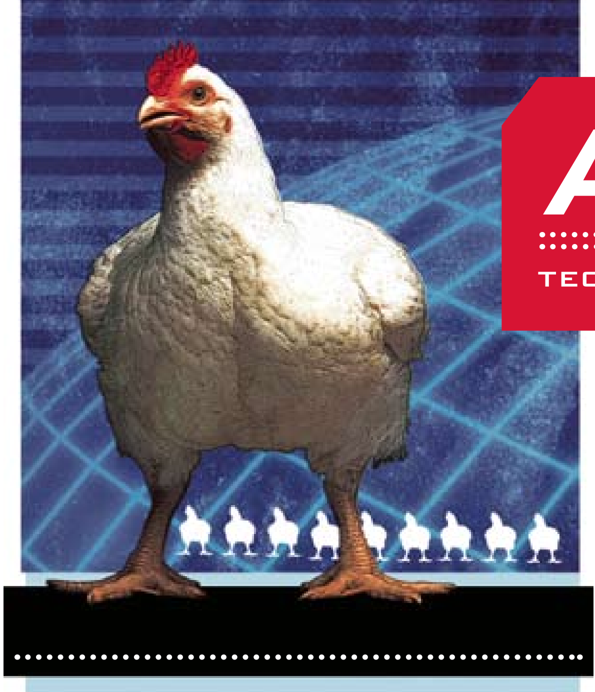

AVIATECH

TECHNICAL INFORMATION FOR THE BROILER INDUSTRY

Feed Physical Quality

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The modern broiler requires optimal feed intake in order to support optimal and efficient growth.

The modern broiler requires optimal feed intake in order to support optimal and efficient growth. Feed form has a significant impact on optimizing feed intake and consequently results in significant profit opportunities.

There are several factors affecting pellet quality – feed formulations, feed conditioning and grinding are considered the most significant.

Pellet quality can be improved significantly with little cost by improving feed production processes, most notably grinding and conditioning. Producing a fine, even grist through the grinding process will optimize pellet quality as can improvements to conditioning temperature, dwell time, steam quality and moisture level.

Management and maintenance of the conditioner and pelletizer can improve durability.

A good quality control program, testing feed physical quality both at the mill and on the farm, will ensure feed physical quality is maintained.

Poultry feeds are formulated to a specific nutrient concentration to support bird performance, however, growth will be dependant upon nutrient intake of the bird.

To achieve optimal and efficient growth, it follows that feed and bird management must be focused on maintaining good levels of feed intake.

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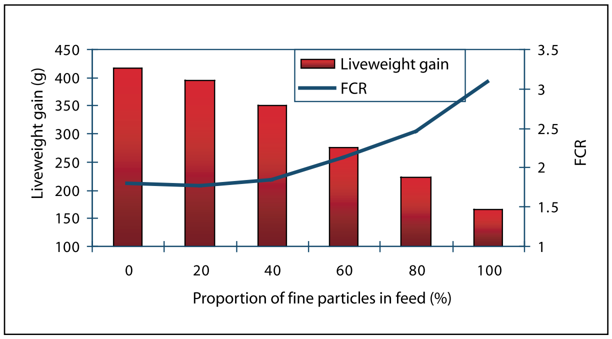
Factors Affecting Feed Intake

Many factors will influence feed consumption; environment and management being two of the most important. Feed form is known to have a significant impact on consumption; poor pellet quality results in the occurrence of fines which have a negative effect on feed intake. Recent research has shown significant effects of increased levels of fines on reducing liveweight and increasing FCR (Figure 1).

Figure 1: The Influence of Fine Particles in the Feed on Broiler Performance between 15 to 35 Days of Age (Quentin et al., 2004)



The majority of commercial broiler diets have been through the pelleting process. However, the durability of pellets can be variable, resulting in levels of fines as high as 50%. Incidences of high levels of fines in the field are associated with poor liveweight and FCR. To maximize performance, the accumulation of fine particles in the feed should be minimized.

It is important to establish the modern broiler's response to high levels of fines. The following two trials, conducted by Aviagen, tested both extreme levels of fines and levels commonly seen in the field.

