



Arbor Acres

Broiler Nutrition Supplement

2009



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Introduction

In the 2009 edition of the **AA+ Broiler Management Manual**, the nutrition chapter aims to supply a concise overview of the most important aspects of nutrition for all those involved in the management of broilers. This Nutrition Supplement provides more detailed information for those involved in decision making on feed specifications and formulations.

Objective

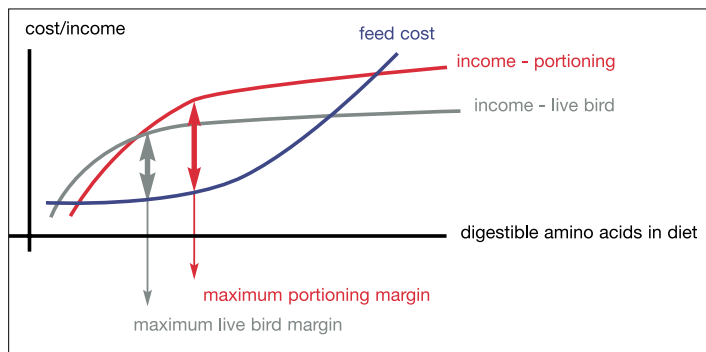
To supply a range of balanced diets which satisfy the nutrient requirements of broiler chickens at all stages of their development and production and which optimize efficiency and profitability without compromising bird welfare.

Principles

Feed is a major component of the total cost of broiler production. Broiler rations should be formulated to supply the correct balance of energy, protein and amino acids, minerals, vitamins and essential fatty acids to allow optimum growth and performance.

It is widely accepted that the choice of dietary nutrient levels should be an economic decision to be made for each company or enterprise. This is especially important for dietary protein and amino acids. Higher levels of digestible amino acids have been shown to improve profitability by increasing broiler performance and especially processing yield. Therefore separate recommendations are given for optimizing margin for live birds and portioned birds. Maximizing live bird profitability is similar to minimizing feed cost per kg live weight. When producing birds for portioning, this relationship changes. To maximize margin from portioned birds, it is often necessary to increase the levels of digestible amino acids in the diet above those levels which produce maximum live bird profitability. This is because of the financial benefit of additional meat yield from portioned broilers. These relationships are illustrated in the below figure.

Figure 1: Relationship Between Dietary Levels of Amino Acids and Profitability



A response to improved nutrition will only be achieved in broiler flocks when nutrient supply, rather than other management factors, is limiting performance.

The diet specifications proposed in this Supplement will allow good performance in healthy broilers kept under good management.

Supply of Nutrients

Energy

The final formulated energy content of broiler feeds is determined primarily, by economic considerations. In practice, the choice of energy level will also be influenced by many interacting factors, e.g. supply of feed ingredients, milling constraints etc.

The conventional method of expressing the energy content of the feed is as the apparent metabolizable energy level corrected to zero nitrogen retention (AMEn). Data on energy contents expressed in this way are available from many sources; in this supplement energy values are based on World Poultry Science Association (WPSA) tables.

The AMEn values of some ingredients, especially fats, are lower in young chicks than in adult birds. Formulating diets for broilers using chick AMEn takes account of this. Expressing energy content in terms of Net energy overcomes the differences in the utilization of ME when it is derived from different substrates (e.g. fat, protein or carbohydrate) and used for different metabolic purposes. The adoption of these new energy systems improves the consistency and predictability of broiler performance.

Some typical energy levels for broiler feeds are indicated in the Appendices. This information is a practical guide and does not represent the requirements of the birds. The energy levels, which will give the best economic return, should be determined under the local conditions in which the broilers are grown.

Key Points

- Energy needs of broiler chickens are affected by maintenance and environmental conditions. Consideration should be given to housing type and ambient temperatures when setting energy levels of feeds.
- Consider using chick AMEn in formulating broiler diets to reduce levels of less digestible raw materials.

Protein and Amino Acids

Introduction

Feed proteins are complex amino acid polymers which are broken down in the gut into amino acids. These amino acids are absorbed and assembled into body proteins which are used in the construction of body tissue e.g. muscles, nerves, skin and feathers.

Dietary crude protein levels do not indicate the quality of the proteins in a feed, protein quality is based on the presence and balance of essential amino acids in the feed ingredients.

The availability to the bird of these essential amino acids is most important and broiler feeds should be formulated using digestible amino acids. It should be noted that the digestible amino acid levels quoted in this Supplement are based on true fecal digestibility, as opposed to apparent fecal digestibility. When the apparent digestibility system is used, the recommendation should be adjusted accordingly.

The levels of crude protein suggested in this Supplement should be seen as a guide; the actual protein level used will vary according to the feed ingredients and will be driven by the first limiting essential amino acid not available in synthetic form.

It is preferable to use high quality protein sources where these are available, especially for broilers under heat stress. Poor quality or imbalanced protein can create metabolic stress, as there is an energy cost associated with its excretion and may also result in wet litter.

Formulation Strategy

Amino acid levels in feeds must be considered together with all other nutrients, including energy levels (refer to Energy Section of this Supplement on page 4 for further details). Recommended levels for those eight amino acids that may be limiting in practical feeds are listed in the Appendices.

Feed formulation aims to supply an adequate and balanced level of amino acids to the bird. To achieve this, it is important that the formulation matrix is routinely updated. Protein levels of ingredients should be monitored by direct analysis of the raw materials being used in the formulations. If changes are seen in protein level of an ingredient, then adjustments should be made to total and digestible amino acid values in the formulation matrix.

Ideal Amino Acid Profile

It is important to supply the broiler with an appropriate balance of digestible amino acids. As an aid to achieving this objective, an Ideal Amino Acid Profile can be used. This is a system where the requirement of the main amino acids that may be limiting in broiler feeds are calculated and then lysine is used as the reference amino acid to which ratios are set for other amino acids.

Suggested ratios for an Ideal Amino Acid Profile are shown in the table below.

