

10.1. CEREALS AND CEREALS CO-PRODUCTS

Corn (or Maize) is the raw material favoured by most poultry nutritionists and poultry producers. However, corn prices in the market have increased dramatically in recent years due to high demand worldwide, the increasing use of corn for production of bio-energy and phenomena of purely financial speculation. In many countries, other grains like wheat, barley, oats, sorghum and broken rice are used successfully. Additionally, grain co-products such as wheat or rice bran are important and valuable feed ingredients in most part of the world. However, their efficient use in monogastric diets is often impaired by the presence of elevated contents of non-starch polysaccharides (NSP).

CORN

Photo: A good quality grain corn





The expected differences in corn composition due to growing conditions, corn variety and processing appear small (protein +/- 1,5%, fat +/- 0,6%, starch +/- 3,0%). Nevertheless, corn is usually the largest component of bird rations so small variations in corn quality have the biggest impact on finished feed nutrient variability. Proximate analysis can determine chemical composition and expected nutrient values but proximate analysis alone can neither determine the quality of starch nor protein.

Recent work indicates that protein digestibility and starch quality (amount of amylase and amylopectin) are variable between batches of corn and have inconsistent effects on nutritive value and animal performance. Corns harvested during the wet season or wet conditions have increased risks of higher levels of mycotoxin contamination than corn harvested in the dry conditions. Prolonged storage of corn with high moisture content prior to drying also increases the risk of fungal infestation resulting in increased mycotoxin production. The more or less drastic drying conditions influence the bioavailability of protein (and amino acids), starch but also pigments. There is a natural degradation of the pigments over time (the longer the storage, the fewer pigments).

Wet corn (silage or inerted) can be used in poultry to replace part of the conventional dried grain corn.

Prioto . Soft wheat

Photo: Soft wheat

WHEAT

In many countries, all year or at specific times of the year in others, wheat is the more cost effective primary cereal in place of corn. Wheat based diets have given good field results. However, a number of factors need to be considered when using wheat.

All major wheat-producing countries report variability in Metabolizable Energy (ME) content. The main reason is the content of non-starch polysaccharides (NSP) which are poorly digested by poultry and interfere with the digestibility of other feed components. The NSP content in wheat may range from 1 to 10% or more, and, is negatively correlated with the ME content, the higher the NSP content, the lower the ME content. Unfortunately, there is currently no rapid easy test available to the feed manufacturer to measure the NSP content. Feed companies can use an enzyme mixture (xylanase & beta-glucanase), that will break down the complex polysaccharides in the gut resulting in improved energy utilization and a higher ME content in the wheat (see exogenous enzymes section).

One of the benefits of wheat is that it contains between 9 - 15% crude protein, compared with 6 - 8,5% crude protein in corn. As a result, the reliance placed on expensive protein sources is lower in wheat-based diets to achieve the desired amino acid levels in finish feed.



When using pellets or crumbles, diets containing at least 5 - 10% wheat bind better during feed manufacture resulting in improved pellet quality and durability. The availability of vitamins such as biotin is lower in wheat based diets (see Table 13).

❖ BARLEY / OATS





Photo: Black oats



With its high rate of crude protein and its lower price, barley has a considerable interest for feeding layers. The energy content of barley is one of the lowest among the usual cereals. Low fat and high fiber rate this cereal seed contributes to their low energy. The main anti-nutritional factors are of barley beta-glucans, soluble non-starch polysaccharides, encouraging the formation of viscous gels by increasing their solubility and undisgestibility. The use of enzyme allows the incorporation of barley at high levels.

Oats is a good source of fiber used in low doses. She would have a stimulating effect on the males (still poorly explained).



WHEAT CO-PRODUCTS



Photo: Wheat bran

The composition of wheat milling co-products (wheat bran, wheat middling...) varies markedly both within and between different geographic regions, suppliers, even between plants of the same provider. While the protein content in samples of wheat co-product can be readily determined, ME values are more difficult to obtain. When components of proximate composition are used as predictors of ME, crude fibre (CF) or neutral detergent fibre (NDF) appear to be significantly correlated with ME content.

❖ RICE CO-PRODUCTS

In most cases, rice bran and rice polishings are the two rice co-products used for feeding poultry. They are good sources of protein, energy, vitamins and minerals (Saunders, 1990). They also contain a better balance of amino acids, particularly lysine and methionine, compared to other cereal grains.

Rice bran is recognized as being highly variable in its composition with respect to oil and crude fibre contents. They depending upon the severity with which the rice is threshed, the extent to which the oil is extracted (Daghir, 1995) and the amount of ground husk mixed in the batch (Ichhponani et al 1980) as indicated by presence of sand/silica in the samples. Full fat rice bran contains 15 to 25% oil depending on the processing technique (significant amounts of linolenic acid).

The feeding value of rice polishings depends upon the degree of polishing to which the grain has been subjected. Typical values range 11 to 13% for crude protein and 10 to 15% for fat.

Besides the variation in chemical composition, problems such as a high moisture content, mould growth and rancidity are often associated with the keeping quality of rice co-products. Both rice bran and rice polishing residues may be used at high levels provided that the batch analysis is well defined and the fat can be stabilized by an antioxidant in order to avoid loss of ME value by an oxidative degradation process.



DRIED DISTILLERS GRAINS WITH SOLUBLES (DDGS)





Photo: Corn DDGS with 2 different origins



Dried Distillers Grains (corn, wheat, barley...) with Solubles (DDGS) or without (classic grain distiller), is a co-product obtained in the dry-milling process to produce ethanol after the fermentation of starch by selected yeasts and enzymes. It has been recognized that DDGS is a valuable source of energy, protein, water soluble vitamins, and minerals for poultry (Jensen, 1978, 1981; Wang et al., 2007).

However, use of DDGS in poultry diets has historically been low due to limitations such as the supply and pricing of the product. It is existing a wide variability in nutrient contents and their digestibilities (Noll et al., 2001) based on suppliers and feedmills. The drying temperature is the critical point. When she is too high, the amino acids can suffer Maillard reactions and also become undigestible.

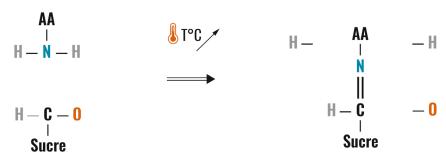
Concerns have also been expressed regarding the levels of the mycotoxins as Fumonisin, Aflatoxin, Deoxynivalenol (DON) and their metabolites in DDGS. These co-products concentrate seed coatings in products such as DDGS and the seed coating is where much of the mycotoxin content of the whole grain is located. Therefore, DDGS represents a concentrated source of any original contamination by mycotoxins in the whole grain.