The first study looked at the impact of different levels of fines fed to 31 days in a North Western European environment. The Control was a good quality starter crumb and grower pellet, Treatment 1 (50% fines) was created by mixing equal weights of fines and crumb or pellets. The fines were created by roller-grinding the control crumb and pellets to less than 0.5mm particle size. Treatment 2 was 100% fines (Figure 2).

Figure 2: Diet Types Used in the Aviagen Feed Form Trial

Treatment 1 *Treatment 2*

The results showed Treatment 1 (50% fines) reduced liveweight by 7%, and Treatment 2 (100% fines) reduced liveweight by 20% compared to the Control (Table 1).

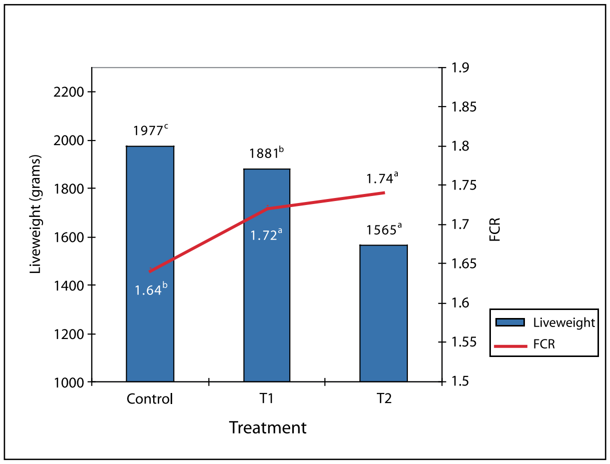
Table 1: The Effect of Feed Physical Form on Broiler Liveweight and FCR at 10, 21 and 31 Days of Age

Treatment	Liveweight to:			FCR to:		
	10 days	21 days	31 days	10 days	21 days	31 days
Control	297 g	975 g	1972 g	1.39	1.53	1.63
1. Mix (50% fines)	287 g	916 g	1835 g	1.42	1.60	1.69
2. Fines (100% fines)	264 g	797 g	1579 g	1.54	1.67	1.71
Standard Deviation	5.32	9.80	17.65	0.0203	0.0241	0.0182
P Value	0.016	0.000	0.000	0.000	0.011	0.008

In conclusion, the trial confirmed that poor feed form significantly reduces performance on a wheat-based diet in a North Western European environment – the higher the level of feed fines, the lower the performance will be, especially at later ages.

The second study was conducted on maize-based diets in an Asian environment, where house temperatures were significantly higher than the first study. The feed treatments were exactly the same as in the previous study. Poor feed quality was reproduced by grinding the pelleted product through a hammer grinder to <0.5mm particle size and then, as in the previous trial, re-blended to create the 50% treatment (Figure 3).

Figure 3: The Effect of Feed Physical Form on Broiler Liveweight and FCR at 35 Days of Age



The effect on performance was similar to the previous trial; the 50% fines mix (T1) reduced liveweight by 4.5% and the 100% fines mix (T2) reduced liveweight by 19%. FCR deteriorated by 6.1% in the 100% fines mix and by 2.2% in the 50% fines mix (Figure 3).

The two trials show that the percentage of fines has a dramatic effect on bird performance with liveweight being reduced by up to 20% and FCR deteriorating by as much as 7%.

The Economic Benefit of Improving Feed Form

The data from this second study can be used to calculate the economic effect of poor feed form.

Description	Bodyweight (g)
100% Pellets	1977
100% Fines	1565
Difference	412

The effect of reducing fines to 0% gave an increase in bodyweight of 412g/bird. In terms of value, if liveweight prices are calculated at $0.71 per kg, this additional weight is worth over $0.29 per bird, therefore a 10% reduction in feed fines is, potentially, worth $0.03 per bird. This calculation is based just on liveweight and does not take into account the effect of feed form on FCR. Using an annualized calculation based on 100 million broilers per year throughput, this represents an increase in profit of $3 million.*

This calculation is based on response data from trial data and assumes the effect of fines addition is linear, however, it does show that there is significant scope for improvement in both biological and financial performance if feed form is improved.