Table 1: Ratios for an Ideal Amino Acid Profile

Digestible Amino Acids	Starter Feed	Grower Feed	Finisher Feed
Lysine	100	100	100
Methionine & Cystine	74	76	78
Methionine	37	38	39
Threonine	65	66	67
Valine	75	76	77
iso-Leucine	67	68	69
Arginine	103	104	105
Tryptophan	16	16	16

NOTE: The information in this table is derived from field experience and published literature.

Balanced Protein

Within this Supplement, reference is made to the concept of Balanced Protein (BP). The Ideal Amino Acid Profile described previously applies both minimum and maximum values to the individual amino acids to produce an exact profile. Whilst this is a useful tool for the nutritionist to refer to during formulation, it has to be recognized that such exact profiles are theoretical in the context of commercial formulation. The concept of Balanced Protein has been developed as a practical application of the Ideal Amino Acid Profile to supply broilers with the correct minimum levels of essential and non-essential amino acids. Using this strategy, the actual protein level used will vary according to the feed ingredients and will be driven by the first limiting essential amino acid not available in synthetic form.

The Balanced Protein recommendations in this Supplement are derived from a combination of both internal Aviagen data on BP response and experiences in the field. Economic responses have been calculated for each region of the world for different weight categories and end objectives – live weight, eviscerated carcass, portioning products. By taking these into account, the full breadth of economic environments are included in these recommendations (see Principles Section, page 4).

Broiler Response to Protein and Amino Acids

The AA+ broiler is particularly responsive to dietary digestible amino acid levels and will respond very efficiently, in terms of growth and FCR, to the recommended levels in the **AA+ Broiler Nutrition Specification**. Higher levels of digestible amino acids have been shown to improve profitability by increasing broiler performance and processing yield. This becomes particularly important when growing broilers for portioning or meat striping. Therefore separate recommendations are given for optimizing portions margin (see **AA+ Broiler Nutrition Specification**).

Key Points

- Formulate using digestible amino acids, following AA+ Ideal Amino Acid Profile recommended (Table 1).
- Consider amino acid levels together with factors affecting feed intake (e.g. energy levels, feed intake control programs, feed form, feeder arrangement) when formulating broiler diets.
- Use high quality sources of protein, especially in circumstances when broilers are likely to suffer heat stress.
- Maintain updated ingredient amino acid and protein values on the formulation matrix.
- Balanced Protein approach produces benefits in broiler and economic performance.
- The AA+ broiler is particularly responsive to dietary amino acid levels. Feeding to AA+ recommended levels provides an economic advantage.

Macro Minerals

The provision of correct levels of the major minerals in the appropriate balance is very important to grow broilers successfully. The macro minerals involved are calcium, phosphorus, magnesium, sodium, potassium and chloride.

Calcium in the diet of broilers influences growth, feed efficiency, bone development, leg health, nerve function and the immune system. It is vital that calcium is supplied in adequate quantities and on a consistent basis to achieve optimum performance.

These responses may require different calcium levels to allow optimum expression, so a compromise must be made when choosing a level of dietary calcium.

The calcium levels recommended in the nutrition tables within this Supplement's Appendices have been produced with the intention of maximizing broiler performance by best satisfying the various requirements of the different functions described above.

Phosphorus, like calcium, is required in the correct form and quantity to optimize skeletal structure and growth. Phosphorus recommendations in this Supplement are based on the classical availability system whereby inorganic phosphorus sources are described as being 100% available and plant sources are described as 33% available. Values of available phosphorus based on toe ash analysis have been found to show correlation with the classical system. Digestible phosphorus is used in some countries as a way of more accurately assessing the phosphorus contribution of materials. Care should be taken to use consistent data on available phosphorus content of feed ingredients and bird requirements.

The use of phytase enzymes will increase the available phosphorus content of vegetable feed ingredients, and in general the use of such enzymes will be beneficial in broiler production. The reduction in phytate arising from the use of enzymes will increase availability of calcium and other minerals.

Calcium: Available Phosphorus. In most instances a Ca:AvP ratio of 2:1 is appropriate for broiler diets. However, there is information available which suggests that in Starter diets a higher Ca:AvP (e.g. 2.1:1) is beneficial to performance and especially helpful in promoting excellent leg strength.

Magnesium requirements are normally met without the need for supplementation. Excessive magnesium (>0.5%) will cause scouring.

Sodium, potassium and chloride are needed for a number of metabolic functions. Excessive levels of these minerals results in increased water intake and subsequent poor litter quality. Shortages can affect feed intake, growth and blood pH.

It is important to control sodium and chloride levels as suggested in the Appendices. In particular, chloride should be accurately controlled by the use of sodium chloride and sodium bicarbonate. In feed formulation all dietary sources of chloride should be carefully identified e.g. in lysine hydrochloride and choline chloride.

There are some circumstances when higher levels of sodium can be used to improve growth rates, notably in pre-starter products.

Electrolyte balance (EB) is important to broilers, especially in heat stress conditions. The anion content of both vitamin and mineral premixes should always be included in the calculation of ionic balance in finished feeds. With practical potassium levels of about 0.85% and the recommended levels of sodium and chloride, an EB (sodium + potassium - chloride) of about 220-230 mEq/kg will be obtained. This is satisfactory and, as indicated, most emphasis should be given to the control of chloride levels.

Key Points

- Provide adequate calcium for the bird following the recommendations in this Supplement.
- Accurately describe phosphorus in feed ingredients and bird requirements in the same units.
- Control chloride levels accurately by using sodium chloride and, where necessary, sodium bicarbonate as feed ingredients.

Trace Minerals

Trace minerals and vitamins are needed for all metabolic functions. Appropriate vitamin and trace mineral supplementation depends on feed ingredients, feed manufacture and local circumstances. Conventional levels of supplementation are recommended for these nutrients. Care should be taken to ensure that suitable forms of each mineral are included in the premix. Organic trace elements have a higher availability in general. There is evidence that enhancement of the zinc and selenium status of broilers may improve feathering and the immune response of the birds. Zinc has been shown to improve foot health.