❖ TEMPERATURE AND MAILLARD REACTION

Particular attention must be paid to all raw materials undergoing a thermal process (extraction, granulation, pressure, drying, etc.). Indeed, depending on the temperature reached, the starch and the sugars can interact by binding irreversibly, this is called "Maillard reaction". The amino acids thus linked are no longer usable by monogastric animals.

Schema: Maillard reaction



We can define a sensitivity by A.A. in this direction: Lysine > Methionine > Arginine > the others A.A.. The first two A.A. impacted, Lysine and Methionine, are also the first A. A. limiting in layers and pullets. It is therefore essential to ensure the quality of the proteins entering the feeds. There are different methods for defining the digestibility of A.A., more or less reliable depending on the raw material (see chapter on raw material). The most reliable, but the most expensive, is certainly the dosage of Lysine, which is to be done in case of proven doubt. A poor or low quality should induce a matrix correction for the protein value, but also and especially for A.A. total/digestible, and sometimes even a degradation of the digestibility coefficients (it is the double penalty for the high temperatures). An extreme solution is not to then use this raw material for PS feed or to restrict it strongly.

10.2. PLANT PROTEIN SOURCES

There are other raw materials high in protein content in addition to soybeans as rapeseed or sunflower meal.

SOYA BEAN MEAL

Photo: Soybean meal 48 (from Brazil)



Soya bean meal (SBM) is a well-established and relatively inexpensive protein source for poultry diets. Harvest, transportation to either storage or to processing should have an effect on the nutritional value of soya bean meal especially amino acid digestibility. Processing conditions of soybeans to generate oil and meal is



perhaps the best understood factor about soya bean meal quality. Insufficient toasting means that SBM contains excessive levels of trypsin inhibitors and excessive levels of lectins.

The quality of the treatments performed on SBM can be measured in the following way for an under-cooking:

- Trypsin inhibitor values of 1.8 to 2 mg / g of soya bean meal (max. 3.5).
- Or expressed as urease activity, 0.00 to less than 0.10 pH units.

Excessive toasting results in protein quality deterioration. There are at least two laboratory methods available to determine the over processing (irreversible Maillard reaction that binds the protein/A.A. with carbohydrates, making them unavailable):

- The most sensitive temperature amino acid is lysine. Definitely, the best method to characterize the "cooking" and that works on all manufacturing processes with heat.
- NIR (Near-Infrared spectroscopy) uses the near-infrared light spectrum to determine the digestible amino acid content of a sample. This makes it possible to correct in real time the amount of amino acids which have been degraded by excessive heating. This method is less precise than chemistry, but faster. There is now continuous NIR, the measuring device is then located on a transporter, a receiving pit and gives a measurement at regular intervals spaced a few seconds!

There are at least two common methods for determining the cooking quality of a soybean meal:

- Solubility of protein in a solution of hydroxide of potassium (KOH) with a target between 75 to 85% (<75% = over-cooking; > 85% = under-cooking).
- Protein Dispersibility Index (PDI), American method which corresponds to a solubility of the protein in water. Principle similar to KOH solubility, with a target between 15 and 35% (<15% = over-cooking; >35% = under-cooking).

There are other methods but not very widely used, such as in vitro digestibility, such as the Boisen method, for example.

SUNFLOWER MEAL

Photo : Sunflower meal dehulled, « Hi-pro »



Sunflower meal is a good vegetable source of protein with amino-acid digestibilities similar to those of soya bean meal and much higher values than those in cottonseed or rapeseed meals. Its lysine content is relatively low but the methionine content makes it suitable for diets in addition to soya bean meal. It is very widespread today especially for alternative systems which need more fiber.



The fiber content of sunflower meal is usually high and variable depending on the dehulling process of the sunflower seed for oil extraction. The reincorporation of hulls allows to get 28% of protein, without hulls, we 35% of protein. This often makes sunflower meal a promising feed ingredient in low energy diluted diets due to the high content of insoluble fiber unextracted sunflower meal. Another characteristic of sunflower meal is that it does not usually have anti-nutritional factors such as those found in soybean, cottonseed and rapeseed meals.

RAPESEED MEAL

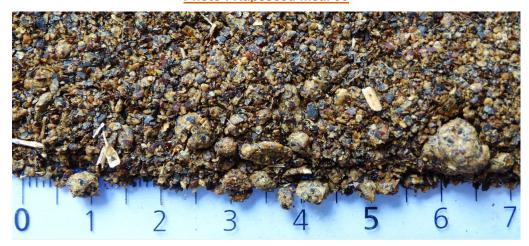


Photo: Rapeseed meal 00

Extracted rapeseed or canola meal is good alternative economical. To use rapeseed meal, it is important to know its origin and especially its glucosinolates contents (it must be 00). Only oilcakes from low-glucosinolates can be used to avoid risks of haemorrhagic liver or reduction of egg size. All of these problems can be managed effectively once a few key points about amino acid digestibility, glucosinolates content and dietary mineral balance are understood. If adequate supplies (low-glucosinolates rapeseed meal) and adequate feed formulation techniques (with digestible amino acids) are used, the levels of inclusion of rapeseed meal in layers may exceed 5%.

10.3. ADDED FAT

The inclusion of raw materials (grains and co-products) that have low ME contents produces a demand for oil/fat in the diets.

_				· · ·				
Oils (plant sources)	Lauric acid C12:0	Myristic acid C14:0	Palmitic acid C16:0	Stearic acid C18:0	Oleic acid C18:1	Linoleic acid C18:2	Alpha- linoleic acid C18:3	Unsat. /Sat.
Canola / rapeseed	-	-	4	2	62	22	10	15.7
Coconut (1)	47	18	10	3	7	2	-	0.1
Palm	0.5	1	45	5	38	10	0.5	1
Soya	-	-	11	4	23	54	8	5.4
Sunflower	-	-	7	5	22	65	0.5	7.3
Linseed	-	-	6	4	18	16	56	9

Table 15a: Indicative fatty acid profile (%) of several vegetable oils (INRA)

⁽¹⁾ Presence of short chains fatty acids C6, C8, and C10 (13%), absent of the other vegetable oils.