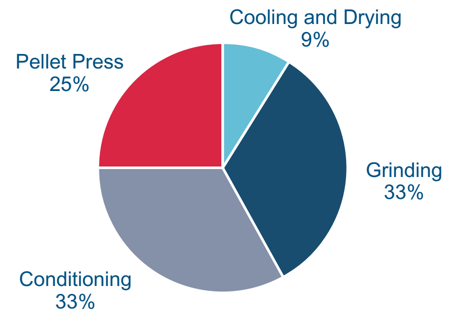
Means of Improving Pellet Durability

Improving pellet durability is an effective means of reducing fines.

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

Feed manufacturing practices will also have an effect on pellet durability and potentially involve less expense than changing raw materials or using pellet binders.

Figure 4: Factors Affecting Pellet Quality – Except Raw Materials (Behnke, 1996)



Grinding of raw materials and conditioning of feed are regarded as the most influential factors affecting pellet durability (Figure 4).

*The figures quoted are based on European growth and economic performance and converted to dollars at an exchange rate of €1 to $1.42.

Grinding

There are several reasons to grind raw materials. It improves uniformity of mixing, increases absorption of steam and increases digestibility of feed. In terms of pellet quality, grinding reduces the amount of large particles which can reduce pellet strength. It also increases surface area for feed particles to adhere. In other words, a finer, even grind can result in better pellet quality. The larger the particle of feed in the ration, the greater the amount of time needed for heat to permeate to the core of the feed particle. This is a factor which must be considered when engineering the conditioner to gain a specific amount of retention time.

Points to consider when grinding are:

- Screen hole size – appropriate for the grist (particle) size and pellet size required.
- Screen placed correct side to hammers – provides more efficient grinding.
- Hammer tip speed – a faster tip speed will produce finer material.

In conclusion, grinding needs to provide a fine, even grist for best pellet quality.

Conditioning

Along with grinding, conditioning is one of the most important factors in achieving good physical quality. Conditioning creates thermal, chemical and mechanical energy; the steam used during conditioning disrupts the structure of the starch and causes gelatinization and also plasticizes proteins and softens fibers (Figure 5).

Figure 5: The Effect of Different Processing Conditions on Level of Starch Gelatinization in Two Different Diet Types (Svihus, 2005)

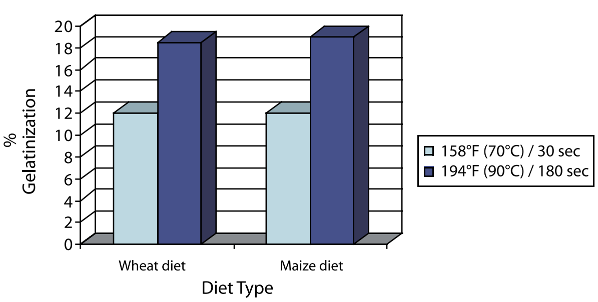
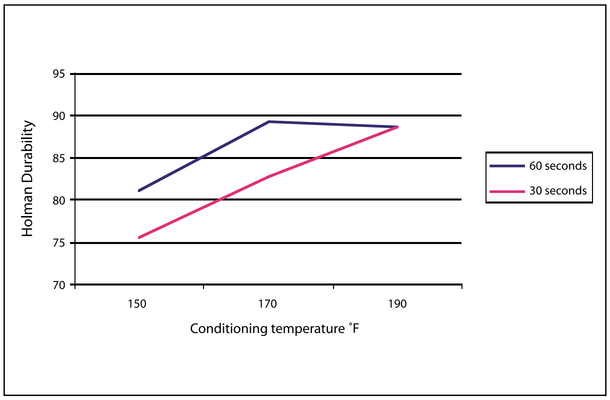


Figure 5 clearly shows that increased conditioning time and temperature increases gelatinization in feed, regardless of the cereal base used. The process of gelatinization creates natural 'glues' which allow the feed particles to compress tightly and adhere to each other when passing through the pellet die. Optimal 'cooking' of feed will result in more durable pellets and reduce levels of fines (Figure 6).

Figure 6: The Effect of Conditioning Temperature and Time on Pellet Durability (Svihus, 2005)



As the conditioning time and temperature was increased, the pellet durability increased (as expressed by a Holmen Durability Index).

Steam Quality

Steam conditioning of poultry diets requires a saturated steam which consists mostly of vapor as opposed to a 'wet' steam which consists of free moisture. Wet steam 'transfers' its heat less efficiently (lower enthalpy of evaporation) than saturated steam and can cause uneven moisture distribution in the mash, resulting in 'choking' or slipping of the pellet die.