Added Vitamins

Appropriate vitamin supplementation depends on feed ingredients, feed manufacture and local circumstances. A major source of variation in supplementation for some vitamins is cereal type. Accordingly, in the AA+ Broiler Nutrition Specification, separate recommendations have been made for vitamin A, nicotinic acid, pantothenic acid, pyridoxine (B6) and biotin in maize and wheat-based feed.

It should be noted that the recommendation for choline is given as a minimum specification in the complete feed.

Many circumstances, e.g. stress, disease incidence, may make birds responsive to vitamin levels higher than those recommended in the Appendices. Increases in the levels of vitamins supplied, in the feed or via the water, must be based on local knowledge and experience. In general, the longer-term strategy should be to remove or reduce any stress factors, rather than to depend on permanent use of excessive vitamin supplementation.

The basic requirement of broiler chickens for vitamin E is 10-15 mg/kg. The need for extra supplementation will depend on the level and type of fat in the diet, on the level of selenium and on the presence of pro- and anti-oxidants. Heat treatment of feeds can result in the destruction of up to 20% of vitamin E. Enhancement of immune response and improvements in shelf-life of broiler meat are observed at vitamin E levels up to 300 mg/kg. The levels suggested in the Appendices are suitable for produc-

tion of healthy broilers under normal conditions but there may be situations, e.g. disease outbreaks, in which higher levels of vitamin E are justified.

Key Points

- Reduce or remove stressors rather than depend on excessive vitamin supplementation.
- Control total choline level, taking account of the contribution of feed ingredients. Avoid using choline chloride in vitamin supplements due to its aggressive action upon other vitamins.

Non-Nutritive Feed Additives

The feed may be used as a carrier for a wide range of additives. It is not possible to give a comprehensive list and Aviagen cannot recommend or endorse particular products. The more important classes of additive that might be considered for use in broiler feeds are listed here. Legislation may control the use of these products.

Enzymes are now being routinely used in poultry feeds to improve digestibility of feed ingredients. In general, feed enzymes are available that act on carbohydrates, plant bound minerals and proteins.

Non Starch Polysaccharide (NSP) enzymes are economically beneficial in wheat-based feeds. These enzymes will also allow greater flexibility in the levels of barley to be included in the ration.

Increasingly, phytase enzymes are being used to enhance phytate phosphorus utilization. When using phytase, consideration must be given to phosphorus levels in the diet, but also to calcium and other minerals.

The use of protease enzymes in diets to act upon vegetable products is developing and carbohydrase enzymes are providing beneficial responses when used in maize-soya diets.

When adding enzymes before heat processing of broiler feeds, there is the potential for a loss in enzyme activity. This may be avoided by spraying enzymes on to the feed at the end of processing.

Medicinal and Prophylactic Drugs. A wide range of medicinal products, e.g. coccidiostats and antibiotics, may be administered through the feed. Veterinary control and authorization in accordance with local regulations is essential.

Antibiotic Growth Promoters/Digestion Enhancers. These products are still being used in some parts of the world. The mode of action involves modification of the gut microflora, with consequential benefits in nutrient utilization.

Prebiotics are a group of substances which stimulate the growth of beneficial, at the expense of harmful, micro-organisms. Oligosaccharides form the largest group of these products at present.

Probiotics introduce live micro-organisms into the digestive tract to assist the establishment of a stable and beneficial microflora. The objective is to provide the gut with positive, non-pathogenic micro-organisms which will then prevent colonization with pathogenic micro-organisms by competitive exclusion.

Organic Acids. Organic acid products can be used to reduce bacterial contamination of the feed (e.g. after heat treatment) and can also encourage beneficial microflora to develop in the digestive tract of the bird.

Absorbents are used specifically to absorb mycotoxins. They may also have a beneficial effect on general bird health and nutrient absorption. There are a range of products available for use as absorbents, including various clays and charcoal.

Antioxidants can provide important protection against nutrient loss in broiler feeds. Some feed ingredients e.g. fish meal and fats, can be protected. Vitamin premixes should be protected by an antioxidant unless optimum storage times and conditions are provided. Additional antioxidants may be added to the final feed where prolonged storage or inadequate storage conditions are unavoidable.

Anti-Mold Agents. Mold inhibitors may be added to feed ingredients, which have become contaminated, or to finished rations to reduce growth of fungi and production of mycotoxins.

Pelleting agents are used to improve pellet hardness. Some examples of pellet binders are hemicellulose, bentonite and guar gum.

Other products of possible use in broiler production include essential oils, nucleotides, glucans and specialized plant extracts. In areas of the world where its use is permitted, formaldehyde can be used to treat/preserve feed.

Broiler Diet Specifications

Diet specifications for broilers are given in the Appendices, for a range of popular production and market situations.

- As-hatched: < 1.9 kg (4.2 lb) live weight.....Appendix 1
- As-hatched: 2.0 - 2.9 kg (4.4 - 6.4 lb) live weight....Appendix 2
- As-hatched: > 3.0 kg (6.6 lb) live weight.....Appendix 3

The most appropriate diet specification will be designed to either minimize cost for live bird production or maximize margin over cost for portioned products required by the processing plant. These specifications may need to be modified for the specific market conditions. Factors to be considered are:

- Final product - live bird or portioned products.
- The supply and price of feed ingredients.
- Age and live weight at slaughter.
- Yield and carcass quality.
- Market requirements for skin color, shelf-life, etc.
- Use of sexed growing.

The Basic Feed Program

Broiler Starter Feeds

The objective of the brooding period (0 to 10 days of age) is to establish good appetite and achieve maximum early growth. The target is to achieve a seven-day body weight of 179 g or above. Broiler Starter should be given for ten days. The Starter represents a small proportion of the total feed cost and decisions on Starter formulation should be based on performance and profitability rather than cost.