Oils and fats are not just a source of energy, they also have an important role in many physiological functions. It is essential to know the fatty acid profile (especially linoleic acid and ratio unsaturated/satured) when using grease and oil as raw material in the diets (Table 15a & 15b). Increase or decrease the linoleic acid content of a diet is a well-known method to adjust the weights of eggs, especially at the beginning of spawning.

In feed "layers", the level of added fat is between 0.5 and 4%. The products of the oxidation of fats and trans fatty acids of vegetable oils (example : recycled oils) are undesirable products in the diet of parent flocks.

Animal products (oils / greases)	C14:0	C16:0	C16 :1	C18:0	C18:1	C18:2	C18:3	C20:1	C20:5	C22 :1	C22:6	Unsat. /Sat.
Grease of ruminants (1)	4	26	4	20	40	3	0.5	-	-	-	-	1
Grease of poultry (1)	1	21	5	7	42	21	2	1	-	-	-	2.3
Salmon oil (1)	4	11	9	5	20	1.5	1	9	12	6	14	3
Cod liver oil (1)	4	3	9	3	25	2	0.5	12	11	5	11	3.2

Table 15b: Indicative fatty acid profile (%) of several animal oils and greases (INRA)

QUALITY OF FAT SOURCES

The quality of fat is critical for a variety of reasons. The first is that poor conservation leads to an oxidation which will lead to a decrease in the energy value (the energy of the most energetic raw material in the ration will be overestimated). The second is that an oxidized fat emits an unpleasant odour for the animals which will influence their consumption. The third is technological, a fat too rich in water/impurities/oxidized will lose its viscosity, so, its ability to bind fine particles. It is therefore necessary to check frequently:

- Humidity/Impurities. Not being able to be considered as fat, it is in the best case a dilution of energy.
- The "final" oxidation via different methods, for example, the Anisidine index. This index makes it
 possible to know the state of oxidation. But he does not know if the fat is being in degradation, also yet
 important factor.
- The peroxide index makes it possible to show whether the fat is in the process of oxidation. This index gives us an indication of the state of conservation, low = stable (or fat is totally oxidized), but no degradation in progress. High = fat is degrading (but the Anisidine index may be very low, if we are only at the beginning of the process).
 - High peroxide + low anisidine = fat not oxidized but during oxidation.
 - o Low peroxide + high anisidine = fat oxidized, the phenomenon is finished.
 - Low peroxide + low anisidine = fat stable and good quality.



⁽¹⁾ Each source is unique because it comes from different animal species, different fatty parts, various processes... These products must be systematically characterized before use and check their stability and regularity over time (preservation, homogeneity, such as the typical undesirable dioxins).

Photo from left to the right: Poultry fat, blended of vegetable oils, soya oil (with impurity), soya oil, palm oil (heated to be liquid), palm oil (oxidation in progress)



10.4. FIBER SOURCES

The fibers are difficult to describe chemically speaking (i.e. fiber diagram), each analysis method represents a different fiber fraction. See Table 3 for their functional roles.

The sources available for laying hens are relatively low. As for other raw materials, here is an overview of the sources often incorporated into formulation.

❖ LIGNOCELLULOSE

Lignocellulose is an "insoluble" fiber from wood. It is not sold as a raw material, but as an additive because the manufacturing processes (extraction, purification, grinding...) are complex. It is widely used in humans & by the pharmaceutical industry and has a strong interest in laying nutrition, especially when no other fiber source is available as with a single corn/soya diet. However, the often very fine particle size implies to use it in addition to other coarser fibers that will have a mechanical impact.

❖ SUNFLOWER MEAL

Sunflower meal (low pro> high pro), are very rich in insoluble fibers. It is the source to have available because it brings fiber and protein for a cost in the end the most economical. High-dose incorporation is not a problem because there are very few anti-nutritional factors in this oilseed. Present in all European formulas, it would have an interest in many other countries all around the globe.



❖ LUCERNE/ALFALFA





Alfalfa is an interesting source for its insoluble fibers, because it is very rich, 4 to 5 times more so than soya hulls, 1.5 times more than oats hulls, for example. It is a source to incorporate when available in small doses. There are many other components that have a positive effect on animals in this legume such as saponins, antioxidants (xanthophylls)...

❖ OATS/BARLEY

"Fiber-rich" cereals can be useful for diversifying the inputs. Recent studies (including human studies) show that the more sources of fiber of different origins in the diet, the more developed and varied the microbiota will be, which is a clear improvement in intestinal health. However, the concomitant use of broad-spectrum xylanases should be favoured in order to compensate for the negative effects of viscosity (in particular for barley). In some countries oat hulls can be found (envelopes are even richer in insoluble fibers).

SOYA HULLS

In many countries, the availability of fiber sources is low except for soya co-products such as hulls/shells that are dehulled during oil production processes. This raw material is rich in cellulose (rather soluble fibers), but it contains a non-negligible part of the insoluble fibers we are looking for.

❖ SUGAR BEET PULP

Photo: Sugar beet pulp





The sugar beet pulp can also be used for its fibers intake, in small doses. With a disadvantage that is the sugar content that is easily fermentable by the microorganisms present in the intestine.

10.5. USE OF EXOGENOUS ENZYMES

Enzymes produced endogenously by poultry are able to digest only 5 to 20% of the NSP (non-starch polysaccharides) present in the feed.

Numerous studies over the past thirty years, with improvements in the technology of production, they became less expensive, are now being routinely used in poultry and poultry breeder feeds to improve digestibility of the diet. For instance, phytase can be used effectively to increase the digestible phosphorus concentration of monogastric rations. Whereas carbohydrases, such as xylanase and beta-glucanase, can effectively increase the diet's energy digestibility of feed ingredients high in NSP (wheat, barley, etc.), but their effectiveness is lower among adults than among the young chick (imperfect digestive system).

In order to obtain maximal benefits from the inclusion of enzymes in animal feeds, it is necessary to ensure that the enzymes are chosen on the basis of the feed composition. In simple terms, the enzyme must be matched to the substrate. Failure to consider the phytate content of the complete diet when assigning an availablephosphorus credit to the phytase product may lead to phosphorus deficiencies, resulting in poor egg production, osteoporosis, and gout. Similarly, failure to consider the xylan or beta-glucan content of the complete diet when assigning energy credits to a carbohydrase product may lead to wrong energy assumptions, resulting in incorrect feed allocation with reduced growth, egg weight, and egg production (energy over-estimated).