The characteristics of the steam affect the conditioning process; saturated steam has been shown to increase mash temperature by 60 ºF (16°C) for every 1% added moisture, while 'wet' steam increases mash temperature by 56 ºF (13.5°C) for each 1% increase in moisture. It has also been shown that poor steam quality can reduce conditioning temperatures by 43 ºF to 52 ºF (6°C to 11°C), depending on the amount of added moisture.

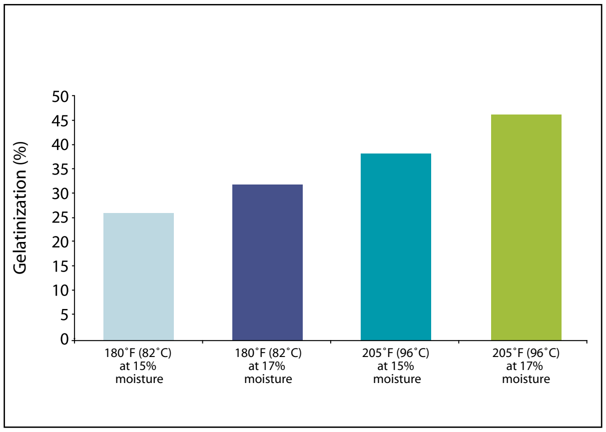
Key points to consider:

- The steam boiler is an intricate part of the conditioning process and must be operated and maintained in a way as to deliver a high quality steam on a consistent base.
- The boiler should be operated at the manufacturer's recommended working pressure and kept to a close working pressure band.
- Removing condensate before the steam reaches the conditioner is important as well as minimizing moisture collecting in the steam by use of steam traps where appropriate.

Moisture

The moisture in the feed that is being processed in the conditioner serves as the conduit for the transfer of the heat into the feed particles. Studies have shown that moisture addition to the meal has a positive effect on the conditioning process. The chart below (Figure 7) indicates the improvement in gelatinization that can be achieved through proper moisture addition.

Figure 7: The Effect of Moisture and Temperature on Level of Gelatinization



Some feed additives can also improve the conditioning process; new moisture and surfactant technologies allow the addition of moisture at the mixer or conditioning chamber which can greatly improve feed pellet quality. The addition of the moisture and the improved pellet quality has been proven to improve the feed efficiency of broilers (see section on surfactant addition, page 6).

Retention Time

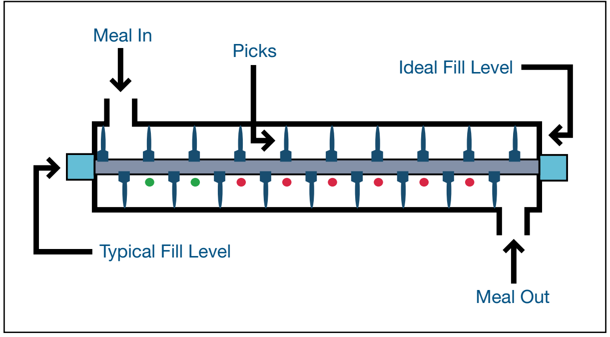
The optimum retention time for any particular conditioner is the amount of time that is required for the heat and moisture to reach the centre core of each feed particle in the ration. The higher the retention time, the greater the degree of gelatinization improving the durability of the pellet (Figure 6). The table below (Table 2) depicts the difference in gelatinization with varying retention times at the same moisture and temperature levels.

Table 2: The Effect of Retention Time on the Level of Gelatinization

Equipment Type	Retention Time	Percent Gelatiniza-
Single Shaft Conditioner	15 to 20 seconds	15-20%
Double Conditioner	40 to 45 seconds	20-25%
Differential Diameter/Speed	120 to 180 seconds	40-50%

A conventional conditioner with a single shaft and a single barrel must be very large in order to achieve the proper retention and mixing time. Typically, a single shaft conditioner will be filled to 50% of capacity. The meal resides in the lower half of the conditioning barrel, thus allowing the majority of the steam to escape over the top of the feed in the path of lesser resistance (Figure 8).

Figure 8: A Single Shaft Conditioner Showing Ideal and Typical Meal Fill Level (courtesy of S Parker)



Increasing the fill level provides greater distribution of steam through the meal as will feeding the steam into the conditioner below the meal.