The digestible amino acid levels described in the Appendices, will allow the bird to achieve maximum early growth. This is important in all modern broiler systems and is of particular importance in the production of small birds, in challenging conditions or when breast meat production is at a premium.

In wheat-feeding areas the use of some maize may be beneficial. Total fat levels should be kept low (<5%) and saturated fats should be avoided, especially in combination with wheat.

Broiler Grower Feeds

Broiler Grower feed will normally be fed for 14 to 16 days. The transition from Starter feed to Grower feed will involve a change of texture from crumbs to pellets.

There is a continuing need for a good quality Grower feed to maximize performance. If any growth restriction is required it should be applied during this period. Use of management techniques, e.g. meal feeding or lighting to restrict feed intake, is preferred. Growth restriction by diet composition is not recommended.

Broiler Finisher Feeds

Broiler Finisher feeds account for the major cost of feeding and economic principles should be applied to the design of these feeds. Changes in body composition can be rapid during this period and excessive fat deposition and loss of breast meat yield need to be carefully considered.

The decision whether to use one or two Broiler Finisher feeds will depend on desired slaughter weight, the length of the production period and the design of the feeding program. Withdrawal periods for drugs may dictate the use of a special withdrawal finisher feed. This feed should be adjusted for the age of the birds but the practice of extreme nutrient withdrawal during this period is not recommended.

Use of Starter, Grower and Finisher feeds as described above form the classic phase feeding regime. As an alternative to this classic system, specialized pre-starter products can be used in the early stages of production.

Pre-Starter Products

The anatomy and physiology of young chicks differs significantly from that of older broilers. Post-hatch the transformation from embryonic absorption of yolk to utilization of feed is accompanied by dramatic changes in the digestive tract. In the first few days after hatching, the pancreas and intestine increase in size almost four times quicker than the body as a whole. The digestive system of the young chick is immature, therefore care must be taken to ensure that the nutrient levels are optimal and the raw materials used are highly digestible.

Use of special 'Pre-Starter' products, some of which contain more digestible raw materials, have been shown to be effective in promoting early development of broilers and improving subsequent processing performance. Such products are often of superior physical quality and provide a feed intake response (see section on Feed Processing and Feed Form, page 15).

Broiler chicks have significant potential for development at this age and the response to increased nutrient levels in this period is well established. Feeding a Pre-Starter product to supply levels of amino acids above the AA+ recommendations will provide an additional growth response.

Although the use of Pre-Starter products involves increased feed cost, they are only used for the first few days of life when feed intake is relatively low and therefore have only a small impact on overall cost of production. Generally, there is a positive response in margin achieved as a result of improved overall broiler performance and increased revenue.

Some features of Pre-Starter products are listed below:

- Use of highly digestible ingredients.
- High nutrient levels, especially amino acids, vitamin E and zinc.
- Use of pre- and pro-biotics.
- Immunity stimulants; essential oils, nucleotides etc.
- Intake stimulants; feed form, high sodium, flavors etc.

Separate Feeding of Male and Female Broilers

When male and female broilers are grown separately there may be an opportunity to increase profitability by using different feeding programs for males and females. The most practical method is to use the same feeds for both sexes, but shorten the feeding period of Grower and Finisher fed to the females. It is recommended that the amount or duration of Starter feed be kept the same to ensure early development.

Key Points

- Design broiler diets to maximize profitability of the whole production chain.
- Formulate Starter feeds to maximize performance rather than to minimize cost.

Feed Quality

Successful broiler production is dependent upon supplying the birds with feed of the highest achievable quality, in terms of ingredients used, processing procedures applied and finally the form in which the feed is presented to the bird.

Feed Ingredients

It is important that the ingredients used to manufacture feeds for broilers are fresh and of high quality. When poorer quality ingredients are fed, non-utilizable nutrients must be catabolized and excreted by the birds, using up energy and creating metabolic stress. Cereals and vegetable feed ingredients are susceptible to fungal growth if stored in hot, humid conditions. Fungi produce mycotoxins that, dependent upon the degree of contamination, may reduce growth rate and feed conversion of broilers. Litter condition may be adversely affected, which in turn could result in increased downgrading of broiler carcasses and greater incidence of problems with foot pads and hocks.

Long-term storage of ingredients, or storage under sub-optimal conditions, may lead to the presence of spoilage products that reduce feed intake or have other detrimental effects on broiler performance and broiler health. When freshness of ingredients cannot be assured, quality control becomes even more critical.

The nutritional value of feed ingredients will vary with source, climate, season and feed processing methods. It is extremely important that the feed formulation matrix is well maintained and accurately reflects the appropriate nutritional values of all ingredients being used. To achieve this, the matrix should be supported by routine nutritional analyses of the ingredients used. This should be part of a quality control program, with the emphasis on ingredients, but also finished feed analysis.

In addition, visual examination and further biological testing for contamination, e.g. salmonellae, mycotoxins, should be carried out.

The range of feed ingredients available for least-cost formulation must be suitable for broilers. In selecting ingredients for broiler diets, consideration should be given to their impact on gastrointestinal health and any physiological impact. If appropriate, limits should be set on the inclusion of ingredients known to cause problems when consumed in excess, e.g. tapioca, low-protein soya. The use of several comparable feed ingredients in ration formulation will reduce dependency on any one. The greater the use of a single ingredient, the more important it is to have effective quality control of that ingredient.

Key Points

- Use high quality, fresh ingredients for broiler feed whenever possible, especially in Starter feeds.
- Maintain an accurate ingredient database for use in ration formulation based on results obtained from a routine analysis program.
- Limits should be set on individual raw material inclusion levels, based on knowledge of any anti-nutritional factors within the ingredient and any concerns on quality and consistency.

Vitamin and Mineral Premixes

A general recommendation is given in the Appendices, for supplementation of feeds with vitamins and trace minerals. Occasionally, circumstances may arise which cause an increase in vitamin requirements. In these situations, the strategic use of water-soluble vitamin products should be considered as a possible supplementation to the vitamins already included in the feed.