CONSTITUENTS OF CELL WALLS Parietal Soluble Lignins Celluloses Hemicelluloses Pectic substances proteins polysaccharides **Total Dietary Fibers TDF** Water-insoluble fibers « Carré's walls » ANALYTICAL METHODS **NDF Neutral Detergent Fiber ADF Acid Detergent Fiber** Soest Van **ADL Acid Detergent Lignin** Weende's crude fiber NON-STARCH POLYSACCHARIDES Insoluble NSP

Schema: Analysis methods and components of the vegetable walls

Since enzymes are proteins, the structure of the enzyme is critical to its activity. The pH, heat or certain organic solvents can alter enzyme structure. Changes in the structure of the protein can decrease or negate enzyme activity. The temperatures to which feeds are exposed during the pelleting or heat treatment process can

Soluble NSP



range from 60 to 90°C under normal conditions. Studies reveal that temperatures over 75°C and pressures can lead to loss of feed-borne and added enzyme activity.

The supplier of the enzyme or your nutritionist should be consulted to ensure the raw material matrix and feed specification values for energy and amino-acids are correctly adjusted for the enzyme being used and for the conditions where the enzyme is used. Consideration must be given to phosphorus, calcium, sodium and other minerals ensuring correct values have been ascribed to the product.

Future developments in enzyme technology will likely focus on more thermo-tolerant enzyme preparations, greater enzyme activity and enzymes which function optimally at low gastric pH values. Additionally, as more is known of the chemical nature of our feed ingredients, better methods of degrading these compounds may be found.

Enzymes can therefore reformulate diets to reduce costs while maintaining performance or being added as an additional component to reduce raw material digestibility variability and increase performance ("on top"). There are no bad enzymes, only bad uses (insufficient substrate, too little activity, competition between additives, over-evaluation of matrix, etc.).

❖ PHYTASES AND PHYTATES

Phytases have been used in the feed industry for close to 30 years. Over that period, the number of products has increased (we are in the third generation) and the recommendations on how to use these products have changed. However, despite several thousand scientific papers, the market is now well established, is widespread all around the globe use of phytase in poultry feeding. Initially, phytases were offered as a means to improve the phosphorus bioavailability from phytate-containing ingredients. However, it was gradually understood that the digestibility of other minerals (notably calcium but also sodium), carbohydrates and amino-acids were also variably influenced by the ingestion of phytase. Phytates are the form of storage of plants for phosphorus. This makes it antinutritional factors. In addition to their effects on digestible phosphorus, they bind other components: Zinc, Peptides, Amino Acids..., which can influence the processes of absorption of these nutrients in the intestine.

Most commercially used phytases are not intrinsically thermostable enough to survive the harsh conditions encountered when feed is steam conditioned and / or pelleted (the last generations have a clear advantage on this point because they have been selected in part for their natural resistance). Two approaches have been employed in order to circumvent this problem: Genetic modification or coating the enzyme to produce a more thermotolerant enzyme. A third alternative way is spraying the phytase onto the feed after the heat treatment and/or pelleting process. To date, the effectiveness of these three solutions is equivalent if they are well mastered. The commercial usage of phytase is based on the assignment of a nutrient matrix to a given dose of the enzyme. Nevertheless, there are differences in the release of nutrients between generations of enzymes (favouring as far as possible the most effective, and therefore the last generations). These factors that influence the extent and consistency of the effects of phytase should be carefully considered when formulating poultry diets, especially for parental diets. For this reason, a programme of frequent enzyme recovery measurements after feed processing is essential (to be made for all enzymes).

Extra-dosing is developing more and more with the latest generations of phytases. This is to double or triple the recommended dose to reduce the use of mineral phosphate. With such doses, greater effects are expected on the ancillary nutrients such as A.A., but may also go as far as totally suppressing the mineral phosphate at the end of laying for CS flocks.

NSPases

It is now well known that NSP can exert anti-nutritive activity in monogastric animals. The NSP of barley, wheat and rye (beta glucan, arabinoxylans or pentosans) are those most intensively investigated. Ingestion of NSP by monogastrics results in increased viscosity of the digesta (Burnett, 1966; Antoniou and Marquardt, 1983). This



increased viscosity reduces the passage rate of the feed leading to overall reductions in performance, sticky droppings and dirty eggs. The addition of enzymes to the diet to address NSP viscosity can improve feed efficiency, improve manure quality and promote the use of alternative feed ingredients, frequently lower in cost.

Enzyme cocktails containing more than one enzyme will often improve the response compared to pure single enzymes (in reality, depends on the substrate), assuming that cost considerations are not ignored. This is due to the fact that feedstuffs are complex compounds containing protein, fat, fiber and other complex carbohydrates. Merely targeting a specific substrate such as Beta glucan may not provide maximal benefits since layers of other substrates may inherently protect some of the Beta glucan. For example, beta glucans and arabinoxylans may be bound to peptide or protein in the cell wall of the feedstuff. Therefore, enzymes able of hydrolysing protein may enhance the activity of pentosanases and beta glucanases.

As a consequence of the mode of action of the NSP-hydrolysing enzymes, an increased utilization of dietary energy may well be expected. In fact, increases in ME values of either whole diets or specific raw materials due to enzyme supplementation have been repeatedly described in the literature. Because of improvements observed in protein digestibility it is tempting for the nutritionist to lower the overall target protein and amino-acids levels of the diet. However, because of the variation in individual amino acid digestibility, caution is advised in doing this in order to ensure adequate levels of limiting amino acids are provided.

❖ PROTEASES

These enzymes have the effect of increasing the digestibility of the protein via their targeted action on this substrate. The overall digestibility of the protein fraction is rather high in poultry, proteases seem to be more intended: to young animals (imperfect digestive systems), a feed with a high protein ratio or a protein of low quality/digestibility. Their use is increasingly widespread throughout the world.

CUMULATION OF VALUATIONS

Particular attention should be paid to the cumulation of potential valuations. Some identical interactions and mode of action mean that 2 enzymes used at the same time will not have the same values as taken separately. If phytase is used with an energy value = 1, more of the protease (energy value = 1), plus a xylanase (= 1): the sum of all these activities will not be 3! But very often 2. There is very little published information on these concomitant uses, it is especially the experience of the nutritionist and the field trials that make us lean towards more caution.

