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Lector notes on chicken farming in warm climate zones

Dr. E.H. Ketelaars

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Author: Dr. E.H. Ketelaars

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Foreword

These lecture notes describe and discuss mainly the physiological background of the managerial measures outlined in ‘the basics of chicken farming’ guide, another title in the AGROMISA collection of educational materials for agriculture and animal production in warm climate zones.

The contents of the underlying text have, to a certain degree, been derived from the book POULTRY PRODUCTION IN HOT CLIMATE ZONES, by H.C.Saxena and E.H.Ketelaars, edited and published by Kalyani Publishers, New Delhi - Ludhiana, India. Some chapters from that book have been revised whereas other chapters have been left out.
We thank Dr Saxena for his kind permission to make use of the above text.

We also thank Mrs. Kathleen Guard (UK) for her help with English language correction of our text.

Bennekom, NL
E.H.Ketelaars

editing and layout by

B.Gietema
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1 The biology of poultry

In order to understand better the physiological background of what is going on in a poultry flock and the effects we can expect from the measures we take, a brief explanation of some major aspects of the biology of poultry is given in this chapter. Four aspects are discussed:

1. Birds are, in many respects, different from mammals, but both animal species are homeotherm, which means that they keep their body temperature at a relatively constant level. Their ways of achieving this, however, are not identical. In other words: their thermoregulation is different.
2. In relation to this thermoregulation, birds have specific energy requirements and thus they respond specifically to different energy situations.
3. There are distinct differences between birds and mammals in their digestion and assimilation of nutrients.
4. Finally the reproduction of birds is obviously different from that of mammals.

1.1 The thermoregulation of poultry

Poultry maintain their body temperature at about the same level over a wide range of ambient temperatures. This process is called thermoregulation.

The body temperature of the adult fowl varies slightly between 41 and 42 degrees Celsius (°C). This variation is based on a number of factors, such as breed, bird size, age, sex, nutritional state, feathering condition, and activity, all being characteristics of the bird itself, and on a number of environmental factors, of which ambient temperature is the most important one.

Light breeds, such as White Leghorn (WL), have a higher body temperature than heavy breeds and are therefore better able to withstand a hot environment. Male broilers have a higher metabolic rate at high temperatures than female broilers. Activity increases heat production, and therefore body temperature, even if to a very limited degree. Finally there is a diurnal rhythm in body temperature, with a minimum at night and a maximum in the afternoon, which also contributes to the above mentioned variation.

However, this variation is small. Generally birds succeed fairly well in maintaining their body temperature at a constant level. How do they achieve this? (see following section)

Sensible and latent heat loss

When the ambient temperature is rising, birds attempt to increase their so-called sensible heat loss, i.e. heat we can sense through conduction, convection and radiation. They try to achieve this by changes in their posture (postural changes) and by movement of their feathers. From a resting position in a cold environment, the birds change to a standing position with their wings open and their necks outstretched, when it is warm.

Group size also affects the heat loss of an individual bird. Young chickens huddle together to restrict their heat loss.

Radiation is the most important form of sensible heat loss, at least under temperate climate conditions. It then represents about 75% of the total heat loss. Under hot conditions radiation obviously decreases.

In addition to these attempts to get rid of heat, birds will try to restrict their own production of heat by reducing their activity, feed intake and production.

However, this may not be enough. When the temperature continues to rise and eventually reaches above the so-called upper critical temperature, birds try to achieve an additional heat loss by means of an increased rate of evaporation. This phenomenon does not cause a change in the temperature of the birds' environment and is therefore called insensible or latent (=hidden) heat loss. The conversion of water into gas (water vapour) in the lungs requires energy (about 0.6 kcal per g water), which is derived from the birds' body. The evaporation is actually increased through an accelerated respiration rate, which means that the birds start to pant. Their breathing frequency rises considerably and as

long as the body temperature of the birds is higher than the environmental temperature, the inhaled air can accept more water vapour. The relative humidity of the inhaled air is another factor (Ch.3).
Continuous thermal panting (hyperventilation) can lead to the excretion of large amounts of CO_2 by the lungs, causing respiratory alkalosis (an abnormal increase in blood pH), with unwanted consequences such as soft-shelled eggs (see Chapter 3). It may be said that hyperventilation is used to increase evaporative heat loss resulting eventually in a lower level of CO_2 in the blood.

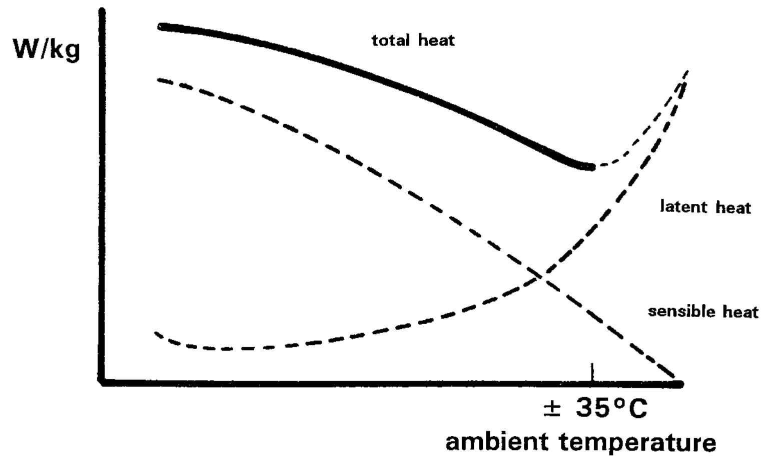


Figure 1: Effect of temperature on heat production and loss

At lower temperatures the ratio of sensible and insensible heat loss is about 50:50, but when the temperature rises this ratio changes. The sensible part decreases and the insensible part increases.
At 35 °C the amount of insensible heat loss is certainly larger than that of the sensible heat loss, the ratio being around 75:25, depending on the relative humidity of the air and the rate of air movement around the birds.

Table 1: The average heat production of some categories of poultry

	kcal/hour	Watts
White Leghorn	8	7
Medium heavy breeds	10	8.5
Broiler parent stock	12	10.5
Broilers	6.5	5.5

Heat stress

Because of the influence of other climate factors the upper critical temperature varies from about 28 to 32 °C. Panting starts at different temperature levels. The body temperature is the decisive factor. When it rises only ½ °C, or even less, above the normal body temperature, panting will start. At that moment the birds suffer from heat stress.
Heat stress therefore can be defined as an unusual physiological response (panting) to high environmental temperatures. As the breathing rate increases more energy is required. In this situation immediate survival has priority over reproductive and performance processes.
Gradual acclimatization to hot climatic conditions appears to be the best defence against poor performance. It will increase heat tolerance in terms of rise in body temperature when exposed to a hot environment.
When temperatures remain at a high level for a long period of time, without interruption by cool periods during the night, birds will find it increasingly difficult to maintain their body temperature at a constant level by only increasing their heat loss. In that situation they must also reduce their heat production: laying hens, by reducing their feed consumption and consequently their egg production; pullets and broilers, by eating less and growing at a slower rate. When these attempts to reduce heat production are not sufficient any longer and heat production keeps rising as a result of heavy panting, a more serious heat stress will occur, eventually followed by death.

Generally diurnally fluctuating temperatures at high levels are beneficial in laying hens as compared with a constant temperature at the average level of a fluctuating temperature.
Cyclic temperatures may have a much less dramatic effect on egg shell quality in the tropics than it has in periods of high temperatures in temperate climate areas, because temperature is usually lower during the dark period, when shell calcification occurs.
Truly adverse environments, however, are expected to increase variation among individuals in productive performance.

1.2 The energy metabolism at high temperatures

The gross energy intake of poultry is used for maintenance and production along the following paths:

Gross energy minus energy in the faeces = Digestible energy; minus urinary energy = Metabolizable energy (ME); minus heat production = Net energy: for maintenance and production.

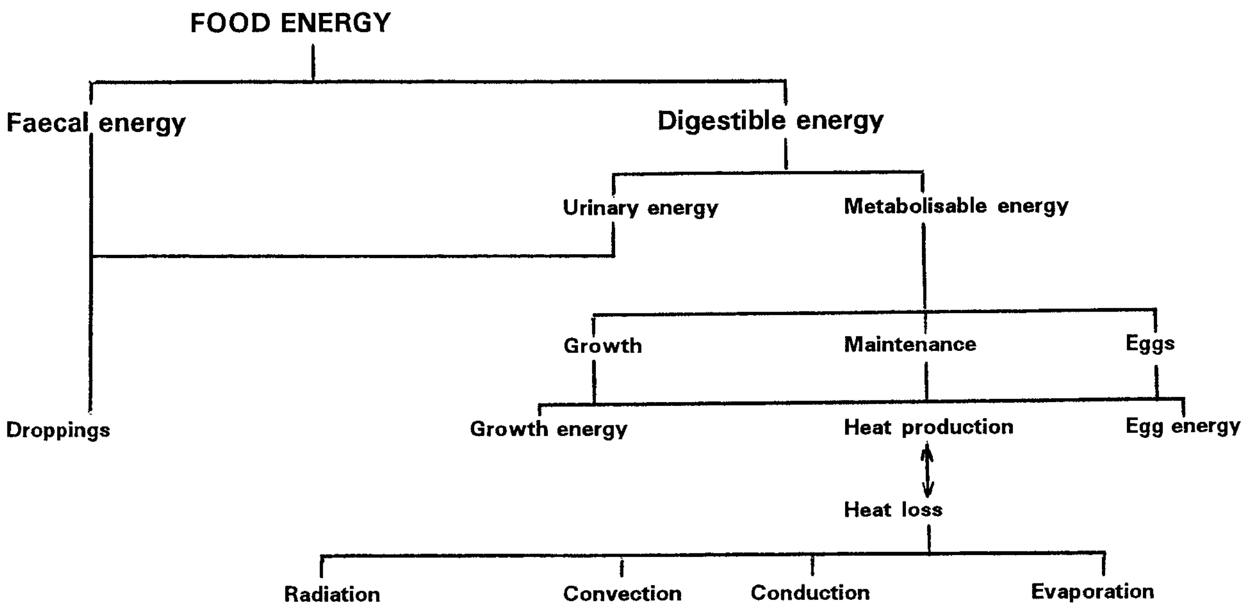


Figure 2:

The ME is used to measure the value of a poultry ration. As ambient temperature rises, the energy requirement for maintenance, i.e. the requirement to stay alive, decreases. In fact this may lead to a more efficient production. The energy requirement for production is independent of the temperature, so if production remains the same, the total energy requirement will be less, leading to a lower energy use per unit of production. Thus higher temperatures need not be harmful at all. On the contrary, they have a positive effect as long as the upper temperature limit, as mentioned before, is not exceeded and provided the production level can be maintained.
Under extreme circumstances things may go wrong. As a result of the lower energy requirement for maintenance at higher temperatures the birds lower their feed intake, as is shown in the following graph:

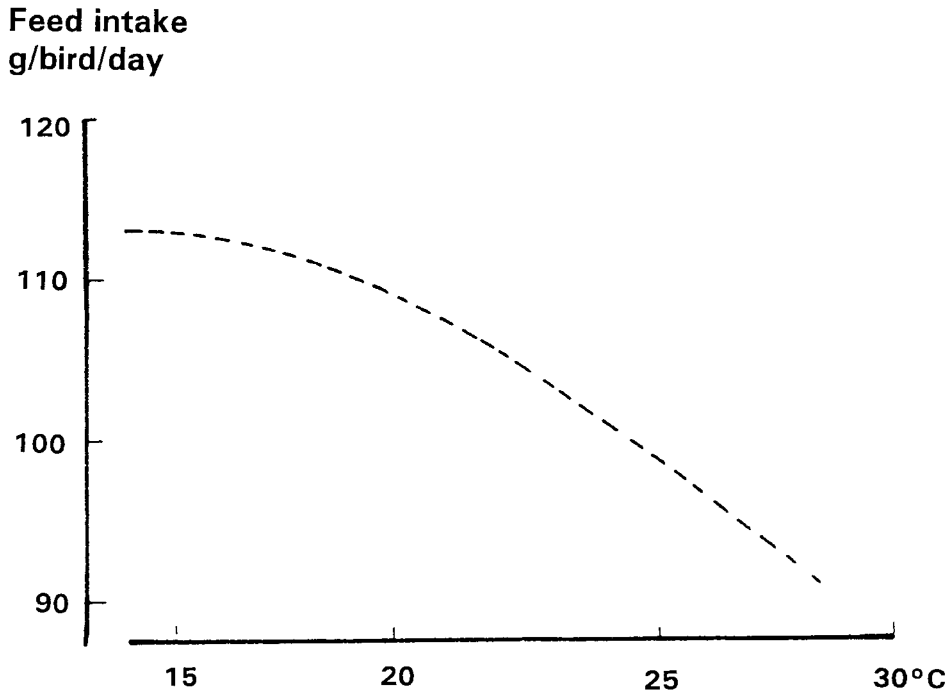


Figure 3: Effect of temperature on feed intake of layers

Laying hens have a ME intake of approximately 1300 to 1600 kJ (or 300 to 375 kcal) at 20 °C, depending mainly on their body size and rate of production. At high temperatures they reduce their feed intake by approximately 1½ % for each degree Celsius temperature rise. Although at the same time heat production also decreases, the energy intake may under continuous hot weather decline to such an extent, that the amount of ingested energy is not sufficient any more to meet both the requirements for maintenance and for production.
Now one may think that increasing the energy content of the diet might be the solution, but this is not the case. Firstly, the birds adapt their feed intake to the energy level in the feed, and secondly, if it might result in a higher intake, the greater basal heat production still leaves less energy available for production (see Chapter 3).
If climate control is not sufficient, we must try to stimulate the feed intake. In this respect we must be aware of the existence of a thermic response to the feeding. This so called thermodynamic effect is normally largest at 2 hours after feeding and at higher ambient temperatures it may last 4 to 5 hours. This is the reason why it is recommended to stimulate extra feed intake at a moment which lies more than 5, preferably 6 to 8 hours, before the moment that a maximum ambient temperature can be expected.

Energy deposition is only small, especially in layers.

Table 2: Energy utilization of laying hens

Daily intake	1200 kJ	100%
Heat production	720 kJ	60%
Egg production	480 kJ	40%
out of which:	deposition of 310 kJ = 25%	
	heat production 170 kJ = 15%	

Table 3: Energy utilization of broilers

Daily intake (3-6 weeks)	1300 kJ	100%
Heat production	650 kJ	50%
Meat production	650 kJ	50%
out of which:	deposition of 520 kJ = 40%	
	heat production 130 kJ = 10%	

1.3 The digestive system of poultry

Birds differ from mammals in the way they digest their food. They have no teeth. Therefore feed particles should not be too big. On the other hand finely ground mash is not suitable for birds. A particle size of around 5 mm is generally preferred for laying hens, and a smaller size of 3 mm ('crumbs') for broilers. These sizes are suitable to maintain feed intake.

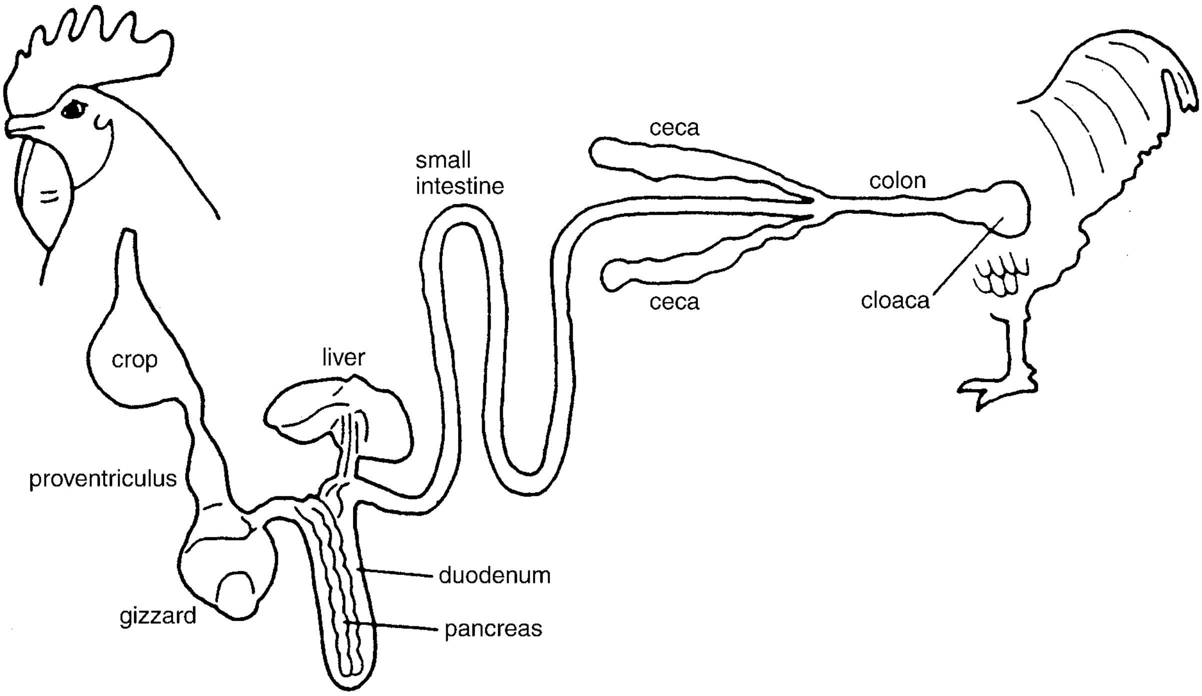


Figure 4: The digestive system of poultry

The food is swallowed immediately into the oesophagus causing a moderate release of saliva in the back part of the mouth cavity. Having passed through the first half of the oesophagus, the food reaches the crop. This is a widened part of the oesophagus, where the food is moistened thoroughly by the already added saliva and the mucus secreted in the oesophagus. There are no mucous glands in the crop itself. This organ only has a storage function, although some enzyme activities have been found on some occasions. The storage ensures a regular supply of food to the first stomach (the proventriculus). In the proventriculus, the first digestive processes actually begin by means of the secretion of hydrochloric acid (HCl) and proteolytic enzymes (some pepsinogens and a relatively high amount of pepsin), which contribute to the breakdown of proteins.

The food then arrives in the gizzard (the ventriculus). This stomach consists mainly of two thick layers of muscular tissue, covered with a corneous lining inside the organ. This protects it from physical damage and the corrosive effect of the acid enzyme mixture flowing into it from the proventriculus. The main function of the gizzard is to grind the ingested feed and to mix it intensively with the digestive gastric juice.

The grinding process is of special importance when the feed consists of rather large particles. Under natural circumstances birds are picking small stones or sand, called grit, to help the grinding process in the gizzard. The question is whether laying hens in cages should be given extra grit or not. Up to now this seems only advisable if the feed contains a high percentage of crude fibre. In the case of mash feed the effect of grit supply seems to be doubtful, although it has been argued that the grit may stimulate stronger muscle contractions and thus could improve the digestion of the food.

Soluble grit, i.e. calcium (Ca) containing particles, in contrast to stone grit, dissolves slowly in the acid medium of the small stomach (proventriculus) and the gizzard (ventriculus), so that a continuous supply of Ca is provided to the intestine. The right form of the Ca source can support this continuous supply.
When the feed has passed the gizzard it arrives in the small intestine or duodenum. Although relatively shorter than in mammals it has the same function, namely a further digestion, through the addition of bile from the liver, and a number of enzymes, and finally the resorption through the intestinal wall.

The last part of the gastro intestinal canal in poultry differs quite markedly from that of mammals. The large intestine (colon) is again relatively short, but the most striking difference is the presence of two large blind ended tubes at the junction of the small and large intestine: the blind guts or caeca. Here an intensive microbial fermentation process occurs, during which some vitamins are synthesized, but these are only poorly resorbed, so that vitamin supply with the feed remains necessary. In the large intestine a further digestion and resorption occurs.

The digestive tract ends in the cloaca, where the urogenital tracts also converge in one common chamber. Birds are different from mammals in having no urinary bladder. Urine and faeces are secreted simultaneously. This phenomenon gives poultry droppings its characteristic appearance of a brownish and/or black mass with typical white material on top of it, originating from the uric acid of the urine. The rate of food passage through the digestive tract of poultry is rather quick: approximately 4 hours in the pullet and 8 hours in the laying hen.

Under hot climate conditions the water consumption is high. This factor may cause watery droppings, as the intestines are no longer capable of re-absorbing the water.
Water plays a very important role in the digestion of the feed, but it also contributes to the cooling of the animal in hot weather. Obviously the temperature of the drinking water must not be too high.

1.4 Reproduction of poultry

Reproduction of poultry takes place through the production and fertilization of eggs to be hatched either by the broody hen or, artificially, by mechanical incubators. The overall efficiency of reproduction, expressed as the number of chickens produced per hen per unit of time, depends therefore, in the first place, on the number of hatching eggs produced and secondly, on the hatchability of these eggs. In this paragraph we will discuss the process of egg production and of fertilization.

The formation of an egg involves a tremendous turnover of nutritive substances. A modern hybrid is able to produce nearly 20 kg eggs, about ten times as much as her own body weight, in a laying period of 14 months. However, her productive capacity declines thereafter, so that only one laying period is practised and sometimes a second one, after an artificially induced moult.

Only one ovary and one oviduct of the female chicken come to a full development. At the age of sexual maturity the weight of the ovary has increased from about 0.4 g in the young chicken to about 2.0 g in the mature pullet. At that time the ovary contains 1000 to 3000 egg follicles. The strong weight increase is due to the rapid growth of 4 to 6 follicles, which develop successively into mature yolks. The release of such a follicle is called ovulation.

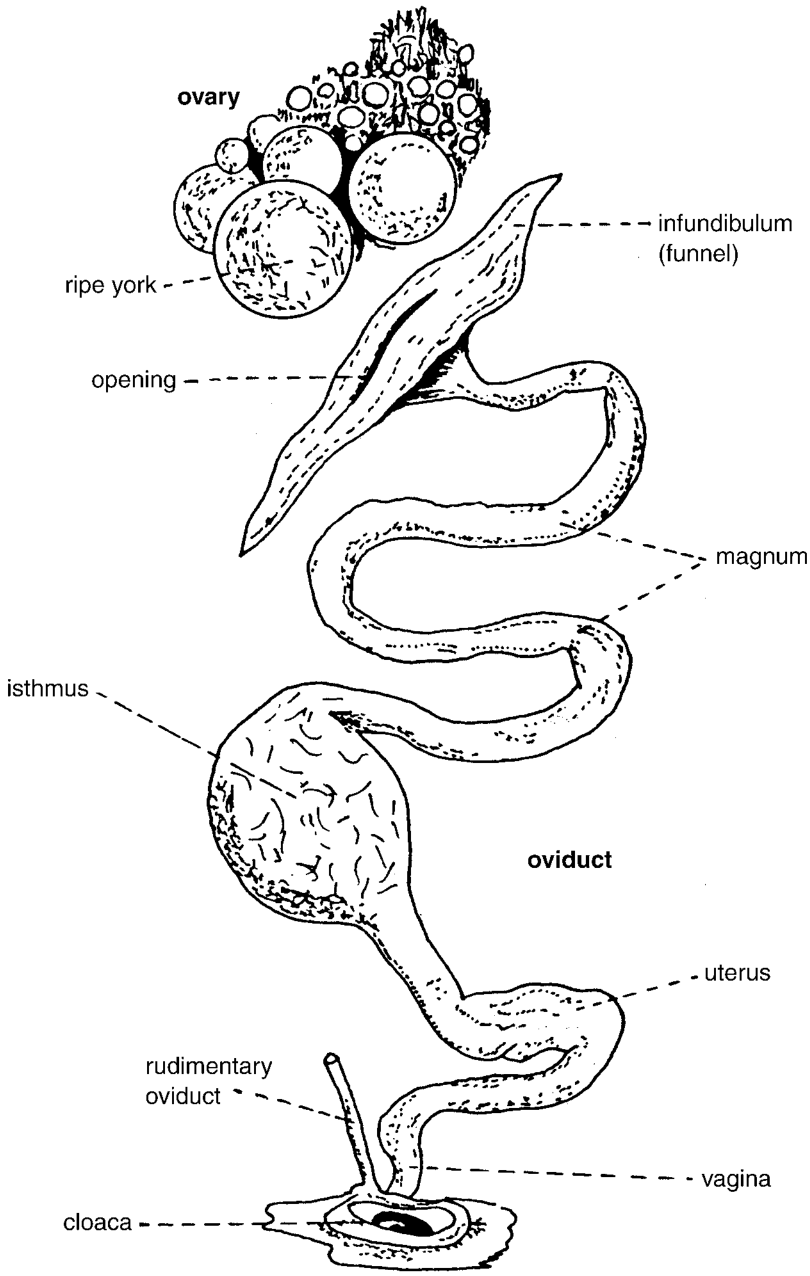


Figure 5: The reproductive tract of the hen

Sexual maturity is affected by a number of external factors, such as season (light), housing and nutrition. Generally those circumstances which increase food intake will advance the reproductive stage (lead to earlier maturity).
Ovulation itself is induced by a complex hormonal activity, in which the follicle stimulating hormone FSH (secreted 15 hours before ovulation) and the luteinizing hormone LH (secreted 4-6 hours before ovulation) play an important role.
Temperature as well as light influence the time of lay, although light remains the main cue.

After ovulation the mature follicle is engulfed in the first part of the oviduct (the infundibulum) and becomes a complete egg on its way through the oviduct.
In the adult hen the oviduct has a length of 70 cm, which, both morphologically and functionally, consists of different regions:

- The infundibulum has a conical section to accept and direct the yolk mass from the ovary into the oviduct; the ovum remains here about 30 minutes.

- The magnum, measuring 35 cm, is the longest part. During ± 2½ hours the albumen is secreted here. This is a mixture of proteins and consists of several layers of thick egg white, around the ovulated follicle or yolk.
- The isthmus, 8 cm long, also secretes albumen and also produces the shell membranes during ± 1-1½ hour.
- The tubular shell gland pouch, 8 cm long, is forming the bulk of the shell. In the meantime water is added. This process takes the longest time in egg formation: 18-21 hours, with some variation, which is very important with regard to the egg production.

The whole egg formation process takes about 25 hours.

The first egg laying or oviposition is generally considered as the onset of sexual maturity of the individual hen, but for a whole flock 'start of laying' is defined as the moment that the flock produces at a certain rate of egg laying, e.g. 10, 20 or even 50 %.

After copulation the spermatozoa fuse with the ovum, lying at the upper surface of the follicle, as it arrives in the oviduct. Thus the first fertilized egg can be laid one day after copulation. Remarkably the spermatozoa are 'stored' in the genital tract of the hen. This is the reason why the hen, when the cockerel is taken away, is still able to produce fertilized eggs for up to at least 2-3 weeks.
In fertilized eggs the chicken embryo lies on the surface of the yolk. Its development starts 5 hours after ovulation, in the oviduct, when the first cell divisions occur. This process goes on during the formation of the egg. Abnormally short or long passing times of the egg along the oviduct can damage the viability of the embryo, causing lower fertility, for example in case of diseases (NCD and IB).
After laying the development of the embryo should stop temporarily and will continue again when conditions are adequate. This a matter of ambient temperatures.

Egg production

Egg production of a flock starts at 20 to 24 weeks of age, depending on genetic and environmental factors such as light, temperature and nutrition. Although there is some evidence that high temperatures tend to delay sexual maturity, the impression is that this is seldom the case in tropical areas. Perhaps this is due to the application of 'stimulighting', or just a question of acclimatization.
After the start, production will reach a peak within 6 to 10 weeks. At that stage the rate of lay will be 80 to 90 %, or even higher (percentage of hens laying an egg on a certain day). This high production level of the flock may continue for a while and then gradually decline until eventually such a low level is reached that the poultry man decides to dispose of the flock.
During the laying period the weight of the egg increases up to the end of this period.
Point of first lay, peak production, and persistency of lay are extremely variable due to genetic and environmental factors.
Hens lay eggs in sequences (clutches) of 1 to 30 or even more, each of them separated by one or more pause days. Normally the first egg of a clutch is laid early in the morning, the following eggs are laid progressively later on each successive day, because the time intervals between the successive eggs are usually longer than 24 hours, the average being about 25 hours.
In the middle of long sequences the interval is usually less than 24 hours, whereas it is often longer in the beginning and in the end of a sequence. Obviously highly productive hens have long sequences with relatively short intervals. At the time the last egg of a sequence is laid in the afternoon a pause occurs.
The regulation of ovulation and oviposition is influenced to a great extent by the periodicity of the light (see Chapter 6).
A similar variation occurs in the duration of the laying period. Cessation of lay is determined by a decrease of hormonal activities, brought about mainly by external causes.
The variation in the rate of lay within the flock can be explained by differences in internal laying, i.e. ovulation not being followed by the formation of an egg, because the ovum is not engulfed in the

oviduct. Another reason for a lower production may be found in a greater number of irregularities at the onset of lay during the first two or three weeks of production.

Obviously the rate of production is affected by the environment. The same applies to poultry meat production. The problem is that many environmental factors are strongly interrelated, and this makes effective management an extremely difficult task. Therefore careful observation and understanding of the environment and its effects on the birds is important, in order to take the right decisions.

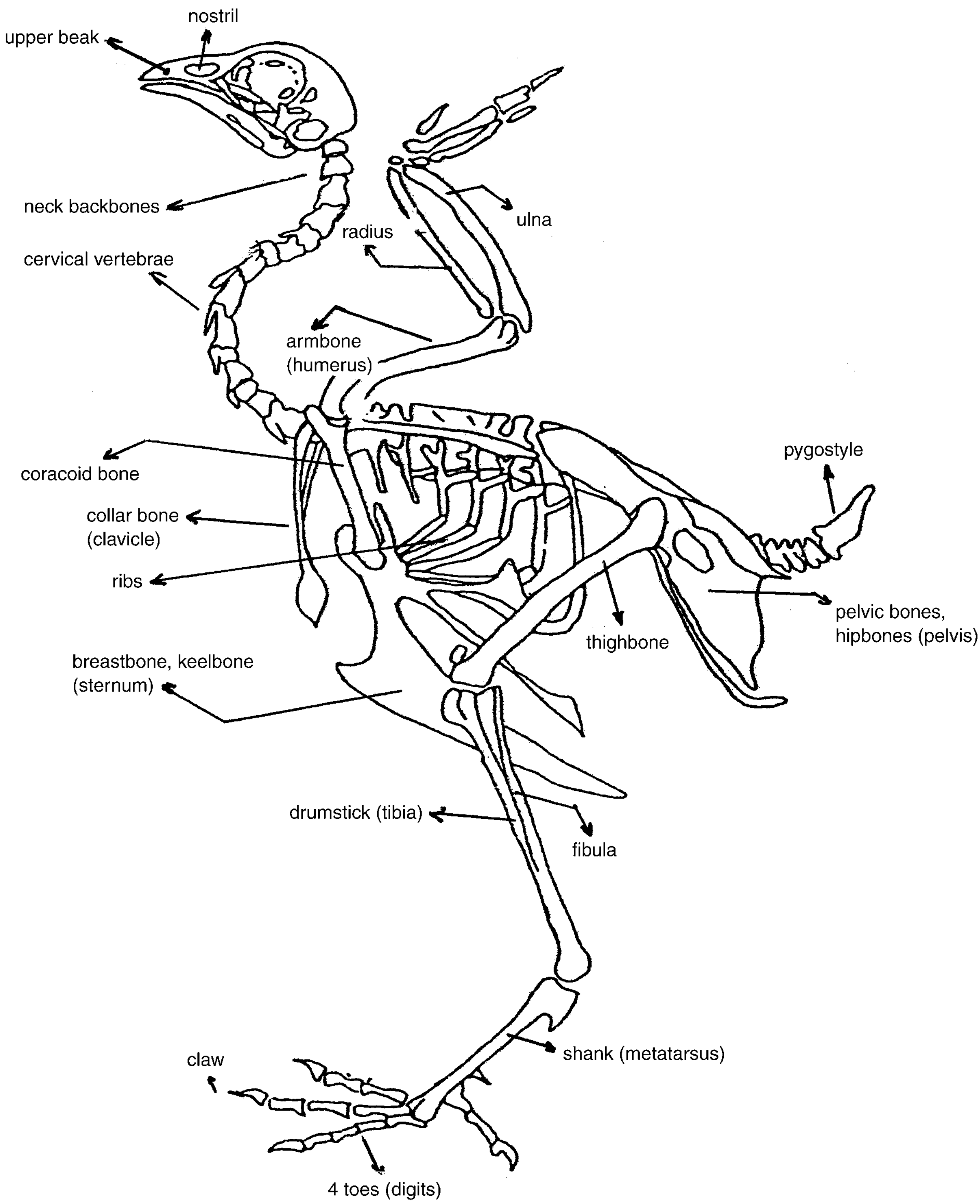


Figure 6: Skeleton

2 Modern poultry breeding

Domestication of poultry is said to have started in South Asia, at least 2000 years ago. The Asian Red Jungle Fowl is generally assumed to be the ancestor of our modern poultry breeds, although evidence has been found indicating that the first domestication of the fowl took place much earlier in China.
In the course of the following centuries all sorts of breeds have originated from isolated groups of poultry, partly by adaptation to the different environmental circumstances, partly by cultivation through man. Poultry breeds which exist today are all different from each other, both in appearance and in performance.
Today pure breeds are rarely used in modern poultry enterprises, with the exception of the White Leghorn (WL). In a way this is still a pure breed, but at the same time it is divided up in numerous groups of crossbreds, formed by the crossing of lines or strains within the breed. These and other hybrids are produced and sold by a very limited number of breeding companies, to poultry farms in almost every country of the world.