Aviagen does not endorse the practice of removing vitamin premix during the final stages of the birds' growth because of welfare considerations.

Practical vitamin supplementation should take into account losses in activity which might occur between premix manufacture and feeding. Selection and source of vitamin products, premixing, storage times and conditions at all stages, and feed processing are the most important factors in vitamin losses. The exclusion of choline chloride from premix is strongly recommended to reduce oxidative losses. Storage conditions should be cool, dry and dark to reduce the risk of oxidation and careful stock control should be exercised. The incorporation of an antioxidant in premixes is recommended.

Key Points

- Ensure appropriate storage times and cool, dark storage conditions between manufacture of premixes and inclusion into the feed. Supplement level must take account of probable losses during feed processing and storage.
- Exclude choline chloride from the premix.
- Include an antioxidant in vitamin premixes.

Fat Sources

Fat, of either animal or vegetable origin, may be added to rations. Animal fats, other than poultry fat, contain more saturated fatty acids, which are less digestible, especially in the immature digestive system of the chick. In Starter and Grower rations, it is advisable to use fats containing higher percentages of unsaturated fats. However, in Finisher rations the potential for high levels of unsaturated fats to have a detrimental effect on carcass greasiness and storage quality should be considered. Combined moisture and impurities levels should be less than 1%. The presence of a significant amount of water promotes rancidity. Solid material residues from the rendering, extraction or fat recovery process can block filters and nozzles.

It is important that the quality of fat ingredients is carefully controlled, see table below.

Table 2: Required Quality Criteria for Feed Fats

Criteria Required for Feed Fats	
Moisture and impurities	max 1%
Monomeric fatty acids	min 92%
Non-elutable material	max 8%
Free fatty acids	max 50%
Oxidized fatty acids	max 2%
Antioxidant	Present

Key Points

- Supply unsaturated fats in starter and grower rations.

Feed Processing and Feed Form

Poultry feeds are formulated to a specific nutrient concentration to support bird performance. However, growth will be dependant upon feed intake, which in turn is influenced by feed form. The highest feed intake and best performance is achieved by feeding good quality crumble/pellets. It is known that high levels of fines have a negative effect on intake, live weight and FCR. The AA+ broiler is very responsive to feed form and recent data show that a reduction in fines of 10% can increase live weight for age by as much as 2%. Reductions in the energy cost of feeding activity by the bird can explain much of the benefits of pelleting on performance.

Pellet durability may be improved by manipulation of diet formulation, use of raw materials with good binding ability such as wheat, barley and rape and the use of pellet binders will have an influence.

Feed manufacturing processes will also have a substantial impact on pellet quality. Grinding of raw materials and thermal conditioning of feed are regarded as the most influential factors affecting pellet quality. Thermal conditioning not only releases the natural bonding agents in the diet but will also improve nutrient digestibility and reduce microbial contamination. When thermal processing, compensation should be made for any heat-induced degradation of vitamins.

Addition of fat post pelleting rather than at the mixer will have a positive effect on pellet durability.

Pellet durability should be tested in the feed mill prior to dispatch of feed, aiming for a Holmen test result of 95% pellets after a 30 second test period or, for the Tumbling Can method, 98% pellets after a ten minute test period.

If durability results consistently fall below these levels, then the feed manufacturing process should be reviewed. This review should consider raw materials being used and the production process, in particular grinding, mixing, thermal processing and pelleting; emphasis should be placed on reviewing mill maintenance.

Broiler growth and FCR will generally be better if the Starter feed is in a sieved crumb form, the Grower should be introduced at ten days of age as a 2-3.5 mm pellet and the Finisher introduced at 25 days of age as a 3.5 mm pelleted product see the table below. Feeding greater than 4 mm pellet, in either the Grower or Finisher period, will reduce feed intake and growth and worsen FCR.

Table 3: Form of Feed by Age in Broilers

Age	Feed Form & Size
0-10 days	sieved crumbs
11-24 days	2-3.5 mm diameter pellets
25 days to processing	3.5 mm diameter pellets

When feeding mash, special attention should be paid to having coarse grist (e.g. particle size) and uniform grist distribution. Satisfactory broiler performance can be achieved on mash if pelleting is not available, especially where maize is the principle cereal. Mash feeds will benefit from the inclusion of some fat in the formulation to reduce dust.

Extended use of crumb products beyond 15 days is not recommended as crumb will depress feed intake and growth/FCR.

Key Points

- Use crumb/pelleted feed for optimum growth and FCR ensuring the percentage of fines in the feed is minimal by maximizing pellet durability.
- Aim for optimum grist size and appropriate cereal source when pelleting is not possible.

Whole Grain Feeding

The practice of presenting broilers with a mixture of compound feed (pellets) and whole wheat has been most widely used in Europe. However, it should be feasible to use any whole cereal grain.

The feeding of whole grain saves costs in feed manufacture and possibly in transport and may be used to facilitate a smoother transition of nutrient supply during the growing period. Whole grain feeding supports a better gut microflora, enhances digestive efficiency and can improve litter condition. There is some evidence that the feeding of whole wheat may increase coccidiosis resistance. These advantages must be set against the loss of carcass yield and breast meat. It must be remembered that the whole grain used should be treated with organic acids to control salmonellae, for which there will be a cost to be incurred.

The level of inclusion of whole grain should be accounted for in formulating the compound feed. The AA+ broiler is very responsive to the level of Balanced Protein in the diet and when the compound feed or balancer feed is not adjusted for the amount of whole grain, birds will achieve a poor growth and FCR, have less breast meat and a greater fat content.

Both the amount of whole grain to be used and the composition of the compound (or balancer) feed must be considered carefully. The aim is to provide sufficient intakes of all nutrients from the combination of compound feed and grain. Individual birds satisfy, to some extent, their own nutrient requirements by selecting an appropriate mixture of the two feeds. Care must always be taken to ensure that intakes of micro nutrients and any medications contained in the feed are sufficient at the dilution rates employed. It is very important when feeding whole grain that the grain is of good quality and is free of fungal/toxin contamination.