The type of conditioning system influences the effectiveness of conditioning. The percent cook or gelatinization is greatly improved with a dual shaft conditioner. The dual shaft conditioner offers a definite advantage over the single shaft conditioner due to the two conditioner shafts, which are dissimilar in diameter and rotate counter to one another. The counter-rotating shafts are laden with picks set at varying angles, which causes the feed to be agitated into suspension within the conditioner barrels. The suspension of the feed particles offers the steam the opportunity to permeate all the feed particles.

The number of picks and the angle or settings for these picks is of extreme importance. The higher the number of picks, the greater the agitation of meal in the conditioning barrel, while the angle of the picks affects the retention time.

To ensure optimal conditioning the following points should be considered:

- Steam pressure into the conditioner needs to be kept low (<2 Bar) and constant as high pressure 'blasts through' the meal. Low pressure steam transfers heat to the meal more efficiently than high pressure steam.
- Steam temperature, on entry to the conditioner, needs to be about 212 ºF (100°C) to adequately condition the feed. Ideally, the temperature in the conditioner should be greater than 176 ºF (80°C).
- The dwell time of the meal in the conditioner will influence pellet durability, depending on the temperatures involved, meal retained longer will generally result in better conditioning (Table 2).
- The level of meal in the conditioner will affect conditioning efficiency, too low and dwell time is reduced, too high and the mechanical effect of the conditioner is reduced.
- The point of addition of steam into the conditioner should be below the meal fill level. If it is above this, steam may not penetrate the meal efficiently.

Pelleting

Along with grinding and conditioning, the actual pelleting procedure has an influence on pellet quality. Meal should enter the pelleter correctly conditioned as this will aid 'shaping' the meal into pellets rather than cooking the meal via friction heat at the die. Excess friction heat in the die can produce a hard brittle pellet rather than a durable one; also conditioning the meal in the conditioning vessel is more cost-efficient than in the pelletizer.

Consideration should be given to:

- Die wear: cheaper dies are usually a false economy as they are likely to be lower quality, resulting in uneven wear and therefore poor pellet quality and throughput.
- The number of die holes will affect the throughput and rate of wear of the die.
- Die hole dimension will affect pellet quality. A longer die hole length and smaller diameter will increase the compression of the meal in the die, however, higher compression levels may produce hard and brittle pellets, but not always durable pellets.
- Faster die speed will increase throughput, but reduce pellet quality.
- Meal must be fed evenly across the full face of the die, otherwise there may be uneven die and roller wear, which results in poorly-formed pellets reducing pellet quality.
- A well maintained die, which is correctly specified, will help maintain pellet quality.

Formulation

The ingredient matrix or formulation is also of extreme importance to the pelleting process. Different ingredients have different levels of pelleting ability and require different levels of conditioning to achieve optimum gelatinization. The table below depicts the different gelatinization temperatures of a selection of ingredients.

Table 3: Gelatinization Temperatures of a Selection of Ingredients

Source of Starch	Temperature Range at which Gelatinization Occurs	
Barley	124-140 ˚F	51-60 ˚C
Wheat	136-147 ˚F	58-64 ˚C
Rye	135-158 ˚F	57-70 ˚C
Oats	127-138 ˚F	53-59 ˚C
Corn	144-162 ˚F	62-72 ˚C
Waxy Corn	145-162 ˚F	63-72 ˚C
Sorghum	154-172 ˚F	68-78 ˚C
Rice	154-172 ˚F	68-78 ˚C

The typical poultry diet is characterized as a high-fat diet. The added fat will usually range from 2% to 5% and the total fat in the ration will be from 6.5% to 10%. The fat, when added at the mixer, is inhibitive to the process of thermal conditioning and to the production of an optimum pellet. The fat serves as an insulator of the feed particle which prevents moisture from entering the feed particle at a rapid rate. When fat is added at the mixer, the particle is coated before entering the conditioning chamber. Due to the normal short amount of conditioning time provided, the moisture does not enter the particle, the heat does not transfer, and therefore there is very little change in the starch composition of the feed. The Pellet Durability Index of poultry feed can be vastly improved by removing the added fat from the feed mixer and adding the fat either at the pelletizer or downstream of the cooler.