2.1 Breeds and hybrids

Modern poultry breeding is carried out by crossbreeding, or hybridization, within one breed (WL) or by crossing lines from different breeds. WL hybrids are light hybrids. Medium weight hybrids are usually composed from several different breeds. The heavy broiler breeder stock originates from two heavy weight pure breeds.
Although pure breeds as such are no longer in circulation for direct commercial use, they still have a large significance as components of the modern commercial endproducts. These breeds are described briefly here.

The WL is a light white feathered bird, laying white eggs. Its low body weight enables it to withstand high ambient temperatures better than heavier birds, but the bird is also rather nervous and it has, of course, a low carcass value.
Medium weight breeds are Rhode Island Red (RIR), New Hampshire (NH), and Light Sussex (LS).
The RIR is dark brown feathered and lays brown eggs. The bird is heavier, quiet tempered, but more susceptible to high ambient temperatures than the WL. However, under poor conditions its viability is probably somewhat better. Its carcass value is higher, but so is its feed consumption. The NH has roughly the same characteristics as the RIR, its feather colour being lighter brown. The LS has been an important component in some of the medium weight laying hybrids. It is a white bird with black striped neck feathers and a black tail (Columbia feather design).
Broiler breeder stock is almost entirely composed of White Cornish (WC) and White Plymouth Rock (WPR). The WC is a heavy, white feathered breed, laying brown shelled eggs. It has been developed for the quality and quantity of its meat. This also applies, though to a lesser extent, to the WPR. The WPR retains a higher egg producing capability.

Initially, in the fifties, crossbreds originating from breed crossing were used. Their performance and viability (hybrid vigour) was better than those of pure breeds. However, in the sixties more and more crossbreds originating from line crossing were produced.
Breed crossing is still applied in some developing countries. They still have a better performance than pure breeds, whereas the breeding method is simpler than line crossing, and it is also cheaper. Large commercial poultry enterprises, however, always use modern hybrids originating from line crossing. They may cost more, but their performance is much better under favourable conditions.

2.2 Selection methods

Response to selection depends, of course, on the extent to which the traits involved are inheritable. This inheritance level is expressed by the so called heritability (h^2). Estimations of h^2-values vary between, and within, populations, and under different conditions. Generally, however, the following values are given:

Table 4:

Trait	h^2
Age at point of lay	0.25
Egg production	0.20
Egg weight	0.50
Egg shell strength	0.30
Body weight	0.50
Viability	0.10

Pure lines are developed primarily by the use of closed flock selection. There are two selection procedures involved. Traits with high h^2-values are basically improved by selection of the best individual birds (individual or mass selection), selection is based on individual performances. Traits with low h^2-values are improved by selection of birds on the basis of the performance of their sibs (family selection).

Apart from selection within the lines, there is also a selection procedure to find the lines with the best combining ability. For this purpose a so-called reciprocal recurrent selection programme is used. In this programme parents are selected on the basis of the results of their offspring in combination with partners from other lines. The parents with the best results are used to produce the hybrids from these particular lines.

The endproducts generally originate from four different lines. This is called a 4-way-crossing. Obviously the grandparent stock in such a programme must consist of pure lines, whereas the parents are hybrids.

Grandparents	AxA		BxB	CxC		DxD
Parents		AxB			CxD	
Endproduct			(AxB)x(CxD)			

Figure 7: Scheme of a 4-way-crossing,with lines A,B,C.and D.

The main reason for the application of a 4-way-crossing is to gain the benefits of hybrid vigour also in the parent phase. Furthermore this approach makes it possible to combine lines with specific qualities, such as a favourable disposition for meat production in the male or sire lines and for egg production in the female or dam lines of broiler breeding stock.

In many countries grandparent stock is available on licensed farms. On these farms no basic research needs to be done. They only provide multiplication farms with the future parent stock. These farms supply the hatcheries with hatching eggs (supply farms) out of which the commercial endproducts (layers and broilers) are obtained. In this situation only the grandparent stock must be imported. That may have the advantage of lower import costs, but on the other hand many organisational problems have to be solved.

Some characteristics of chickens may be linked to the sex of the bird, because the genes for such characteristics can be situated on the same chromosome as the sex determining gene. It is possible in some strains to distinguish male from female day old chickens by a difference in colour. One of the European breeding companies used to sell a brown layer, the mother of which is white and the father brown feathered. The day old cockerels are white (Lohmann Brown).

2.3 Selection results

Compared to 50 years ago the egg production capacity of laying hens and the growth rate of broilers has increased tremendously, due to striking improvements in housing, management and nutrition, and also to real progress in the upgrading of the birds' genetic disposition.
Over the last ten to twenty years the genetic improvement in rate of lay has continued with an annual progress of 1 to 2%. At the same time genetic selection has advanced sexual maturity, in days of age, by approximately 1 day per year. However, egg weight did not decrease, it even showed a slight increase.
Nowadays a 20 kg egg mass at a 2.00 feed conversion is considered to be a realistic breeding goal. Small experimental groups of hens are even reported to lay more than 90% on average with nearly 64 g of egg weight and a feed conversion of 1.90! These hens weighed 1.56 kg at the start and ended at 1.69 kg in 336 days. Such results would also be achievable in well managed poultry farms.
Broiler end weight is reached in ever shorter periods of time and has advanced at a rate of 1 day per year; at the same time the reproductivity of broiler breeders has been improved by 2 chicks per hen per year.
These results have been achieved by selection within the chosen lines and by combining the most suitable lines.

2.4 Random sample tests

Poultry farmers can choose their stock by consulting the results of Random Sample Tests (RST). These tests are set up in special testing stations, where the results of entries from different companies are compared. For this purpose samples of hatching eggs are collected at random at the supply farms. All the eggs are hatched together at the station and the chicks thus obtained are also reared together, under the same conditions.
Laying hens and broilers can be tested, but broiler tests are not always carried out, probably because integrations or integrated farms would like to know more about the performance of the parents of the broilers involved. Both categories must be evaluated together in order to determine the profit to be expected. Broiler breeders are, however, seldom tested, but if they are it should be done in combination with their offspring.

Technical as well as economic data are collected. In the Dutch RST station at Lelystad the following data are currently published:

hatching and rearing data:
- eggs candled after 18 days hatching (%)
- chicks from eggs set, and chicks from fertile eggs (%)
- mortality in the rearing period, 0-2 and 0-17 weeks, (%)
- feed consumption per pullet at 18 weeks (kg)
- body weight per pullet at 6, 10, 14, 17 and 18 weeks (g)

laying period (140-500 days of age):
- adult mortality (%)
- age at 50% production (days)
- hen day production in the 13th 4-week-period i.e.persistency (%)
- number of eggs per hen day
- egg weight (g)
- number of eggs per hen housed
- egg mass per hen housed (kg)
- final body weight per hen (kg)
- feed intake per hen (kg)
- feed conversion ratio f.c.r. (kg feed per kg eggs)
- income over feed costs

A broiler test may cover the following data:

- chicks from eggs set, and from fertile eggs (%)
- mortality (%)
- final body weight of males, females and total (g)
- growth per chick per day (g)
- feed conversion ratio f.c.r. (kg feed per kg final body weight)
- performance index (% surviving chicks × growth per chick per day in kg × 100/f.c.r.)

Differences between entries are certainly sufficiently large to eliminate poor products and are, at least, helpful in discriminating between the better products. The repeatability of the obtained results in RST's is quite reasonable, although some genotype × environment interactions may occur, when RST's in different climate zones are involved. Therefore more RST stations in tropical areas might be useful. Such RST's could be a significant stimulus to improve the local poultry industry.

2.5 Prospects of poultry breeding in tropical areas

Commercial poultry enterprises and many smaller farms in the tropics are using modern hybrid strains as described above with good results. However, additional improvement of these hybrids in view of tropical conditions might be possible. Considerable differences in adaptability to high temperatures have been found between breeds and genotypes. Another feature sometimes noted, is the probability that selection for low consumption of quality feed under moderate climate conditions may lead to poor performance in hot climate areas with suboptimal feeds. Therefore it may be worthwhile investigating the possibility of combining a good performance ability with the capability of tolerating a warm environment. Among the traits which may contribute to such a capability, body size is considered to be the most important one. It has been recognized that genetically determined differences in body weight clearly affect the ability of heat tolerance. Experimental work carried out by German and Malaysian researchers gave strong indications in this direction. This may lead to the necessity of selection for lower body weight in layers.

Further possibilities may be expected from the use of major genes. Genes are the hereditary factors on the chromosomes in the body cells. Major genes are single genes, influencing one trait by a simple mode of inheritance (dominant or recessive). They are easy to manipulate and to transfer to existing populations. The most promising ones with direct tropical relevance might be the genes for dwarfism, naked neck and frizzle (reduced feathering). The dwarf gene, already used in current broiler breeding, could be used successfully under tropical conditions.
Reduction of feathering will of course increase heat loss by convection and conduction. However, a lot more work has to be done in order to avoid unwanted genetic correlations with other traits.

There are distinct strain and/or breed differences in the response of birds to heat stress. But the modern breeds do fairly well. In experiments dealing with WL and the indigenous Sinai fowl, for instance, it appeared that, although the performance of the WL at 41 °C was reduced by 30%, it still outperformed the Sinai breed in terms of egg production.

New developments

The latest development is the use of DNA technology. The DNA (desoxyribonucleid acid) in the chromosomes determines the sequence of the genes. DNA technology aims to change the existing hereditary pattern of the animal. There is a growing interest in genes which play a role in regulating disease resistance. Production characteristics are much more complicated and not yet quite understood at this level.

The first step in this technology is to know exactly the nature and composition of the gene involved. This gene must then be isolated and multiplied. The most complicated step is the next one, namely to insert the gene into the DNA of the host. Research is being done on two methods: injection into a fertilised egg, or the use of a virus as a vector. The last one seems to be the most promising one. Whether the gene will express itself correctly and continue into future generations remains to be seen, but at present convential breeding systems are still necessary.

Poultry farmers should always make a careful choice of stock. Studying the results of RST's, either from the area itself or from elsewhere, is only one helpful way or means of making the right choice. Supplementary information, from one's own experience, or from colleagues, may also be valuable, as the conditions on the own farm may not be comparable to those on the RST's.

3 Environmental requirements of poultry

Environmental factors affecting poultry performance include temperature, relative humidity (RH), air velocity, quality of the air inside the house, and altitude.
They are all, to a great extent, interrelated to each other. From Chapter 1 we know, for example, that temperature and RH, in particular, interact strongly. In humid areas birds are much more susceptible to high ambient temperatures because of the reduced possibility of loosing heat by water evaporation. Heat tolerance can be improved by air movement in order to increase heat loss through convection. There is also interrelation with other environmental factors, such as the housing system, nutrition and climate control. Light is also an important factor. Light influences activity; up to 25% of the heat production is related to activity.
Finally acclimatization may alter the effects of single climate factors. Thus the observed effects of single climatic factors only have a relative value. That is why the concept of 'effective temperature' has been introduced, indicating that the effect of the ambient temperature differs in relation with the effect of other factors which are present.

3.1 Temperature effects

In Chapter 1 (see paragraph energy metabolism at high temperatures) we have seen that the ambient temperature affects the performance through its effect on the energy requirement of the bird for its maintenance. As energy is mainly derived from the food, it is easy to understand that poultry attempt to regulate their feed intake in accordance with the prevailing environmental temperature. At high temperatures, say at 30 °C, feed intake decreases considerably, whereas the energy requirement starts to increase. Thus the hen becomes energy deficient and will soon no longer be able to maintain her performance at an acceptable level. Poultry performance under tropical conditions is therefore determined mainly by the actual feed intake, both in adult and in young birds, but this is on energy basis. Research gives evidence that temperatures above 31 °C do not affect the requirements for protein, lysine or vitamin A. Nutrient adjustment could therefore alleviate the adverse effects of heat stress.

Water intake becomes more important with rising temperatures, as it is used to control body temperature in passing a large amount of heat to the water. Moreover, poultry use the water as a coolant for external evaporation or to get rid of the heat from their heads during drinking positions.
The question arises whether there is an optimum temperature level for each of the categories of poultry involved. The optimum values would be those which lead to maximum profitability. However, the difference between performance and costs varies according to the local situation and time, so that the economical optimum may well be different from the physiological one. However, it seems that 20-25 °C may well be the most profitable ambient temperature.

Direct and indirect temperature effects on poultry

Day old chicks are not really homeotherm during the first 3 days of their life. They cannot regulate their body temperature efficiently which is why they require a warm environment: ± 35-32 °C during the first 3 days and 30° after 1 week. However, their ability to regulate their body temperature grows with age. The ambient temperature can gradually be lowered after 1 week, and then by weekly reductions of 2-3 °C, from 30° to 20 °C at 4 weeks of age. Higher temperatures reduce feed intake and thereby, at least to a certain extent, their growth rate. Low temperatures would increase feed intake unnecessarily. The recommended temperature for the growing period, therefore, ranges from 20 to 25 °C.

In pullets a too low feed intake depresses not only growth rate, but can also retard sexual maturity by some days. The effect on the subsequent laying period is assumed to be small. Only egg weight may be slightly reduced. However, we must keep in mind that these effects are not always observed. Temperatures may vary and climate control is not always effective!

Temperature effects on the performance of laying hens are of more importance. Numerous experimental data indicate that, at least in the range of 15 to 25 °C, temperature changes result in changes in feed intake amounting to 1½ % on average per degree C. At higher temperature levels the decrease in feed consumption will be much greater. Generally for layers an optimal temperature of 20-21 °C is recommended, but it may range from 20 to 25° without adverse effects.

A reduction in feed intake as a consequence of high environmental temperatures does not necessarily mean that egg production should decrease too, as the birds need less energy for their maintenance. If such a decline does occur this is generally caused by an actual reduction in the intake of nutrients other than energy. According to this view a lower egg production in hot climates is, in most cases, caused by an inadequate supply of protein, and/or minerals and vitamins. A decrease in egg production can therefore be considered as an indirect effect of high ambient temperatures. If this is true, it leads to the conclusion that under high temperature conditions a well balanced diet can prevent a production decline within a temperature range to 30 °C, at least as far as number of eggs is concerned.

Egg weight, however, is already affected at lower temperature levels, i.e. from 25 °C or less, depending on the breed involved and on the prevailing climate and other environmental conditions. Generally the reduction of egg weight amounts to 0.2 to 0.4 g per degree C temperature change. Again we must not presume that such effects always occur and certainly not that the size of the response will always be the same. A great variation may be observed. Differences in egg weight have even been found in different tiers of laying cages!
Lower egg weights are the result of less energy being available for production while the number of eggs produced is still maintained. All factors affecting energy intake will therefore be of influence on the actual effect on egg weight.
Generally egg weight is, to a great extent, related to body weight. This correlation is observed within breeds and in hot climate conditions as well. Moreover, body weight is equally influenced by the energy metabolism as is egg weight. Lack of energy therefore also results in a lower body weight and consequently it is also considered to be a result of high ambient temperatures.

Prolonged exposure to high temperatures will, starting from 27 °C, cause a deterioration of egg shells. Heat stress may produce an adverse effect on egg shell quality in three ways: by reducing feed intake and thus calcium intake, by interfering with the calcium carbonate formation in the shell and by upsetting the acid-base balance in the blood. However, it is mostly not a consequence of Ca deficiency, brought about by a reduction of feed intake, at least as long as the dietary Ca level meets the requirements, but a result of a disturbed carbon dioxide metabolism (see Chapter 1). The occurring high respiration frequency, or hyperventilation, causes low levels of carbon dioxide and at the same time of Ca-ions in the blood. This is probably the reason for the occurrence of softer egg shells.
If no measures are taken when ambient temperatures are continuously high, then eventually the number of eggs produced will decrease. As nutrient adjustment would not work, we call this a direct effect of high temperatures.

For broilers between 3-8 weeks of age, a growth rate depression of 20 g per bird per degree C is estimated above 27 °C. Others state that in broilers, feed intake and weight gain, decrease linearly with the rising ambient temperature above 28 °C. At that stage even feed efficiency decreases, especially in males.
However, you should not be surprised in observing a great variation in responses to the ambient temperature, as the type of bird, the level of metabolizable energy in the feed, production level, acclimatization, feather cover, activity, etc. determine the effect on feed intake.

From the above mentioned considerations we can conclude that the optimal temperatures for pullets, laying hens, and for broilers, range from approximately 20 to 25 °C. A wider range is not necessarily harmful as long as daily temperature fluctuations occur and the proper management measures have been taken to control the ambient temperature. For the most economic temperature, feed and egg prices are critical.

3.2 Relative humidity

Humidity in the poultry house arises from the respiration of the birds, their faeces and bacterial processes in the litter.
As pointed out in Chapter 1, poultry try to loose their superfluous heat by means of evaporation through an accelerated respiration. The extent to which this evaporative heat loss actually will relieve the heat load depends on the question, how much water can be evaporated, and this, in turn, depends upon the water content of the ambient air. The relative humidity (RH) of the air determines the effectiveness of the birds' attempts to loose heat by evaporation. This is the reason why hot humid environments are generally extra stressful for poultry. Heat produced by the birds in hot climates can to a small degree be removed by sensible heat loss. The greater part of the heat must disappear in the form of latent heat through evaporation of water into the inhaled air. Heat loss in humid, hot climate zones is therefore hard to achieve.

Research gave evidence that increasing RH from 65 to 95% at 24 °C had no effect on feed intake or weight gain. At 30° it did affect feed intake, body weight gain and egg mass considerably. In temperate climates an average level of 70% RH is generally recommended. Lower values may be better still but are very hard to achieve, at high costs of ventilation. Under these circumstances it is assumed that levels beyond this limit will cause the litter to become wet, while there is a limit in the absorption capacity of the litter. Wet litter provides a favourable environment for parasite development (coccidiosis and worm infections). Furthermore it gives rise to the development of ammonia (NH_3) in the air, which favours the outbreak of many respiratory diseases. It can also cause breast blisters in broilers and otherwise lower the quality of the broiler product.
There is no reason to believe that these consequences would not be present in the tropics, but the higher temperature will in most cases delay the occurrence of such situations. High temperatures with low RH levels are less detrimental and easier to deal with, particularly by means of evaporation systems. Nevertheless a RH of 70% should preferably not be exceeded.

Generally the RH is probably less important than the temperature. The impact of the combination of temperature and RH can be estimated by means of the so called temperature-humidity index. In this index the dry bulb temperature and the wet bulb temperature are combined in the ratio of 70:30 respectively. In this way extremely high temperatures with relatively low RH levels are still more harmful than rather low temperatures with relatively high RH levels.

3.3 Air velocity

In tropical regions where high temperatures prevail together with high humidity levels, the only way to reduce the effect of a heat load is by increasing the rate of air movement. When air is passing the surface of the birds, heat is lost through convection. Naturally the effect depends on the difference in temperature between the surrounding air and the surface of the birds. The greater this difference the greater the cooling effect. The same holds for air velocity, the greater the velocity the greater the effect.
These are general rules, however. For example, there is a limit to increasing air speed, as experiments have revealed that air speed levels above 2½ m/s are no longer beneficial. When the ambient temperature is nearly as high as the body temperature of the birds, air speed levels can be detrimental. Furthermore we must keep in mind that in cold environments, and during cool periods at night, the

air velocity can be too high, particularly for young birds. Generally air speeds at birds' level should, during cool periods, not surpass the limit of 0.15 m/s.
At higher temperatures the following guidelines are given. Day old chicks: not more than 0.3-0.5 m/s; at 4 weeks: 1 m/s, but not more than 0.75 m/s when the birds are sleeping. At high temperatures ± 2 m/s is advisable.

3.4 Effective Ambient Temperature (EAT)

As seen before, the observed temperature effects are the result of changing energy requirements for maintenance. The variation in responses to temperature changes is therefore brought about by differences in other factors as well, as long as they also affect the energy metabolism. Such factors are: strain, age, body weight, and feather cover of the birds. Furthermore, we can assume that postural changes, caused by temperature changes, lead to different levels of activity, which in turn also affect feed intake. Finally differences in the duration of the heat exposure and the level and composition of the dietary energy can affect the responses to the ambient temperature.
From this point of view the concept of Effective Ambient Temperature (EAT) has been developed. It is defined as a result of a complex of factors (air temperature, air velocity, humidity, surface temperature and other variables such as floor type and insulation), which interact. It expresses the total effect of a particular environment on the animal's heat balance, but is hard to quantify.

As to the effect of strain, we know that light breeds, like WL are less susceptible to heat stress, whereas broiler breeder stock is, apparently, very sensitive to high temperatures. Broilers also have a very poor heat tolerance, particularly males, which grow more rapidly. This declines with age.
The optimal temperature (if any!) for broiler parent stock is lower: 18-20 °C. As a result, losses in egg production, fertility and hatchability may occur earlier than in laying flocks under the same environmental circumstances.

The heat increment of the diet plays also a role in the variable responses to high temperatures. This increment is lowest when a greater part of the ME is derived from fat in stead of carbohydrates. Excess of protein may have an even worse effect. At high temperatures this could aggravate the situation, as protein has a relatively high heat increment increasing the heat burden of the hen. On the other hand, the results of adding fat are not very consistent; addition of 3-4% of palm oil may be beneficial. In order to prevent the adverse effects of high temperatures in the tropics, a higher nutrient density, other than energy, is generally recommended, particularly for laying hens. Dietary adaptation as such is not so successful in broilers, because here a more direct temperature effect is involved.

Interactions with housing systems may also occur. Cages, for example, may reduce the possibility of heat dissipation through convection. This is another factor contributing to the general idea of the 'effective temperature'.

Table 5: The 'Effective Temperature' Concept

Temperature effect	Interactive factors
High temperatures reduce: ➢ feed intake ➢ growth ➢ egg weight ➢ egg shell strength	Bird factors: ➢ - strain ➢ - age ➢ - body weight ➢ - feather cover ➢ - activity
	Climate: ➢ duration of exposure ➢ temperature fluctuations ➢ relative humidity ➢ air velocity
	Management: ➢ housing system ➢ climate control ➢ disease prevention

Responses to high ambient temperatures are often registered in experiments in which rather constant temperature levels are maintained. In interpreting these results we must keep in mind that under practical conditions temperature levels continuously change, at least as a consequence of day and night fluctuations. So a day-time temperature of 35 °C need not be very detrimental as long as the temperature at night drops to 20 °C. For example: the effect of high temperatures on egg shell strength is not apparent when the 24-hour temperature ranges from 20 to 35 °C, whereas a cycle ranging from 27 to 35 °C would certainly bring about a negative effect. That is why the use of ventilation fans at night can generally prevent adverse effects of high day-time temperatures. However, the smaller the difference between day and night temperature, the more negative effects can be expected from high day-time temperatures.
Another factor to observe is the rate of temperature increase and the duration of exposure. Heat waves which occur suddenly have a detrimental effect, in an otherwise temperate climate. Fortunately poultry in tropical zones have ample opportunity to acclimatize, i.e. to adapt.

In summary, the combination of temperature, RH, air velocity and the environment in the broad sense of the word, including the housing system, the nutritional situation and the way the birds are kept, determine the level of the 'effective temperature' and thereby the actual temperature effect.

3.5 Air quality

Air quality standards are of course only a matter of concern in controlled environment housing systems. However, if there is an unsuitable location, with poor ventilation, ammonia (NH_3) levels could increase and become detrimental. In many publications carbon dioxide (CO_2) is also mentioned as a potential air contaminant. Under normal circumstances we can ignore this factor, it will cause no harm as long as the NH_3 is under control by ventilation. NH_3 levels which are too high do not occur often when there is sufficient ventilation and the manure is not stored too long.
For CO_2 a maximum level of 3000 or even 6000 ppm is suggested. Even in temperate climates with minimal ventilation rates these levels are seldom reached.
For NH_3 a maximum level of 25 ppm is recommended. Generally we can assume that this level has been reached as soon as we ourselves experience irritation of eyes and nose on entering the house! However, under hot climate conditions, ventilation generally has to be high already (to control the temperature), so that air quality standards are nearly always maintained.
High levels of NH_3, e.g. 25-30 ppm, may cause:
- keraconjunctivitis by irritation of the mucous membranes of the eye especially in birds of 2-3 weeks of age,
- negative effects on the respiratory tract (lowered resistance to respiratory infections),
- reduction in respiratory rate and depth,
- reduction of appetite and decreased body weight gain and feed efficiency,
- negative effect on laying capacity and egg quality,

- breast blisters on broilers.
- levels over 30 ppm may result in a higher susceptibility to infections.

In closed environment houses, high amounts of dust particles in the air can be a nuisance and even become harmful when they consist of small particles, which may enter into the respiratory tract, carrying large amounts of pathogenic micro-organisms and thus causing infections. Generally dust particles have a size ranging from 1 to 450 μ. In dry environments particles < 5 μ may be a danger to human health as they can carry pathogenic organisms, causing irritation or allergic reactions. Per m^3 of air not more than 10 mg of dust is kept as a safe margin.
Dust production can be reduced by feeding pellets.

3.6 Effects of high altitude

There is much evidence in literature that at high altitudes the prevailing low oxygen concentration has detrimental effects on the embryonic development of chickens. At increasing altitudes hatchability generally decreases. Field evidence varies. Some sources state that this decrease initially may amount to 10% per 300 m increase in altitude and probably more than that at very high altitudes. Others, however, report a decrease in hatchability of 15% at 1000 m and 30% at 2000 m. The effect depends partly on the location of the breeder flock, whereas there are also hereditary differences in adaptability to lower oxygen concentrations involved. Adaptation can develop through a greater ability of the embryo to form haemoglobin in the red blood cells and through the development of a greater heart volume of the growing embryo to compensate for the lower oxygen level. Locally produced eggs may reveal a lower porosity of the shell which may restrict the diffusion of gasses at lower atmospheric pressure.
The low partial pressure of oxygen at high altitudes causes hypoxia (inadequate oxygen supply) with lower lung activity and a higher arterial pressure. This affects the working of the heart and may lead to heart failure and accompanying symptoms, called ascites.
In order to solve the problem, addition of oxygen has been applied with success, but the costs of this solution may be too high. Increasing the ventilation rate could provide more oxygen, but as the humidity level at high altitudes is naturally low, humidity is lowered simultaneously, so other problems may arise.
In most cases it may be preferable for birds to lay the hatching eggs at higher altitudes, but for them to be hatched in a lower area. This gives the advantage of a better performance of the parent stock in a cooler environment, coupled with a greater hatchability at lower altitude. Transportation will have to be carried out with great care and of course, costs should be borne in mind.

Broilers, being fast growing birds, are also susceptible at high altitudes. In a number of cases a reduced growth rate and even high mortality have been observed. Fast growing birds have a high level of metabolism and thus an increased oxygen requirement. Moreover, the metabolism is activated still more at the lower temperatures at higher altitudes.
However, the idea is being accepted more and more that the symptoms of high altitude diseases can also be observed in lower regions and that this ‘disease’ is a multifactorial syndrome, though it is more prominent in higher regions.

4 Housing

Although housing costs represent only a small percentage of the total costs of production, housing is of utmost importance for optimal results. Housing conditions may have a dramatic effect on the health of the flock and thereby on its performance and efficiency. In discussing the optimal environment for poultry we will restrict ourselves to the control of the main characteristics of the house climate, i.e. the ambient temperature, the humidity and the quality of the air inside the house. In order to achieve the optimal conditions our most important tools will be: insulation, ventilation and cooling.
Poultry houses in hot climate zones are designed mainly to protect the birds inside from the outside solar heat load. In general the type of house is, therefore, strongly related to the type of climate involved. In hot and humid climate conditions open houses are preferred, whereas in hot and dry regions controlled environment houses are more appropriate to the situation. Controlled environment houses are much less effective in warm, humid weather and too expensive in operation.

4.1 Planning and location

Before starting the actual building of the house it is necessary to choose the most suitable location. From an infrastructural point of view the following aspects are the most important ones:

- Accessibility for all types of transport.
- Water and electricity supply.
- Sufficient space for possible future expansion.

If more poultry houses are to be built on one site, special attention should be given to an adequate distance between the houses, particularly when poultry of different ages are housed on the same site. In that case a distance of 100 m is recommended, but proper hygienic precautions might be of even more importance.
Open space between the houses is also necessary to give room for ample ventilation, especially when open houses are involved. For the same reason building in a valley might not be advisable.

Building materials should be highly durable and resistant to solar heat deformation. Hollow brick blocks and roof insulation contribute to heat buffering by minimizing heat convection, conduction and radiation.

There are three types of intensive poultry housing systems:

- the deep litter or built up litter system,
- slatted or wire floor systems or a combination of one of these floor types and litter,
- the cage or battery system.

Generally covering the floor with slats or wire is done in temperate climates in order to prevent damp litter. This might be less necessary in tropical areas but partly slatted or wire houses are useful in periods when litter conditions may be poor. Moreover, contamination with parasites is avoided. A raised section, the droppings pit, is covered with wire mesh or slats. This section can occupy one to two-thirds of the total floor area.
In broiler houses the litter system is preferred, giving less rise to skin lesions and other defects.

4.2 Open poultry houses

Open houses are actually the only option in warm, humid regions. Both the location and their design are totally directed to minimizing the possible negative effects of the high outside temperatures. Moreover, open sided houses are certainly cheaper.

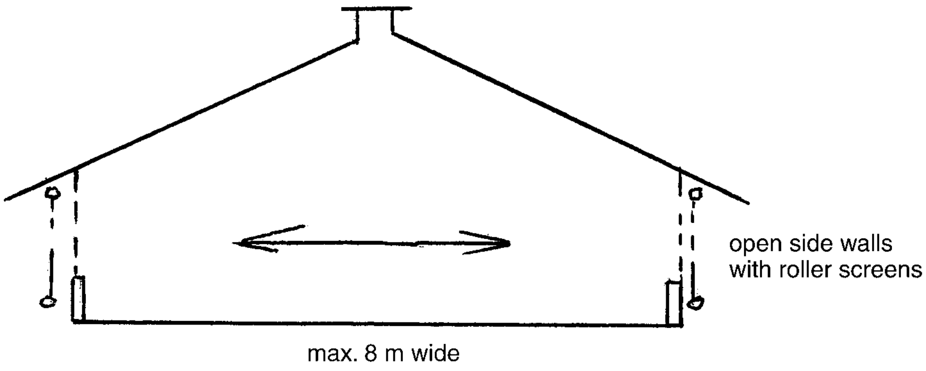


Figure 8: Open house

Poultry houses in warm climates are built preferably in an east to west direction, so that direct sunlight does not fall on the side walls during the hottest part of the day. A vertical surface facing the equator receives less direct solar radiation than one facing the east or west. Another aspect for consideration is the prevailing wind direction, although this might be of minor importance.
The walls should be shaded by a roof overhang or by trees and shrubs. Reflection of ground heat should be prevented by applying ground vegetation extending approximately 3 m from the walls of the poultry house. Concrete should be avoided.
A roof overhang of 1 metre or more prevents rain from falling into the inside of the house and provides more shade.

The design of an open house is basically a simple one, but there are a number of details to observe, which might have a decisive implication.
The long sides are left open to maximize air movement, so that ample fresh air can get into the house. In most cases wire netting or other materials, such as wooden or bamboo slats, are used as a protection against theft and/or predators from outside. A low dwarf wall is built usually to prevent water from penetrating into the house. Such a wall may normally be only 25-30 cm high, so that plenty of room is left for fresh air, but in some regions, sudden changes in the weather may require walls of at least 60-80 cm. In that case a solid construction of the end wall may also be sensible. Furthermore it is advisable to install adjustable roll-down plastic curtains in the side walls in case of periods of rain and wind. The end walls can also be partly open, but in most cases a solid construction up to the ridge is preferred.

A high roof pitch of 30 to 40 degrees assists natural ventilation by increasing the 'stack effect', by which cooler air is drawn in through the sides of the house while the warmer air is escaping through an open ridge. Such a ridge should certainly be installed in relatively wide houses, i.e. more than 8 m. A high ridge will also reduce heat radiation to the birds from the underside of the roof. However, in calm weather, as is usually the case in tropical regions, open ridges are not very effective. In many cases the open side wall is not high enough, so that air movement is limited. If, in such cases the angle of the roof with the wall is also low, the roof is too near to the birds causing more solar heat being passed on to them. A higher ridge increases the volume of the house, thus contributing to a better inner air quality. If the roof is rather steep causing an elevated ridge, the side walls can remain relatively low.

A further reduction of the radiant heat load can be obtained by the use of reflective low-emissivity paint, preferably white. Because of their high reflectivity and low emissivity
aluminium roofing sheets are quite an effective solution.

In order to reduce the peak temperature during the midday hours, the roofs of open houses can be insulated. However, this is seldom done for two reasons. In the first place it is doubtful whether it

would be really effective as the heat radiation is still reflected from all sides, and, secondly because of the high costs which may not be justified in view of the uncertain effect. This might be a good reason to use material of plant origin which is locally available (palm leaf, maize stalks, etc.). This would certainly contribute to the reduction of the radiant heat load, but on the other hand it often encourages rats and other vermin to live in it.
Solar radiation can also be reduced by planting trees and shrubs around the house which may

provide some shade and absorb at least a part of the radiant heat around the house. Shade itself reduces radiant heat load by 30 % or more. However, there is also radiation from other sources, such as the roof and hot grounds around the house. Ground cover vegetation prevents reflected heat entering the house and trees can give some shade without inhibiting the circulation of air. On the other hand low vegetation may give rise to build-up of insect populations which can act as transmitting agents for viral infections, so it is recommended to clear an area of e.g. 3 m away from the house.
Surrounding buildings, especially when they are painted white, may increase heat reflection unless they are situated south-west of the poultry house. Generally birds on litter suffer less from radiation from the roof than birds in cages which are nearer to the warm roof and cannot move away.
For hygienic reasons a concrete floor is recommended as it can be cleaned more easily than a mud or plain soil floor.

4.3 Controlled environment poultry houses

Complete environmental control is only possible in a closed house. This must be artificially lit and ventilated. Inlets and outlets should have a plate or device (baffle) to prevent light entering the house. Although such a house may be very expensive, it should achieve a greater production efficiency, especially in rather hot and dry climates.