10.6. QUALITY CONTROL PROGRAMS

Feed quality-control programs are targeted to deliver feeds that consistently contain the formulated nutrients in an available form and contain minimal levels of undesirable substances. A formula is not something fixed, it evolves, changes; quality control must be put in place to achieve the greatest possible stability/regularity over time.

* RAW MATERIALS QUALITY CONTROL

It is important to pay attention to the quality of the ingredients from an economic as well as technical point of view. By assuming good quality of manufacture, dosage and mixing of a feed, it is possible to explain for the most part the origin of variations in nutrient contents by the variability of the ingredients. Ingredients must be described in terms of analytical values and physical and/or sensory characteristics. Ingredient assessment that only considers colour (example: heat damage), odour, contaminants and texture generally will fail to identify much of the variation in ingredient quality.

Every quality control program should include a combination of rapid appropriate tests at the feed mill (e.g. moisture, test weights, rancidity, etc.), and combined with periodic analysis more completed at a reliable laboratory



(ideally accredited). The frequency of these analyses is often linked to the variability and tonnage of each ingredients. A rapid analysis (NIR for example) on site may lead to the rejection of certain deliveries deemed deficient. It also helps to demonstrate to the raw materials suppliers, the quality commitment of the feed manufacturer.

If the rapid inspection of important ingredients at the feed mill suggests a risk of poor quality, and without waiting for the chemical analysis, then use a safety margin for energy (ME), proteins etc., in order to anticipate a lower digestibility:

- e.g. corn, in normal conditions = ME 3360 kcal, if poor quality, use 3200 kcal/kg;
- e.g. soya bean meal, in normal conditions, crude protein 46%, if poor quality, use 45% (or lower).

Basic nutrients which must be analysed regularly are humidity, crude protein, starch, crude fiber, ash, crude fat and the main minerals like calcium, phosphorus, sodium and chloride. However, analysis of amino acid contents especially lysine, methionine and threonine are beneficial where possible. These represent the nutrients that must be listed for every raw material in order to build a raw material matrix. This matrix needs to be adjusted on a regular basis based on local ingredient information. It is absolutely impossible to build a locally accurate matrix based only on published tables from reference sources or the internet. While this simple fact seems to be obvious, it is very often forgotten in practice. Create a matrix accurate, consistent, maintained and alive, it's a job either!

Sampling is a critical part of any quality-assurance program. Steps involved with collecting a representative sample include following a sampling scheme; follow a sampling plan, collecting numerous samples to ensure it is representative; using the correct sampling equipment and procedure; inspecting the sample for its sensory characteristics and finally mixing the subsample for laboratory analysis. Always retain a portion of the subsample for possible later analysis.

Ideally, each new batch of grain or grain co-products should be sampled because grains tend to be unpredictable in nutrient content according to their source, supplier, process... When suppliers are bound by local law to meet guaranteed analysis (feed/raw material label with nutrients), raw materials may not have to be sampled quite so often. But trust does not forbid control.

If premixes are purchased from a reputable company, it is not necessary to routinely send samples for expensive vitamins laboratory analysis. Nonetheless, it is a good idea to sample each shipment of premixes and keep samples stored in freezer. This sample permits further analysis if problems with premixes are suspected.

In all cases, it is recommended to carry out a regular audit of your raw materials suppliers to know well the critical points of their process and the risks or undesirables potentially present in their/your raw materials. The objective is to adapt its quality control so that it is as economical and relevant as possible.

❖ PROCESS CONTROL

The process by which high-quality ingredients are made into high-quality feeds involves three components within the feedmill: personnel, machinery and procedures. The company commitment to quality must be supported by everyone from top management down to all feed mill employees. Any employee who discovers a problem with a batch of an ingredient should be recognized for their commitment.

Equipment selection, operation, repair and troubleshooting can become a very complicated process which cannot be covered in this guide. However, considering the special characteristics of breeder feeds, it is important to emphasize :

- Verification of the cleanliness of equipment including the delivery truck.
- Meters and scales: batch scales should be inspected at least once each month, while micro-ingredient procedures and scales should be checked weekly (a regular physical inventory should be done for these micro ingredients that are often expensive or dangerous).



- Grinding and granulometry of the feed.
- Mixing efficiency (minor ingredients and main raw materials) related to risks of insufficient or too long
 mix time (to be checked at least twice a year). Risks include mixers used beyond/below their designed
 capacity and worn, altered or broken equipment.
- Spraying system, injection of liquid in mixer: these industrial processes are delicates to master well. Regularly check the condition of the injection nozzles, the flowmeters, make a regular physical inventory... Liquids more or less viscous/tights tend to clog the circuits.

Attention must be given to accuracy of inclusion of premix and feed additive such as phytase. Into feed, there must be assurance that the minerals, vitamins and all feed additives are blended into the feed in a homogenous manner. A test of homogeneity and cross-contamination is recommended once a year by manufacturing line.

❖ FINISHED FEED QUALITY

A program of monitoring the quality of finished feed should be agreed between the supplier and the feed buyer. This will minimize disputes and claims. Indeed, we need to ensure that an analysis of a sample of feed is well representative of the diet actually provided. This agreement should include sampling method, sampling frequency, and procedure for comparing the actual diet analysis with the diet specification, tests for contamination, microbiological status and the storage of samples. Routine laboratory analysis of finished feed should be conducted each month at the minimum and as regularly as possible depending on the tonnage.

It is recommended to keep samples of all delivered feed on farm for at least 3 months or preferably the lifetime of each flock to assist the diagnosis of any future performance problems while not forgetting these samples may play an important role in understanding microbiological problems such as salmonella contamination. Conservation must be protected from light, heat and moisture.

The practical difficulties in achieving the exact control of feed composition emphasize the importance of continuous monitoring of flock performances.

Note: The time taken for feed to reach the birds after manufacture should be as short as possible. This is especially important under conditions of high temperature and humidity. Indeed, the loss of vitamins as well as other type of damage (including mould development) are then accelerated in these difficult conditions. Mixtures of acids may help to better conservation, but they only delay the inevitable development of mould.



11. FEED CONTAMINANTS AND FEED HYGIENE

All feed must be considered a potential source of bacterial infection: particularly Coliforms and Salmonellae. Breeder feeds must be decontaminated, especially if recurring microbial pathogen control is required.