Used together with the **AA+ Broiler Nutrition Specifications** in this Supplement (Appendices), safe inclusion rates of wheat are given in the table below.

Table 4: Safe Inclusion Rates of Whole Grain in Broiler Rations

Ration	Inclusion Rate of Grain
Starter	zero
Grower	gradual increase to 10%
Finisher	gradual increase to 15%

NOTES: *These inclusion rates are particularly applicable to wheat. It is possible to increase these inclusion rates provided care is taken to make suitable adjustments to the composition of the balancer feed to prevent excessive dilution of the overall diet.*

Whole grain must be removed from the feed two days before slaughter to avoid problems in evisceration at the processing plant.

Key Points

- Account for the inclusion level of whole grain when formulating the compound feed.
- Maintain intakes of micronutrients and drugs at suitable levels.
- Store grain carefully, avoiding high moisture contents and mycotoxin contamination and treat with organic acid to make sure disease organisms are not introduced to the flock.

Feed and Heat Stress

Feed and nutrition have a significant influence on the way broilers respond to heat stress. One of the most successful ways to aid the health, welfare and performance of broilers during periods of heat stress is to employ good nutrition and feed management practices as described in this Supplement.

Good feed physical quality (crumbs, pellets or mash) will minimize the energy expended to eat and thereby reduce heat generated during feeding. Optimal feed form will also increase compensatory feed intake more efficiently during the cooler periods of the day or night. It is usually best to encourage compensatory feed intake at night.

Increasing nutrient intake during heat stress may have an adverse affect on survivability, however increasing the digestibility of nutrients and use of specialist micro ingredients have been shown to have benefits.

For protein, consideration should be given to increasing amino acid digestibility rather than amino acid density. Excess protein should be minimized and amino acids balanced. The use of synthetic amino acids instead of intact proteins will aid bird performance.

Supplying energy in the diet using fats rather than carbohydrates is beneficial. Lipid contains three times as much energy as carbohydrate, resulting in less waste heat and a lower heat increment of feeding.

It is important to consider vitamins and minerals in connection to heat stress. Heat stress increases the birds' urinary and fecal excretion of mineral and trace elements and increased respiration rate depletes blood bicarbonate. Supplementation with sodium bicarbonate or potassium chloride has been shown to be beneficial in reducing the affects of heat stress. This may be due to the affect of minerals increasing water intake.

The following vitamins are known to have a positive affect on the response of birds to heat stress; vitamin E, D, A, C, nicotinic acid and some B-Complex vitamins.

A general approach is to increase the level of vitamins by 1.25% per degree centigrade as the temperature rises from 21 to 28°C. If temperatures exceed 28°C, then further increases in vitamin levels should be made at the rate of 2.5% per degree centigrade. This guideline is dependant upon the vitamin levels used in the standard supplement. Under no circumstances withdraw vitamins from the diet.

Other additives shown to have benefits in improving heat tolerance are:

Betaine – osmoregulator increases efficiency of absorption of minerals and trace elements

Glucose – increases energy required for extreme temperature

Asparin – increases birds tolerance to heat

In heat stress situations, the choice of coccidiostat should be considered carefully to avoid those associated with increased mortality via increased heat production.

Litter Quality

Litter quality directly affects the health, welfare and performance of the bird. Poor quality litter, with a high moisture content, may result in increased levels of ammonia within the broiler unit. This has the potential to produce increased respiratory stress and increased levels of carcass damage. Poor quality litter is also associated with incidences of pododermatitis and hock burn. Therefore, the maintenance of good litter quality is not only beneficial to the bird but also to the producer.

There are a number of factors involved in litter quality, including ambient environment, bird husbandry, unit management, enteric condition and nutrition.

Provided suitable management, health and environmental practices are followed, the following nutritional strategies will help to ensure litter quality is maintained.

Excess levels of crude protein in diets should be avoided and the diet formulation should be well balanced. There are a number of formulation strategies that can be implemented to assist in this:

- Formulate on a digestible amino acid basis.
- Maintain raw material matrix with relevant and updated values for protein and, most importantly, the digestible amino acids used in formulation.
- Refer to the Balanced Protein concept and use this within formulation. This will help to ensure that the diet supplies protein matched to the requirement of the bird whilst avoiding excesses.
- Salt levels should be kept balanced to avoid increased water intake which can be a primary cause of wet litter. The Electrolyte Balance should be referred to by the nutritionist during the formulation process and a target of 220-230 mEq/kg should be the aim. Accurate descriptions of the sodium, chloride and potassium levels of raw materials should be maintained on the formulation matrix and the AA+ recommendations for these minerals should be followed (see Appendices).
- Ingredients of low digestibility or of particularly high fiber level should be avoided.
- Providing a digestible form of fat in the diet will help avoid enteric issues. Fats of particularly poor quality, and of low digestibility, must be avoided.
- The use of exogenous enzyme products helps to reduce gut viscosity, which will improve litter quality. The nutritionist should take care to ensure selection of the correct and appropriate enzyme.

Welfare and Environment

All feed formulations should be produced with due consideration to the welfare of the broiler and potential impact upon the environment should also be taken into consideration. As a general rule, the practices and nutritional strategies outlined in the preceding sections of this Supplement will form the basis of a successful welfare and environmental strategy. The most important areas where particular consideration is required are outlined below:

Welfare

Balanced nutrition should be supplied to the broiler to maintain a practical and sensible growth profile and to prevent nutritional deficiencies. Protein needs to be supplied as a balance of amino acids. The levels of macro minerals must be supplied at adequate levels and in balance. Special reference should be made to calcium and phosphorus and the Ca:AvP ratio to avoid skeletal disorders. Equally, sodium levels are important along with Electrolyte Balance to avoid deficiencies and maintain good litter. Vitamins and trace minerals must be supplied at adequate levels to avoid the metabolic disorders associated with deficiencies. Biotin and zinc have been identified as assisting in the prevention of pododermatitis. Maintaining good quality litter will also assist with limiting the incidence of pododermatitis (refer to preceding section on Litter Quality, page 18).