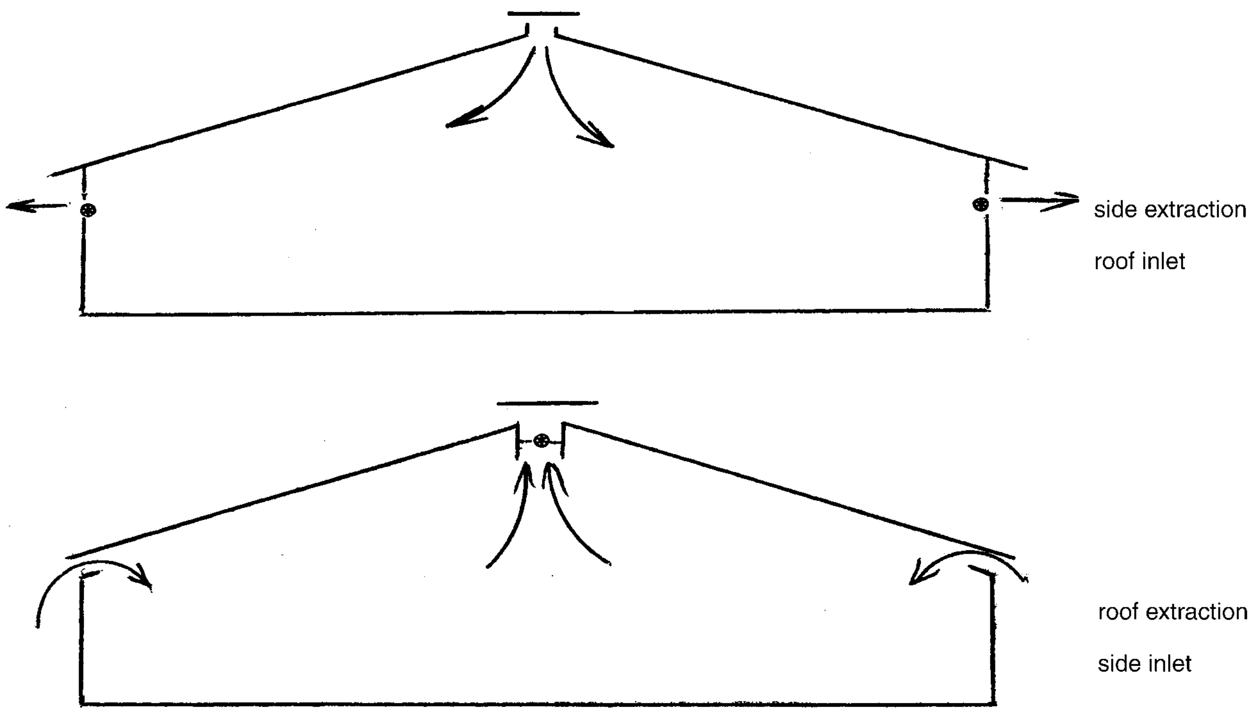


Figure 9: Controlled environment houses

Unlike open houses, insulation is necessary, in order to reduce heat gain resulting from high outside temperatures, by retarding the transmission of radiant heat. Insulation materials are bulky, porous, light weight materials with countless little air spaces, such as: blankets, usually containing processed fibreglass, mineral wood or cellulose fibres; loose-fill insulations in bags or bales; rigid materials,

such as fibreglass, fibre board, polystyrene, polyurethane or polyisocyanurate, in blocks or sheets; foam insulation and foil insulation by reflecting materials, such as aluminium foil.
The total thermal transmittance of a controlled environment house is given in the form of the so called U-value, which in general should not be higher than 0.4 or 0.5 W/m^2/degree C. The lower this value the better, because low values stand for low heat conductivity. Actually the building U-value is the sum of the component U-values of the walls, roof and floor. Each of the composing materials has its own thermal conductivity, called k-value. Again the lower the k-value the better!
Generally the following k-values are valid for the materials involved:

- timber wood 0.15
- mineral wool or glass wool (glass fibre) 0.04
- expanded polystyrene 0.04
- polyurethane foam (low density) 0.04
- extruded polystyrene 0.03
- polyurethane foam (high density) 0.02

The lower the k-value of the used materials the less material is needed to achieve a proper insulation.
Cavities in the construction reduce the thermal conductivity, provided they are not ventilated. Therefore hollow brick blocks and light weight aerated concrete are often used in wall constructions.
All the insulating materials must be applied in such a way that they cannot assimilate the moisture, produced by the birds' respiration and droppings. Water is highly heat conductive. That is the reason why modern insulation materials are resistant to water vapour.
Although all the parts of the house should consist of low heat conducting materials, the roof is the most important element. A possible construction is that of a double aluminium sheet with an insulating material in between the two skins. Usually this material consists of at least 8 cm of mineral wool or 6 cm polystyrene or 4 cm high density polyurethane foam. The walls can be insulated by fixing 4 cm mineral wool sheets against the inner side of a slit wall. Insulating materials should be resistant to insects, fungi, sand, dust and water.
In order to minimize solar heat gain, windows allowing the entry of solar radiation should be avoided.

Although not often constructed, buildings with a large thermal mass (thick stone hollow walls) will reduce the diurnal variation in temperature. Such housing types will only absorb the heat slowly from outside so that the effect of the daily maximum temperature is reduced. However, this method of constructing poultry houses will probably be too expensive.

5 Climate control

Before discussing environmental control by ventilation and cooling, the terms which indicate the properties of air should be defined:
Dry bulb temperature: is the temperature of air registered by an ordinary thermometer. This temperature is independent of the air's moisture content.
Wet bulb temperature: is the temperature of air registered by a wet bulb thermometer. A wet bulb thermometer is a normal dry bulb thermometer which has wet material wrapped around the bulb. When the wet material around the thermometer bulb is exposed to a fast air stream, it cools the bulb by evaporation. This wet bulb temperature depends on both the dry bulb temperature and the water vapour content of the air.
Relative humidity (RH): is the ratio of the actual vapour pressure to the saturation vapour pressure of the air at a given air temperature. The warmer the air the more water vapour it can contain.
Enthalpy, or heat load of the air: is the total heat content (sensible and latent, see Chapter 3) of the ambient air.

The above mentioned air characteristics can be compared in a so-called Psychometric Chart, also named a Mollier Diagram (see figure 7).
The dry bulb temperature is on the vertical coordinate. At the top of the figure the water vapour content is set on the horizontal line. At a given amount of water per kg of dry air the RH decreases with a higher air temperature. The relation between the air temperature and the vapour pressure at saturation (= 100% RH) is a curvilinear one, the 100% RH line being the 'saturation line'. The whole pattern of the chart is thus determined by the mutual relations between air temperature, vapour pressure and RH. If you know the dry bulb temperature and the wet bulb temperature, you can easily find the RH from the chart.
The wet bulb temperature can tell us to what temperature air can be cooled by evaporative cooling. At a 100% RH the temperature of this wet bulb thermometer will be the same as that of a dry bulb thermometer. At lower RH values, which is normally the case, evaporation of water from the wet wrapping occurs and, consequently, the temperature of the bulb drops. Thus the lower the RH, the lower the wet bulb temperature. This temperature provides us with a clear indication of the attainable cooling effect under the given circumstances.

Example: when the dry bulb temperature is 30 °C and the wet bulb temperature 25 °C, you will find the corresponding RH by following the diagonal or enthalpic line (because the heat load remains the same) and this shows that the RH is a little more than 65%.

If, in another situation the dry bulb reads 35 °C and the wet bulb 28 °C, the RH of the air is 60%, it would seem that this air could be cooled down to 28 °C. However, the actual reduction inside the house will be lower, due to the fact that only the air at the point of entering the house will be 100% saturated by moisture. In practice an actual reduction of only 80% of the theoretical value is usually recorded and therefore the result could be a reduction to only 30 °C. In the meantime the added amount of water will give rise to a higher RH of the inside air. As a rule it is assumed that the inside RH should not increase beyond a maximum of 70%. This could mean that in our example the outside air of 35 °C, containing 60% RH, may not be cooled to 30 °C if the increased amount of moisture is not removed by the ongoing ventilation.
Another example: If the outside temperature is 40 °C and the wet bulb temperature is showing a 25 °C level, the outside RH would be only 30%. In this situation the inside temperature could be reduced much more, may be to 28 °C, despite the high outside temperature.

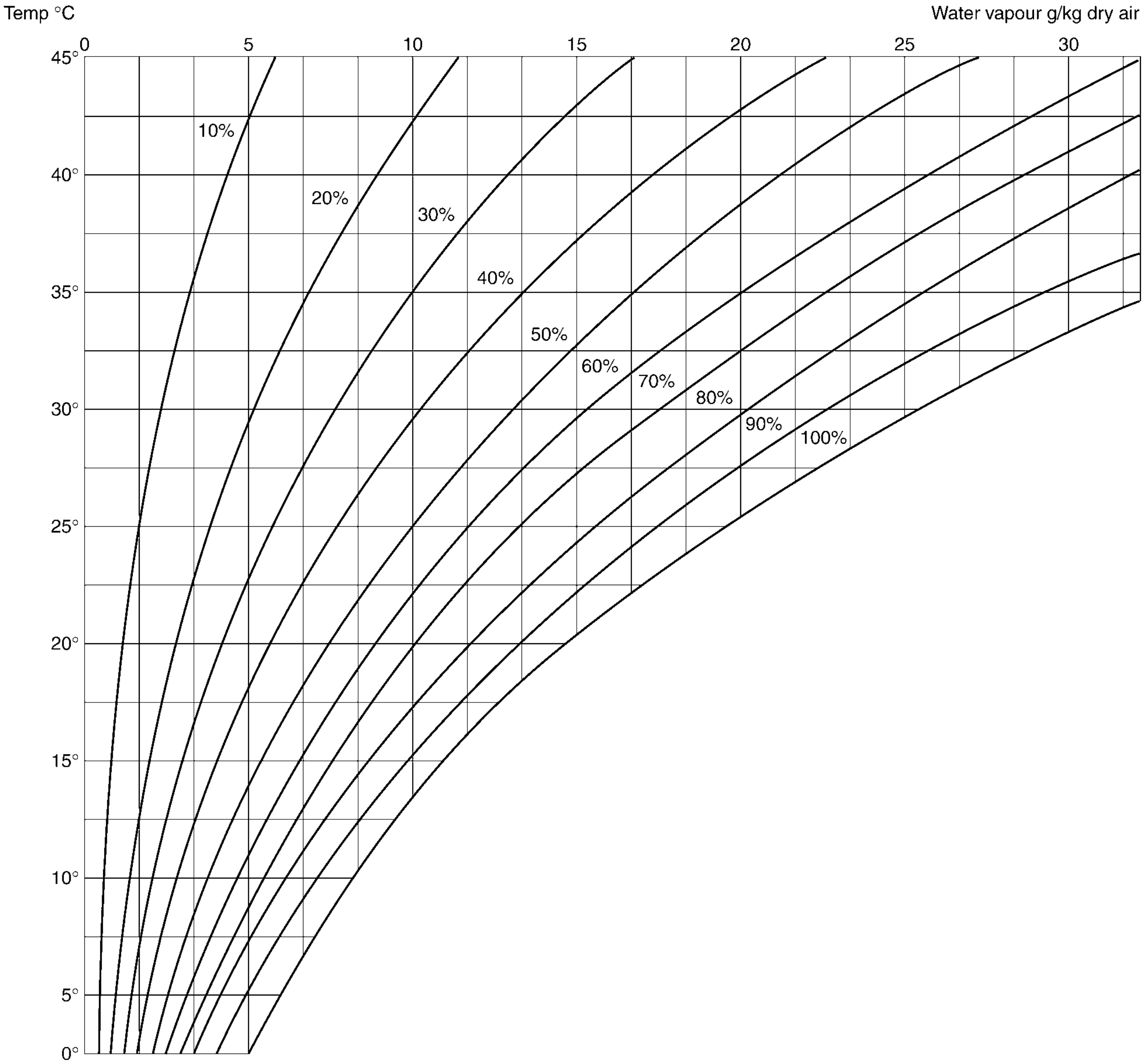


Figure 10: Mollier Diagram for Humid Air

If we add moisture to air of 35 °C and 30% RH, it will change into air with a lower dry bulb temperature, due to the water evaporation and of course a higher RH level. To find out how much the temperature will decrease when inside the house a RH level of 75% has been reached, we have to follow again the diagonal line and we see that the ambient temperature will then be around 23 °C. During the heat of the day, when both the dry bulb and wet bulb temperatures are at their peak, the difference between them is greatest. Consequently the greatest potential for cooling is obtained during that time of the day.
Extractor fans will help in extracting the moisture from the house and the heat. A so-called pad and fan combination will therefore reduce the difference between the dry and wet bulb temperature.

5.1 Ventilation of open houses

In tropical areas with a hot and humid climate it is virtually impossible to keep poultry in closed houses. It would cost too much to provide the birds with the optimal climatic conditions. Therefore open houses are the only option.
As we have already seen, the provision of shade from a roof with a large overhang, together with a partial wall, and vegetation around the house will reduce the solar heat load. However, in addition to

this it is necessary to use everything possible to stimulate the natural ventilation of the house, even intensifying it by increasing air movement with the installation of some extra fans. Introduction of such an additional air flow carries away both heat and moisture. Generally air movement caused by wind does not occur often in tropical regions. Therefore, even in open poultry houses air replacement can be too little if these houses are rather wide (say, more than 8 m) and the partial side walls are relatively high (say, more than 50 cm). The negative effect will be even higher when the houses are built too close together.
The installation of fans does not only favour the rate of ventilation but also causes air movement in the vicinity of the birds by which the convectional heat loss of the birds is promoted. The air velocity may be accelerated to 2½ m per second. However, at very high ambient temperatures, i.e. more than 41 °C (the average body temperature of poultry) a high air speed can be detrimental in carrying extra heat to the birds and thereby adding to the heat load.

5.2 Artificial ventilation of closed houses

We are able to replace the air inside the house with fresh air from outside by means of artificial ventilation, thus ensuring a lower ambient temperature, and a net removal of moisture and other air components.
Most poultry handbooks distinguish between the required rate of ventilation and the required air flow pattern. The latter is very important in temperate climates. Cold air streams entering the house may cause problems at bird level because it gets too cold. In hot climates, however, such problems will rarely occur so that the air flow pattern is of secondary importance. Therefore we can concentrate almost exclusively on the required amount of fresh air to provide.
Firstly, a minimum ventilation rate is needed in order to provide the birds with sufficient amounts of oxygen and to remove excessive amounts of carbon dioxide and moisture and also to prevent build up of ammonia. On the other hand ventilation should not lead to waste of electrical energy. However, this aspect of ventilation is of minor importance in tropical zones. A high ventilation rate is practically always necessary to keep the inside temperature as low as possible. Under those circumstances the above mentioned requirements of air exchange are quite easily and adequately met.

Climate control standards

Temperature	20-25 °C
Relative humidity	60-80% (50-70% at temperatures above 25 °C)
Air quality	NH_3 max. 25 ppm
	CO_2 max. 0.3-0.5 vol.%
Air velocity	max.0.2 m/s at low and max.2 m/s at high temperatures

The question remains how much air should be provided by the ventilation equipment and consequently how many ventilators of a given capacity should be installed.
The ventilation requirement is derived mostly from the heat balance of the poultry house. This balance consists of the heat production of the birds (also occasionally from artificial heating) on the one side and of the heat losses through ventilation (and transmission in temperate climates) on the other side. In hot weather conditions there is another source of heat production in the form of solar heat gain by transmission during the day. During daytime a maximum of air exchange will be necessary. Thus we formulate the heat balance of poultry houses in hot climate zones as:

$$Hs + AHg = Htr + Hve \qquad (1)$$

where Hs = sensible heat production (W per bird)
A = total surface of walls and roof (m^2/bird)
Hg = solar heat gain (W per bird)
Htr = heat loss by transmission ($W/m^2/°C$)
Hve = heat loss by ventilation

Heat loss by transmission (Htr) can be written as:

$$Htr = UA\Delta T$$

where U = average thermal conductance of walls and roof ($W/m^2/°C$)
A = total surface of walls and roof (m^2/bird)
ΔT = difference between inside and outside temperature (°C).

Heat loss by ventilation (Hve) can be written as:

$$Hve = 0.35\ V\Delta T$$

where V is ventilation rate (m^3/bird/hour) and 0.35 is used because the heat capacity is $W/m^3/°C$.
Note: In some handbooks you may find a value of 1.26 in stead of 0.35 due to the use of different units; 1.26 kJ/hr = 0.35 W (= J/s).

Substitution of these two heat loss factors in equation (1) gives

$$Hs + AHg = UA\Delta T + 0.35\ V\Delta T$$

$$\text{or } V = \frac{Hs + AHg - UA\Delta T}{0.35\ \Delta T}\ m^3/hr/bird \qquad (2)$$

In a modern well insulated poultry house the values of A and U are relatively low. On average A may amount to 0.1 and U to 0.5. Thus the value of $UA\Delta T$ is almost negligible. Therefore equation (2) could be written as:

$$V = \frac{Hs + AHg}{0.35\ \Delta T}\ m^3/hr/bird$$

From this equation it is evident that the required ventilation rate in a modern environmentally controlled poultry house depends strongly on the difference we allow between inside and outside temperature. The smaller the difference we allow, the more ventilation capacity should be installed. If a difference of 3 °C would be acceptable and solar heat gain (AHg) would be compensated for by $UA\Delta T$, equation (2) would run as:

$$V = \frac{Hs}{0.35\ \Delta T} = \frac{Hs}{0.35 \times 3} \approx Hs\ m^3/hr/bird$$

Thus generally the capacity of the ventilation in m^3/hr to be installed should be about the same as the total heat production of the birds. The sensible heat production of a WL laying hen is about 7-8 W at 20 °C, broiler breeder hens produce about 10-11 W per bird, and broilers about 5-6 W at the end of the growing period. Although sensible heat production varies with age, body weight, feather cover, activity, a.o., these values could provide us with adequate ventilation standards. Yet it is recommendable to raise the installed amount of ventilation in order to be able to cope with very high ambient temperatures. We must keep in mind that the inside temperature will always be higher than the outside temperature. So generally ventilation requirements could be as follows:

pullets	± 6	m^3/hr/bird
laying hens	± 10	,,
breeder hens	± 12	,,
broilers	± 8	,,

In artificially ventilated houses fans can be installed in different ways:
- roof extraction with wall inlets,
- wall extraction with ridge inlets,
- cross ventilation (both fans and inlets in the wall),
- positive pressure with a blown inlet and wall outlet.

Extraction systems using fans extracting air from the roofs are the most common systems. Wall extraction may be more efficient in the tropics than in temperate climates with side winds. The inlets should provide a high inlet air speed which provides a better air distribution. Cross ventilation will in many cases give rise to a poor distribution of fresh air.
Pressurised systems are seldom practised.
Ventilation rate can be adjusted either by installing groups of fans and using varying numbers or electronically.

5.3 Evaporative cooling

Previously we understood that evaporation has a cooling effect on the air because of the evaporation process, which requires energy taken from this air. The lower the RH of the air, the greater the evaporation and therefore the greater the cooling effect. The RH is decisive as to the extent to which the latent heat loss can contribute to the total dissipation of heat.
This principle is applied when we install evaporative cooling systems in poultry houses. The level to which the outside temperature can be reduced inside the house depends on the prevailing outside RH and therefore the system is preferably used in hot and dry regions.

We must keep in mind that the ambient air can absorb more moisture during the hot hours of the day than during the night. An evaporative system could be used effectively during the afternoon but not in the morning. This means that evaporative cooling could also be applied temporarily in rather humid regions. Apart from daily fluctuations, seasonal fluctuations also may occur, during which time temporary use of the system may be justified.

There are several practical applications of evaporative cooling. Generally water is conveyed to a system of absorbent material called pads, consisting of porous material, either mineral fibre or cellulose, and is drawn through the house by fans located in another part of the house. The water-saturated pads provide a continuous amount of moisture to the incoming air stream, thus forming a ‘pad and fan’ system. The system should be reliable, simple to operate and easy to maintain. Sometimes home made pads, consisting of wood wool fitted inside cheap wire net mesh, are hung over the air inlet areas. Soaked with water from a perforated plastic pipe they can cool the incoming air. But usually more sophisticated systems are applied.
The thicker the pads the more effective they are. A recurring problem is that, in the case of brackish water, the pads may become blocked by salt or other sediments from the water, or by sand. The pads must be replaceable, or at least removable for cleaning. Blocking can be prevented by using longitudinally covered gangways along the wall in which the system is mounted. For this purpose spinning discs are often used. The air inlets in the walls can be constructed in such a way that deposition of sand is avoided.
Chemical impurities and bacterial contamination should be avoided. Chemical treatment, although in most cases probably too expensive, can nevertheless solve many problems. Any blocked pads require replacement.
The system may also become blocked by build up of slime moulds, which may lead to clogging by trapping dust and other solid particles.

If the water is of good quality, nozzle cooling can be employed. Nozzles spray water onto a horizontal screen. However, this system requires a lot of water.

The pads are usually located in a side wall, opposite fans, and extend usually from □ up to ½ of the length of the house. In very long houses fan banks are located in the middle of the side wall and evaporative pads on the ends.
The size depends on the cooling requirement. Recirculation systems are needed to recycle the water. Although more water than actually evaporated should be provided, it is possible that too much water may be supplied, which can block the air flow. Air speed could be 1 m/sec, but varies with the type of pad and this should be checked with manufacturers. There is more water actually consumed than evaporated, so the water must be able to flow away.
Apart from the supporting extractor fans additional fans can be installed inside the house in order to cause some air movement which, as we have seen, will have an additional cooling effect. Moreover, it will contribute to a further mixing of the incoming air with the inside air, which may prevent differences in temperature levels at different places inside the house.

Evaporative cooling should actually be started when the dry bulb temperature rises above 27 °C and should be discontinued when the house RH exceeds about 70-75%. Hot air (temperature 45-48 °C) with a low moisture content (RH 10-15%) in the middle of a hot day would be suitable to be cooled.
If cloud cover occurs in the late afternoon, there will be only a small nocturnal fall in temperature. In that situation it would be wise to operate cooling devices all night.
Sometimes a ‘dual system’, both with evaporative and fan cooling, is used. This system seems to be appropriate when the RH and the temperature often change. The extractor fans are switched on when the indoor temperature rises 2 degrees above the set point. If this is insufficient, the water circulation pumps of the evaporative cooling system are switched on. Jet fans can be used to mix the inside air with the incoming fresh air. It is essential to prevent air entering the house from any other part than the pads or fans.

Not all the cooling systems are of the ‘pad and fan’ type. In some cases water is sprayed or fogged in passage ways around the house so that the hot outside air has to pass through a curtain of water and is thus cooled. However, such a spray system, without a screen, may cause wet litter which is undesirable. However, it is cheap to install and if adequately designed, it can produce a more uniform house temperature than the pad system.
The pad and fan system is probably the most effective cooling system. It gives a maximum cooling effect of 2-3 degrees above the theoretical ‘minimum’: the wet bulb temperature, as the air is at ± 90% RH as it leaves the cooling pad. For example at a given starting temperature of 45 °C and 45% RH, it is possible to reduce the inside air temperature to 35 °C if the RH is raised to 80%.
Whatever system is used, protection against rats and other vermin is necessary, as they may look for shelter in these cool and shady places.

5.4 Other cooling systems

Roofs can be cooled by the use of rooftop sprinklers. Here again the evaporation of water cools the area and radiation of heat through the roof is reduced. The effect, however, is comparatively low and huge amounts of water are required. It may be better to use this system as an emergency measure rather than using it regularly.

In-house fogging seems to be more effective than rooftop sprinkling, since improvements have been made in increasing nozzle pressures which have reduced the size of the water particles. However, it may cause a very wet environment. Operating for 15 minutes each hour could be a solution.

Moving air over the birds by means of special, large fans removes heat from the birds, but its cooling effect is again rather limited and it is very difficult to create a uniform air movement pattern throughout the house. In experiments air velocities of 0.1-2.5 m/s appeared to be able to maintain body temperature 1 to 2 °C below those of birds kept at low air velocities, when the ambient temperature reached 40 °C.

Total sensible heat loss increases with increasing air speed, but convective heat loss eventually may be diminished as the heat loss by radiation decreases once the surface temperature is lower. Above 40 °C, i.e. above the body temperature of the bird, increasing air velocity makes things worse. However, in the humid tropics the use of a high air velocity may be the only possibility to cool the stock.

5.5 Maintaining air quality

Under tropical conditions air quality will seldom give problems, as replacement of air always takes place, either naturally in open houses or artificially in environmentally controlled ones. However, ammonia may sometimes cause some difficulties, for example when an open house is too near buildings or shrubs and air movement by wind is absent.
Ammonia formation is attributed to microbial decomposition of uric acid in the manure. It is lighter than air. Although the ammonia content in the poultry house is more or less detectable by humans at a concentration of 25 ppm or more, actual measuring is done by means of so-called Drager tubes.
It seems that ammonia can be (chemically) bound by an extract of Yucca schidigera, thus reducing atmospheric ammonia in confined facilities.

5.6 Computerized climate control

Computerized environmental control can be very helpful in both egg and broiler production.
Air temperature, humidity and ammonia levels can be automatically controlled nowadays, as well as water consumption, feed intake and lighting schedules. Thus daily feed rations can be automatically adjusted on the basis of the environmental temperature, egg mass produced and body weight increase. A large number of sensors are connected to a microcomputer, which controls fans, baffles and other devices to maintain the desired climate conditions.
A group of hens should be weighed continuously and this should be coupled with the registration of the ambient temperature, daily egg mass and the projected weight increase according to the curve on the feeding diagram.
At the same time the computer can take over management functions in assessing laying performance, daily feed consumption, etc.
Field data already indicate the possibility of decreased feed consumption together with increased egg production. Using computerized systems is a matter of time, but most of all a matter of benefits exceeding the costs.

6 Lighting

Lighting is an important tool in the hands of the manager for optimal performance of the flock. Poultry is very sensitive to light, particularly to periodical changes of the duration of the light cycle. Light enters the eye and stimulates, through the hypophysis in the brain, the release of various hormones which will affect the maturation of pullets and the ovulation of adult birds. In addition to these endocrinological effects, light also affects the activity of the birds and their food intake. It is very important to make a distinction between these different effects in order to make the right decisions in lighting management.

6.1 Installation of lights

Artificial light can be supplied by installing either electric (tungsten) bulbs or fluorescent tubes. The latter are more efficient because a higher percentage (24%) of the input of electric energy is transformed into visible radiation than in tungsten bulbs, where this is only 7%. Therefore the fluorescent tube generates a higher amount of light. This is the reason why floor systems need 3-4 W per m^2 from bulbs and only 1 W from fluorescent light tubes. The cost of tubes is higher, but on the other hand their life span is several times longer than that of electric bulbs. A disadvantage of tubes is that they give rise to a more uneven light distribution. For this reason it is necessary to install the tubes in such a way that the nearest cages are not lit excessively, usually ± 50 cm above the top tier. Generally the distance between bulbs in floor systems should be approximately 1½ times as large as the distance to the floor.

If fluorescent tubes are chosen it is better to install high frequency tubes (26,000 flashes/sec) than the low frequency ones (100 flashes/sec).

6.2 Lighting replacement pullets

Increasing daylengths stimulate sexual maturation of the young growing bird, while short days and decreasing daylengths have the opposite effect. At latitudes further from the equator this phenomenon is more pronounced than in the tropics. In northern regions the day of hatch, under natural conditions, determines the date of sexual maturity. This is because of the greater difference in daylength. Under tropical conditions, this effect will be smaller.

Light also affects feed intake, and thus the body weight and activity of the bird.

For the tropics it may be useful to know that a constant daylength of 12-14 hr causes earlier sexual maturity. Longer or shorter constant daylength delays maturity, but a change in daylength has a greater influence. The greater the increase in daylength the greater the stimulating effect on maturity, especially during the last half of the rearing period. However, if pullets mature too early it could result in too many cases of prolapse of the oviduct, cannibalism and small egg size.

Decreasing daylength causes a delay in sexual maturity, generally resulting in an increase of the average egg weight.

Light schedules for growing pullets are designed to prevent these detrimental effects. Generally such programmes are based on the principle that during the rearing period the daylength should be either constant or gradually decreasing, preferably to 10 hr per day. Longer days are less effective.

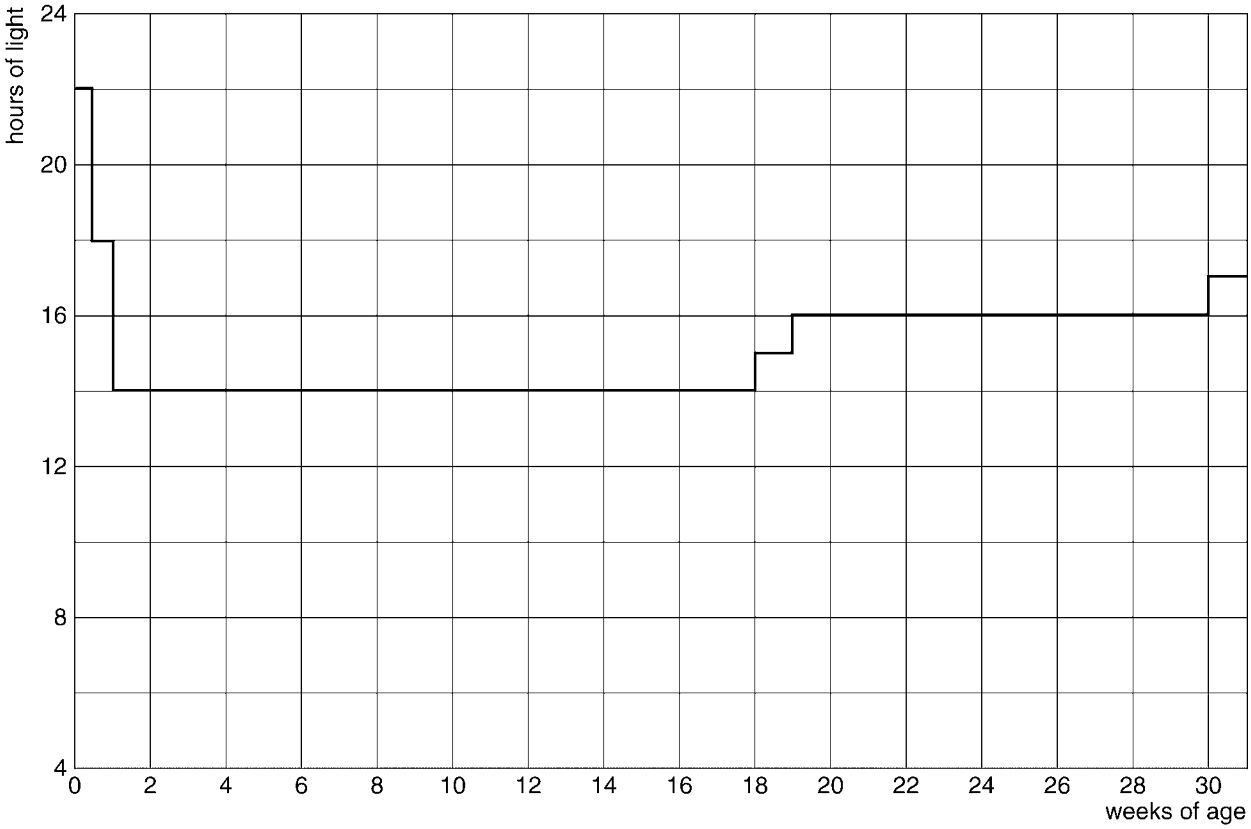


Figure 11: Lighting schedule in open house

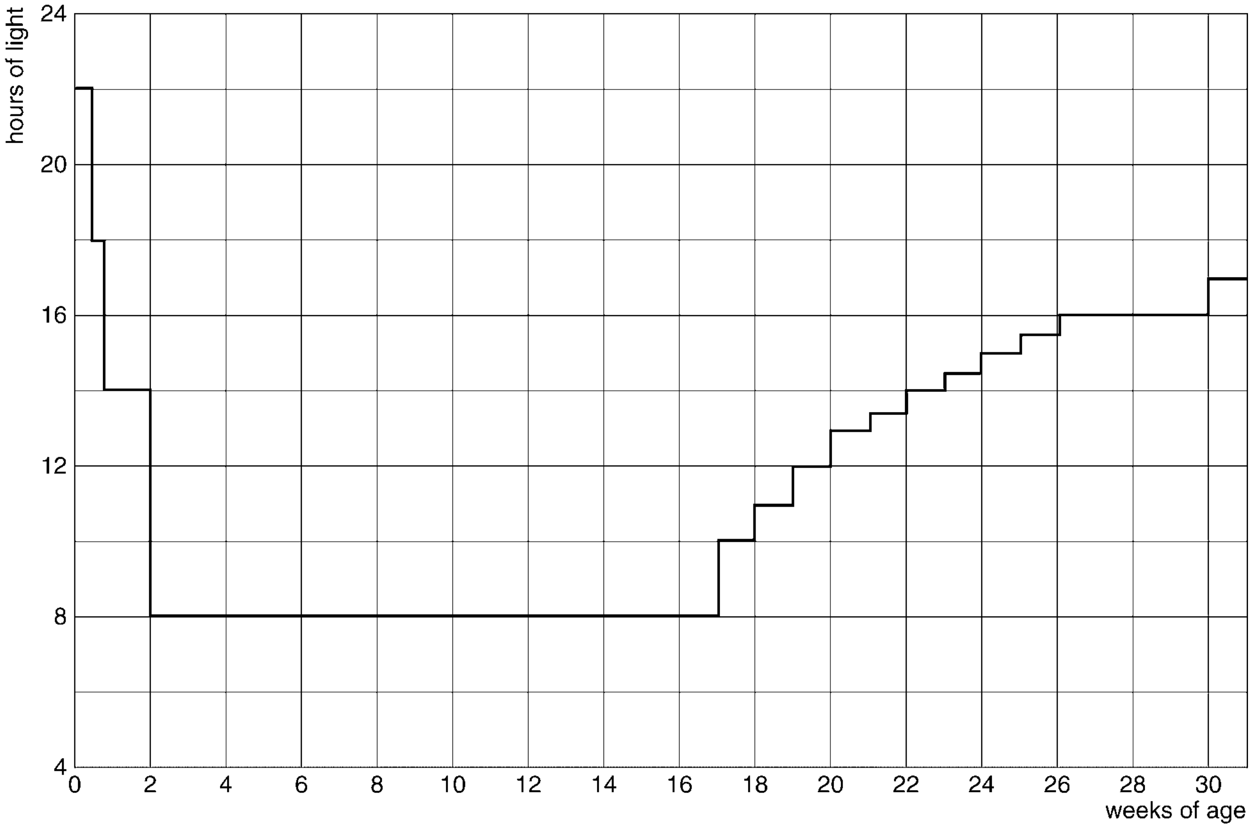


Figure 12: Lighting schedule in a windowless lightproof house

Under tropical conditions the seasonal fluctuation may not be large, but the use of open houses at places further from the equator might affect maturity as previously described and justify some measures to be taken.
Near the equator, with only small deviations from a 12 hr daylength, it does not seem advisable to take measures to prevent early maturing. However, a constant daylength of 14 hr could be used. This might be beneficial for feed intake compared to shorter days and thus more preferable under tropical conditions.
Further from the equator the so-called step-down step-up system could be used. This means that at the start of the growing period artificial light could be provided to such an extent that in the following weeks the daylength can be reduced by half an hour per two weeks, until 16-18 weeks of age. Obviously the daylength at the start of the schedule should then be 10 times half an hour, = 5 hours, longer than the natural daylength at 16-18 weeks of age.
It is also possible to start with a 23 hr day during the first week, which can be reduced weekly until the birds are receiving only the natural daylength at the start of maturity.