The growth of moulds on feedstuffs (grains, finished feeds) and the elaboration of toxins by these moulds (i.e. mycotoxins) are a prevalent problem due to their detrimental effect on poultry performance and reproduction. By some estimates, mycotoxins affect as much as 25 to 40% of the world's feed crops each year.

11.1. MOULDS AND MYCOTOXINS

There is a huge interest in these naturally occurring chemical compounds due to their adverse effects, their wide variety of clinical signs and their more or less severe economic losses.

Identification of mycotoxin contamination is made difficult because the symptoms are often vague, non-specific and can also be associated with other diseases or go relatively unnoticed. Some of the problems associated with mycotoxicosis in poultry are as follows :

- Reduced weight gain and decrease of uniformity in rearing. Increase feed clean up time.
- Decrease serum proteins. Increased liver and kidney weights. Liver and kidney lesions.
- Induced immune-suppression/depression.
- Altered feathering.
- Reduced egg production, fertility and hatchability. Smaller day-old chicks.
- Low quality of day old chicks.

❖ MOULD GROWTH

Fungal contamination of grain and poultry feed is versatile and pervasive. Mould spores are commonly found in the soil, on decaying plant debris. They are transported to the plants by air currents, water movement and insects. It can start in the field, or on the crop itself, or during post-harvest transport and storage. Environmental factors such as moisture content (> 14%), optimum temperature and insects are the main factor in the activity of moulds.

Whether they are field or storage fungi, these micro-organisms require nutrients for growth. Therefore, the presence of mould in grain and feed will reduce the available nutrient content. Nutritional deficiencies associated with mould growth in grains and feeds include decrease in dietary energy values (Bartov et al, 1982), altered amino-acid profile and reduced vitamin levels. This lead to a negative impact on animal performance together with feed refusal (smell and taste are modified) and more or less specific pathology (enteritis, black tongues...).

MYCOTOXIN CONTAMINATION

Among thousands (USDA, 1999), well over 300 mycotoxins are currently identified. The important mycotoxins studied are aflatoxins, ochratoxins, trichothecenes, fumonisins and zearalenones. These toxin agents are ubiquitous in distribution all around the world and have been isolated from a wide variety of grains, oilseeds, etc. The response of a poultry receiving a dietary mycotoxin will depend upon numerous factors. These factors include weight, age, physiological and health status of bird. Combined effects between several mycotoxins (synergistic effect) and most importantly, the dose coupled with the duration of feeding that dose (= amount consumed). It should also be kept in mind that a threshold dose must be reached (table 16) before a response to the dietary mycotoxin will be noted/notable.



Table 16 : Estimated r	<u>minimum leve</u>	el of main my	<u>/cotoxins to a</u>	affect performances

Mycotoxin (ppm)	Pullets	Layers (1)
Aflatoxin (B1)	50	20
Fumonisin (B1+B2)	1 000	800
Ochratoxin	25	10
T2 Toxin	100	50
Vomitoxin (DON)	500	400
Zearalenone	75	50

⁽¹⁾ These levels are to be taken into account individually! Synergies or antagonisms between mycotoxins are still very little studied. However, it is believed that they can interact negatively with performances below these levels if several mycotoxins are present.

In contrast, if the level of contamination is high, the response may occur rapidly and with a high degree of severity. Acute mycotoxicosis outbreaks are however rare events in modern commercial poultry production. More commonly, low mycotoxin doses that may go undetected are responsible for sub-chronic, non-specific effects that result in reduced efficiency of production and greater susceptibility to other infectious diseases, especially with long production cycle.

We recommend that each new crop must be properly characterize the "average" contamination to assess the risk and thus adapt the doses of mycotoxin binders. In parental, the use of a binder is recommended systematically for safety.

MOULDS AND MYCOTOXINS CONTROL

The most cost effective prophylactic measure to protect investments in grain, feed and animal performance is a comprehensive risk management program that starts by cultivation practices, appropriate drying of cereals after the harvest and finished by the storage. Prevention of condensed water on the silos walls and elimination of pests and mites are also important. There were also be humidity controls from a representative sample. The "risky" grain can be blended with clean grain and/or given to species of animal less sensitive to the mycotoxins like broiler of more than 20 days of age rather than high value breeders (be careful, some local regulations prohibit now the dilution of contaminated batch with healthy batch).

The detection of mycotoxins, though, is difficult and sampling methods do not provide consistency in their results. In addition, specialized laboratory equipment supported by qualified technicians is needed.

Speciality feed additives, known as mycotoxin organic adsorbents or inorganic binding agents are the most common approach to prevent mycotoxicosis in animals. It is believed that the agents bind to the mycotoxin preventing them from being absorbed. The mycotoxins and the binding agent are excreted in the manure. Be aware that not all binders are equally effective. Many may impair nutrient utilization and are mainly marketed based on in-vitro data only. In addition to using toxin adsorbents/binders in feed, an additional solution especially when facing trichothecenes (T-2, DON) toxins, is to provide early protection for the liver (hepato modulator), the main organ that supports detoxification of toxins and metabolites.

The completed breeder feed should be treated with a mould inhibitor per security.

Several commercial products are available and are generally mixtures of organic acids (i.e. acetic acid, sorbic acid, propionic acid...), which, in combination, prevent the growth of a wide variety of moulds. If the incoming feed ingredients are thought to be of poor quality (i.e. if a cereal contains many cracked and mouldy kernels, or has a mouldy odour), it should be treated at reception to avoid any development during storage. This will prevent further



mould growth but will not negate the nutrient destruction that has already taken place as a result of earlier mould growth. It will not eliminate mycotoxins that have already been produced. These raw materials contaminated, must not be used in breeder feeds.

11.2. FEED-BORN MICROBIAL CONTAMINATION: SALMONELLA

It is estimated that about 15% of the Salmonella contaminations in poultry products are caused by feed. One of the major challenges for feeding poultry includes the use of Salmonella-free feed. This is a standing request of many breeding companies because consumers demand and expect Salmonella-free food products.

Zoonosis have only become a focus of attention in the last fifteen years. Salmonellosis is generally accepted to be one of the most important zoonosis transmitted by meat and eggs (Escherichia coli & Campylobacter sp. are also common). Salmonella cannot be entirely eradicated, but it can be controlled. Breeding flocks free of salmonella have been considered as a fundamental pre-requisite for a better control of Salmonella at broiler/layer level.