Animal By-Products also offer a challenge to optimum pellet quality, due to the fact that the available 'starches' in the products are either unsuitable for material bonding through gelatinization, or have already been denatured through the cooking process of the product. High levels of meat in the diet (above 5%) can also cause production loss as well as lower pellet quality. The production drop occurs as the meat 'starches' caramelize on the walls of the holes of the pellet die. This tacky build-up closes the hole diameter and creates higher friction as the feed passes through the die. The pellet amperage increases as the production drops.

Surfactant Addition

Recent studies have indicated that the incorporation of food-grade surfactants added to the meal can enhance the overall conditioning of the feed. The surfactant reduces the surface tension of the water, thus allowing a much faster permeation of the feed particles during the conditioning process. Moisture serves as the conduit for heat transfer into the feed particles, therefore, if the moisture permeates the feed at a faster rate, heat transfers to the feed in the pelleting conditioner faster.

Conveyance and Transport System

Improper conveyance, elevation, or handling can cause deterioration of the pellet quality before the feed reaches the feed pans. The delivery equipment, which delivers the pellets with the least amount of degradation, should be selected. The design, speed, and type of elevators and conveyors can play a significant role in pellet degradation.

The truck delivery system and the delivery systems at the farm can also be detrimental to pellet quality; systems which operate at higher revolutions per minute seem to do greater damage.

Quality Control

Pellets should be tested for durability on an ongoing basis. The aim is to test the ability of the product to remain as a whole pellet from the mill to when it is presented to the bird. It is therefore important to test the product, in the mill, in conditions as close as possible to those in the field.

There are generally two mechanisms available which mimic field conditions:

1. The tumbling can – involves placing a weighed sample of material into a rotating chamber for a set period of time, usually 10 minutes at 50 r.p.m..

2. The Holmen tester – the weighed sample of pellets are pneumatically conveyed around a closed pipe, usually 30 seconds (see below).

The Pellet Durability Index figure (P.D.I.) is calculated by measuring the amount of fines derived from the test as a percentage of the sample added.

The guideline durability for 2 to 3mm pellets is as follows:

Test	Durability Index	Time
Tumbling Can	98%	10 minutes
Holmen test	98%	30 seconds

Samples of delivered feed should also be taken at the farm and sieved to establish the levels of fines and assessed relative to target.

Mash Feeds

Use of mash feeds is not uncommon and excellent performance can be achieved when broilers are fed coarse and uniform mash feeds. Broiler mash feeds should not be confused with fines; a mash feed is a uniform coarse-ground material with, usually, no thermal processing, while fines are smaller particles (<1.0mm) derived from physical degradation of pellets.

Coarse mash feeds are often fed to promote gizzard yield. The following figure (Figure 9) shows the effect of feeding whole grain wheat versus ground wheat on broiler gizzard development. The gizzard exposed to whole wheat is better developed than that fed on ground wheat. If gizzard yield is a criterion, then feeding a coarser ground mash may be more effective than a finer ground material.

Figure 9: The Effect of Form of Wheat on Gizzard Development (Hetland and Choct, 2003)

Whole Wheat *Ground Wheat*

It is important to distinguish between coarse mash feeds and fine mash; poor quality mash can contain significant quantities of excessively ground fine material which can have the same negative effect on broiler performance as poor quality pellets.

In Summary:

- It is vital that feed intake is optimized to achieve optimal growth.
- Feed form has a significant impact on broiler performance.
- Improving feed form produces significant profit opportunities.
- Feed form may be improved at little cost by manipulating feed formulations and/or optimizing feed manufacturing practices.
- Grinding, conditioning and pelleting practices make a significant contribution to pellet quality.
- Assessing pellet quality at the mill and farm is essential to ensure improvements made to pellet quality are maintained.

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Aviagen provides customers with detailed Product Performance Objectives, Management Manuals and Nutrition Specifications as the basis for managing their flocks. Successful production of day old chicks or grown broilers depends also on the understanding and attention to detail in the day-to-day management of stock. This document is produced by Aviagen's Technical Transfer Department as one of an ongoing series. These give background information on various topics to provide an understanding of the principles which are essential to successful management of both breeders and broilers. While the principles should have a broad relevance to most regions and production strategies, certain aspects may be directed to more specific situations.

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