In closed, windowless, light proof houses several lighting schedules are possible. A light proof house is not easy to achieve. Light proofing may be checked by staying in the house for 5 minutes on a bright day with the lights off and with full ventilation. This is of special importance in rearing houses.
In such a light proof house a constant daylength of 8 hr, from 2 weeks to 16-18 weeks of age, is often applied. This scheme has about the same delaying effect as a step-down system and is simple to apply. In the case of stepping down we start with a daylength of 23 hr (1 hour of darkness is assumed to be necessary in order to prevent panic in case of an electricity break down), followed by a weekly reduction, leading to 8 hr at 16 weeks of age.

6.3 Lighting laying hens

As soon as the birds come into lay, egg production is stimulated by increasing daylength. Modern hybrids do mature early so that delaying should not go on too long. Therefore the daylength may be increased again after 16-18 weeks, depending on the kind of birds involved, either naturally or by means of artificial light supply. If, for instance, a constant pattern of a 14 hr day has been applied, a weekly increase in light of 15 minutes or half an hour can be given until a maximum of 16 or 17 hr of light is reached. More than 17 hr of light is not necessary. The age at which you should give a longer day is usually indicated by the breeding company involved. We must be well aware of the fact that if a delay is too prolonged, it can result in the egg production not reaching its full potential.
Do not increase daylength before the birds have reached the weight recommended by the breeding company. Otherwise body weight will remain too low, persistency of lay will decline too soon and egg size will be too small. Only increase when body weight reaches the recommended level without comb development.

Hens in lay should never be exposed to a decreasing daylength. Therefore in open houses some supplementary lighting is necessary if the natural daylength decreases markedly. Around the equator, with approximately 12 hr light during the day, the normal procedure could be to provide 14-16 hr light each day.

In environmentally controlled light proof houses, all sorts of schedules can be used. The most common schedule comprises a rapid increase from 8 hr at the start of lay to 14 hr at an age of 22-24 weeks, followed by a gradual increase from 14 to 16 hr after peak production is reached. So a step-up program is used followed by a constant daylength thereafter.

Example of a lighting programme throughout the rearing and laying period:

1-3	days	23	hours
1-17	weeks	8	,,
17-18	,,	10	,,
18	,,	11	,,
19	,,	12	,,
20	,,	13	,,
21	,,	13½	,,
22	,,	14	,,
23	,,	14½	,,
24	,,	15	,,
25	,,	15½	,,
26-30	,,	16	,,
after 30	,,	17	,,

6.4 Intermittent lighting

So far we have discussed common lighting schedules, for instance 16 hr light per day, being written as 16L:8D (16 hr light and 8 hr dark in a day of 24 hr). However, there are other schedules in use nowadays which are called intermittent lighting (IL) schedules. They can only be used in closed houses.

There are several types of IL, but what they all have in common is that only a small portion of light is supplied, at intervals, during the time when normally continuous lighting is provided. The lighting period is therefore subdivided in shorter periods of light and dark.

Examples of IL:

1 Symmetrical schemes: 4 × (3L:3D) or 3 × (4L:4D),

2 Asymmetrical schemes: 2L:12D:2L:8D or 6L:2D:6L:10D and others.

Surprisingly these schemes are not substantially less effective than the usual 16L:8D type, although the symmetrical ones may generally depress egg production, while at the same time improving egg weight and shell quality. The background of this phenomenon is the existence of a so-called photo-sensitive period during the day of 24 hr, presumably present from about 11-16 hr after dawn. It is not the duration of a light or dark period which is important, but the moment that light is provided. When light is given during the sensitive period the hens will react as if there has been a prolonged period of light.

For example: no substantial difference in performance has been observed between 16L:8D and 14L:4D:2L:4D. Neither was this the case with 2L:12D:2L:8D, the second light period in this scheme being interpreted by the hens as the start of a new day.

However, 8L:4D:8L:4D and 4L:2D:4L:2D schemes do reduce egg number while bringing about a better egg size and shell quality.

IL generally causes a lower feed consumption, less egg breakage and less problems with heat stress probably due to less activity. However, in some cases egg production is also a little lower, especially with the symmetric schemes.

The IL schemes certainly save electricity, but may make working times more complicated.

In many countries a special programme, the Bio-Mittent-Lighting Programme (BMLP) is recommended. This programme follows the original 16L:8D schedule, but in every hour of the lighting period, part of it is replaced by darkness. For the application of this scheme we need a special time switch with intervals of 15 minutes. Special attention is also necessary for the supply of water, because the birds generally only drink during the periods of light. The scheme should not be applied when the feed intake is not sufficient! BMLP saves feed and
electricity and lowers heat stress (less activity) and shell damage.

Lighting schedules also influence the time of egg laying within the day. In a normal schedule, with a 14 hr lighting period, starting for instance at 5 a.m. and ending at 7 p.m., most eggs are laid in the morning. Stimulation of the ovulation for the formation of the next egg occurs about 8 hr earlier under the influence of the release of the luteinizing hormone (LH). This LH release normally seems to occur in the dark, so eventually if an egg is laid later in the day, the LH release would not take place and therefore the egg laying stops for one or more days.
It is quite understandable that in the case of a symmetric IL scheme egg laying is spread equally over the day.
IL is also applied in broilers.

Experiments have been carried out with so-called ‘ahemeral days’, which are either shorter or longer than the normal 24 hr cycle, but these programmes are not used in practice. Long cycles (28 hr), however, may improve egg shell quality and egg size. If this scheme is used, light proof houses are necessary.
Ahemeral cycles affect the number of eggs laid. If the cycles are shorter than 24 hr the number of eggs declines almost linearly for cycles between 24 and 21 hr. With cycles longer than 24 hr, rate of lay remains almost the same when birds are placed under 25 hr cycles, but it declines linearly as the cycle gets longer up to a 33 hr cycle.
For cycles between 26 and 28 hr, the reduction in rate of lay is not as great as the increase in egg size, so by combining these results, egg output under these cycles is slightly higher than under normal 24 hr cycles. On the other hand, the reduction in rate of lay for cycles longer than 28 hr or shorter than 24 hr is greater than the increase in egg size and so egg output under such cycles is lower than that under a 24 hr cycle.
Eggs laid under 27 and 28 hr cycles have shells which are 6-10% thicker than if laid under normal cycles. In addition the percentage of abnormal eggs is also reduced.
The increase in egg size following the use of ahemeral cycles was found to be associated with the extra time spent in the oviduct.

6.5 Light intensity

It is generally assumed that a light intensity of 5 lux at feed trough level is sufficient to stimulate sexual maturity and egg production. To be on the safe side, however, it is usually recommended to maintain an intensity of 10 lux. In a house with light and dark spots an intensity of 10-30 lux will give the best results.
Higher light intensities may not initially be harmful for growth or egg production, but they do not increase egg production and in the long run they may give rise to outbreaks of feather pecking and cannibalism and they certainly bring about unnecessarily higher electricity costs. Moreover they cause higher activity and therefore a higher energy requirement.

Generally the right intensity is achieved when 3-4 W/m^2 is installed for a tungsten filament lamp and 1 W/m^2 for fluorescent tubes at a height of 2 m above the floor at distances of about 5 m. A 40 W tungsten bulb provides minimally 5 lux light intensity at a distance of 2.5 m; a fluorescent tube gives at least 4 times as much.
In cages, in particular in the case of tier cages, it is almost impossible to provide an evenly distributed light intensity at different heights. Placing more bulbs at medium height can help to reduce the variation. As much light should be installed as is necessary to provide sufficient light in the dimmest parts in the house. In order to prevent a too high intensity in the top tiers and too little in the bottom tiers, it may be necessary to install light bulbs or tubes at medium height in the aisles in between the battery rows.

During the growing period of replacement stock and broilers very low intensities can be used after the first days, during which the chickens have to find their food and water. After an initial light intensity of 20 lux or more, 1-5 lux is enough, with a minimum of 0.5 lux.

6.6 Lighting to encourage feed intake

Apart from endocrinological reasons related to performance there may be different reasons to provide extra light to poultry in a tropical region. As pointed out in Chapter 1 high ambient temperatures may cause energy deficiency due to low feeding activities during the hot hours of the day. Therefore lighting during the cool morning hours and/or in the evening is a useful method to stimulate feed intake.

However, a conflicting situation may arise if the method is applied during the growing period of replacement pullets. On the one hand lighting, which inevitably brings about some lengthening of the day, is required to supply sufficient feed energy, but on the other hand the increase of the daylength should be avoided. Under certain circumstances the manager should decide to what extent the above measures should be taken. Probably a constant day length is a good solution.

Increasing the length of the day during the laying period is no problem at all, as it is effective for both feed intake and egg production.

7 Poultry nutrition

Poultry feed provides the bird with energy (from fats and carbohydrates), proteins, minerals and vitamins. Nowadays additives and preservatives are added for medical reasons or to promote growth. Besides this, water is a main ingredient of the bird's daily ration!

7.1 Dietary energy concentration

The energy values of poultry feeds are expressed in Metabolizable Energy (ME), i.e. the gross energy in the feed minus the energy in the droppings. The ME units are kcal or mega joules (MJ) equalizing 240 kcal. ME values vary according to the kind of feed involved, but also in connection with the environment. Generally feeds in tropical areas show somewhat lower energy levels than in temperate zones, partly because tropical feed ingredients are often richer in fibre content and thus lower in energy, and partly because the energy level of the diet can be slightly lower under warm conditions. Although evidence about the latter is scarce, experiments show that increasing the dietary energy concentration in laying feeds above 2750 kcal/kg does not result in a higher energy consumption. Thus it seems that the use of high energy diets under tropical conditions will not improve layer productivity.

Temperature does not influence the energetic efficiency of conversion into eggs (about 25%, see Chapter 1) but only accounting for feed can lead to misleading results.

7.2 Protein sources

Protein sources include by-products which come from the processing of oil-bearing seeds, such as soya beans, sesame seed, cotton seed, rape seed and sunflower seed. Some of these are less suitable because of unwanted anti-nutritional substances, such as gossypol in cotton seed, glycosides in many other feedstuffs and a trypsin inhibiting factor in soya.

Protein quality is mainly a matter of amino acid composition. Lysine is one of the most important amino acids, but for poultry the sulphur containing amino acids methionine and cystine are also important. Previously animal protein was necessary to make these amino acids available, but nowadays proteins of plant origin are sufficient if supplemented by the above mentioned amino acids in synthetic form. Thus different protein levels need not to affect performance, provided the diets are balanced in amino acids. Some fish meal or meat and bone meal is often added, depending on price considerations. Poultry feed may be deficient in methionine when the protein in the feed is derived from soya. Poultry needs methionine as well as cystine, but cystine can be synthesized out of methionine. Experiments have shown that cystine may be 45-50% of the total methionine plus cystine content.

In broilers an energy response under heat stress only seems valid where adequate intake of lysine can be realized. Lysine supply is of particular concern under warm environmental conditions.

The NRC (National Research Council, USA) recommends for layers 0.70% methionine and cystine and 0.93% for broilers from 0-21 days and 0.72% from 21-42 days; in some Dutch experiments higher requirements were found, up to 0.88%, for that period.

7.3 Energy-protein ratio

Poultry under tropical conditions need less energy for maintenance, whereas the requirements for other nutrients remain the same. Higher levels of these other nutrients are therefore necessary. In other words, in hot climates higher nutrient densities can prevent a decline in egg production and egg weight and improve feed efficiency. A deterioration of shell quality, however, cannot be prevented in this way, as this is more a direct effect of temperature. In broilers a higher concentration of other nutrients per unit of energy is of no use, because the characteristics of a broiler are also mainly influenced directly by temperature and not through the intake of energy.

Egg mass is related to daily protein intake rather than protein level in the diet. In research 1 g of reduced protein intake below 14 g led to a decline of egg weight of 2.9 g, regardless of the temperature.

7.4 Mineral requirements

Adequate supply of minerals includes not only the well known calcium (Ca), phosphorus (P) and other minerals, such as magnesium (Mg), potassium (K) and sodium (Na), which should be given in rather large amounts, but also the so called trace elements, such as manganese (Mn), iron (Fe), zinc (Zn), copper (Cu), cobalt (Co), iodine (I) and selenium (Se).
Some of these, e.g. Mg, may be present in sufficient quantity in the used ingredients, but in most cases addition of minerals has to take place. It is too costly to analyze these trace elements in all feed ingredients, so it is cheaper to add minerals to the ingredients routinely.

Ca and P are very important for egg laying birds, since Ca is the main constituent of the egg shell, which almost completely consists of calcium carbonate ($CaCO_3$).
Generally a 1% Ca diet can be fed to pullets until they start to produce, but then the Ca level must be increased quickly, just prior to, or at least at, laying maturity.
In many studies , the Ca requirement for laying hens is stated as a percentage of the diet. This may be misleading if no feed intake value is taken into account. The absolute amount of required Ca depends mainly on the level of production. Egg shell weights initially increase with age. Therefore the requirement is greatest at peak production and should then gradually decrease. Ca deposition per egg continues to increase with age, and, despite the fact that the number of eggs declines and thereby the total amount of Ca per hen per day would slightly decrease, still higher amounts per hen per day are recommended, because the utilization of the ingested Ca declines.
We can estimate the required amount of Ca, based on the production of Ca in the egg shell. One egg contains 2.2 to 2.3 g Ca. Assuming that 50% of the supplied Ca is used for egg shell formation, it means, that for each egg 4.6 g of Ca is required. Further assuming that the average egg production per hen is 80%, the hen would require 3.7 g Ca per day. If 110 g of feed is consumed, it means that the feed should contain 3.5% Ca. If, however, the feed intake is lower, the percentage should be higher, particularly at high performances.
Generally a diet containing a minimum of 3.75% of Ca would in most cases be sufficient to ensure a consumption of the required 3.75 g per hen per day, but in tropical conditions with low feed intakes, 4% might be necessary. Excessive levels of Ca probably do not have an adverse effect. If so, it will presumably be due to additional factors, such as high levels of other minerals in the source of $CaCO_3$ which is used.
The officially stated requirement in g/hen/day has steadily increased. The NRC recommended 2.27 g in 1944, 2.46 in 1960, 3.00 in 1977 and finally 3.75 in 1984.
Ca in flour form seems less effective than Ca in coarse granular form. A reduction in feed intake, for instance due to high temperatures, may also directly affect shell quality in a negative way.
In the case of shell quality problems, Ca intake should be increased by ± 1 g per hen per day depending on age and the severity of the problem. So, if in older hens egg shells become abnormally thin, it may be recommendable to try to enlarge the Ca-intake up to 4.75 g per hen per day. This may be achieved by adding some limestone to the feed, or, probably better still, broken oyster shells, although various research papers do not give any evidence of different effect between good quality limestone and oyster shells in improving eggshell quality. Both sources should contain 38-39% Ca. However, larger particles of $CaCO_3$ may be beneficial.

The optimum P requirement is still uncertain, but it should be decreased during the laying period as high P levels are detrimental to shell quality. Therefore not more than 0.6% P is recommended, out of which 0.4% in a non-phytine form. Only a part (± 30%) of the plant or organic P (phytine) is available for digestion, so the requirements are given in total and in available amounts. The NRC recommends 350 mg available P per hen per day or 0.32% in the feed.

In hot climate conditions an adequate level of biologically available P is essential (0.45-0.50% or 0.65-0.72% total P before peak). Later 0.40 (0.57 total) may be sufficient. Too low levels of dietary P cause cage fatigue, cannibalism, prolapse, fatty liver disease, and other problems.

From different experiments the following requirements have been derived for WL:

Table 6:

Calcium		Phosphorus	
Weeks in production		**Total**	**Available**
19-36	3.75 g/hen/day	700 mg	500 mg/hen/day
37-52	4.00 ,,	600 ,,	400 ,,
53-	4.25 ,,	500 ,,	300 ,,

Feeding of sodium bicarbonate ($NaHCO_3$), up to 1% in the feed, or dissolving it in water, has been reported to improve the egg shell under heat stress, if the level of sodium chloride (NaCl) is restricted (the Na/Cl ratio should be 1:1).
Poultry feeds always contain sufficient amounts of Mg and K because these minerals are amply present in poultry feed ingredients.
The utilization of Ca and Mg is around 60%. P is utilized up to 70-75% and K and Na up to 85%.
Excesses of Na, K and Ca will cause watery droppings and lead to a decrease in growth rate and feed efficiency. Na should be kept under 2 g/kg and Ca and K under 11 g/kg.

A number of minerals and especially the so-called trace elements (because only very limited amounts of these elements are necessary) are not always sufficiently provided through the feed ingredients. In such a situation there are two possibilities: either it is indicated how much of the nutrient involved should be present or additional quantities are recommended.
For Ca, P and Na usually the first method is chosen. This means that we must know the level of these elements in the feed ingredients which are used in formulating the feed. With regard to trace elements, however, it would be difficult to rely on the levels in the ingredients, therefore these elements are added.

Mineral requirements, as listed by a Working Group of the European Federation of Branches of the World Poultry Science Association WPSA, are expressed in g per kg feed and in g per MJ ME and are given here in an adapted form:

Table 7: Mineral requirements for growing birds, in g/MJ ME

	Ca	Av.P	Mg	Na	K	Cl
Broilers (0-6 wks)	0.75-0.6	0.3	0.33	0.1	0.15	0.1
Pullets (0-12 wks)	0.5-0.6	0.3	0.27	0.1	0.13	0.1
(13-20 wks)	0.5	0.27	0.27	0.09	0.12	0.08

Table 8: Mineral requirements for laying hens of 1.8 kg, in mg/hen/day

Egg mass (g/hen/day)	Ca	P (non phytine)	Mg	Na	K	Cl
50	3800-4375	280	45	125	150	135
60	4500-5200	320	50	140	165	155
70	6000	355	55	160	180	175

For broiler breeders: Mn, Zn and Se are important.

7.5 Vitamin requirements

Vitamins are either fat soluble (A, D, E and K) or water soluble (all the B vitamins and C). They are usually added to the feed in the form of premixes.
For vitamin A supply also carotinoid-containing ingredients are used:

Alfalfa meal	40-620	mg/kg meal
Maize	10-50	,,
Paprika (fruit of certain peppers)	275-1650	,,

Both natural and synthetic products are effective, but the above table shows that natural sources are quite variable in carotinoid content.
A, B, D3 and E are the most important vitamins for poultry. Vitamin E seems to reduce heat stress mortalities. Biotin would have a beneficial effect on growth rate in hot weather.
There is some evidence, although not always consistent, that addition of vitamin C might improve both egg production and egg shell quality in layers, hatchability in breeders and growth in broilers, by reducing the negative effects of stress.

Table 9: Deficiency symptoms

	Sources	**Symptoms**
Vitamin A	Green feeds, yellow corn, animal feeds	Infections, less appetite
Vitamin B1	Green feeds, cereals	Nervous signs, less appetite
Vitamin B2	Green feeds, animal products	Slow growth, curled toe, paralysis
Vitamin B12	Animal feeds, fermentation products	Slow growth
Vitamin D3	Animal fat	Rickets in chicks,
		rings in egg shells
Vitamin E	Green feeds, germs of grains	Nervous disorders in chicks, oedema
Vitamin K	Green feeds, soya	Haemorrhagic syndromes in intestines and muscles
Calcium	Limestone, oyster shells	Soft egg shells

General advice: if possible supply feed with a premix, so that all the necessary minerals and vitamins are provided.

7.6 Phase feeding

Recently phase feeding has become common practice in all categories of poultry.
Some years ago only one feed was supplied for the whole laying period, with only extra oyster shells (1-2%) being supplied at the end of it. However, as the requirement for energy, protein, Ca and P changes with age, phase feeding has been introduced. There are three phases during the period of lay, in which the requirements are formulated as follows:

Table 10:

Metabolizable energy (kcal/kg)	2850	2800	2800
Crude protein level (%)	18	16.5	15
Ca %	3.50	3.75	4.25
Digestible P %	0.36	0.32	0.32

The advantage of such a feeding programme is that a lower protein level at the end of the laying period can lower a too high egg weight, increase feed consumption and improve feed utilisation.

In layer feeds, protein content is higher in the beginning and decreases towards the end of the laying period together with the amino acids lysine and the sulphur containing amino acids methionine and cystine. The Ca-content increases and P-content decreases.

Table 11: Example of phase feeding for WL:

Age in weeks >	**17-20**	**20-45**	**46-65**	**after 65 wks.**
ME (MJ/kg)	11.2	11.4	11.2	11.2
Crude protein (%)	17.5	17.5	16.5	16.0
Methionine (%)	0.36	0.36	0.35	0.33
Meth. + cyst. (%)	0.68	0.68	0.65	0.61
Dig. meth. + cyst. (%)	0.56	0.56	0.54	0.50
Lysine (%)	0.85	0.79	0.79	0.71
Dig. lysine (%)	0.70	0.65	0.62	0.58
Typtophane (%)	0.20	0.20	0.19	0.18
Threonine (%)	0.60	0.58	0.53	0.50
Calcium (%)	2.00	3.75	3.90	4.00
Phosphorus (total %)	0.65	0.63	0.58	0.53
Phosphorus (available %)	0.45	0.44	0.37	0.36
Natrium (%)	0.16	0.15	0.15	0.15
Chlorid (%)	0.16	0.15	0.15	0.15
Linoleic acid (%)	1.00	2.00	1.50	1.20

In broilers different feeds are supplied in one growing period. During the first 2 weeks, with fast growth, a concentrated feed is given with a high percentage protein and amino acids and a lower energy content. A coccidiostat must be added (Nicarbazine e.g.).
From 2 to 5 weeks the energy level is increased - fortunately in this period more fat can be given - but the protein content is lowered, whereas at the same time the sulphic amino acids content is increased. Also in this phase a coccidiostat is added.
From 5 weeks to the end, again less protein and amino acids are given. A coccidiostat is not allowed in Holland in this phase.

7.7 Use of local products

In some countries local cereal production may be encouraged. Sorghum and millet are more drought resistant than maize.
The feed potential of some non-conventional by-products has yet to be fully evaluated. Waste products also offer possibilities for use as a feed stuff. Generally the replacement in diets with these products should preferably not exceed 5%.

7.8 Thermogenic effect

Ingestion of food causes increased heat production, called 'specific dynamic heat production' or heat increment. The extra produced internal heat is still larger in the case of nutritionally unbalanced diets. This process can explain the fact that fasting chicks survive longer when exposed to heat stress.
Thus under tropical conditions it is important to remember that at a certain time after feeding, an extra output of heat occurs, which may be particularly detrimental in case of heat stress. It is assumed that this effect is largest at 4-5 hours after feeding and may go on for
8-10 hours. Therefore it may recommendable to let the birds have a last feed intake long before the maximum house temperature is expected. In practical terms: try to feed the birds as early as possible in the morning or late in the evening, so that the metabolic heat does not increase the heat load even more.
If the birds do not finish their ration within 3-5 hours after feeding, it would be recommendable to offer a more concentrated feed.

7.9 Feed intake and utilisation

The amount of feed intake of a laying hen depends on the quality of the feed, the body weight of the bird, its performance and the environmental temperature. In order to estimate the required amount of feed (2800 kcal ME per kg body weight) per day the following standards could be used:

at 2 kg body weight (for maintenance)	65 g
for each 100 g difference in body weight adjust	2.5 g
for each g of egg mass	1 g
for each degree C deviating from 20 °C	1.5 g

Hence, if hen weight is 1.8 kg, daily egg mass production 56 g and the ambient temperature 24 °C, the required feed intake can be calculated as follows:

1.8 kg hen:	65 – (2 × 2.5 g) =	+60 g
56 g egg mass:	=	+56 g
24 °C:	minus 4 × 1.5 =	–6 g
	+	110 g

Laying hens show a more pronounced increase in egg production at the onset of lay than in feed intake. Therefore for a short period a negative balance regarding energy, Ca and P supply, could arise. Certainly under hot climate conditions weight loss may occur, so a more concentrated feed and some hours of light at night might be advisable.

The utilisation of the feed supplied may be expressed in terms of feed conversion (kg feed per kg product) or feed efficiency (kg product/kg feed). Although the latter may be preferable as a measure for efficiency in the strict sense of the word, the conversion factor is also widely used.
As can be concluded from the foregoing, feed conversion is dependent on strain, body weight, age, temperature and the feed itself.

Although feed intake, rate of performance, ambient temperature, etc. influence the levels of daily requirements, some recommended daily nutrient intake figures for layers are as follows:

Table 12:

	Per hen per day
Metabolizable energy (kcal)	300-320
Crude protein (g)	16-19
Calcium (g)	3.8-4.1
Available P (mg)	500-600
Sodium (mg)	190-200
Linoleic acid (g)	1.4-1.6
Lysine (mg)	750-850
Methionine (mg)	350-400
Methionine and cystine (mg)	650-700
Threonine (mg)	650-700
Tryptophane (mg)	190-215

In floor systems a supplementary supply of insoluble grit, consisting of small flint stones, may stimulate feed utilization by its contribution to the grinding of the feed in the gizzard. About ½ kg per 100 birds per week is recommended. The need for grit is questionable when modern feed is used. However, in areas which have relatively poor feed resources, where the feed contains a lot of coarse fibre, the addition of grit may well be important.

7.10 Pellets or mash?

Selective feeding may occur when using mash, especially when feeds have different particle sizes. Coarse materials are consumed first and fine materials are left for the birds down in the feeding line. This will cause a difference in diet within the flock. Feeding crumbles or pellets ensures the consumption of a well balanced mixture of all ingredients. The birds have no chance to choose!

Pelleted feed does increase feed consumption, which is advantageous in tropical circumstances, while the energy of the feed is used more efficiently. Feed wastage is less, and pelleting is a way to destroy pathogenic organisms. It is possible to add propionic acid as a mould inhibitor.
Broilers which are fed pelleted feed, gain more weight and consume less feed per kg growth. Day old broiler chickens can handle 3 mm pellets, but usually crumbs are used. The feed is first pelleted in 5 mm pellets and then crumbled.

7.11 Bacterial contamination

Salmonella and campylobacter contamination in the production and processing stages
occur very easily. One fly or a mouse carrying these bacteria may infect a whole flock of birds hitherto non-infected!
Hygiene is of utmost importance. It is also the consumer who should be aware of this. In the kitchen 'clean' poultry products become easily infected by the above bacteria resulting in stomach and intestinal disorders (diarrhoea).

Salmonella levels can be reduced by:
- use of organic acids and salts,
- lowering the pH of drinking water and disinfection of watering lines (Salmonella bacteria grow optimally at a pH of 7),
- disinfection of feed mill and equipment weekly with chlorine dioxide or a similar product,
- disinfection of the poultry house after each flock.

7.12 Residues

Nowadays many people are concerned about a possible contamination of poultry products by residues from the feed. The feed may contain noxious elements such as heavy metals and additives, which may be passed on into the product. Well known are the long-established organochlorine insecticides, such as DDT, dieldrin, hexachlorobenzene, lindane, etc. Among the heavy metals attention must be drawn to lead, cadmium and mercury, which may accumulate in the liver, kidney and bones.
It goes without saying that poultry products should not be contaminated in this way
When coccidiostats are used - in broilers and replacement birds - withdrawal periods are prescribed in many countries.

7.13 Feed silos

For optimal use of a feed silo on the farm the main prerequisites are:
- storage for 10 days,
- 2 days between ordering and delivery and possibly 2 days for the weekend,
- extra space of 1 m^3 for safety purposes,
- average specific gravity of pellets of 0.7 and of mash 0.6

If for instance, the daily use is 900 kg, the calculation for the needed silo volume would be: 10 × 900 kg + 4 × 900 kg + 700 kg (1 m^3) = 13,300 kg or 13,300 ÷ 700 = 19 m^3 pellets or 13,300 ÷ 600 = 22 m^3 mash.

7.14 Proper storing conditions

When the temperature is high both raw materials and finished products are likely to deteriorate in quality during storage. Unless some precautions are taken the temperature and humidity levels may cause chemical changes and growth of fungi and insects. Unwanted biological processes will occur if the moisture content is too high. At 8-14% of moisture content, some insect infestation may start. At 14-20% mould growth will take place and bacterial growth at 20-25%. Above 25% even germination

can occur. Therefore moisture content should be kept as low as possible, and not exceed 13%. The optimal temperature range for maximal fungal acitivity is 35-40 °C.
Sometimes the bacterial and/or mould contamination on animal protein sources may be such that feeds without animal protein sources are preferred in order to reduce the bacterial load!
The most common toxin problems from moulds are either aflatoxin or fusaritoxin. Use of mould inhibitors and keeping equipment clean and dry are necessary.
Vitamins and other additives can only be stored in special cooled storage facilities.

The transportation of mixed feed, and its storage on the farm should be as short as possible. Otherwise oxidation of additives, rancidity of fats and protein losses may take place.

8 Feed formulation

Efficient feeding can only be achieved by the manufacturing of feeds which meet the nutrient requirements at the lowest costs. The composition of such feeds is therefore called: ‘least cost formulation’. Consequently formulations of the same kind of feed will differ from time to time, as the raw materials may show large variations in price. In addition to this the nutrient requirements may also vary due to variable local and seasonal factors. Under such circumstances nutritionists must make the right choice between the available raw materials and ingredients, considering both the price and suitability. Formulation of feed is almost exclusively a matter of comparing and using ingredients on basis of the costs per unit of nutrient available.

Feed manufacturing has been practised in Europe and America since around 1900. Nowadays it is done all over the world. Proper combinations of yellow corn and correctly processed soybean meal, plus small additions of methionine, vitamins and minerals, can provide adequate rations for all sorts of poultry. But this wide spread corn-soya formulation cannot always be manufactured everywhere as the ingredients are not always available in ample quantities.
A great variety of raw materials are used all over the world including many by-products, obtained from the oil and cereal manufacturing industries. However, not all of these are readily available everywhere. In many countries major components of poultry feeds must be imported.

Cereals, being mainly energy sources, are generally supplemented by protein sources from plant and/or animal origin, to which minerals, vitamins and some additives are added. Because of a lack of foreign exchange local products are often used. In Africa, for example, a lot of sorghum is used (50-60%), wheat bran (10-20%) and oil seed cake (6-12%), supplemented by oyster shells and vitamin-mineral premixes.

8.1 Energy sources

For energy supply a large number of grains are used, such as maize, barley and wheat, sorghum and/or milocorn or broken rice. In case of scarcity or when cereals are priced high there are a number of grain replacers available, such as tapioca (a product from cassava roots). This is a useful feedstuff containing a high digestible starch, but it has low levels of vitamins and minerals and particularly has a low content of sulphur containing amino acids. Moreover, special processing needs to take place in order to remove the toxic cyanogenic glucoside out of the product. Supplementation with methionine, up to 0.15%, is necessary. It can be included in broiler diets (max.10 %) and in layer rations (max.20 %).

Table 13: Relative values of some important grains

	Energy value (maize = 100)	**Digestible nutrients (maize = 100)**	**Fibre content (%)**
Maize	100	100	2
Sorghum	95	99	2
Wheat	96	100	2.5
Barley	83	94	6.0
Oats	76	88	11.0
Rice	78	101	9.0

Other sources of energy are oils and fats. The nutritive value of oils and fats for poultry varies, depending on their chemical composition and the age and type of birds. Adult chickens use oils and fats more efficiently than young birds (0-6 weeks).
Utilization of fat ME is 10-20% more efficient than ME from carbohydrates. However, substitution of carbohydrates by fats may have negative effects in young birds, especially in broilers. In the Netherlands up to 10% of fat is added in broiler rations, less in layer rations.

In the tropics a formulation with a (too) high energy level will not happen easily. In many countries in the tropics, local by-products may be used such as rice bran and other by-products, giving relatively high levels of crude fibre in the feed.