A broad range of Salmonella can be isolated from poultry. However, the most relevant to the poultry industry are broad host range serovars multi-species: Enteritidis (SE) and Typhimurium (ST), and host specific (to poultry) serovars Pullorum and Gallinarum. Other serotypes in the top 10 of causes of human salmonellosis cases included: Infantis, Hadar and Virchow.

Many strategies such as in feed antibiotics or vaccines have been tried and tested to control Salmonella in the poultry industry but none of these Salmonella control strategies have been successful on their own. Therefore, the control of Salmonella must be considered in terms of an integrated approach combining improved hygiene, biosecurity and management practices including specific nutritional technology.

Feed has traditionally not been considered a major source of SE for breeder flocks when it does not contain animal protein ingredients. However, some co-product used in breeder feed may contain various type of salmonella. Monitoring has shown that vegetable raw materials may have similar levels of Salmonella contamination to animal sources. The most common vegetable raw material found to be contaminated is oilseeds protein such as sunflower, rapeseed, palm kernel and soya (especially because they pass through harbours, involving a risk of contamination by harbour birds).

Salmonella bacteria are moderately resistant to the environment and are inactivated by most disinfectants, formaldehyde gas, heat and extremes in pH.

Breeder feeds must be safe, it must therefore be treated systematically either by heat treatment, additives (acids, formaldehyde, etc...).

❖ ENTEROBACTERIACEAE LEVEL AS INDICATOR OF SALMONELLA CONTAMINATION?

Enterobacteriaceae are a group of gram-negative bacteria, non-spore forming bacteria that includes Salmonella, Escherichia coli, and other enteric bacteria. The level of enterobacteriaceae in feed is a strong indicator of the feeds microbial quality and therefore level of enterobacteriaceae in feed is considered a reliable indicator of raw materials and feed quality.

When enterobacteriaceae levels are high, the probability of Salmonella contamination is also high and concomitantly, when enterobacteriaceae levels are low the probability of Salmonella contamination is low. The "acceptable" maximum levels of enterobacteriaceae, where action needs to be taken, have not been determined for all feeds or feed ingredients. In Europe, a maximum limit for enterobacteriaceae has been established. In breeder feed, the maximum acceptable level of enterobacteriaceae is 100 cfu/g with a target level of 0 cfu/g.



To achieve this, a very strict feed control program is recommended building on heat treatment of the compound feed, use of feed additives and regular checks at defined critical control points (CCP) in feed mills.

❖ CRITICAL CONTROL POINTS (CCP)

The following CCPs have been identified and indicate where process-monitoring samples should be taken in feed mills in order to effectively identify frequent contamination problems with ingredients or post-processing contamination:

- Dust taken from ingredient auger system below or behind the intake pits.
- Dust from ledges inside tops of raw materials silo's and bins. Or dust from ingredient sieves or spillage from ingredient bin augers if bins are inaccessible or do not accumulate dust.
- Swabs from coolers, taken below coolers or on associated framework, at the pellet shakers. Or for mash ration lines take dust from finished product bins or augers.
- Dust from ledges near to feed discharge points.

The processing equipment in the feed mill must be designed to allow easy and effective cleaning. Special attention should be focused on mill hygiene during the maintenance and shut down periods.

For a feed production of more than 10 000 MT per year, a monthly sampling at each CCP listed above is the minimum required. In the case of feeding grand-parent stock, the sampling frequency at each CCP can reach 1 per 150 MT produced.

Where a result is obtained with more than 1 000 enterobacteriaceae cfu/g, the following should be taken:

- Re-sampling at the CCPs and analysis;
- Serotype any positive samples;
- Implement the necessary cleaning and disinfection program;
- Additional investigation including evaluation of raw materials;
- Inform the raw material supplier of the results if a specific ingredient is the reason of the contamination.

❖ DEDICATED HEAT TREATMENT LINE

Traditionally, Salmonella control in finished feeds, such as poultry breeder feed, has been attained by heating the feed through a manufacturing process such as pelleting. However, at standard pelleting temperatures (65-70°C) total de-contamination is highly unlikely. Furthermore, subsequent multiplication of any residual Salmonella and re-contamination, especially through the cooling system, may occur.

For effective de-contamination, the best system consists of a dedicated heat treatment line for poultry mash feed or both pellet and mash diets. Dedication starts prior to heat treatment and includes all routing through the heat treatment process to dedicated bulk out-loading bins and from there to the bulk delivery vehicles.

The heat treatment is made from two specific equipments:

- Regarding heat treatment itself, a defined combination of a set temperature for a set period of time, at
 a set relative humidity must be consistently applied to the finished feed (these settings are specific to
 each type of equipment). Out of the « thermiseur », feed can be pelletized or crumbled or maintained in
 mash.
- The system requires a cooler to return temperature and moisture to the pre-treatment levels. All the air supply to the biosecure milling facility should be filtered through a comprehensive specific air circulation



system especially after the de-contamination process. The closed cooling is positive pressure relative to that of the factory.

Maintenance, the frequency of manual cleaning by specific personnel, decontamination of hot air circuits (70 - 80°C) and bacteriological controls are also very important factors in the success of this technique.

One of the advantages of the concept is to enable breeders to continue mash feeding which increases the time it takes the birds to consume their daily allowance (see chapter on feed presentation).

❖ FEED ADDITIVES FOR SALMONELLA CONTROL

Some feed additive products are sold for salmonella control in the feed. To date a number of products have gained commercial acceptance, including short chain fatty acids (formic, acetic, propionic and butyric acids) and formaldehyde (forbidden product now in several European countries). They all demonstrate anti-Salmonella properties.

Medium chain fatty acids (C6 to C12; caproic, caprylic, capric and lauric acid), essential oils, probiotics, prebiotics and glycans have also been listed. However, these products will limit colonization of the gut by Salmonella sp. but may not have sufficient bactericidal properties.

The development of such feed additives for the control of Salmonella has been somewhat empirical and often the concentrations used in commercial operations is determined by the cost of addition rather than scientifically determined minimum inhibitory concentration as determined by the supplier.

The antibacterial activities of organic acids are also dependent of the temperature, moisture, dose of acids and time between addition of acids and feed consumption by the birds. The actions of acids are relatively slow and 48 hours' exposure appears to be a minimum for best efficiency.

Note that some of the commercial acids products can be corrosive to the mill equipment (to check before use).

These organic acid and formaldehyde products may also help in preventing re-contamination during the handling, storage and transportation phases.