Environment

Minimizing excess crude protein levels in the feed by formulating to balanced levels of digestible essential amino acids, rather than to minimum crude protein levels, will minimize nitrogen excretion. The section on Protein and Amino Acids, pages 5-6, earlier in this text fully explains the concepts of Ideal Amino Acid Profile and Balanced Protein, which can be used to reduce nitrogen excretion. Recent work has helped to add quantitative information to the extent of reductions in excretion. For example, it has been determined that a one-percentage point reduction in feed protein level

(e.g. from 20% to 19%) leads on average to a reduction in both nitrogen excretion and ammonia emission of 10%.

Phosphorus excretion can be reduced by feeding more closely to the birds' requirement and utilizing phytase enzymes. Refer to the Macro Minerals Section on pages 7-8 of this Supplement for further details on phosphorus nutrition.

Notes

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Appendices

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Appendix 1: Nutrient Specifications for As-Hatched Broilers Grown <1.9 kg (4.2 lb) live weight

		Starter		Grower		Finisher	
Age fed	days	0-10		11-24		25-slaughter	
Energy	kcal ME	3025		3150		3200	
	MJ ME	12.65		13.20		13.40	
AMINO ACIDS							
		Total	Digest ¹	Total	Digest ¹	Total	Digest ¹
Lysine	%	1.43	1.27	1.24	1.10	1.09	0.97
Methionine & Cystine	%	1.07	0.94	0.95	0.84	0.86	0.76
Methionine	%	0.51	0.47	0.45	0.42	0.41	0.38
Threonine	%	0.94	0.83	0.83	0.73	0.74	0.65
Valine	%	1.09	0.95	0.96	0.84	0.86	0.75
iso-Leucine	%	0.97	0.85	0.85	0.75	0.76	0.67
Arginine	%	1.45	1.31	1.27	1.14	1.13	1.02
Tryptophan	%	0.24	0.20	0.20	0.18	0.18	0.16
Crude Protein	%	22-25		21-23		19-23	
<i>For optimal portions margin it is recommended that amino acid density be increased up to 5% in all diets.</i>							
MINERALS							
Calcium	%	1.05		0.90		0.85	
Available Phosphorus	%	0.50		0.45		0.42	
Magnesium	%	0.05-0.50		0.05-0.50		0.05-0.50	
Sodium	%	0.16-0.23		0.16-0.23		0.16-0.20	
Chloride	%	0.16-0.23		0.16-0.23		0.16-0.23	
Potassium	%	0.40-1.00		0.40-0.90		0.40-0.90	
ADDED TRACE MINERALS PER KG							
Copper	mg	16		16		16	
Iodine	mg	1.25		1.25		1.25	
Iron	mg	40		40		40	
Manganese	mg	120		120		120	
Selenium	mg	0.30		0.30		0.30	
Zinc	mg	100		100		100	
ADDED VITAMINS PER KG							
		Wheat based feed	Maize based feed	Wheat based feed	Maize based feed	Wheat based feed	Maize based feed
Vitamin A	iu	12,000	11,000	10,000	9000	10,000	9000
Vitamin D3	iu	5000	5000	5000	5000	4000	4000
Vitamin E	iu	75	75	50	50	50	50
Vitamin K (Menadione)	mg	3	3	3	3	2	2
Thiamin (B1)	mg	3	3	2	2	2	2
Riboflavin (B2)	mg	8	8	6	6	5	5
Nicotinic Acid	mg	55	60	55	60	35	40
Pantothenic Acid	mg	13	15	13	15	13	15
Pyridoxine (B6)	mg	5	4	4	3	3	2
Biotin	mg	0.20	0.15	0.20	0.10	0.10	0.10
Folic Acid	mg	2.00	2.00	1.75	1.75	1.50	1.50
Vitamin B12	mg	0.016	0.016	0.016	0.016	0.010	0.010
MINIMUM SPECIFICATION							
Choline per kg		1600		1500		1400	
Linoleic Acid		1.25		1.20		1.00	

Digest¹ = Digestible

NOTES: These feed specifications should be used as a guide. They require adjustment for local conditions and markets. A Withdrawal feed should be fed to meet local requirements for drug withdrawal times. This can be formulated to the same standards as the Finisher or to a slightly lower specification.

Appendix 2: Nutrient Specifications for As-Hatched Broilers Grown 2.0-2.9 kg (4.4-6.4 lb) live weight