8.2 Protein sources

By-products from the oil seed processing industry are used mostly as protein sources, especially soybean meal, sesame meal, groundnut meal, cotton seed meal and similar products, but also by-products from the grain processing industry, such as wheat bran, rice bran and maize gluten.
In order to meet the protein requirements we look to amino acid levels rather than to protein, as these amino acids represent the value of the proteins involved.

Table 14: Amino acid composition of some protein sources

	Requirement per 20 g protein (NRC)	**Actually present in 20 g of protein from:**			
		Soybean meal	*Cotton seed meal*	*Groundnut meal*	*Maize gluten*
Lysine	1.00	1.30	0.78	0.92	0.38
Methionine	0.40	0.30	0.29	0.16	0.47
Cystine	0.35	0.35	0.49	0.28	0.33
Tryptophane	0.20	0.26	0.24	0.20	0.10

From this table we see that soybean meal protein supplies the highest levels of essential amino acids in 20 g compared to the other protein sources. The lysine content is especially high.
Supplementation with animal protein is possible but not as necessary as it used to be. Any ration can now be formulated on basis of amino acid requirements, because the most important ones are synthesized. Nowadays not only lysine and methionine, but also tryptophane and threonine can be added. Sometimes addition of animal protein should be avoided due to the probability of poor quality and/or high price (fish meal).

8.3 Mineral supplementation

Minerals like Ca and P are derived from other ingredients, for example meat and bone meal, fish meal and other ingredients, but also exist in mineral form, for example as di-calcium-phosphate (DCP), limestone and salt.

8.4 Use of by-products

If for one reason or another ingredients which are commonly used, such as yellow corn and processed soybean meal, are not sufficiently available, the use of other ingredients becomes necessary. In the course of time more and more by-products of industrial processes have been included. These now form the largest part of the industrially manufactured feeds, although some limitations are imposed, due to the possible presence of unwanted substances, such as excessive fibre and/or toxic compounds. Moreover, they may vary considerably in composition as there are so many differing processing methods involved, one being more successful in retaining valuable substances than another. Modern processing methods lead more and more to less valuable by-products. Quality control is, therefore, always necessary.

Corn by-products result from corn milling processes, either dry or wet. The most modern one is the dry milling process. Useful by-products of this process are corn germ meal and corn gluten meal, the latter being rich in protein, and, although it is deficient in the amino acids lysine, threonine, tryptophane and arginine, is notably adequate in methionine and cystine. Many by-products are obtained from commercial wheat milling.
One of the most important criteria in evaluating these by-products is their crude fibre content. In rice producing areas rice bran is often used as a valuable feedstuff. However, it can contain too many

hulls. Moreover, its high oil content makes it prone to rancidity unless properly stabilized by an anti-oxidant.
All these by-products are meant for replacing proteins rather than cereals.

Soybean meal is known as one of the best proteins of plant origin due to its high content of essential amino acids, with the exception of methionine and cystine. Many by-products of the oil processing industry, however, are often deficient in several amino acids. Cotton seed meal, for example, is deficient in lysine, methionine and leucine. Groundnut meal in lysine, sulphic amino acids and threonine. Corn gluten meal is not a complete amino acid source. Coconut oil meal should be supplemented with methionine and lysine. All these by-products can, therefore, be used but only if they are supplemented with synthetic amino acids in order to meet the amount of amino acids which are actually required.

A number of plant protein sources contain anti-nutritional substances. Very well known are the trypsine inhibiting factors in soybeans, but also some cereal products contain such inhibitors, mainly located in the germs.
Cotton seed meal contains gossypol and some deleterious fatty acids. The gossypol can be rendered innocuous by addition of iron salts to the diet. Deleterious glucosides are also present in rape seed meal.
The variability in processing methods of plant protein sources (e.g. solvent extraction versus expelling) causes a great deal of variation in nutritive value, including the availability of amino acids. Overheating in the processing of by-products can also reduce the availability of amino acids.
The most frequently used animal protein source is fish meal, but its application has decreased because of the increased price. Good quality fish meal is one of the best ingredients in poultry feeds. However, the quality is variable. Oxidation often occurs due to the high content of unsaturated fatty acids. Therefore addition of antioxidants such as ethoxyquin is necessary. Finally, the use of fish meal is limited in order to prevent fishy flavours in meat and eggs.
Meat and bone meal and poultry by-product meal are suitable feedstuffs in poultry feeds. Autoclaved feather meal is used in small quantities, due to the imbalance in amino acids. Recently meat and bone meal has become suspect generally because of the BSE scare (cattle, sheep).

Amino acid imbalance and the presence of anti-nutritional substances are the main reasons for restricting the use of the current by-products. Some examples of maximum inclusion in Holland are, in percentages:

Table 15:

	Chickens	**Adult hens**
wheat by-products	0-10	10-20
corn gluten meal	7.5	10
rice bran	5-7.5	10
groundnut expelled/extracted	7.5	7.5
coconut expelled/extracted	-	5
meat and bone meal	7	7
alfalfa grass meal	0-5	7.5

8.5 Non-conventional feedstuffs (NCF)

Among the locally available feedstuffs, so called non-conventional feedstuffs (NCF) are also used. The necessity to reserve the available food ingredients for human consumption and the high costs of importing valuable by-products has forced many countries to investigate the possibility of using all kinds of waste. Rubber seed meal, for example, contains relatively high amounts of protein (about 30%) but the crude fibre content is also high and the quality of the protein is low because of a deficiency in lysine and methionine. In addition rubber seeds contain the cyanogenic glucoside linamarin. Formation of hydrocyanic acid (HCN) can be prevented by storage, crushing and heating or dry-

ing. Inclusion of 20% is reported to have been successful provided the crude fibre content is not too high and sulphic amino acids are added.
All sorts of leaves have been investigated for use as a feedstuff. The best known example is the use of ipil-ipil leaves (Leucaena leucocephala). Up to 10% may be used in broiler rations but higher levels are not recommended because of the presence of mimosine, which is an antagonist of tyrosine.
Cassava leaves are also reported to be satisfactory, provided the HCN-content is low and again with addition of methionine.
Generally we must be careful in using these, and other sorts of waste because of the presence of toxic constituents. It is always necessary to investigate their use in carefully designed experiments before using them as feedstuffs. Do not use them unprocessed and only include them in limited concentrations, e.g. only 5%. More research as to their potential use is needed.

8.6 Nutrient requirements of poultry

The nutrient requirements of poultry can be found easily in ‘Nutrient Requirements of Domestic Animals’ edited by the National Research Council (NRC) of the United States, or ‘The Nutrient Requirements of Farm Livestock’, edited by the Agricultural Research Council in Great Britain. However, we must always remember that these data only give a guide to the nutrients required, not the actual, and exact amounts of, nutrients which we would like to use in our feed formulation. It is advisable to observe a certain margin of safety. Such a margin is necessary because of large variations in nutrient composition of raw materials, differences in feed processing technology and differences in storage conditions, all of which may affect the nutritive value of the ingredients. We must also not forget that the formulated feed allowances are expressed in percentages, whereas the requirements are absolute amounts, which in fact, not only vary with the type of bird, but also with feed intake, as affected by the environment and the level of performance.

8.7 Premix formulation

The main problem of premix manufacturing is accurate weighing. However, weighing devices which are really accurate may be rather expensive. Therefore centralized premix factories offer the best solution.
In Europe the capacity of an adequate premix factory may amount to 40,000 tonnes per year, with a local working area of several hundreds of kilometres. The choice of size and location is merely a matter of weighing the costs of manufacturing against the costs of transport.
Premix manufacturing may have to cope with difficulties caused by the occurrence of static electricity, dust problems and problems caused by cross contamination.

Basically there are only a limited number of premix formulations to compose. The most important formulations can be derived from the table with the current feed formulations in Holland as shown in the following table.
Growers and broilers may need two slightly different premix formulations, layers and parent stock can be provided with the same one, as broiler parent stock have a much higher feed intake than the current laying hens.
In practice, however, we find a large number of premixes, as every customer may have his own preference and often wants to add additives other than trace elements and vitamins. A premix may also contain anti-oxidants, growth promoters, antibiotics, coccidiostats and amino acids. However, the latter can be added separately.

Table 16: Some average feed standards as followed in the Netherlands

	Growers		Layers	Broilers	
	0-6 weeks	*6-18 weeks*		*0-3 weeks*	*3-7 weeks*
ME (kcal/kg)	2,800	2,800	2,800	3,200	3,250
Crude protein(%)	20	15-16	15-16	21-23	19-21
Lysine (%)	1	0.80	0.75	1.2	1.1
Meth. + cyst.(%)	0.80	0.70	0.65	0.90	0.80
Ca (%)	0.80	0.70	3.6	1	0.80
Av. P (%)	0.45	0.35	0.35	0.50	0.40
NaCl (%)	0.25	0.20	0.25	0.28	0.25
Linoleic acid (%)	1	1	1.5-2.0	1	1
Fe (mg/kg) *	20-40	20-40	20-40	20-40	20-40
Mn (mg/kg)	60-70	60-70	30-70	60-70	60-70
Cu (mg/kg)	4-10	4-10	4-10	4-10	4-10
Zn (mg/kg)	40-50	40-50	50-60	40-50	40-50
J (mg/kg)	0.8-1.8	0.8-1.8	0.8-1.0	0.8-1.0	0.8-1.0
Co (mg/kg)	0.5	0.5	0.5	0.5	0.5
Se (mg/kg)	0.05-0.1	0.05-0.1	0.05-0.1	0.05-0.1	0.05-0.1
Vit.A (IU/mg)		8.5-10	7.5-10		10-12
Vit.D3 (IU/mg)		1.5-2	1.5-2		2-2.5
Vit.E (mg/kg)		7.5-10	7.5-10		10
Vit.K3 (mg/kg)		1	0.5-1		1.3-1.5
Vit.B1 (mg/kg)		-	-		1
Vit.B2 (mg/kg)		4	4		4-5
Niacin (mg/kg)		17.5-28	10-17.5		30
Pantothenic acid (mg/kg)		6.5-7.5	7-10		7-7.5
Vit.B6 (mg/kg)		0.5	0.5		1
Vit.B12 (mg/kg)		15	20		15
Biotin (mg/kg)		-	0.25		-
Folic acid (mg/kg)		-	-		0-1
Choline-chl. (mg/kg)		175-200	200-300		220-350

* = added quantities

8.8 Least cost formulation

Generally a feed would contain 8-10 ingredients along with a premix containing mineral trace elements and vitamins. In the case of lowest cost formulation the actual formulation is done by computer, using the nutrient requirements of the category of poultry involved, the list of available ingredients, their composition, their costs, and the restrictions to be made as to their usage. One may start with a fixed quantity of some ingredients (for example the premix and the salt), but also maximum and minimum are indicated.
Special attention should be given to the ambient temperature to which the birds are going to be exposed, because nutrient requirements vary with temperature. Nutritionists will give special consideration to these changing requirements in feed formulation. This is clear for differences between regions, but seasonal differences could also be taken into account. For example, in regions with a continental climate showing large differences between summer and winter. In tropical areas feed formulations may not vary over time, but they will, as pointed out before, certainly be different from feeds in temperate climates. As the requirements for nutrients, other than energy, do not decrease under hot climate conditions, the feed must always be formulated to provide adequate intake of protein, minerals and vitamins, at least in layers. In broilers this interaction between temperature and nutrition is negligible.

If there is no computer aid, formulation can be done by hand. Using a list of available raw materials, with their nutritive values and their prices, a formulation with different levels of ingredients is composed. Apart from maximum inclusion (i.e. never more than so and so much) of some rather unknown or risky products, such as NCF's, maximum inclusion rates of more current ingredients can also be taken into account.

As far as nutritive considerations are concerned, this is mainly a matter of unwanted presence of substances, such as excessive fibre or some anti-nutritional factors, but also components of feedstuffs which affect the storing quality of the feed (rancid fat) are taken into consideration.
Yet restricted availability, price and lack of quality control may lead to some risks. Always remember that any ingredient of questionable origin or quality should be analyzed. If this is not possible, use these ingredients only at a very low level. Be cautious with so-called bargains! If using non-conventional feedstuffs, usually not more than 5% should be included. Apart from premixes (1%) and some minerals, such as Ca, minimum inclusion levels are not relevant.

Table 17: Suggested maximum inclusion rates (%)

	Chicks	**Pullets**	**Layers**	**Breeders**	**Broilers**
Barley	25	40	40	40	10
Maize	60	25	50	50	60
Maize gluten meal	10	10	10	10	5
Sorghum	30	25	30	30	30
Wheat	30	30	30	30	30
Cottonseed meal	10	10	10	10	10
Groundnut meal	10	10	10	10	10
Rapeseed meal	5	10	0	0	5
Soybean meal	40	25	40	40	40
Fish meal	10	0	10	10	10
Meat and bone meal	10	10	10	10	10
Alfalfa	5	10	5	5	0
Tallow	5	0	3	3	5
Molasses	2.5	5	5	5	2.5

The most suitable solution must be found by ‘trial and error’. The nutritive values of the ingredients must not be overestimated. Most feed manufacturers will maintain a certain margin of safety.
The fibre content of grower diets should not exceed 4 per cent. High fibre foods such as wheatings and sunflower should be restricted in these feeds.
Some consistency in use of ingredients should be maintained, as abrupt (and large) changes in diets are not desirable. In practice, however, the effect of changes would not be detrimental, provided that the same chemical qualities are maintained.

9 Manufacturing of feed and quality control

Feed manufacturing is essentially a grinding and mixing operation. Exact weighing is a very important prerequisite, especially where small amounts of feedstuff are involved, such as in premixes.
First the chosen raw materials are passed through grinders. A uniform particle size is necessary in order to avoid selective feeding i.e.the coarse particles being consumed first, and the finer material is left for low ranking birds. If this happens the first group would get more energy and the latter more protein. Sieving tests can be carried out to check that the feeds are being ground to the required particle size.
During the grinding process the ingredients pass screens and beaters, which need to be properly maintained and replaced when necessary.
There are two types of mixers generally available for the mixing process: the relatively small vertical one, with a capacity of 1-2 tonnes per hour, and the horizontal one, more suited for large commercial feed plants. Before starting the milling process the optimum mixing time should be established.

9.1 Quality control of ingredients

Apart from the milling procedure, the quality of any compound feed is determined by the quality of the raw materials which have been used. The biggest constraint in poultry feed formulation is often due to the large variation in quality of feed ingredients and simultaneously a lack of analyzing facilities.

Routine checks of incoming ingredients should be made for colour, smell (not mouldy), texture-acceptable particle size (absence of lumps or water damage), uniformity, cleanliness, moisture content and, if delivered in bags, minimum breakage or tearing of bags. Reject materials should not be unloaded.
Samples should be representative for the consignment in question. In bulk deliveries it should consist of at least 10 probes per load. In case of delivery in bags a minimum of 10% of the bags should be sampled. From this sample a suitable sub-sample must be obtained for the laboratory analysis. These samples should be well stored.

9.2 Quality control at the laboratory

A laboratory for quality control should contain:
1 A ‘Weende’ proximate analysis facility for the assessment of moisture, ash, crude protein, crude fat, crude fibre, starch, sugar and gross energy.
2 Facilities for the analysis of macro and micro minerals.
3 Facilities for the analysis of amino acids and free fatty acids.
4 The possibility to assess anti-nutritional factors (ANF).
5 A laboratory for the study of microscopic aspects of feed quality, in vitro digestibility, etc.
6 A laboratory for microbiological control (total cell counts, salmonella, fungi etc.).

On most of the materials (except, for example, premixes), a Weende proximate analysis is made. This must be a matter of routine. Procedures can be found in handbooks on quality control of feedstuffs.

Quality control at the feed mill comprises the assessment of moisture content of the grains received. At levels above 12% considerable heating takes place which results in fungus infestation and possibly aflatoxin contamination.
In grains the maximum moisture content should be 12-14%. If the moisture levels are excessive, the consignment should either be rejected or dried to a safe level.
Soybean meal should be checked for protein, fat and crude fibre content and for the quality of toasting. Ash (sand!), starch and crude fibre content should be analyzed in tapioca. In brans of wheat and

rice the uniformity and maximum moisture content must be determined. In fish meal not only crude protein but also salt and heavy metals need to be checked.

Quality control of the manufactured feeds is carried out to check that the products meet their specifications. Even after a control check of the raw materials a control check of the final product is usually done, as things can go wrong during the manufacturing process.

9.3 Manufacturing of pellets

Pelleting is normally carried out by treatment of the meal mixture with steam, subsequently the meal is transformed into pellets. The pellets must then be cooled and dried down to an acceptable moisture content as rapidly as possible. Pelleting has clear advantages compared with the meal form of the feed, particularly in broiler feeds, through:
- a higher feed intake,
- less feed waste,
- a slight increase of the energy level of the feed (3%),
- less segregation of particles of different size,
- reduction of bacterial contamination,
- less problems with feed jams in large feed bins.

However, there are also some problems to overcome:
- Raw materials must be ground to finer particles.
- The binding capacity of the constituents must be enlarged, usually by adding molasses, to a maximum of 2 %.
- The pelleting process needs special technological measures, so pellets are more expensive than mash.

In general, but especially in broiler feeds, it might be desirable to raise the energy content of the feed. Pelleting and the addition of fat are the proper means to achieve this.
Layer feeds are usually in mash form, as pellets induce the birds to pecking and overconsumption. However, the higher feed intake might be considered as an advantage in hot climate conditions. Broiler feeds are always pelleted if the facilities are available.

The most effective way to increase the energy level of feeds is the addition of fat. However, in doing so there may be some problems with regard to the flow capacity of the feed, as it becomes sticky if too much fat is added. Generally a maximum of 3% is recommended, but in the case of pelleting further problems can be expected with the hardness of the pellets. Therefore a maximum addition of 2% is preferable. More fat could be added if oil is sprayed on the surface of the pellets at the moment they leave the die of the pelleting machine.
Fats not only increase the energy content, they also reduce dustiness and may improve the palatability of the diet. Usually animal fat is used.

10 Water supply

Water is an essential ‘nutrient’ especially in hot climate zones. The body of the young chicken contains about 75% water or even more, whereas in adult birds the water comprises about 55%. Eggs contain 65% water. In particular the albumen contains a lot of water (more than 85%). Furthermore it is a necessary element in a number of metabolic processes, it transports other nutrients and removes body wastes. In the tropics it is essential for the stabilisation of the bird’s body temperature through the evaporation of water from the respiratory tract (see Chapter 1).
Water is, for the greater part, provided in the form of free available drinking water (75%), but also the metabolic water, released as a product of the digestive processes (almost 20%) and the water from the feed should be taken into account. Water is voided through the droppings (70-80%) and eggs (about 15%) and partly vaporized.
In this chapter both the quantity and quality of the drinking water is discussed.

10.1 Water consumption

Generally water uptake is particularly influenced by the ambient temperature, but also by the amount and quality of the diet, age of the bird, body weight and level of performance.

As the temperature rises chickens consume increasing amounts of water in order to be able to dispel excess heat, although some acclimatization may take place. Generally water intake at 32 °C is about twofold the consumption at 20 °C, about threefold at 37 °C and nearly fourfold at 38 °C. Experiments have shown that between 10-27 °C water intake may increase by about 3 g per degree Celsius, but beyond that level the increase amounts to 11 g per degree.

Some ingredients in the feed, especially mineral compounds, give rise, in many cases, to a larger water uptake. The occurrence of wet droppings is well known when higher levels of tapioca are fed, as a result of imbalance in dietary minerals (K), because more soya is then necessary. Others say that it is a matter of the presence of indigestible starches and/or toxins.
The structure of the feed may also alter water uptake. Mash feed with a fine texture seems to stimulate water consumption, whereas feeding pellets may have the same effect as the birds seem to have more time left to drink.
High levels of sodium (Na) in the feed make the birds thirsty, so the feed should not contain more than 0.5% salt (NaCl).
Different drinking systems also cause differences in intake. Experiments have shown that drinking cold water immediately decreased the respiration rate. In practice an improvement in egg production was also observed.

Both feed and water recording is important in the interest of good management. Regular measurement of the water consumption is one of the most important tasks of the poultry manager. An increase of water intake may be an indication of an imminent disease, as sick birds sometimes start to drink more. The intake of water can also be a measure for feed intake. Usually feed intake decreases 1-2 days after the intake of water declines. Water consumption has a direct effect on the faeces composition. An increase leads to wetter droppings and consequently a poor litter condition.
At 20 °C the water intake is about two times as much as the feed intake, but this ratio increases to even 5 times as much at a temperature of 35 °C or more, mainly because of the necessity to compensate for the loss of water through the high evaporative heat output.

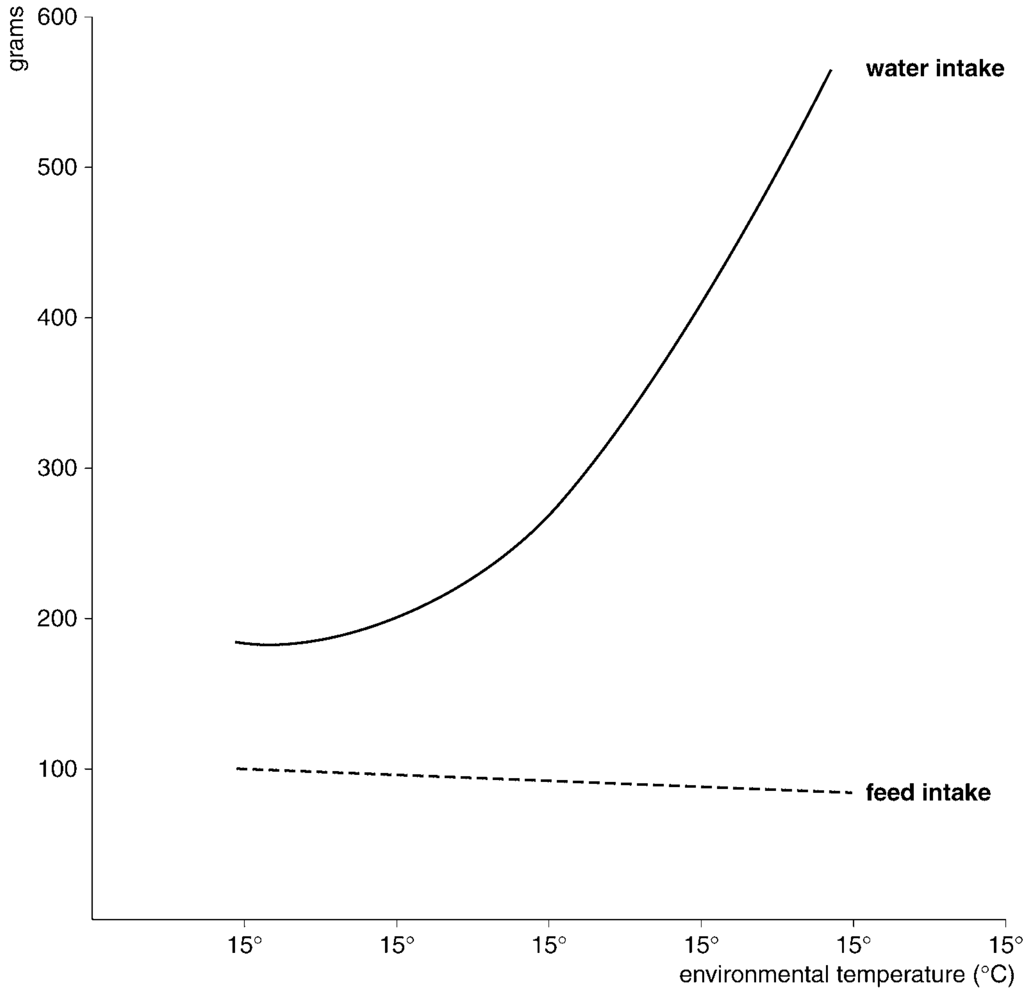


Figure 13: Environmental temperature and water intake

However, always check first on waste or leakage in the supply system!

Poultry cannot go without water for more than a couple of hours without showing adverse effects on performance. Water deficiency will always lead to a marked reduction of feed intake and a severe drop in egg production in layers. Water shortage also depresses egg size. Moreover, it may lead to abnormal egg composition, because water is added to the egg being formed in the heat of the afternoon (actual laying usually taking place the next morning).

10.2 Quality of drinking water

Under tropical conditions drinking water should be cool, i.e. if possible have a temperature of 10 to 15 °C. This may possibly be achieved by covering or insulating water supply pipes and/or the use of continuous flow waterers.

Supply of cool drinking water results in less metabolic heat to be dissipated, so it will immediately relieve the heat load of the birds. Consequently in experiments, a decrease of the respiratory rate has been observed. The resulting reduction in energy use will lead to better performance, whereas feed intake will increase.

Secondly, the drinking water should be clean, which means that it should be free from pathogens and undesirable mineral components. If a poultry farm uses water from own wells it is necessary to analyze the water before using it. First of all it should be clear, colourless, odourless and without sediments. Well water should be deironized and a pump should raise the pressure.

In addition there should be a check on bacterial contamination, in particular the presence of E.coli. The total bacterial count should be less than 3000/ml and E.coli should be totally absent. In the case of bacterial contamination the water should be chlorinated.
Finally the drinking water should be checked for the presence of a number of chemical substances listed below:

Maximum levels:

➢ Total solids	500 ppm
➢ Total hardness ($CaCO_3$)	below 60 soft, over 180 very hard
➢ Acidity (pH)	between 5 and 8;
if medicines are added not lower than 6	
➢ Salt (NaCl)	3000 ppm
➢ Chlorides (Cl)	300 ppm
➢ Iron (Fe)	1 ppm; if > 3 ppm blocking occurs
➢ Sulphates (SO_4)	30 ppm
➢ Nitrates (NO_3)	50 ppm
➢ Nitrites (NO_2)	5 ppm
➢ Ammonia (NH_4)	0.5 ppm

10.3 Water supply system

The supply system should be checked regularly and carefully for blockages, including inspection of filters, storage tanks, pumps, valves and supply pipes. In low pressure systems blockage and leakage may occur. These blockages may be caused by minerals present in the water (sand or lime, iron etc.), but also by slime forming bacteria. Filtration can remove the mineral blocking but not the biological one. For this purpose chlorination may be necessary. If drinkers are cleaned by means of chlorination, one must keep in mind that chlorine is only effective at a pH level of 7-8. It controls water borne pathogens (E.coli, salmonella), removes slime and algae build up in the water lines and can prevent disease transfer in open drinking systems.

Water shortage alarms, which detect a lack of water in a line of nipples by means of sensors, signalling the absence of water to a station, could be very useful under tropical conditions in particular.

10.4 Drinking water equipment

Water availability should be ensured by a sufficient number of drinkers, correct drinker height and a good distribution throughout the house.
Drinking points should be available over the entire floor area. Poultry must have access to their drinking water at all times, so in floor systems the placing of watering devices should be arranged in such a way that the birds are not unduly hindered in reaching them. Generally birds should not be forced to walk more than 5 m to find their drinking water. In layer houses at least half of the drinkers should be placed in between the feeders and the laying nests. Day old chicks should not need to walk more than 2 m to reach a drinker.
Watering equipment should be easy to clean. Furthermore, the devices must be designed in such a way that spillage of water around the drinkers does not occur, in order to avoid wet litter.

There is a great variety of drinking water equipment. The following is an overview.

1. Round drinkers:
For very young chickens (0-14 days) hand type mini drinkers are mostly used: 1 drinker for 50 chickens. Hanging bell type drinkers can be used from day old throughout the whole growing period. In the free standing position the lip of the water trough must be at the same height as a mini drinker in order to be suitable for young chicks.

In modern floor units automatic round drinkers are used, suspended with a cord from the ceiling and provided with a valve for automatic water supply when the drinker gets empty. If the diameter is approximately 30 cm we need 1 drinker for 100 replacement pullets or laying hens and 150 broilers. If the diameter is larger the numbers can be increased proportionally. As a rule of thumb we use a standard of 1-2 cm drinking space per bird. The height of the lip of these drinkers must be some cm above the tail of the birds to prevent spillage.

2. Shallow V-shaped drinking troughs:
These troughs are usually installed along the whole length of the house with a constantly running water flow. The trough must be fixed at an exactly horizontal level. The height of the water level in the trough can be regulated through a floating device in a cistern.

3. Short drinking troughs spread all over the housing surface:
Open drinking troughs may be used in cages, but these are usually found in older cage types. Nowadays drinking cups or nipples have come into use. Usually there are 2 nipples installed per cage.
In floor systems the number of birds per nipple should be:

0-6 weeks	10
7-18 weeks	6
after 18 weeks	4

Both cups and nipples make it possible to minimize cleaning work, but there is a risk of blocking due to mineral deposits such as iron. If no metal parts are present in the supply system, a 10% solution of hydrochloric acid (HCl) can be used to remove the blocking deposits. In the case of cups or nipples regular checking for a possible reduction of water pressure is necessary.
In many cases nipples are provided with cups or troughs underneath so that water spillage is prevented. This type of construction may also prevent overconsumption.

In the tropics trough drinkers are more suitable than nipple drinkers, as they encourage water consumption. It is even stated that under temperate conditions the nipple/cup and nipple/trough drinkers (combinations of nipples with drip cups or troughs) have the advantage of avoiding overconsumption of water, thus preventing water spillage and wet litter. On the other hand it is well known that nipples and low pressure cup drinkers limit body weight slightly.
An advantage of trough drinkers is that heat loss will certainly increase if a hen's head can be kept moist through immersion into the trough drinker. Even a minimum immersion of the wattles has proved to be helpful compared to no immersion at all.

Nowadays two cups are mounted on a carrying frame, which can serve as an introduction to the cup system itself.
Broiler cup drinker systems for floor management provide clearly visible fresh water in the cup with minimal spillage. These cups need no cleaning.

For broilers, supplementary chick drinkers must be used for the first 2-5 days.

Drinking space for broilers:

round drinkers	175-200 birds per drinker
troughs	1 cm per bird
cups	35-50 birds per drinker
nipples	15-20 birds per drinker

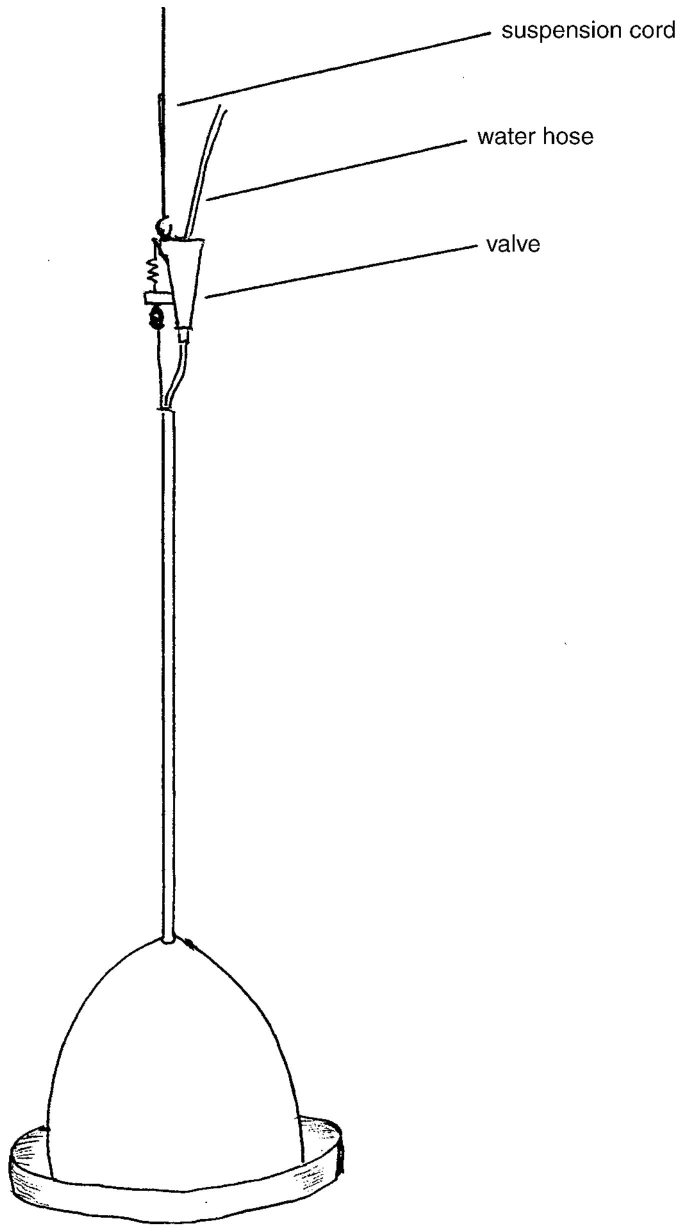


Figure 14: Automatic round waterer

11 Broiler breeder management

Although the technical support given by poultry breeding companies is very good and provides well documented guidelines to the manager of broiler breeder parent stock, it may be useful to discuss some problems which may occur.

Broiler breeders should produce as many fertile hatching eggs as possible at the lowest feeding costs. On average broiler parent stock is kept for 40 weeks production, the laying period being from 24 to 64 weeks of age. During this period the hens may grow from ± 2.5 kg to ± 3.5 kg (cocks from 3.2 to 5.2 kg). Egg production may range from 160 to 180 eggs, resulting in 150 to 170 hatching eggs per hen housed. An average fertility rate of at least 85% must be achieved, resulting in at least 80% hatchability and therefore about 120-135 saleable chickens.
Mortality during the rearing period should not be higher than 5%, and about 7% during the laying period.
The problem which most often occurs is low production of hatching eggs. Some flocks do not achieve an adequate peak of production and show a rapid decline afterwards. There are a number of reasons for disappointing results, including infections with parasites and diseases such as synovitis and IB.