❖ RISK OF RECONTAMINATION

One of the biggest challenges in producing salmonella-free feed is to avoid any kind of recontamination during cooling, delivery and storage of the feed. Recontamination occurs when dust and residues in the cooler or feed transport system, inside the mill, in feed trucks, in the storage and in the farm feed system become incorporated into the breeder feed. Dust and feed residues contain high levels of mould and bacteria which result in an increased incidence and increased level of bacteria/mould in the feed consumed by the animal. The highest risk of contamination is in the cooler because it is a hot and humid zone favourable to the bacterial and fungal development. The cooler must be located in an isolated room to avoid condensation that is very dangerous. The fact of having an overpressure in this room avoids contamination coming from the factory.

All vehicles used to transport of breeder feed should be subjected to a risk based cleaning and sanitizing programme to ensure they are maintained in a clean state with no build-up of waste material. Ideally, separate vehicles should be designated specifically for breeder feed but it is recognised that resources may not allow this. Therefore, if vehicles are used for the carriage of other materials, they must be appropriately cleaned of organic matter, sanitised using approved disinfectant and procedures and dried before being used to transport breeder feed. Organic matter reduces the effectiveness of disinfectants so scratching if needed and removal of dust inside each truck's compartments is essential. Schedule of feed deliveries should give priority to the farms with the highest health rating to be the first in a sequence of visits by the same truck.

Although some special supplements like organic acids are very useful to keep the feed salmonella-free until it is consumed by the birds, the major problem is often the storage and handling of the feed at the farms.



11.3. CROSS CONTAMINATION

Feed ingredients and premixes should meet acceptable and if applicable, statutory standards for levels of pesticides and undesirable substances. Excessive dosages, inappropriate use of feed additives and cross-contamination of feed can pose a serious risk to breeder flocks.

It is generally acknowledged that under practical conditions during the production of mixed feeds, a certain percentage of a feed batch remains in the production circuit and these residual amounts can contaminate subsequent feed batches including breeder diets.

Manufacturing procedures should be used to avoid such cross-contamination (for example: flushing, sequencing and physical clean-out) between batches of feed and feed ingredients containing restricted or otherwise potentially harmful materials such as certain animal co-product meals and veterinary drugs. These procedures should also be used to minimize cross-contamination between medicated and non-medicated feed and other incompatible feed. In cases where the safety risk associated with cross-contamination is high and the use of proper flushing and cleaning methods is deemed insufficient, consideration should be given to the use of completely separate production lines, transfer, storage.

11.4. OTHER UNDESIRABLES

There are other toxic and/or undesirable substances that can contaminate feeds. Without making an exhaustive list, it is necessary to monitor :

❖ HEAVY METALS

Often derived from mineral sources, each origin/quarry is different on these criteria. Some trace elements come from recycling, so they tend to concentrate these unwanted metals. Vegetable raw materials can also accumulate if they are present in the soil in a significant way. The risk goes from a more or less serious poisoning to death.

❖ PESTICIDES / HERBICIDES / FONGICIDES / INSECTICIDES

All these "control" molecules during the life of a raw material (culture as storage) can accumulate if dosages and rest periods are not well respected. Given the low doses often found, the impact is more diffuse but a disturbance of reproduction, a decrease in immunity are possible.

GENETICAL MODIFIED ORGANISM

Some customer specifications, such as organic production, prohibit the use of raw materials (and additives) derived from Genetically Modified Organisms (GMO). Consumer demand is increasingly being developed in Europe and North America for this type of product.

MEDICINES. ANTICOCCIDIENS

These molecules, even at low doses, have an impact on the animals that consume them. Ensure that there is no incompatibility between species during manufacturing sequences at the feed mill (or transport). Multi-resistant bacterial strains are emerging with all the difficulty of managing these "super-bacteria" in human health. It is therefore necessary to use them at least and always wisely in order to avoid as much as possible the development of these "new super-bacteria".



❖ MELAMINE

A few years ago, a fraud with this substance led to a systematic control in Europe of protein-rich raw materials from certain Asian countries. When analysing protein with common chemical methods, melamine looks wrongly to protein. It is therefore believed that a 50% protein soybean meal is used whereas it actually has only 30% or less. In addition, it is toxic to animals consuming it (mortality observed on dogs and cats and even in humans).

DIOXINS & POLYCHLOROBIPHENYLS (PCB)

Dioxins are ubiquitous pollutants formed during combustion processes during many industrial activities (waste incineration, metallurgy...). They also result from natural events such as volcanic eruptions and forest fires. The term "dioxins" comprises 210 different compounds belonging to two families of chlorinated polycyclic aromatic hydrocarbons: PolyChloroDibenzo-para-Dioxins (PCDD) and PolyChloroDibenzoFuranes (PCDF). 17 have significant toxicological effects (carcinogenic and teratogenic properties).

PCB form another family of chlorinated aromatic hydrocarbons consisting of 209 compounds (or the like). They have a different origin than dioxins. They were produced intentionally by humans from the 1930s and were used for example in electrical transformers, building materials, etc. Their production and use has been banned since 1987, but they are still found today "everywhere". 12 compounds have toxicological properties similar to those of dioxins and are referred to as "Dioxin-like PCB" = "Dioxin-like".

These pollutants can be found in all raw materials (milk, meat, etc.), but these are compounds that tend to concentrate in the fat (they are lipophilic). Particular attention should be paid to sources of fat such as animal fats and oils. Animal products also tend to accumulate these compounds (meat meal, fish meal, etc.).

SAMPLING

It should never be overemphasized that in all cases a representative sample (sample size, number of elementary samples, sampling sites, etc.) must always be obtained. This is sometimes very difficult on mash feeds for undesirables like mycotoxins which by definition have a heterogeneous distribution in raw materials. There are official/recommended methods: for example, for mycotoxins and for a single batch of raw material, 20 minimum elementary samples must be taken to reconstitute a coherent mean sample.

Controlling all these undesirables improves not only the performances of our farms but also the quality of what we humans, consume in the end!



We hope that this guide will provide you with enough insight into the nutrition of pullets and layers, even if it only raises a number of issues that are too long to develop here. It is carried out with the objective of popularization so that it can be used everywhere around the globe, in climates contexts, raw materials ... very varied and increasingly fluctuating.

It is necessary to always have the opinion of a local nutritionist who knows perfectly the market context, raw materials, undesirables, etc., in order to adjust our recommendations to your particular situation, to field results but sometimes also to each customer!

Novogen Team





Caring for life
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