		Starter		Grower		Finisher	
Age fed	days	0-10		11-24		25-slaughter	
Energy	kcal ME	3025		3150		3200	
	MJ ME	12.65		13.20		13.40	
AMINO ACIDS							
		Total	Digest ¹	Total	Digest ¹	Total	Digest ¹
Lysine	%	1.43	1.27	1.24	1.10	1.09	0.97
Methionine & Cystine	%	1.07	0.94	0.95	0.84	0.86	0.76
Methionine	%	0.51	0.47	0.45	0.42	0.41	0.38
Threonine	%	0.94	0.83	0.83	0.73	0.74	0.65
Valine	%	1.09	0.95	0.96	0.84	0.86	0.75
iso-Leucine	%	0.97	0.85	0.85	0.75	0.76	0.67
Arginine	%	1.45	1.31	1.27	1.14	1.13	1.02
Tryptophan	%	0.24	0.20	0.20	0.18	0.18	0.16
Crude Protein	%	22-25		21-23		19-23	
<i>For optimal portions margin it is recommended that amino acid density be increased up to 5% in all diets.</i>							
MINERALS							
Calcium	%	1.05		0.90		0.85	
Available Phosphorus	%	0.50		0.45		0.42	
Magnesium	%	0.05-0.50		0.05-0.50		0.05-0.50	
Sodium	%	0.16-0.23		0.16-0.23		0.16-0.20	
Chloride	%	0.16-0.23		0.16-0.23		0.16-0.23	
Potassium	%	0.40-1.00		0.40-0.90		0.40-0.90	
ADDED TRACE MINERALS PER KG							
Copper	mg	16		16		16	
Iodine	mg	1.25		1.25		1.25	
Iron	mg	40		40		40	
Manganese	mg	120		120		120	
Selenium	mg	0.30		0.30		0.30	
Zinc	mg	100		100		100	
ADDED VITAMINS PER KG							
		Wheat based feed	Maize based feed	Wheat based feed	Maize based feed	Wheat based feed	Maize based feed
Vitamin A	iu	12,000	11,000	10,000	9000	10,000	9000
Vitamin D3	iu	5000	5000	5000	5000	4000	4000
Vitamin E	iu	75	75	50	50	50	50
Vitamin K (Menadione)	mg	3	3	3	3	2	2
Thiamin (B1)	mg	3	3	2	2	2	2
Riboflavin (B2)	mg	8	8	6	6	5	5
Nicotinic Acid	mg	55	60	55	60	35	40
Pantothenic Acid	mg	13	15	13	15	13	15
Pyridoxine (B6)	mg	5	4	4	3	3	2
Biotin	mg	0.20	0.15	0.20	0.10	0.10	0.10
Folic Acid	mg	2.00	2.00	1.75	1.75	1.50	1.50
Vitamin B12	mg	0.016	0.016	0.016	0.016	0.010	0.010
MINIMUM SPECIFICATION							
Choline per kg		1600		1500		1400	
Linoleic Acid		1.25		1.20		1.00	

Digest¹ = Digestible

NOTES: These feed specifications should be used as a guide. They require adjustment for local conditions and markets. A Withdrawal feed should be fed to meet local requirements for drug withdrawal times. This can be formulated to the same standards as the Finisher or to a slightly lower specification.

Appendix 3: Nutrient Specifications for As-Hatched Broilers Grown >3.0 kg (6.6 lb) live weight

		Starter		Grower		Finisher 1		Finisher 2	
Age fed	days	0-10		11-24		25-42		43-slaughter	
Energy	kcal ME	3025		3150		3200		3225	
	MJ ME	12.65		13.20		13.40		13.50	
AMINO ACIDS									
		Total	Digest ¹	Total	Digest ¹	Total	Digest ¹	Total	Digest ¹
Lysine	%	1.43	1.27	1.24	1.10	1.06	0.94	1.00	0.89
Methionine & Cystine	%	1.07	0.94	0.95	0.84	0.83	0.73	0.79	0.69
Methionine	%	0.51	0.47	0.45	0.42	0.40	0.37	0.38	0.35
Threonine	%	0.94	0.83	0.83	0.73	0.72	0.63	0.68	0.60
Valine	%	1.09	0.95	0.96	0.84	0.83	0.72	0.79	0.69
iso-Leucine	%	0.97	0.85	0.85	0.75	0.74	0.65	0.70	0.61
Arginine	%	1.45	1.31	1.27	1.14	1.10	0.99	1.04	0.93
Tryptophan	%	0.24	0.20	0.20	0.18	0.17	0.15	0.17	0.14
Crude Protein	%	22-25		21-23		19-22		17-21	
<i>For optimal portions margin it is recommended that amino acid density be increased up to 5% in all diets.</i>									
MINERALS									
Calcium	%	1.05		0.90		0.85		0.80	
Available Phosphorus	%	0.50		0.45		0.42		0.40	
Magnesium	%	0.05-0.50		0.05-0.50		0.05-0.50		0.05-0.50	
Sodium	%	0.16-0.23		0.16-0.23		0.16-0.20		0.16-0.20	
Chloride	%	0.16-0.23		0.16-0.23		0.16-0.23		0.16-0.23	
Potassium	%	0.40-1.00		0.40-0.90		0.40-0.90		0.40-0.90	
ADDED TRACE MINERALS PER KG									
Copper	mg	16		16		16		16	
Iodine	mg	1.25		1.25		1.25		1.25	
Iron	mg	40		40		40		40	
Manganese	mg	120		120		120		120	
Selenium	mg	0.30		0.30		0.30		0.30	
Zinc	mg	100		100		100		100	
ADDED VITAMINS PER KG									
		Wheat based feed	Maize based feed	Wheat based feed	Maize based feed	Wheat based feed	Maize based feed	Wheat based feed	Maize based feed
Vitamin A	iu	12,000	11,000	10,000	9000	10,000	9000	10,000	9000
Vitamin D3	iu	5000	5000	5000	5000	4000	4000	4000	4000
Vitamin E	iu	75	75	50	50	50	50	50	50
Vitamin K (Menadione)	mg	3	3	3	3	2	2	2	2
Thiamin (B1)	mg	3	3	2	2	2	1	2	2
Riboflavin (B2)	mg	8	8	6	6	5	4	5	5
Nicotinic Acid	mg	55	60	55	60	35	40	35	40
Pantothenic Acid	mg	13	15	13	15	13	15	13	15
Pyridoxine (B6)	mg	5	4	4	3	3	2	3	2
Biotin	mg	0.20	0.15	0.20	0.10	0.10	0.10	0.10	0.10
Folic Acid	mg	2.00	2.00	1.75	1.75	1.50	1.50	1.50	1.50
Vitamin B12	mg	0.016	0.016	0.016	0.016	0.010	0.010	0.010	0.010
MINIMUM SPECIFICATION									
Choline per kg		1600		1500		1400		1300	
Linoleic Acid		1.25		1.20		1.00		1.00	

Digest¹ = Digestible

NOTES: These feed specifications should be used as a guide. They require adjustment for local conditions and markets. A Withdrawal feed should be fed to meet local requirements for drug withdrawal times. This can be formulated to the same standards as the Finisher or to a slightly lower specification.



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