11.1 Housing of parent stock

Broiler parent stock is usually kept in floor houses, either with complete litter or with a combined slat-litter system.
As broiler breeders are very susceptible to warm environments, sometimes a location is chosen in an up-country hilly region where the temperature may be more temperate. Open houses as well as closed, environmentally controlled, houses are built. It depends on the local climate conditions which system should be chosen. However, it seems that closed houses would only be suitable in rather hot areas.
Broiler breeders are adversely affected when housing temperatures exceed 30 °C, both in performance and in hatchability of the eggs, as males suffer very much from heat stress.
In floor houses some bacterial contamination of the eggs, causing lower chick quality, may occur due to dirty eggs and floor eggs. Combined litter-slats usually give less floor eggs than complete litter. The nests should preferably be put on the slatted floor. A totally slatted floor would be possible if the birds are also reared on slats. If reared on litter a high rate of bumble foot may occur. However, the combined litter-slat system is presumably the best system for hatchability, egg production and feed efficiency.
Wet litter may occur when:
- housing is inadequate (ventilation, insulation),
- the housing density is too high,
- drinkers are inadequate,
- nutrition causes wet droppings (soya, barley, salt if higher than 0.35%).

Moisture should not exceed 46-48%.

Cages are only used in case of artificial insemination. In some countries cages for hens with cockerels are also found. However, the results do not seem to be very satisfactory. Naturally these cages should be higher, ± 60 cm. In a cage of 180 cm × 90 cm a number of 24 hens with 4 cocks are recommended.

11.2 Feed restriction during the rearing period

Full feeding of broiler parent stock causes problems with fertility and production, particularly in a hot climate. Restriction programmes have been introduced allowing the birds to consume only about 80% of the feed that they would eat under ad libitum conditions. These programmes are meant to prevent excessive growth, early maturity and small eggs. Some breeding companies recommend to start feed restriction as early as 3 weeks of age; others wait until 6-8 weeks. During the restriction period we must know the body weight we are aiming at, at point of lay, to be able to carry out the right feeding schedule. An early start in weight control is necessary to achieve a steadier and slower growth. Weighing of birds should take place at least every 2 weeks. About 2% of the birds should be weighed, at least 50-100 birds.
If you find underweight, feed a little more; in the case of overweight refrain from adding more to the actual amount of feed.

Although restriction should be mainly an energy restriction, quantitative restriction is the most practised way of restriction. Slightly higher levels of protein and Ca are recommended, for instance 16% crude protein and 1.1% Ca in a feed with 2800 kcal per kg.
In restricting feed consumption we must try to get close to the lower limit of the body weight range recommended by the breeding company until 15-16 weeks. Thereafter we can allow for a faster increase of weight so that by 20 weeks of age the average weight would be close to the upper limit. This will result in a better condition at point of lay.
After a gradual increase of feed intake until 8 weeks it may be necessary to stabilize the amount of daily feed given from 8 to 15 weeks and then allow a gradual increase again until 24 weeks. Total feed intake may then amount to ± 10 kg for the hens and less than 15 kg for the cocks.

Feed restriction is only possible with sufficient feed trough length (8 cm until 8 weeks, 15 cm thereafter and 10 cm for round feeders) and a quick and adequate feed distribution throughout the house. Making partitions in a long house and rapid feed supply improve feed distribution. Some prefer the skip-a-day method (2 days supply in 1 day), because then a larger amount of feed can be spread better over the day and also because the low ranking birds then get their ration more easily. Under warm climate conditions it is preferable that an every day programme is used. In each system adequate feeding space is necessary to maintain the right flock uniformity (i.e. 80% of the birds having a body weight between 10% above or below the average weight). Sufficient feeding space is provided if not more than 10, preferably less, birds per metre trough length are allowed or not more than 15 birds per round tube feeder.

Table 18: Recommended nutritional composition of feeds for broiler parent stock

Age in weeks:	**1-8**	**9-20**	**21-42**	**>42**
Metabolizable energy (kcal/kg)	2750	2750	2750	2750
in MJ/kg	11.5	11.5	11.5	11,5
Crude protein (%)	18.5	14.5	17	16
Calcium (%)	1.0	0.8	3.4	3,7
Available Phosphorus (%)	0.45	0.35	0.45	0,35
Sodium (%)	0.16	0.16	0.16	0,16
Methionine (%)	0.38	0.29	0.35	0,32
Methionine + cystine (%)	0.67	0.52	0.63	0,59
Lysine (%)	0.95	0.65	0.76	0,72
Linoleic acid (%)	1.4	0.8	1.5	1,2

Table 19: Another example of nutritional composition

	Starter	Grower	Breeder (after 22 weeks)
Energy (kcal)	2850	2800	2750
Crude protein (%)	18	16	17
Ca (%)	0.5	1.1	3.1
Available P (%)	0.45	0.55	0.5
Crude fat (%)	3-4	3-4	3-4
Crude fibre (%)	2.5-3	3-5	3-5
Linoleic acid (%)	1.4	1.3	1.4

Changing from grower to breeder mash should take place gradually, for instance over a 1 week period at the age of 22 to 23 weeks.
Always keep in mind that more or less feed than recommended in the breeder's guideline may actually be required, depending on the actual situation with respect to feed quality and structure, and climatic conditions.

11.3 Lighting

Usually a short day length is maintained, for example 8 hours starting at 4 weeks of age until 18 weeks. Then 1 hour extra is given during the 19th and 20th week, and 2 hours extra during the 21st and 22nd week. At point of lay a sudden increase in daylength is recommended. Broiler breeder pullets seem to respond more slowly to light treatments than laying type birds. So at an age of 23 weeks 15 hours of light are supplied, which subsequently can be prolonged to 16-17 hours.
Feed intake should increase before light stimulation starts, for instance at 16 and 19 weeks respectively. At the onset of lay, body weight increases as the ovary is growing to maturity; moreover, we want hatching eggs to have the right egg weight as soon as possible. For this purpose a correct body weight is also necessary, therefore the feed should have a high percentage of crude protein together with a high lysine and linoleic acid level as these amino acids stimulate egg weight.

11.4 The laying period

The most precarious and sensitive period for broiler breeders is the period from the onset of lay until some weeks after peak production. In this period the flock should be carefully observed as to its performance and condition. This is also the period in which disease infections can be expected. Apart from performance the weight gain should also be observed, as too much gain after peak production can be detrimental to egg production.
Problems arise when:

1 The flock is late maturing due to late and slow light stimulation. Overfeeding may occur and the flock will not reach a high peak, whereas the egg production will decline faster than it should do. If not overfed the flock may eventually perform satisfactorily. Care should be taken not to overfeed the birds in an attempt to speed up maturity!
2 The flock may be underfed at the onset of lay. In that case the increase in the rate of production will slow down.
3 The flock shows uneven uniformity. As a consequence it will only slowly climb to a rather low peak, as the birds do not peak at the same time, but the peak period may be long with an acceptable persistency.

The feeding level during the laying period should be based on actual egg production and ambient temperature. So when production starts, the weekly feed allowances must increase faster during the increase to peak production and then slow down. When there is no further response to the increasing feed supply, it should stop. We must keep in mind that broiler breeders have a high energy requirement for maintenance. The energy requirement becomes almost constant until ± 40 weeks of age. After that time feeding is controlled again and slowly reduced, at least in temperate climates. Experiments with a stronger restriction than normal, under temperate conditions, led to at least as good results as those under normal restriction programmes. Under warm climate conditions such a restriction would probably not be adequate. During the laying period feed consumption may be ± 150 g per hen per day; that means a consumption from, for instance, 120 g per bird per day at the onset of lay gradually rising to 155 g at 40 weeks and then decreasing again.

Feeding time in the early morning may have the advantage of the cool period, but the disadvantage of coinciding with laying time. Yet it may be the best time as feeding after laying will coincide with the hottest part of the day.
A daily ration of 5 g of grains per bird may improve litter condition and fertility rate.
At high production levels it may be recommendable to supply additional broken oyster shells or granulated limestone.
It is unnecessary to say that good flock records are indispensable!

For the laying period the following general recommendation could be followed:

Table 20:

	Temperate climate	**Hot climate**
Metabolizable energy (kcal/kg)	2.750	2.600
Crude protein (%)	16.5	16.5
Methionine (%)	0.33	0.33
Methionine + cystine (%)	0.60	0.60
Lysine (%)	0.75-0.80	0.75-0.80
Calcium (%)	3.0	3.0
Available Phosphorus (%)	0.40-0.50	0.40-0.50

Table 21: Some other examples of feed formulation

	kcal	**c.p.**	**meth.**	**m.+ cyst.**	**lys.**	**Ca**	**av.P**
Growing period 0-4 wks	2800	20	0.4	0.75	1.01	0.95	0.45
Growing period 4-24 wks	2700	14	0.26	0.55	0.61	1.00	0.35
Laying period	2750	15.75	0.31	0.59	0.82	2.80	0.35

Also three phases during the growing period are observed; e.g. from 0-3, 4-9 and 9-22 weeks of age.

Table 22: Example of formulation of breeder feed in Holland (average)

Age	**20-62 weeks**
ME in kcal/kg	2825
% protein	16.7
% digestible lysine	0.61
% dig. meth. + cyst.	0.57
% Ca	3.52
% P	0.57
% available P	0.36

Usually a high concentrated feed is supplied at the start of the laying period. In hot climates still higher levels of digestible amino acids may be necessary.

11.5 Measures to promote fertility rate

Broodiness still occurs in heavy broiler breeders. Sometimes 2-3% of the hens show broodiness symptoms in sitting too long in a nest and eventually not leaving it. The best way to combat this habit is interrupting the process by putting the birds in a different environment without a nest. Although you may not be sure whether the hen involved may return, it is believed that if caught a second time, it would be better to slaughter the bird.

Hatching egg supply farms are usually requested to deliver the eggs on basis of 80% or more fertility. Factors affecting fertility are numerous.
In cocks, fertility decreases with age, particularly after 1 year. The environment also plays a role. The light intensity should be at least 3 lux/m^2. High temperatures are harmful, so temperature fluctuations are beneficial under these circumstances. On wire floors lower fertility can be caused by sore foot pads among the males. These males should be removed immediately as they are no longer fertile. Do not cover more than half of the floor space by wire.
Clipping of spurs of the cocks at an age of 40 to 45 weeks reduces damage to the hens and increases fertility. Strewing a little grain, for example 5 times a day, increases copulation activity and is therefore effective on fertility. The afternoon could be the right time, as then the eggs have been laid, but this would not be effective in a warm environment.
In hot climates the cock-hen ratio should be 1:8 rather than 1:10.
Diseases and nutritional factors also influence fertility. Protein deficiency causes lower fertility even before the egg production is affected. Animal protein supply is important.

Causes of infertility can be checked in the eggs which appear infertile after candling at 7 days incubation. Candling as such may not be sufficient because the so called ‘clear’ eggs may still contain an embryo, which died in a very early stage. The backgrounds of infertility can also be checked in the eggs which remain on the trays of the incubator after the chicks have been removed (see Chapter 12).

Separate feeding of cocks and hens increases fertility. In Holland an improvement of up to 10% was observed. Male feeding systems may consist of an auger or cable conveyor transporting the feed to height adjustable pans which are not reachable by the hens. Special grills placed over the female feed troughs prevent access by the males.
Experiments with separate feeding gave evidence of a better fertilization by separately fed cocks in the second half of the laying period. Contrary to what is generally assumed, this result was not due to lower body weight of the cocks (which is always the case in separate feeding), as the experiment was arranged in such a way that the separately fed cocks had about the same weight as the controls. Apparently the mating conduct is decisive for fertilization results.
If separate feeding is chosen we must ensure that both sexes are not underfed. Further research appears necessary.

11.6 Artificial insemination in cages

If large males are used with dwarf females, artificial insemination (AI) may become common practice for broiler parent stock, but could also be useful in normal parent stock. Semen is collected 3-5 times a week and diluted 1 to 5 times. It cannot be stored for a long time, so it is usually used almost immediately. The hens are inseminated once a week. Production of hatching eggs by means of AI in cages has some advantages: higher housing density, only 1.5-2% males needed instead of 10% in floor housing, probably higher fertility rates, no floor eggs, less contamination problems, lower feed costs, better labour conditions but also higher labour costs!

11.7 How to produce good quality hatching eggs

Eggs to be set for hatching should have the right weight; this means that the first small eggs in the laying period are not suitable. Mostly a minimum of 52 g is required, but in this respect the market also plays an important role!
Egg shells should be whole and clean. Contamination can be prevented in several ways. First of all the nesting material in the egg supply farm must be clean, dry and free of faecal material. The egg must dry off quickly after laying. The more moisture remains on the shell, the more bacterial contamination may take place. Regular replacement of the litter, for instance every month, is recommended. Litter conditions in the breeder house also influence the quality of the nesting material.

Collect clean eggs separately from soiled and dirty eggs. Most hens will keep using the same nest, but some, especially low ranking birds, lay their eggs on the floor. These floor eggs have high levels of bacterial contamination and should not be set, unless newly laid. In Holland dirty eggs showed a 6-8% lower hatchability. A limited amount of dirt can be removed easily, so that soiled eggs can still be mixed with clean eggs and used for hatching. Really dirty eggs should not be used unless washed properly. Filthy eggs should be discarded at all times.
Washing the eggs may improve the results, but these are never as good as those from clean eggs, so prevention is better. This can be done by placing the nests in due time in the laying house, i.e. at least 1 week before the onset of lay. From 16 weeks of age the hens start to inspect the nests. Provide sufficient nesting space (5-6 hens per nest). The hens must have easy access to the nests. Conventional individual nests give the best results. Avoid light and air streams in the nests. Start with a thin layer of litter; further litter can be added later.
Eggs must be collected at least twice, but under warm climate conditions preferably 4 times daily (2-3 times in the morning and another time in the afternoon) or more. Frequent egg gathering minimizes breakage and cross contamination from egg to egg.
At the moment of laying, an egg has a temperature of ± 41 °C. The embryonic development has already started by then, but as the egg cools, this development slows down and will eventually stop at ± 25 °C, so attempts should be made to lower the temperature of the egg within 5-6 hours after laying to a temperature below 25 °C. If the eggs are left too long in the nests, a sort of preincubation would occur, causing more early embryonic mortality.

If egg washing is considered it should be done adequately:

- remove cracked eggs,
- wash as quickly as possible after egg collecting,
- use good quality water (avoid iron containing water),
- keep the temperature of the water between 40 and 45 °C,
- do not wash longer than 4-5 minutes,
- use the right concentration of a normal household detergent: 5-10 g/litre,
- rinse with clean water, which should be slightly warmer than the egg, otherwise it will be sucked into the egg,
- replace the water at least once a day, preferably once every 2 hours,
- let the eggs dry after washing, preferably at 22 °C,
- keep them apart,
- clean the washing machine each time after use.

11.8 Fumigation of hatching eggs on the farm

If despite all preventive measures, contamination still occurs, disinfection of eggs is necessary. Fumigation is most effective when it is done on the farm. In Holland it was observed that disinfection led to a 2% higher hatchability. It has become obligatory in the framework of the so-called Internal Production Control programme.
There are 2 methods of disinfection:

1 Dipping of eggs in a solution of 0.5% Halamid during 15 seconds at a temperature of 41 °C.
2 Use of formaldehyde gas in a disinfection room between grading and storage.

The eggs should be disinfected within a few hours after collection. Formaldehyde (formalin) is most effective at a temperature of 25 °C - preferably not higher - in a relatively humid environment (RH more than 70%). The eggs should be clean, because organic material impairs the disinfecting action.
For 1 m^3, 21 ml formalin must be mixed with 21 ml water. The mixture is then poured onto 17 mg potassium permanganate ($KMnO_4$). The developing gas will do the job within 30 minutes.
Afterwards fumigation is done at the hatchery (see Chapter 12).

11.9 Storage of hatching eggs

During transportation and storage, hatching eggs are usually placed with the pointed end down in order to prevent damage at the blunt end, keeping the air space in its original position. However, during long storage times it could be advisable to store with the blunt end down. This will give the dormant embryo greater protection, keeping the yolk near the centre of the albumen. When in the incubator, eggs should be placed with the small end down. Regular turning (90°) in the incubator presumably has a beneficial effect.
Once again, the egg shell should be free from dirt, faeces and blood and undamaged. Store the eggs away from floors and walls so that air circulation can take place.

Storage time should be as short as possible. Even in temperate climates no longer than 4 days is recommended.
Research has shown that hatchability starts to decrease 2-3 days after laying. Prolonged storage also increases the incubation period and causes higher embryonic mortality. Actual storage should not last longer than 7 days, but under warm conditions no longer than 3 days. Eggs from older hens are affected most by long storage times.
If longer storage times are inevitable, the temperature in the egg room must be lowered.
The temperature should depend on the duration of the storage:

0-4 days	18-20 °C
4-7 days	16-18 °C
7-10 days	14-16 °C
> 10 days	12 °C

The RH in the room should be 80% or more. If water loss from the eggs is allowed this will lead to a deterioration of egg white and promote embryonic mortality.
It may be useful to ventilate the egg room at night, at least when temperatures are low. Adding some moisture to the room (wet floor, water troughs) will not only produce a higher RH, but also contribute to keep the temperature down. Storage at too low temperatures, however, causes condensation (‘sweating’) on the shell, which has a negative effect on hatching results.
If chemical sanitizers are used to minimize bacterial contamination, the disinfectant solution should be warmer than the eggs.
There are some reports indicating that pre-warming of hatching eggs just before setting increases hatchability, but this may only be the case when the eggs are stored for more than 2 weeks and when lower storage temperatures are used. It appears that such pre-warming automatically occurs in warm climate conditions.
Some research findings suggest that storing hatching eggs in plastic bags will reduce the decline in hatchability, especially when the storage period is prolonged, water vapour loss being the most important factor. It was found to be of little importance if the eggs were stored for less than 2 weeks. Similarly, enclosing eggs in plastic and flushing them with nitrogen gas could also improve hatchability.

11.10 Standards of performance

The performance of broiler breeders varies, not only due to differences in management, but also because of differences in genetic potential. The productivity of parent stock is related negatively to the growth potential of the offspring. Therefore the performance of broiler breeders and broilers should be judged together.
Some technical standards used in the Netherlands for cost calculation purposes of hatching eggs can be used as a guide line:

Cycle length:	rearing 28 days (19-22 weeks of age)
	laying 266 days (23-60 weeks)
	cleaning and empty 45 days
	Total cycle length 344 days.

Housing density: 5.5 breeder hens per m^2, 10% cocks
Performance: 146 hatching eggs and 10 table eggs per hen housed
Feed intake: 110 g per bird per day during rearing and 160 g during laying, including grain
Mortality: hens 10%, cocks 35%, including culling
End weight: hens 3.6 kg; cocks 4.8 kg
Depreciation: house 4%, equipment 8%
Maintenance: house 2%, equipment 3%
Number of birds per labourer: 8,000

11.11 Integrated broiler production projects

For the set up of an integrated broiler production project it is necessary to use as accurately as possible, performance standards for the calculation of the required parent stock capacity.
First of all the time cycle of the hatching egg supply farm should be set. This cycle may vary with different breeds. An example is given as a guide line:
 24 weeks rearing
 40 weeks laying
 4 weeks cleaning period
Total duration of one time cycle 68 weeks.

If, for instance, 1 million broilers should be produced per year, the required number of hatching eggs can only be calculated if some standards are assessed as to the rate of losses during production, processing and the rate of hatchability.

Example: the hatchability is assumed to be (as a conservative estimate) 75%. During the growing period mortality of the broilers would be 5%, whereas another 1.5% could be lost during processing.
So the required number of hatching eggs per year will be:
100/93.5 × 100/75 × 1,000,000 = 1,426,000 hatching eggs.
Say that - safely estimated - 140 hatching eggs per hen housed per cycle are produced. Then the number of hens to be housed per year should be: 1,426,000 ÷ (140 × 52/68) = 13,320.
Taking into account that during the rearing period, due to selection and mortality, 10% is lost, the number of day old female chickens to start with should be 100/90 × 13,320 = 14,800 plus 15% cockerels (usually 15% cockerels are added to the female day old chicks in order to be able to select cockerels at an age of 6-7 weeks).

In order to avoid the risk of disease we would prefer to house these 14,800 chickens in several places, for instance on 4 farms, with a capacity of 3,700 hens, which then could be stocked in sequence at intervals of 17 weeks. If the housing density would be 3/m^2 the housing facilities on these farms should measure 3,700/3 = 1,230 m^2, which could be achieved by building 2 houses on each farm, each measuring ± 60 m × 10 m.

The capacity of the hatchery could be calculated as follows:
In order to produce 1,000,000 broilers in one year, at a mortality rate of 5%, 100/95 × 1,000,000 = 1,052,632 chicks should be hatched and therefore 100/75 × 1,052,632 = 1,403,509 eggs have to be set. If setting takes place twice a week, that would mean 100 times a year, so each time at least 14,000 eggs should be set. The total setting capacity should then be 6 × 14,000 eggs, as hatching will take place each 3 days within 18 days of setting. The hatching capacity would then be about
85/100 × 14,000 = 11,900 eggs, as 85% of the eggs set are assumed to be fertile and transferred to the hatcher. If 90% would hatch, that would give in a whole year
100 × 90/100 × 11,900 = 1,071,000 day old chicks, which at a mortality rate of 95%, will deliver slightly more than the 1 million broilers we aim to produce.

12 Hatchery management

Hatchery results depend on many factors, including the circumstances of the hatching eggs supply farms. In the hatchery itself temperature, humidity and ventilation are the most important factors; they are all mechanically and/or automatically regulated. Some problems may still remain, especially from the sanitation point of view.

12.1 Effects of hatching eggs supply farms

The hatchery manager should know where the eggs come from, so that he/she may have an idea of the health status (including the vaccination programme) of the parent flock, the age of the birds, the age of the eggs and the management at the farms (disease prevention, fumigation programmes, etc.). If the hatchery results are less than expected, the hatchery manager can take into account the situation at the supply farm(s) involved.
Transport of hatching eggs from the supply farm to the hatchery probably always has a negative effect on hatchability. It should be done in such a way that the damage is as little as possible. Long distances should be avoided. The vehicles involved should have properly functioning spring suspension (no shocks). Differences in temperature and altitude between the two locations should be very small or none at all.

Fertility rate of the parent stock can only be checked after the eggs are incubated. It is the job of the hatchery manager to pass the findings on to the parent stock manager.
The most accurate way to check fertility, and also the stage of embryonic mortality, is to break the eggs which are left after the chicks have been removed from the tray. The contents of the eggs can be classified into 4 categories:

- infertiles,
- early embryonic mortality, that is: until the 4th day,
- mortality between the 8th and the 14th day,
- mortality from the 19th to the 21st day.

We can then distinguish three main periods of mortality, each with their own history.

12.2 Storage and disinfection at the hatchery

Hatching eggs should be trayed with the large blunt end up, because the head of the chick develops in the air space at this side of the egg. If it is done the opposite way round some embryos would turn round and develop with their heads near the small end of the egg. This position would cause problems at hatching time, because there would be no air cell to help them to start respiration. Therefore hatchability would be reduced considerably. Such a so-called malposition of the chicken (head in small end of the egg) would cause embryonic mortality in the last stage of the incubation.
Around the 20th day the air space of the egg is broken into and the chicken starts to breathe. The production of carbon dioxide (CO_2) increases and about 24 hours later the chicken will hatch.
In order to prevent condensation on the eggs, eggs which are taken from the storage room and placed on setter trays on trolleys, to be put into the incubator, should not be too cold.
Eggs are placed on the trays with the blunt end up. The filled trolleys are then driven into a special fumigation chamber and disinfected. Fumigation in the setters (instead of special chamber) may reduce hatchability. The fumigation chamber should be airtight and have smooth internal walls and floors so that easy cleaning is possible. Disinfection is usually carried out with formaldehyde (formalin), which kills bacteria and viruses as well as moulds. Usually 45 ml of a 40% solution of formalin is used together with 30 g of potassium permanganate ($KMnO_4$), per m^3. The formalin solution is poured onto the potassium in a tray. The temperature in the chamber must be above 20 °C and the RH not lower than 75%. The whole process should last 30 minutes. A small fan in the room may contribute to a better distribution of air between the eggs.

Formaldehyde gas can also be generated by heating paraformaldehyde prills in a heater.
Disinfection with formalin after transfer from the setter to the hatching department causes a yellow colour in the chicks. This has no significant disinfecting effect but the trachea of the treated chicks are damaged, this damage still being evident 5-12 days after hatching.

Hatching eggs stay in setters for 18 days (of the total incubation period of 21 days). The setters determine, to a high degree, the success of the hatchery. Some important things should be kept in mind:
- Keep setter records. Egg sources, fumigation, percentage of hatch and unusual happenings should be recorded in order to be able to study possible influences on the process.
- Use proper sanitation procedures if you have to visit your egg supply farms. Take notice of their storage temperatures, frequency of egg gathering, etc.
- Check the temperature regularly; also RH, air flow and cleanliness of your egg room.
- Check the setter controls frequently. Check also the temperature levels on several spots inside each setter. Use a psychrometer to check RH. Check the air movement.
- Stick to your schedule of egg transfer from the setter to the hatcher.

12.3 Temperatures and RH during incubation

Temperature is the most critical factor during incubation. Deviations from the optimal temperature (37.5-37.7 °C) cause mortality and affect the time of hatching. The lower the temperature, the later the hatching through a slower growth rate of the embryo. The frequency of malpositions also increases with temperature deviations. Generally the eggs are more sensitive to overheating than undercooling.
High temperatures cause higher embryonic mortality, a shorter duration of incubation and leg and navel abnormalities, especially after 10 days of incubation. The coinciding low RH causes sticky chickens loosing moisture, so that they are more sensitive to lack of water during their first days of life.
Low temperatures will delay hatching time. Navels may be open and infected. Here also characteristics of high RH can be observed: sticky and relatively small chicks.
In modern incubators with forced ventilation the temperature is kept between 37 and 38 °C. If the air is not moved the temperature at the upper side of the eggs should be higher: 39.5 °C. Generally the temperature during the first 19 days is maintained at ± 37.5 °C and a little lower (36-37 degrees) on the 20th and 21st day. Temperatures might differ within the incubator, but this should be avoided as much as possible.Small eggs need a higher temperature.

The RH within the setters is usually about 50% but it may fluctuate without serious negative effects. Sometimes the RH is somewhat raised during the first 3 days of incubation (65%), but afterwards it should be lower. Some evidence has been obtained that 58-60% would be optimal. Too high RH levels seem to be more harmful than low levels, especially in eggs from older hens. Heavier eggs would benefit from a lower RH.
It is often recommended to increase the RH after the transfer of the eggs to the hatcher, but this has not been supported by evidence from experiments. Yet at this stage the moisture loss from the eggs increases, so a higher RH seems to make sense. Usually about 75% RH is recommended or even 80%. When the first chicks hatch, the RH will automatically increase. Then it should be lowered again, for example to 60%, in order to stimulate the drying process of the chicks.
There is some evidence that RH should be a little higher in the tropics, as it would restrict water loss.

12.4 Ventilation of incubators and hatching room

The correct amount of ventilation of the incubators can only be determined by experience, as the machines vary considerably. Management guides may give some indications. Generally the following gas concentrations are maintained:
- maximal 0.4% CO_2 in the setter,

- maximal 0.5-0.7% CO_2 in the hatcher,
- inside the hatching room itself 0.04-0.05% CO_2 would be acceptable.

A somewhat higher CO_2 concentration is said to stimulate embryonic development, but could have a negative effect on hatchability. Yet some sort of 'CO_2 shock' has been practised successfully. It consists of shutting off the fresh air in the hatching room as soon as 20% of the chicks are out. After about 60-70% of the chicks have come out fresh air inlets are opened again.
Generally, control of ventilation is one of the most important factors in obtaining a high hatchability. Each unit must receive fresh air from outside, thus ensuring a minimum of air pollution in the hatchery itself.

12.5 The incubation process

During the incubation the embryo gets all its nutrition from the egg contents. At hatching time part of the original yolk is still present in the new born chick as a reserve feed. Consequently water is more important to the young chick, during the first couple of days, than feed.
As the incubation process proceeds the egg looses weight. This weight loss is determined by the conditions in the incubator and certain characteristics of the eggs set. For example, it varies according to the thickness of the shells and the size of the eggs. Larger eggs loose relatively less water than smaller eggs, therefore they require a lower environmental humidity than small eggs.
Hatchability would be optimal if the weight loss amounts to 10-12%, or ± 0.6% per day. It starts slowly, increases slightly in the second week and then rapidly after the 17th day. At the same time the air space in the egg grows from 0.5 cm^3 to 9-10 cm^3 at the 21st day. Regular weighing of incubated eggs can give a valuable indication as to the prevalent RH.
Subsequent stages of the developing embryo could indicate at which stage embryonic mortality has occurred in order to assess systematically the causes of embryonic mortality. By 7-12 day candling and breaking out of the embryos we can determine fertility and early embryonic mortality. To check the standards of the supply farm a minimum sample of 4 trays per flock should be used.
Regular break out analysis can provide valuable information as to the background of hatchery problems. Embryonic mortality usually occurs in 3 peaks: in the first, the second and the last week, the highest during the first and the last period (± 30 and 50% respectively). If the egg contents at candling are clear this means that the eggs have not been fertilized; this may be due to disturbances in mating behaviour or incorrect storage conditions. Early embryonic mortality is caused particularly by wrong storage conditions (high moisture losses), but also by poor quality eggs, feed deficiencies (especially all kinds of vitamins B or E), egg contamination, wrong incubating conditions (temperature, RH and ventilation and inadequate turning) and diseases. Mortality during the last week is mostly due to wrong hatching temperatures. The cause of dead chicks after pipping is usually from malpositions, unsatisfactory incubation conditions, especially a too high or too low CO_2 level. If the chicks hatch too early it may be caused by too small eggs or a too high temperature and/or a too low RH. If hatching is too late, temperature and RH may have been too low. Uneven hatching occurs when the size of the eggs is different and in case of disease in the parent stock.

Poor quality chicks are usually the consequence of poor incubating conditions including contagious diseases, feed deficiencies and incorrect disinfection procedures. Navel infections are often the result of salmonella and/or coli contaminations.

On average hatchability could be 80%, depending on the number of unfertilized eggs and embryonic mortality.
Turning of hatching eggs is necessary, in particular in eggs from older hens. It is usually done 24 times a day, during the first 18 days. This is most important during the first incubation week. There is no necessity for turning after the 15th day although it does not appear harmful to continue this. The time between one turning and the next one gives the embryo 'the chance to rest'. A constant back and forth motion would be bad for the hatchability.

The turning angle should be 45 degrees.

Transfer of the eggs from setter to hatcher should take place at the end of the 18th day, when the first chicks start pipping. Not before the 18th day and not later, as then some chicks may already start to hatch in the setter, although it would not harm the chicks or the hatch. At this time the eggs are candled.

The incubation time will vary. Usually it is 21 days and some hours. Variation depends mainly on the incubator involved. About 36 hours between the first and last hatch is possible, depending on egg size, storage, health of breeding stock, and the temperature distribution in the hatcher.
When most of the chicks have hatched and been dried for a couple of hours, the time has come to take them out of the hatcher.

12.6 Hatchery sanitation

Hatchery sanitation is very important. High bacteria levels will favour disease outbreaks and weaken the chicks. The most important part of sanitation is cleanliness. Disinfection only plays a small part.
The primary source of contamination is the hatchery refuse (shells, unhatched eggs, dead chicks, etc.). This should be removed as soon as possible. Wash down, clean and disinfect the hatchers, trays and buggies thoroughly. The floor of the hatchery should be cleaned every day. Give special clothing and shoes to visitors.
The design of the hatchery should be such that people and air follow the same route as the eggs. The ventilation system must be adapted to this design. The air flow should never pass back from ‘dirty’ areas, such as hatchers, to ‘clean’ areas, such as the setters and egg holding rooms.
Routinely monitoring microbial populations on off-hatch days by taking samples from all parts of the hatchery and equipment could be useful.
In modern hatcheries saving of labour is achieved by means of electric chick counting systems and automatic packing in 1,2 or 4 compartment chick boxes.

For transportation of the day old chicks cardboard boxes with four compartments, each for 25 chicks, are still the most suitable, but also the most expensive. During hot weather the number of chicks per compartment could be reduced to 20. Plastic boxes have been developed which are more common now. They are returnable, hence used again, so extra sanitary precautions are necessary to ensure safe re-use.
Transportation should be carried out as quickly as possible, at a temperature as low as possible (preferably 22 °C between the chick boxes) with adequate ventilation around and through the boxes. Delivery should take place early in the morning or at night. Overheating and lack of oxygen may occur. Measures should be taken to ensure that the ambient temperature near the chicks is not higher than 3 °C. Inside the boxes the temperature may become much higher than intended, which is detrimental. Special care should be taken that the chick boxes are not overpacked and that some air movement is possible between the boxes.

12.7 Sexing of day old chickens

The usually applied vent sexing for separating male from female chickens introduces stress and requires extra labour. Therefore feather sexing has been introduced both in layer and broiler strains. Raising male and female broilers separately may have a good future, as by now more and more heavier weights are required. Male chickens can be kept longer due to their higher growth potential.
Feather sexing is carried out by comparing the rows of feathers on the chicken’s wing. These feathers can either be equal in length or different, the underneath row being longer or shorter than the top row. These characteristics can be sex linked and thereby supply a means to distinguish both sexes.

13 Pullet rearing

Pullet quality is highly decisive for the success of a laying operation. That is the reason why some poultry farmers leave the rearing of their hens to a specialized rearing farm. One may also find rearing is too important to leave it in the hands of outsiders! Whatever choice is made, rearing is certainly the basis for success in the subsequent laying period. The objective of rearing is to get a uniform flock of well developed healthy birds.

13.1 Housing and equipment for pullets

Although modern vaccination programmes may enable us to rear pullets on multi-age rearing sites and even on laying sites, it is certainly advisable to practise only the all-in all-out system.
In (humid) tropical regions, pullets will usually be reared in floor housing, either on litter or on wire or slatted floors. Cage rearing, however, may be a good alternative in drier areas. This system gives rise to less parasites and less feed requirement. Cage dimensions may be ± 60 cm × 100 cm for 18 pullets to be reared to 18 weeks, or ± 100 cm × 200 cm for 50-60 birds.
If a controlled environment type house is used it should be light proof (less than 0.2 lux being seeable) and well insulated, with a controllable ventilation system.
Housing density in a floor system should not exceed 10/m^2 during the last weeks, preferably less in hot climate areas. In cages allow at least 600 cm^2 per bird.

During the brooder period simple feeders are provided, mostly in the form of trays. Small fountain drinkers - with 25 cm diameter suitable for 70-80 chicks - are placed directly on the litter. During rearing, feed troughs (10 cm feed space per bird) or round store feeders can be used. This type of feeder needs less feeding space per bird (5 cm), but under tropical conditions they may not be suitable to store the feed any longer than 2 days, because of possible risks of the feed becoming rancid.
Round automatic drinkers are used in this period.

Feeding space at long feeding troughs in cm per bird:

0-6 weeks	5 cm
7-18 weeks	10 cm
after 18 weeks	12 cm

Rearing requires a meticulous sanitation programme. After use the houses should be thoroughly cleaned and disinfected and then left empty for at least two weeks. It is strongly advisable to provide rearing houses with a disinfection room. Visitors should disinfect shoes or use boots from the farm and change clothes.

13.2 Arrangements for receiving day old chicks

Good quality day old chicks - vital and uniform in weight - are a must to start with. There should be not too much time between hatching and arrival at the farm. Their maternal immunity is important. The chickens must be properly debeaked and/or wing clipped. At their arrival the house temperature should be at the required level and feeders and drinkers well distributed on dry litter. Place the chickens directly from the boxes near drinkers and feeders in groups under localized heaters (spot brooding).

Heating can be either whole house heating or local heating, the last one being cheaper, but less easy to control. Standard installation in Holland is about 150 W/m^2 floor area.
Local brooding equipment may consist of gas/air systems with hanging radiant infrared gas brooders. Heaters can be connected to a common air supply duct. Extra air supplied in this way gives a better burning efficiency and clean combustion.

Electrically heated brooders claim considerable energy savings up to 50%, compared to the conventional radiant heaters.
It may be recommendable, even under warm climate conditions, to use only a part of the house in the brooding stage. It reduces heating costs and is easier to supervise.

During the first days chickens should be kept near the heat source within cardboard surrounds in order to reduce heat loss and prevent draughts. The surrounds should be about 50 cm high and placed about 1-2 m from the brooder.
For the first week 35 to 30 °C is necessary at chicken height. During the second week the temperature may gradually be reduced to 25° and after the second week a further decline is allowed, usually up to 20° and it should remain at that level. In hot climates it will not always be possible to maintain such a low temperature. However, as long as the temperature does not surpass 25°, nothing can go wrong. Above 25° the feed intake may suffer and above 30° even some heat stress may occur. On the other hand we know that temperatures which are too low can easily give rise to digestive disturbances and respiration problems. The behaviour of the chickens is the best standard of judgement of the temperature.

Usually egg trays or other easily accessible materials are used to feed the young chicks during the first week, arranged around and near the brooders alternately with drinkers. Feeders used thereafter should be adjusted for height, not only to make them reachable for the chickens but also to avoid feed wastage.
Small round drinkers are used for the first week, being replaced thereafter by automatic hanging drinkers or other drinker types, also adjustable for height as the birds grow.

The light intensity during the first couple of days should be sufficient to enable the birds to find feed and water easily and quickly. Later the intensity is dimmed to prevent the chickens from feather pecking or cannibalism.
Chickens in floor housing, having been brooded on litter, must at an age of 4-6 weeks be encouraged to go up on a raised section by means of run-ups. If they are brooded right from the beginning on a raised floor, it is necessary to cover the wire mesh or the slats with paper which after a week or two can be removed.

13.3 Debeaking

In hot weather and particularly in spots with bright sunlight in open houses, feather pecking followed by cannibalism may occur in young pullets. At point of lay there is also a risk of an outbreak of vent pecking possibly developing into cannibalism as well. This can be prevented by beak trimming.
Debeaking may be done at 1 day of age, but 6-10 days seems to be better. An age of 3-6 weeks is also chosen, probably because of the higher risk of pecking after the feather change from 3 weeks. If done at an early age it generally should be repeated before laying. Results are better at the younger ages, provided it is carried out in a proper way. In very young chicks the tip of the beak is pressed firmly against a heated blade thus removing a small tip of both the top and the lower mandible. In older chicks usually one third of the length of the lower mandible is cut and a little bit more from the top one. Great care must be taken to cauterise the stump portion effectively.
Beak trimming should not be done when the birds are under stress. Provide a higher feed level (3-4 cm) after debeaking and also keep the water sufficiently deep, so that the birds can feed and drink without problems. Feed only mash, not pellets or crumbs. Give extra light during the night.
In most cases there is a reduction in feed intake over a variable duration. The discomfort or pain is not well known, but if light intensity cannot be controlled, beak trimming is the only alternative to prevent feather pecking and cannibalism. In environmentally controlled houses dimming light intensity is usually sufficient to avoid pecking and cannibalism.

Note: Whether or not to apply ‘debeaking’ has become an issue in the EU. A fact is that so far (we are in the year 2001) no alternative has been found effective against featherpecking and cannibalism.

13.4 Feeding schedules

Feeding programmes for pullets are meant to follow the growth curve, as it is assessed for the pullet strain involved, in order to arrive at the correct starting weight at point of lay for the whole flock.
The number of feeds during the rearing period varies. Some time ago only 2 feeds were given: a starter until 8 weeks of age (c.p. 19%) and a grower from 8 until 22 weeks (c.p. 14%). Now much more is known about the requirements of growing pullets. Sometimes four feeds are supplied nowadays, as feed is better adapted to the changing requirements of the young pullet. For example a starter feed (0-6 weeks), a grower (6-12 weeks), a developer (12-18 weeks) and a prelay ration from 18 weeks until point of lay. The protein content of the prelaying ration is raised to 17% and the Ca level to 2%, keeping the available P to about 0.45%. At 20 weeks the birds get a layer feed, containing as much as 19% protein with corresponding increases in minerals and vitamins. The feed composition may then be as follows:

Table 23:

	Starter 0-6	**Grower 6-12**	**Developer 12-18**	**Prelay 18-20 weeks**
Crude protein (%)	19-20	15-16	15	17-18
Met.energy (kcal/kg)	2860	2770	2700	2750
in MJ/kg	12	11.5	11.3	11.5
Methionine (%)	0.40	0.34	0.34	0.38
Lysine (%)	0.95	0.72	0.72	0.75
Calcium (%)	1.0	1.0	1.0	2.0
Available P (%)	0.5	0.4	0.4	0.45

Another feeding schedule could be: starter (0-3 weeks), grower (4-9 weeks), developer (9-15 weeks) and a prelay feed (15-18 weeks). Here a still earlier maturity is taken into account and the layer feed is also supplied earlier.
Much emphasis is laid on the quality of the prelaying feed, because in this period pullets are developing rapidly towards laying maturity, requiring a high concentration of nutrients.

Feeder space allowances, in floor systems:
0-6 weeks 2.5 cm; 6-18 weeks 5.0 cm. In batteries: 3 cm and 6 cm respectively.
Drinking troughs: 0-6 weeks 1 cm; 6-18 weeks 2 cm.

Table 24: Some rearing results of the Random Sample Test RST at Lelystad (NL)

	WL	**MS**
Mortality 0-2 weeks (wks)	0.6	0.3
Mortality 0-18 wks	2.4	0.8
Kg feed consumption per pullet present at 18 wks	5.33	5.58
Kg live weight at 18 wks	1.203	1.416
Kg feed consumption from 18 wks until 20 wks	1.41	1.50
% pullets between 90 and 110% of average weight	72.3	74.7
% pullets between 80 and 120% of average weight	97.3	97.0

In practice some insoluble grit is still given to assist the bird in breaking down feed particles and, if necessary, litter material and other foreign objects. The grit can be spread on the feed in the troughs - not in chain feeders as it may damage the device - and later supplied in special containers.

13.5 Lighting

Current laying stock matures earlier than previously. The age at sexual maturity for an optimum egg yield is also earlier than before, although there is still a rather large variation between different genetic stock. When pullets start to lay before the optimum age is reached, egg size will be reduced, but more total eggs may be produced. However, when maturity is delayed, egg size increases but the total egg number may be reduced due to the later start.
Do not start 'stimulighting' when the birds are not ready for it. It would lead to less uniformity and lower the average body weight. In most cases stimulighting can start at 18 weeks of age or even earlier, since modern hybrids mature early. At the same time laying mash, containing more protein and calcium, can be given.
A conflicting situation may arise when light should be used in order to stimulate feed intake, for example during morning and evening hours, to such an extent that the birds would mature too early. A constant long day might be the least risky one.

13.6 Weighing in order to get a uniform flock of pullets

On many rearing farms a representative sample of pullets is weighed regularly throughout the rearing period, usually starting at 6, but sometimes at 3 weeks of age. Usually 1 or 2%, or 100 birds per flock, are taken. The purpose of this is to check the growth rate of the flock and its uniformity.
If some variation is expected, an early start gives the opportunity to adjust management in an early stage. A later control may be too late for any possible adjustments to be made. The frequency of weighing may vary, some weigh every week, others less frequently. Where birds are kept in cages all birds in the same cage should be weighed every time, so the same sample is weighed.
Every weighing is done on the same weekday at the same time.

Flock uniformity is defined as the percentage of pullets having a body weight between + 10% and - 10% of the average weight of the flock. A uniform flock has 80% or more between this range. It causes a faster increase of production, reaches a higher peak production, with longer persistency.
This is quite understandable. If the uniformity is low, the differences in body weight cause variation in the time needed to reach maturity, so that great differences occur in the onset of laying and arriving at peak production.
If the uniformity is low, measures should be taken. The basis of good uniformity is that all the birds get equal chances to gain weight. Therefore measures to promote uniformity are:

- Start with a good quality uniform group of day old chicks.
- Prevent high density housing.
- Distribute the birds equally over the floor area or cages, preferably before 3 weeks of age. Maintain an equal cage density.
- Distribute feed in such a way that all the birds have a chance for feed intake. In this respect feeder space allowance and feeding time are of utmost importance.
- Give feed as pellets or crumbs, as this excludes selective feeding.
- It may be that supply of daily feed in one feeding time gives every bird a chance to eat.
- Cull light birds.
- Adequate beak trimming.

Pullets which are too heavy have a higher maintenance requirement and probably more mortality due to prolapse. Light birds mature later and peak lower, whereas egg size will be small. However, it is not the final weight of the pullets after the rearing period which is decisive for production. More important is the composition of the body and especially the development of the ovary. Sexual development starts around 16-17 weeks of age.

13.7 Special measures under hot weather conditions

Although the optimum temperature for rearing after 4 weeks of age would be 20-25 °C, much higher temperatures may be recorded. Under tropical conditions, that is: high temperatures with a high RH, we can only increase the air movement in the poultry house. In dry areas cooling systems can be put in operation. As long as the ambient temperature is below 30 °C, it is possible to rear good quality pullets, particularly when cooling off occurs during the night.
Supply of fresh, cool water is the main concern under these circumstances. Water pipe lines must be placed deep under the ground or be well insulated to ensure cool water.
As in temperate climates, floor house densities may be 9-12 per m^2, we assume that 10 is certainly a maximum under tropical conditions.

13.8 Record keeping

Keeping good records in the rearing period is essential. It provides us with information about the way the flock has developed. The following items can be recorded:

- Day of hatching.
- Number of day old chicks received.
- Daily mortality and culling.
- Body weight and uniformity at the weighing dates.
- Feed consumption, specified to category of feed.
- Daily water intake.
- Lighting schedule.
- Temperatures measured at various spots in the house.
- Vaccination scheme, medication and postmortem results.
- Debeaking.
- Number of pullets at 18 weeks.

13.9 Transport to the laying house

Pullets are mostly moved to the laying facilities at 17-18 weeks of age in order to give them the opportunity to get accustomed to their new environment before lay. The birds should be caught and handled carefully, but some stress and, consequently, some weight loss seems unavoidable. Under hot weather conditions it is necessary to transfer the birds during the evening or early morning, when it is relatively cool.
Transportation crates should be properly disinfected. Avoid putting too many birds in one crate, especially in hot weather conditions. In a standard crate of 100 cm × 60 cm × 25 cm only 15 pullets should be placed and if transportation is over rather long distances even 12 might be advisable.
Do not supply feed for about 10 hours before transport.
When the pullets have arrived, the lighting schedule should not be changed for the first 3 days. During these days the light intensity should be high, so that the pullets find feed and water easily in their new environment. Allow ad libitum feeding and take care of adequate water supply. Provide the same feed as on the rearing farm. After arrival body weight may temporarily decrease but as soon as feed intake revives it will recover.

14 Layer housing and equipment

Depending on the prevailing degree of humidity in hot climate zones there are two options for housing layers: open houses in wet climates and environmentally controlled closed houses in dry regions. Both are described in Chapter 4. Within these two types there are many different ways of implementation, ranging from simple shelters in combination with a free range system to the most sophisticated modern cage units. However, technically highly advanced systems are not always the best. Sometimes a rather extensive system may fit in better with the local integrated way of farming, and, although inferior from a technical point of view, such a system may be more profitable to the farmer than a more intensive system. Large scale operations, however, do better in using intensive systems in order to be as efficient as can be, with high performances at relatively small costs.

14.1 Extensive systems

In many tropical and subtropical areas part of the laying stock is still kept in a free range system. Poultry is allowed to move about to find feed and lay their eggs in various places. Often some kind of primitive shelter is provided for the night. The feed of the birds consists of grains and grain by-products and all sorts of wastes. Despite the poor housing and the unbalanced ration, and consequently the relatively low performance, poultry in such circumstances can act as effective converters of waste into valuable products without substantial costs. Extensive systems are thus highly valued in integrated farming, as long as the eggs produced are not for the greater part needed for reproduction, because mortality rates are usually high. However, better housing, suitable equipment, some measures to restrict chicken mortality and probably some supplementary feeding may lead to more satisfactory results for the (small) farmer. Maintaining a higher degree of hygiene would be the main managerial concern.

14.2 Modern intensive systems

Housing highly productive stock in large layer operations can either be done in floor systems or in cages. The environmental requirements involved are described in Chapter 3, whereas general housing and managerial aspects are described in Chapters 4 and 5. In this chapter some more details about floor and cage systems are given.

The question: floor housing or cages, is difficult to answer. A lot of research has been carried out to evaluate the systems, but the results were far from consistent, because the experiments were seldom comparable. A preference for one or the other will probably originate from considerations other than managerial aspects though less exposure to pathogenic organisms, labour saving and ease of management are mentioned as advantages for the cage system. Moreover, it is, generally speaking, by far the most efficient one, but the required investment per hen could be the main constraint.

14.3 Floor systems

There are many types of floor systems. In a broad outline we can distinguish between complete deep litter systems and wire or slatted floor systems.
Litter may consist of all sorts of materials: wood shavings, straw, crushed corn cobs, shredded corn or sugar cane stalks, grain hulls and other absorbing materials, as they are locally available. Due to microbial breakdown and the birds' activity usually fresh litter has to be added regularly, so that a thick layer of litter arises, from which the term 'deep litter' has been derived.
A litter system may well be developed on a simple but hard earth floor, but a concrete floor is to be preferred, because it can be cleaned and disinfected more effectively. To avoid wet and caked litter it is recommendable to keep the housing density on a relatively low level, i.e. not higher than 3-4 birds per m^2.

In modern floor systems 1/3rd, 1/2 or 2/3rds of the floor area is taken up by a droppings pit covered with wire or slats. The more wire or slatted floor the higher the housing density can be, because the greater part of the droppings collects in the enclosed pit area, giving a reduced contact with the droppings while the litter area has more chance to remain dry. Under these circumstances stocking density can be increased to 5-8 birds per m^2, which saves investment costs per bird.
The pit area may be situated down the centre of the house or along the sides. The latter situation may be preferred because it may be easier to remove the manure through openings at the bottom of the side walls. The pits should be at least 80 cm high if the droppings are not removed during the laying period.
Either slats or wire can be used. In Europe slats, measuring 3.7 cm × 1.2 cm with a 2.5 cm gap in between, have proved to be successful, provided hard wood was used. Wire floors mostly consist of 7.5 cm × 2.5 cm wire mesh with perches on top at a distance of 35 cm, to prevent crowding.

Generally it is preferable that the equipment is installed on the slatted or wire floor, so that the greater part of the droppings collects in the pit.
In small flocks the feeding equipment may consist of rectangular troughs or round feeders which can be filled manually. Traditional wooden feed troughs should not be overfilled in order to avoid feed wastage. They must be fitted with an anti perching device, such as movable round perches.
Feeders should be distributed evenly throughout the house within a reasonable distance (4-5 m) of a drinker. All feeders should be designed to prevent feed wastage. Evidence has suggested that as much as 5% or more of the feed is wasted. A low, even depth, of feed should be maintained in troughs or other containers with so-called waste lips (anti-waste profiles) and installed at a suitable height to avoid scratching and dragging feed from the troughs.
Feeding space should be at least 10 cm per bird, under hot conditions probably more (12 cm).
Feed can be supplied 4 times a day to keep the feed level low and prevent feed wastage. On the other hand this might be risky in tropical areas where there is a chance of a low feed intake due to the high ambient temperature.

In large flocks mechanical feeding is installed, either in the form of a chain feeder or pans, which are filled mechanically by an auger. In chain feeders the 7 cm wide flat chain links became the favourite type. This feeding equipment requires 10 cm feeding space per bird. Attention should be paid to the possibility of selective feeding at the outgoing line of the chain. Pellets will minimize selective feeding.
After the chain feeder auger systems came into use with pans mounted along the length of a tube, or conveyers, consisting of overhead tubes carrying the feed to the pans through downpipes. Now the trend is away from chain feeders to these pan feeders, both in layers and in broilers. Generally the well designed pan feeders are easy to install and to maintain, and cause less feed wastage, thus being easy to manage. In terms of feed waste they also might be better, although a well managed chain feeder, with low feed levels, may also be used satisfactorily.
Water supply is described in Chapter 10.

In small units eggs can be collected by hand from individual litter nests fitted in 2-3 tier stacks against the wall. These nests should be 25-30 cm wide, 35-40 cm deep and 40 cm high at the front side, with a 15 cm high edge at the front to give the bird a feeling of a protected nest environment. In open houses nest blocks across the house are preferred to keep the sides open for proper ventilation.
Arrangements should be made to prevent the birds from roosting on and sleeping in the nests by mounting anti-roost grills, which in downward position can serve as a perch and in upward position close the nest opening. The perches should be installed at 20-25 cm from the nests to enlarge accessibility and 20 cm underneath the nests to facilitate nest inspection by the birds. This is important to prevent floor laying (see Chapter 15).
In so-called roll away nests, the sloping nest floor mostly consists of plastic covered wire or a more attractive material. This nesting type is labour saving, but gives rise to more floor eggs.
Both litter and roll away nests can be constructed for automatic egg collection.

Community nests consisting of a large box measuring 60 cm × 180 cm, for about 100 hens, may save labour, particularly when provided with an automatic egg collection system, but they are probably not so suitable in hot weather conditions.

14.4 Cage systems

Various types of cages have become standard practice in modern laying houses all over the world. The central element of the system is a cage, in most cases built of wire, with variable dimensions, but generally 45-50 cm wide, 40-45 cm deep and about 45 cm high. The cage floor slopes to one side to let the eggs roll away to the egg collection area outside the cage.
Feed troughs and drinkers are attached to the cage, mostly at the front side.
Cage types are determined by the way the cages are arranged with respect to each other. Thus we distinguish three main cage types:
1 Single deck or flat deck cages.
2 Stair step or A-frame cages in 2-4 tiers.
3 Vertical tier cage systems in 3-5 tiers.

Feed is provided either by hand or mechanically, drinking water by means of drinking troughs at the gangway side of the cages or nipples and/or cups inside the cage. Egg collection may also be mechanised.
The manure heaps up underneath the cages, except for tier cages. These can be provided either with platforms underneath the cage or with manure belts to convey the manure to one end of the house.
Cage density should not be too high, irrespective of the climate involved, but certainly not in warm climate zones. Generally 400 - 500 cm^2 minimum floor area is provided. Less space may give rise to increasing risks of lower production and feed efficiency and higher mortality. In hot climates more space should be given, to facilitate heat dissipation.

The most important aspects of a cage system to be observed are:
- Easy monitoring of the birds.
- Prevention of injuries by an adequate cage design. Construction of partitions and front doors may trap the birds and cause injuries or death. Horizontal wire mesh reduces neck feather damage.
- Simple and easy opening of the cage doors. Sliding doors ease initial stocking and also the depopulation and daily inspections.
- Anti-waste provisions, for example rims on both sides of the feed trough.
- Minimal egg damage through the right slope of the cage floor (7-8 degrees), resilient cage floor structure and sufficient distance between birds and eggs.
- Strength of spot welds.

In general all types of cages are suitable for hot climate zones, provided sufficient amounts of fresh air can enter into the cages. Therefore there might be a preference for low density cage types, such as stair step or single cages, which give less rise of obstacles to the fresh air flow. Single cages make recording of egg production easy and reduce heat stress problems.

Cages in warm and humid climates can only be installed, if:
- the poultry house is not too low (2-2.5 m side height and 3.5-4 m at the centre) in order to maintain a sufficient distance between the birds and the often (very) hot roof.
- fresh air can reach the birds inside the cage,
- cage density is not too high.

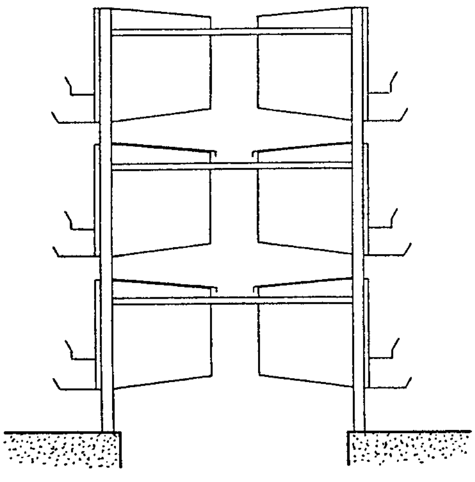
In environmentally controlled houses all sorts of cages are possible, provided the climate control works satisfactorily.

Maintenance of equipment is very important. Prevent rusting by regular cleaning and greasing. Try to clean feed store and drinkers regularly. Initiate a maintenance programme for ventilation equipment. Clean fan blades and louvres. Check the tension of the fan belts. Check the alarm system and generator.

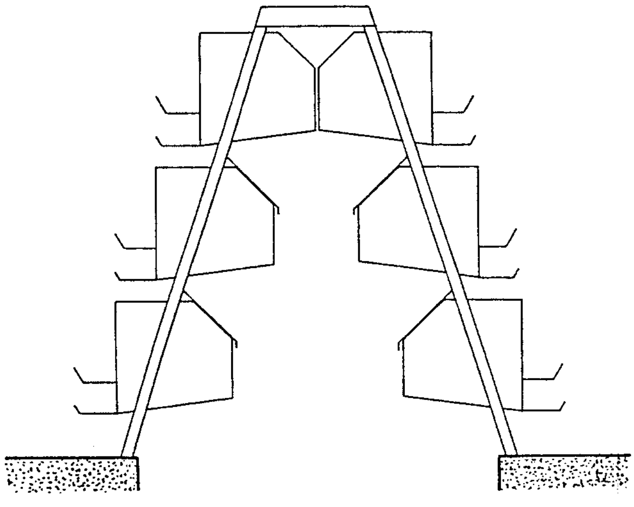
Note 1:
In the European Union there is increasing public concern about the well-being of poultry housed in cages. Gradually cages will have to give way to a modified type of housing considered to be more ‘chicken-friendly’, i.e generally allowing more freedom of movement to the chickens. By the year 2010 or somewhat later the use of the present cages may be prohibited altogether. This will undoubtedly increase the housing costs.

Note 2:
June 2001, a report from Denmark states that in ‘biologically-kept’ layer flocks 16% of the hens die prematurely because of cannibalism, against 5% of hens kept in cages.
In Holland the situation is little better; half of the ‘biologically-kept’ flocks show canniballism with on average 12% losses (peaking at about 40%, un ugly site).
A researcher writes:
‘We have reduced laying hens to machines with which little can go wrong, by keeping them in cages and by trimming their beaks. But when you give them more room they will start to show their natural behaviour (pecking!) which is not what we like.
Provided that there is no pecking and cannibalism, the well-being of ‘biologically kept’ hens is at its best. But if you consider general health and care of laying hens, the battery cage is by far superior. It is difficult to find a healthier hen than the battery hen: the group in the cage is stable, there is always feed, water and fresh air, and relatively little dust and ammonia. Also for the owner himself the cage is healthiest: relatively little dust, no reaching down and other stressful body movements’.

Note 3:
Year 2003, a researcher in NL writes:
‘The perfect chicken house does not exist. Large supermarket chains in NL have said that as from next year they will only sell ‘biological’ eggs, because the battery cage would harm the well-being of the hens. This is not true. For instance, the amount of ammonia in ‘biological’ houses may be 4 to 30 times higher than that in houses with cages.



3 tier battery cages



stair step cages

Figure 15: Common battery cages

The well-being of a healthy ‘bio-chicken’ is better than that of a battery cage chicken. But sick bio-chickens can less easily reach feed (and medicines) because of the pecking order in the flock. In addition, litter and droppings together make for good growing conditions of harmful organisms. On top of this biological houses are often so dusty that it affects the lungs of the workers.
The consumers will have to make up their minds. If they want chickens to range freely (for some part of the day), they must be prepared to pay more for the products and take an outbreak of a chicken disease for granted.

15 Management of floor housing

An effective and adequate management of large layer complexes is only possible if rearing and laying units are separately located. Only in this way spreading of infectious diseases can be avoided. Furthermore, all the units should be run according to the 'all in-all out' principle. Multi-age poultry units are to be rejected.

From the start of egg production the body weight should slowly increase. Control of weight gain (by representative weighing) provides adequate information about the development of the birds and gives an idea of whether the feed intake is sufficient or not. If it is too low, first the body weight decreases, then the egg weight and finally egg production will go down. Weighing should take place in the early afternoon, when the eggs have been laid.

15.1 Litter management

In floor systems litter is present either on the entire floor or on a part of it. Under tropical circumstances the thickness of the litter should not be too deep in order to enable the birds to loose some heat to the floor. If there is no concrete floor a thick layer is better in order to activate bacterial life, which may contribute to better litter quality in terms of looseness and absorbability. Good quality litter should be dry, friable and loose, so that moisture can evaporate and be carried away by ventilation. Wood shavings and saw dust are popular litter materials, but in tropical areas rice hulls, corn cobs, peanut hulls, etc. will also be quite suitable.
Litter condition is affected by the kind of litter, climate and climate control (ventilation), housing density, diseases (especially those causing wet droppings), amount of water intake, nutritional factors influencing the water content of the droppings (especially mineral levels) and the use of drinkers.
Moisture can be controlled by lowering water levels in the drinkers and replacing wet litter by dry material. Moisture content should not exceed 25%; this means that the litter should only slightly adhere to the hand when touched
Poor litter quality will produce a high level of ammonia causing many diseases, poor performance and low product quality.

15.2 Measures to cope with high temperatures

Preventing lower performance, as a consequence of high temperatures, is mainly a matter of maintaining an adequate feed intake and ample supply of drinking water by providing sufficient drinker space. Refill feed troughs every day. Regular stirring of the feed also stimulates feed intake. It may be recommendable to reformulate the feed by replacing part of the carbohydrate calories with fat calories.
To reduce activity, and at the same time to stimulate the intake of feed, the birds in open houses should be fed during the cool parts of the day, 2-3 hours before sunrise and after sunset. In environmentally controlled houses, of course, more feeding times can be introduced. The mere putting into operation (starting) of a mechanized feeding system stimulates the birds to eat. Generally feeding may take place 4 times a day, but 6 or more times may be practised. If a low feed level, preferably of 1 cm thickness, can be maintained in order to prevent feed wastage, more feeding times should be offered and probably also at a higher speed (for example 12-18 m per minute) for a quick and even feed supply. Mash feeds, which are preferred for layers, may otherwise easily give rise to demixing and selective feeding.
Continue maximum ventilation during the night. Avoid overcrowding and try to ensure that the birds spread evenly in the pen and do not crowd in cooler areas.

15.3 Avoiding floor eggs

Egg collection is very time consuming: about 50% of the daily labour may be involved, especially when many floor eggs have to be collected.
Floor eggs cause several problems in laying operations. Labour to collect floor eggs is costly and many eggs may be broken or soiled or dirty.
The percentage of floor eggs is usually highest at the start of lay. Then 10-15% floor eggs is normal. Medium hybrids seem to be more inclined to floor laying than light hybrids. After collecting the floor eggs during the first 4 weeks at 1 hour after the lighting has started, this percentage should go down to 2% or less.
Nest type certainly influences the frequency of floor eggs. Litter containing nests are more attractive to the hens than roll-away nests. After inspection by the hens roll-away nests are often avoided.
Nests should be dark and cool and provided with comfortable bedding, free from moulds. Install them in a quiet place to ensure rest and a 'pleasant' environment. For good accessibility, perches should be placed in front of the nest in such a way that the hens can easily inspect the nests. Therefore the perches should be mounted not too close to and somewhat lower than the nest opening. Perching is an important factor; in this respect rearing conditions are important. If pullets have not learnt to perch, they fail to do so in the subsequent laying period and do not reach the nests.
Usually one nest for 4-5 hens is recommended and the birds should not have to move too far to find a nest.

At the onset of lay do not collect eggs from the nests too early in the day, to avoid disturbing the hens when they try to enter the nests in the morning. Hens seem to have to learn to lay in nests. After a while they are consistent in laying either in nests or on the floor. For the rest of the laying period, however, frequent removal of the eggs (4-5 times a day) is advisable to maintain the internal egg quality as much as possible and to minimize egg breakage.
The pullets should be moved to the hen house early enough to have the opportunity to inspect the laying nests. Putting the nests in place 2 or 3 weeks before the onset of lay is advisable where litter nests are concerned.
In large groups more floor eggs are laid than in small groups, indicating that social factors may also be involved ('chicken sociology').

15.4 Possible feed saving by culling

Culling, in order to separate low producing or non-laying hens from good layers, is a time consuming task and therefore often neglected. Yet the removal of obviously sick and non-laying birds is always worthwhile. The main characteristics of good layers are: a large smooth vent, bluish white, because the yellow pigment gradually disappears, widely spread pubic bones (so that 3 fingers can be put in between) and a full, soft belly. In general low producers have dry vents and less flexible pubic bones. They are yellower than good producers.
There are several occasions during the laying period that an inspection on unproductive birds can take place.
The first is at an age of about 40 weeks, when peak production has passed. Not all the hens need to be taken out, but only those which give rise to doubt as to whether they are still productive.
At an age of 50 weeks another culling can be done. The third and last one should take place around the 65th week of age.

15.5 Induce moulting or not?

All over the world induced moulting seems to have become a standard husbandry practice. The objective is to extend the production period with another one after inducing a short rest. It certainly has some advantages. It lowers working capital requirements and is on average more profitable in terms of a higher return on invested capital. It may also cut production in a situation of over-production and low prices. In some countries it may be practised to save foreign exchange. Technically, if carried out properly, it leads to better egg quality, but it may also bring about a higher mortality and thus a lower utilization of housing capacity.

There are several methods to force the birds to stop egg laying, in other words to induce moulting. The procedures may vary, but they always include feed and/or water withdrawal, light restriction or feeding special diets deficient in Ca or other minerals. Usually daylength is decreased, for example to 8 hours or less, and feed is restricted to a mere coarse grain diet (oats). Withdrawal of water is generally judged to be cruel and not necessary, although it is also done. In hot climate conditions a severe restriction of water could cause problems, so only a light restriction limited to the first day, could be done.
Generally the moulting is started at 60 weeks of age, but it might be better still to start when egg production is just above 60 % as the flock will be in good condition. If the procedure is effective there should be a complete cessation of egg production after a few days. This lasts for a period of 4-8 weeks. Thereafter a second production period of 6-8 months follows, with larger egg sizes and a better egg quality.

The procedure followed in the Netherlands is as follows:
- reduce daylength back to 8 hours,
- supply only whole oats as feed for 12 days,
- give again 40 g feed from 13 to 20 days and 50 g from 20 to 26 days,
- bring light back to 9½ hours at 27 days and increase daylength gradually again.
- increase feed amount also gradually again after 4 weeks from the start to ad libitum.

With this method egg production usually stops after one week and the body weight is reduced by 20-30%. After a rest for 5-7 weeks a second laying period starts, which may last for another 6-7 months.
Thus the production period of a moulted flock lasts on average: 50 weeks in the first period, 6 weeks of rest, 34 weeks in the second period, so 90 weeks or 20 months in total, whereas a normal laying period without moulting would last only 15 months. On average it appears to be paying, but it is not generally applied (in the Netherlands). For an economic evaluation the results of 3 two-cycle moulted flocks should be compared with 4 'normal' flocks.
Even three-cycle moulting programmes are carried out, with 3 production periods of 9, 6 and 5 months respectively.

15.6 Daily routine duties in laying operations

The most important managerial task is maintaining an adequate health status of the flock. This is mainly a question of observation and sanitation. In addition to this every poultry operation should be run according to the all in - all out principle. After every production period the whole operation must be completely depopulated. The houses should be thoroughly cleaned and disinfected (see Chapter 20).

A regular inspection for signs of parasites both external (lice and mites) and internal (worms) is necessary. Indications that something may be wrong can be obtained from observing decline of feed intake, smaller eggs, and changes in the texture and colour of the droppings.
Observe the general behaviour of the birds. Remove dead birds. Check the house temperature and the feed and water supply. Also control consumption of feed and water. Deviations from the normal indicate that there is something wrong. Keep records of production and feed and water consumption.

16 Cage layer management

Cages are certainly more efficient than floor systems, in feed utilization, in using housing capacity and in labour efficiency. Generally body weight is higher in cages and so is egg weight. A better feed conversion is caused by lesser activity in cages. The mortality in cages is at least as high or even somewhat higher than in floor systems, although this is very difficult to compare as causes of disease differ. Parasite infections occur less often. Coccidiosis may still be observed but to a lesser degree. Egg production is on the whole about the same as in floor systems. Egg quality in cages is as good or even better because there are less dirty eggs.
The greatest advantage of cages is the absence of floor eggs and the possibility of better supervision including the culling of unproductive birds.

16.1 Measures to alleviate possible heat stress

Caged birds in the tropics should have more space to move about than those in temperate climates. But this depends also on the climate control in the house. In open houses it might be more necessary than in environmentally controlled houses. More space promotes heat dissipation by radiant heat transfer and will also encourage feed intake.
A caged layer hen cannot move about and look for the climate that suits her. Therefore we must provide as uniform an environment as possible. Differences along a cage row can produce different nutrient requirements, so that productivity can suffer.
At high temperatures a supply of fresh air near the birds in the cages given by means of tubes appears to be effective.

16.2 Prevention of feed waste

In order to prevent feed waste in cages usually a trough feeder is fitted to the front of the cage. The feed is transported either by a hopper or a mechanised system, e.g. a chain, a spiral system, a screw auger or a cable with discs. Wastage appears to be highest in the hopper and trough system. Hens draw the feed towards the cage side of the trough, heap it up and throw it away by quick movements of their heads (flicking), causing a lot of feed to be wasted outside the trough at the cage side. The construction of the trough is of great importance. Its depth should be not more than 10 cm and its edge at the cage side should be about 18 cm above the cage floor. At this side it must be provided with a lip to avoid the feed being thrown out. The lip should be rounded to the trough side.

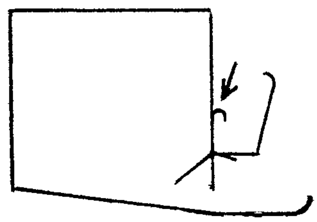


Figure 16:

Troughs should not be overfilled. Feed hoppers, either manually or mechanically moved along the food trough, are simple to use and relatively cheap. If the caretaker pays attention to equal distribution of the feed in front of the hens a lot of wastage can be prevented. A levelling shoe, attached to the feed hopper, gives an equal quantity of feed in front of each cage.
In this system hens are usually fed twice a day, in the morning and in the evening, which is in accordance with the natural feeding habit of the birds.
In chain feeders a maximum height of 1 cm of feed above the links is the best way to prevent wastage. Cable feeding always gives the same quantity of feed to the birds and may therefore be preferred.
Another factor affecting feed waste is cage density. High density gives less feed space per bird, thus less feed waste. However, as cage density should be restricted, it should not be used as a measure to decrease feed waste.
Improperly debeaked hens waste more feed.

Generally feed wastage should not exceed 1-2%. If higher, measures should be taken. The amount of waste can be measured by weighing the wasted feed at the gangway side of the cages, being approximately 20% of the total amount of waste.
Often feed wastage is the cause of a poor feed conversion.
Attention should be paid to the feed composition along the chain feeder. In some trials more and heavier eggs have been found at the ingoing side, possibly due to selective feeding. A higher chain speed, 12 to even 18 m per minute instead of 4 m per minute, is often advised to prevent this. But it is not certain that selective feeding would occur in warm environments as feeding activity is usually lower. Auger systems would be better in this respect.

16.3 Daily supervision

Adequate daily supervision may comprise:

- Checking the water supply in the morning. Blockages by sediments or air bubbles in the pipes can stop the water supply.
- Daily brushing and cleaning of the water troughs.
- Checking the feed supply. Usually there are at least two feedings a day, but in case of the necessity of a low feeding level more feedings should be given. If there are only two feedings, regular feed stirring will increase the feed intake. Check the daily amount of feed, especially during hot periods, in order to take measures in due time.
- Checking the health status. Remove sick and dead birds immediately. If time is available also some culling of unproductive birds could be done.
- Checking the ventilation. Ventilators should be cleaned and checked twice a year as a rule. Cleaning can be carried out by a simple brush or by a compressor to blow the dust out of the ventilator house. Do not use water, as it may damage the ventilator.
- Checking the lighting.
- Checking for the occurrence of parasites. External parasites (lice, flees and mites) are more frequently found than expected. They cause restlessness and even lower egg production. The more wood in the construction the more chance of mites. Clean the house regularly and spray insecticides, but with due care, as some chemicals can leave residues in the eggs and meat. Read the manufacturers' instructions carefully and follow them. In many cases the insecticides are not allowed to be used directly on the birds or on eggs, feed and water. Most of the time they are applied on slatted or wire floors.

16.4 Removal of manure

Manure dries easily in deep pit plants. The manure falls directly into the pit underneath, or, in case of tier cages, from the upper tier onto deflectors between tiers. These droppings are removed daily by means of scrapers. The manure underneath the cages will dehydrate soon by fermentation and by the warm air.
In temperate climates drying through a tube above the manure belt is by far the cheapest method.

17 How to collect eggs of good quality

Collection of eggs must lead to as many eggs as possible of a high quality. In order to define egg quality, first a brief description is given about egg formation and composition, quality aspects and factors affecting these. Next is indicated how to improve egg quality and the role of the egg collection systems.

17.1 Composition of the egg

The egg consists of one reproductive cell (the ovum), surrounded by material which is meant for the development of the embryo: the yolk and the albumen, 'packed' in a shell. In the ovary of the hen follicles develop one by one under the influence of hormones. When the first one matures, being a complete yolk with the ovum as a germinal disc on top of it, the others are already in successive stages of development, 'waiting for their turn'. The yolk is released and enters into the oviduct. Ovulation has taken place. Subsequently the whole egg is formed, as described in Chapter 1.

The newly laid egg contains approximately 65% water, most of it in the albumen, and consists of 30-33% yolk, 58-60% albumen and 9-11% shell and shell membranes. The yolk is the richest part of the egg, containing around 33% fat and 17% protein, whereas the albumen contains around 11% protein and almost no fat.
The yellow colour of the yolk is affected by colouring substances in the feed: carotenoids and xanthophyll. Although this has nothing to do with the nutritive value, consumers generally insist on intensely yellow yolks. In this respect large egg layer operations often have to compete with small producers in the country, who are delivering eggs with a yellow yolk colour which consumers find attractive. In certain countries it is worthwhile to stress that eggs which are for consumption are produced in flocks without cocks, and thus infertile (hence sometimes called 'vegetarian eggs'), as some consumers refuse to consume eggs with a living germ.
Normally in fresh eggs the yolk is situated in the centre of the egg, more or less kept in its place by the so called chalazae: winded strings of protein on two sides of the yolk.

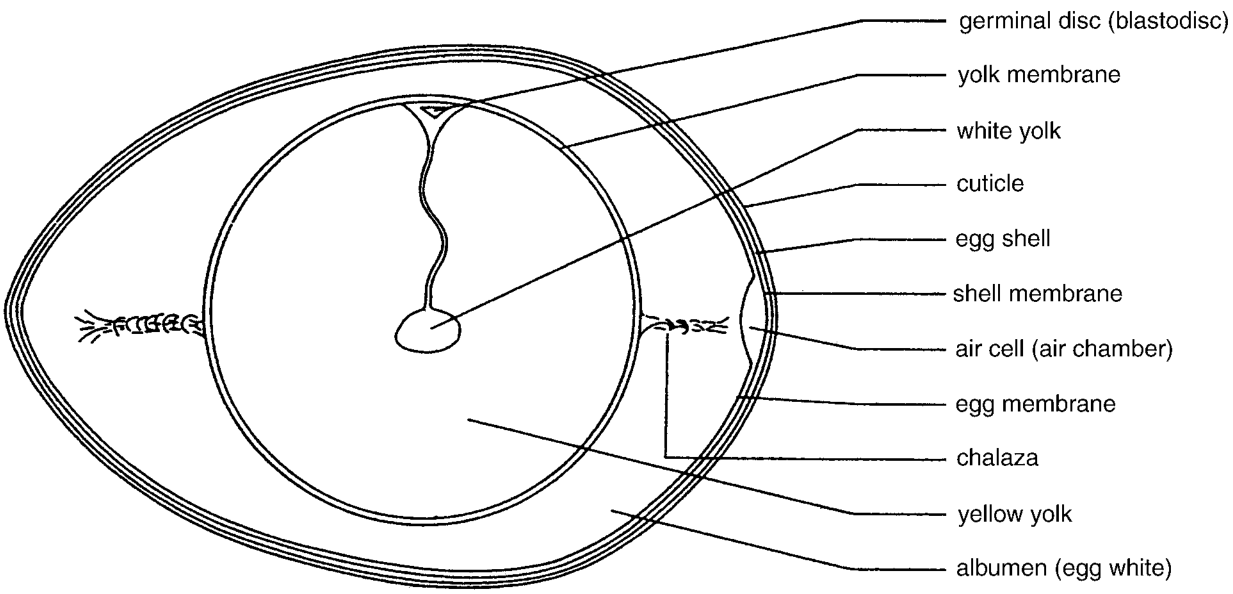


Figure 17: Egg section

These strings can deteriorate, this is influenced by the duration and conditions during the storage periods.

Around the yolk a layer of albumen is found, characterized by a high viscosity and therefore called the thick albumen, an excellent source of protein and vitamin B (riboflavine). On the outer side of the egg white another layer is found with a lower viscosity and therefore called the thin albumen.
The egg content is surrounded by two membranes, an inner and an outer one. The inner one follows the shrinking of the egg content caused by the cooling off after laying. Consequently an air space is formed at the blunt end of the egg between the two membranes. This space grows with time.
The shell consists of calcium carbonate ($CaCO_3$). Its colour may be white or brown, in different intensities, but again this colour has nothing to do with the internal quality or the nutritive value of the egg.

17.2 Egg quality

There are external and internal egg quality aspects.
Externally we distinguish the egg weight, the egg shape, the strength of the shell and shell cleanliness. Shell strength has been studied intensively, being an important characteristic both for the producer and the consumer.
Internally the colour of the yolk, the albumen quality, the size of the air space and the presence of unwanted substances (blood and meat spots) are of importance.
All of them are more or less critically judged by the consumers, if not now, then surely they will be in the future.

17.3 How to increase egg weight

If egg weight is paid for, measures can be taken to maintain or even to increase it.
Egg weight is determined by the breed or strain involved, the age of the hen, its body weight (positively correlated with egg weight), the composition of the feed, particularly the energy and crude protein content, the ambient temperature (on average 0.4 g reduction per °C) and the lighting schedule. The egg weight in cages is nearly always higher than that in floor systems.
In case of low egg weights, check the genetic potential of the strain involved and then pay attention to feed composition and climate. Lighting at the onset of lay affects egg weight through the body weight gain. If ‘stimulighting’ starts late, the first eggs are larger, but some retardation after 17-18 weeks of age might well decline the subsequent egg production. Yet this cause has only little effect on total egg mass, as the number of eggs is usually higher when egg weights are lower. For example, reducing the age at point of lay by one week may result in average egg size reduction of 1 g but an increase of 4-5 eggs laid.
The feed quality also affects egg weight. Generally every nutritional deficiency, including water, will lower the egg weight, the energy and protein levels being the most important ones. A positive effect could be achieved by adding more linoleic acid up to 1½%.
Some diseases, such as NCD and IB, will also damage egg weight.
Egg storage at high temperatures and low RH increases the loss of moisture from the eggs and thus lead to egg weight loss. In tropical areas even 85% RH is recommended.

17.4 Shell strength and ways to improve it

Many eggs become broken or cracked on their way from the hen to the consumer and their number appears to be increasing. Poultry farmers often blame the decline of shell strength, but it should be emphasized that there are also many on-farm causes of breakage.

Shell strength used to be measured in terms of shell thickness, mostly measured at the widest dimension of the egg, because the shell differs in thickness, the pointed end being the thickest. The egg shell thickness ranges from 0.30 to about 0.40 mm. Shell thickness, however, does not wholly determine the strength of the shell. Its crystalline structure, for example, also affects its strength.

Later shell strength was measured more directly by measuring the breaking strength and/or the deformation. For the first purpose pressure is put on the egg until the shell breaks, usually at a weight of 2.5-3.5 kg. In measuring the deformation the egg is loaded with a weight so that the bending or deformation, in fact its elasticity, can be measured.
Finally there is the popular specific gravity measurement: egg weight divided by egg volume, with values ranging from 1.040 to 1.090 with 1.085 being good (egg weight less egg weight in water = egg volume).

Biological, environmental and managerial factors affect egg breakage. The most important of the first group are hereditary factors, the age of the hens and nutritional aspects.
Any factor which accelerates egg formation, decreases the shell strength. The h^2 of shell strength is ± 0.30. In the course of the laying period the shell quality deteriorates, probably because of a decreasing ability to mobilize Ca from the intestine and the skeletal frame, but also because the egg weight increases during the laying period, resulting in relatively thinner shells.
As stated before, high temperatures can reduce shell strength. This may partly be caused by a reduction of feed intake, as long as the Ca content of the feed is not adapted, or in the form of a direct effect of the temperature, as a consequence of a high respiration rate (panting), causing alkalosis in the blood. In obvious cases 'night cooling' might bring an improvement, as the egg is formed mainly during the night.
The housing system and husbandry factors also affect egg shell quality. Intermittent lighting schemes may increase shell strength, although probably causing a reduction in egg mass production. Ahemeral lighting schedules (deviating from the normal 24-hour cycle) improve shell strength, particularly a 28-hour day.
Nutritional factors, such as Ca and P supply and vitamin D are already mentioned in Chapter 7. Hens which are highly productive need more Ca than the usually recommended 3.5%, especially in hot climate zones (probably 4-4.5%), and the Ca should preferably be given in the form of oyster shells, or at least as rather large particles of lime stone, as these remain longer in the gizzard. The P level should be not too high: 0.4% available P or 0.6% total P is sufficient. The Na:Cl ratio should be 1:1. If problems occur, first see if sufficient intake of Ca takes place. Although much has been reported about supplements other than Ca sources and vitamin C, their effect is very doubtful.

The most important factors are the managerial ones: the frequency of egg collection and the quality of egg handling. Even the strongest shells cannot stand poor management and poor egg handling. The highest breakages occur after the egg has been laid, in cages, during collection, on the egg collection belt and during packing.
Cage construction is important. If too many eggs are retained in the cage, cracks will occur more frequently. On the other hand the slope of the cage floor should not be too strong, not more than 7-9 degrees, because at higher slopes the eggs may collide causing small star shaped cracks. For the same reason egg collection should take place more than once a day. Moreover, the cage floor should allow eggs to pass rapidly from the cage to the collection area. To this purpose wire netting should be 1 × 2 inch rather than 1 × 1.5 and wire thickness about 2 mm, rather than 2.5 mm.

Once the eggs arrive into the collection area they should slow down again to avoid collisions. Finally transport and packing require utmost care.

17.5 Other aspects of egg quality

Eggs must also be clean. Soiled and dirty eggs can be prevented by minimizing floor eggs or dirty cage floors and egg belts. Dust and residues from cracked eggs must be removed regularly and leaking nipples must be rapidly repaired.
The egg shape is mainly genetically determined (h^2 = 0.40-0.50). It is measured by dividing the width of the egg by its length, which, multiplied by 100, gives on average a value of 75-80. Low values may give rise to breakage problems when the eggs are packed in trays.

Egg shell colours are mainly genetically determined, but high temperatures may also cause a paler colour. Diseases also influence egg colour, particularly NCD and IB.
Egg shells do not always have a smooth surface. Misshapen and abnormal shells often occur in older hens, but diseases and other external stresses may be involved. If the growing egg inside the hen is slightly cracked it will be partly repaired by additional calcification. This shell abnormality is detected by candling and is called ‘body checked’ eggs. Its number increases with flock age and, quite understandably, with increasing numbers of hens per cage.
‘Pimpled’ eggs are also more frequent in older hens. Corrugated shells are caused by IB. Coated eggs, with a ‘sandpaper’ texture on the shell surface, are caused by a too long retention of the egg in the shell gland, due to external disturbances.

17.6 Internal egg quality

‘Nature’ only knows the egg as a reproductive tool fitting the proper development of the embryo (a miracle in itself!). Nature does not know that humans want to consume the egg. There is little that men can do to influence egg composition and other characteristics of the freshly laid egg, apart from influencing the colour of the yolk through the feed, by natural or artificial feed additives.
Albumen quality is an indication of freshness. Large air cells and watery thin egg whites can be caused by an either too long or an inadequate storage (too warm and too dry). Eggs should be stored at 10-15 °C in cooling units, at a RH of 70-80%. Windows are not necessary. In the case of mechanical cooling the temperature should not be much lower than outside temperatures when delivered, as in such a situation condensation on the egg surface (‘sweating’) will occur. In warm climates 16-18 °C will be satisfactory.
Watery albumen is also brought about by the diseases NCD and IB. Substances from rape seed meal and cotton seed meal can affect the colour of the albumen.
The internal egg quality in terms of firmness of egg white is expressed in so-called Haugh units, measured by a special device, which measures the height of the contents of a broken egg.
The albumen quality deteriorates with age, which is speeded up at high ambient temperatures and delays in collecting and/or cooling.
Blood spots in the albumen or, usually, on the yolk are attributed to stressing factors around ovulation time. The defect is seen more in cages than in floor systems. Nutritional factors, like deficiency in vitamin K, may also be involved.
One of the complaints regarding commercial egg quality is about ‘poor taste’. Several factors can be involved. One is the presence of trimethylamine, caused by too much fish meal or rapeseed meal in the feed.

17.7 Egg collection and egg handling

Eggs can be collected manually or partly or fully mechanized.
Manual egg collection in baskets before delivering the eggs in trays will cause some extra breakage. Therefore it is better to collect eggs directly into trays, which can be carried along on a lorry in a gangway or on a lorry hanging on a rail, mounted to the ceiling of the poultry house.
In modern large laying units eggs roll away from the nest or from the cage floor onto an egg belt, which transports the eggs to the packing room. This system can be fully automated when the eggs from the belt are transported further by means of cross conveyors to a fully mechanized packing system. Such an automatic egg collection device enables the farmer to collect eggs outside the actual laying house in a central egg collection room. That is labour saving and healthier, particularly if the house is dusty.
In the case of tier cages vertical elevators are installed.

There are several types of farm packers available. They can save as much as 75% of labour time. Full trays can be directly transferred to containers, which are used for transporting the eggs to the packing station or processor. Machines can grade and pack eggs automatically into trays and cartons.

Mechanical egg handling is not necessarily more detrimental to eggs than manual egg handling. If all junctions and connections are properly constructed egg damage can be greatly reduced. This, however, is not always the case. Sometimes breakage occurs, when the conveyor speed is too high or when too many eggs are transferred at a time. Supervision is important.

If grading provides price differentials it may be a great incentive to the poultry farmer to improve egg quality. First quality eggs should be fresh, free from extraneous odour, have a clean normal and undamaged shell, clear limpid albumen, a visible but not clearly discernable yolk on candling, which does not move away from the centre of the egg, and an imperceptibly developed germ cell. The air cell should be stationary and not exceed the height of 6 mm. Sooner or later such standards will be applied everywhere in the world.

18 Production standards, records and costing systems

We must aim at the best economic results within the possibilities of the genetic potential of the flock. Generally this aim will be presented by the breeding companies which provide us with the standards we can use to check whether our management is successful.
However, there are still other standards, for example used in Random Sample Tests RST, and, particularly important, management data with a financial background.

18.1 Production standards

From a RST in the Netherlands we derived the following data:

Hatching and rearing (growing):
- eggs candled after 18 days hatching (%)
- chicks from eggs set,and chicks from fertile eggs (%)
- hatching egg weight (g)
- chick weight (g)
- mortality in the rearing period 0-18 weeks (%)
- feed consumption per pullet at 18 weeks (kg)
- body weight per pullet at 18 weeks (g)

Laying hens:
- laying period (days)
- mortality (%)
- age at 50 % production (days)
- hen day production in the 13th 4-week-period = persistency (%)
- number of eggs per hen day
- egg weight (g)
- number of eggs per hen housed
- egg mass per hen housed (kg)
- income over feed costs
- final body weight per hen (kg)
- feed intake per hen (kg)
- feed conversion ratio f.c.r. (kg feed per kg eggs)

Broiler test:
- chicks from eggs set, and from fertile eggs (%)
- mortality of males, females and total (%)
- final body weight of males, females and total (g)
- growth per chick per day (g)
- feed conversion ratio f.c.r. (kg feed per kg final body weight)
- performance index (% surviving chicks × growth per chick per day in kg × 100/f.c.r.)

For broiler parent stock the same data as in laying hens can be used, added with data about the number of hatching eggs, fertility rate and hatchability (see Chapter 11).

Some other standards are usually provided by the breeding companies, such as:
- average egg production (%)
- peak production (%)
- total egg production
- percentage production per hen per day = total eggs per period × 100 / average number of hens

- hen housed per cent production = total eggs to date × 100 / number of pullets housed × number of housing days
- egg quality (breaking strength or Haugh units)

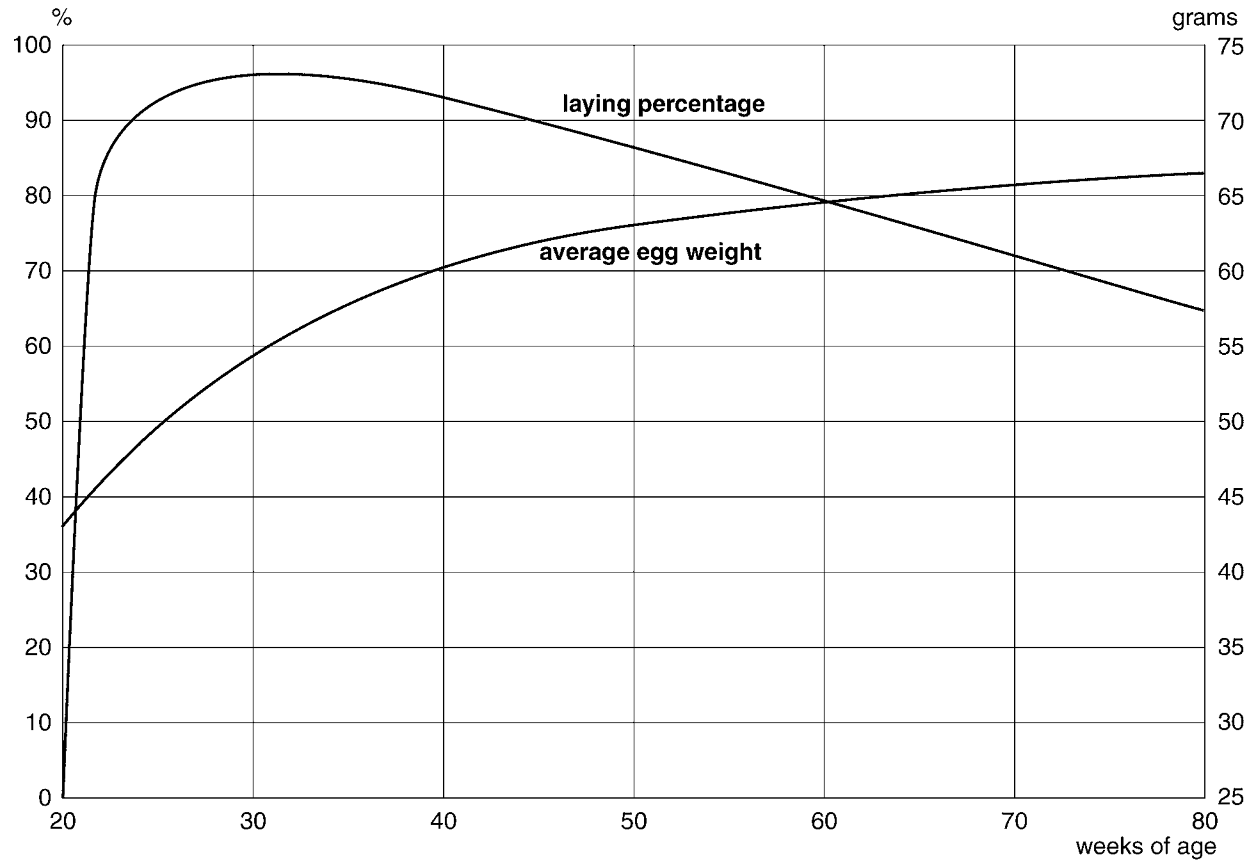


Figure 18: Age, laying percentage and average egg weight

Hen day production = total number of eggs produced / average number of hens present
(= total number of hens each day / number of days).
Hen housed production = total number of eggs produced / number of pullets housed at the start of the laying period.

The hen day production is a good indicator of how the live hens are doing, so it is a good measure of productivity.
The hen housed figure is a measure for the performance as a whole, as it also accounts for mortality.

18.2 Examples of cost calculations

The technical and financial data of our enterprise are used in cost calculations.

a. Costs per pullet

Assumptions:

- Investments in buildings and equipment.
  Costs of investments in buildings and equipment, consisting of depreciation, interest and maintenance of buildings and equipment respectively. For example:
  For buildings: 5% depreciation, 5% interest, 2% maintenance = 12%.
  For equipment: 10% depreciation, 5% interest, 3% maintenance = 18%
- Feed consumption and feed price.
- Length of the rearing period, for example 18 weeks.

- Mortality, for example 5%.

Costs per pullet:
A. Variable costs :

➢ day old chicken (=1.05 × price d.o.c.)	...
➢ feed costs	...
➢ medicines, vaccinations, disinfections	...
➢ electricity costs	...
➢ heating costs	...
➢ costs of drinking water	...
➢ costs of debeaking	...
➢ interest (d.o.c. + ½ feed costs) (interest rate)	...
➢ litter costs	...
➢ miscellaneous	...
	+
sub total	...
B. Fixed costs:	
➢ costs of housing:	
(0.12 × price/m^2)/(2.5 × number of birds/m^2) × 100/95	...
(0.18 × costs of equipment per bird / 2.5) × 100/95	...
➢ labour costs	...
	+
Total gross costs	...
C. Side revenues (broken eggs, culls, manure, empty bags, etc.)	...
	–
Total net costs per pullet	**...**

See the STOAS guides 'the farm as a commercial enterprise' and 'farm accounting' on this subject.

b. Egg costs

Assumptions:
- Costs of investment in buildings and equipment:
  buildings: 5% depreciation, 5% interest, 2% maintenance = 12%
  equipment: 10% depreciation, 5% interest, 3% maintenance = 18%
- Feed consumption (for example 110 g / hen / day) and feed price
- Production, for example 75% per hen day, egg weight 60 g
- Production period: start production 2 weeks, 60 weeks production period, 2 weeks cleaning; in total 64 weeks = 448 days
- Cost price pullet
- Mortality, for example 10%
- Culled hens
- Miscellaneous
- Labour

Costs per hen housed:
A. Variable costs:

➢ pullet costs	...
➢ feed costs	...
➢ electricity costs	...
➢ drinking water	...

- medicines, disinfections, vaccinations ...
- miscellaneous ...
- interest of stock: 0.10 × (pullet + (feed costs × 0.9)) × 434/365 ...
- litter costs ...

——————— +

sub total ...

B. Fixed costs:

- housing costs: 0.12 × investment/hen × 448/365 ...
  0,18 × equipment/hen × 448/365 ...
- labour costs ...

——————— +

Total gross costs ...

C. Side revenues:

- manure ...
- slaughtered hens ...

——————— –

Total net costs **...**

Costs per egg = total net costs / number of eggs produced = ...

19 Broiler production management

Broilers are usually kept in floor systems. Cages have some advantages: they enhance feed efficiency, the birds suffer less from parasites (no coccidiostat required), litter which may be expensive and in short supply is not necessary, and the interflock cleaning period is shorter. By removing small birds a higher uniformity can be achieved. On the other hand cages give rise easily to problems such as breast blisters and/or infected feather follicles, and wing and leg fractures. Moreover, the investment is probably, in most cases, higher than that of a floor system. Thus usually the floor system is used but in some countries cages are successful. These cages may measure 100 cm × 60 cm and contain 18-19 chickens. In this chapter we deal with the floor system only.

19.1 Choice of stock

One of the first, and presumably one of the most important, decisions to take is the choice of the type of strain to work with. Broiler chickens are crossbreds from selected strains of heavy breeds. These hybrids, often also called strains, may differ considerably in their potential performance. Their genetic disposition could be assessed in Random Sample Tests (RST), where entries of different broiler strains are compared under the same environmental circumstances, but broiler tests are not carried out very often and broiler testing does not give the complete picture if fully integrated enterprises are involved. In that situation the egg laying potential of the parent stock should also be taken into account. Fast growing chickens generally originate from parent stock with lower egg production and therefore these chickens are more expensive. In integrated systems it is the combination which is important.

19.2 Housing

There are different sizes of broiler houses, but some general principles must be observed. In large, and particularly wide houses, climate control may be more difficult to achieve than in smaller houses. A width of 8-10 m seems to be optimal as long as natural ventilation is applied.

In Europe wider houses, even to 14-16 m wide, are used with a length of 60 m or more, but then of course mechanical ventilation is installed.

A concrete floor is a must in order to be able to clean and disinfect the house thoroughly after each batch. Walls and roof should be well insulated, e.g. with polystyrene or polyurethane sheets, at least 3-5 cm thick (see Chapter 4).

Broilers are usually kept on litter. Housing on wire or slatted floors is possible, but these systems may give rise to breast blisters and leg problems, just as in cages, and thus lead to a lower quality.

Stocking density varies, for the greater part depending on the live end weight of the broilers. In Europe 22 birds or more per m^2 are customary. During the summer season a lower density is preferred. We do not recommend such a high housing density in tropical countries. Lower densities give more chance for the birds to loose heat. Moreover, housing density is a matter of weighing housing costs per bird against the risk of a reduced growth rate and loss of quality.

In tropical areas where the housing is usually cheaper and simpler, a much lower stocking density is applied, e.g. 10 to 15 birds per m^2.

19.3 Feed efficiency

The most important costs in broiler growing are the feed costs. They may amount to as much as 60-70% of the total costs. The broiler manager must therefore try to keep these costs as low as possible. The obvious way to achieve this is by a favourable feed efficiency, sometimes defined as the ratio of the broiler live weight divided by the amount of consumed feed, but the reversed ratio is also often used. We call this the feed conversion ratio (f.c.r. or FCR).

This efficiency depends on many factors: the genetic disposition of the strain involved, the type of feed, climate control, disease prevention and the daily management.

19.4 Daily management

Adequate management starts with proper preparations for the reception of the day old chicks. The house should be prewarmed to at least 32 °C, provided with dry litter on a clean floor and with fresh drinking water. The litter may consist of all sorts of materials as long as it absorbs moisture. The layer thickness depends on the ambient temperature. The layer should not be too thick in warm environments; 3 cm will do.

When the chickens arrive we must pay utmost attention to their behaviour. Are they lively and do they form a uniform flock?
Give them sufficient light immediately (about 20 lux) so that they can find water and feed easily. After a few days the light intensity should be decreased to 1-2 lux to reduce the activity of the birds and prevent them from pecking each other.
The quality of the day old chicks is a decisive factor for a successful flock. If the mortality during the first days is unusually high, there might be something wrong with the hatch.

After the first day you should start to check daily: the temperature, feed and water consumption, litter condition and behaviour and health of the chickens. Also the growth rate should be followed closely. Weighing of broilers can be done nowadays by means of electronic live bird weighers.

Broilers are usually vaccinated against IB at the first day, at the hatchery, or at 2-3 weeks of age, on the farm; against NCD and Gumboro at 1-2 weeks of age.

Generally, separated raising of cockerels and hens may give a somewhat higher live end weight and better uniformity, but the costs are not fully compensated.

19.5 Temperature control

The temperature on the first day should be at least 32 °C, but not higher than 35 °C, at chicken height. It must then gradually be reduced to 30 °C at the end of the first week. Thereafter the temperature may decrease 3-4 °C per week so that it arrives at a level of 20 °C at an age of 4 weeks. From that age the temperature should be maintained at that level or some degrees higher, but preferably not higher than 25 °C. If under tropical conditions this is not achievable we have to accept the consequences, but we must continue our attempts to make circumstances as favourable as possible.
For heating purposes a number of devices are available: propane or natural gas brooders, infrared radiant brooders, and also central heating. Space heaters are often used. Check the temperature and air quality regularly during brooding. Control airflow patterns.

Suggested temperature schedule:

Week 1	32-30 °C
Week 2	30-26 °C
Week 3	26-23 °C
Week 4	23-20 °C
Week 5 to end	20 °C

As already pointed out, high temperatures reduce feed intake and growth. Temperature levels can be controlled by ventilation. Under hot climate conditions the ventilation capacity should be approximately 5 m^3 per chicken per hour, with inlets amounting to 1.5 cm^2 per m^3 ventilation. If it is not possible to keep the ambient temperature at acceptable levels this way, cooling must take place. In hot and humid climates in the tropics this will merely mean increasing air movement. In dry and hot regions evaporative cooling can be applied (see Chapter 5). As pointed out before, the lower the RH of the air, the greater the evaporation and therefore the greater the cooling effect. However, broilers reared under an evaporative cooling regime are more susceptible to excessively high temperatures, for example during transport, than those exposed to a normal cyclic regime.

Fluctuations may not be avoidable, but they will not be very harmful. Adjustment of the climate is more effective than nutritional adjustment.

When purchasing ventilators check their capacity (m^3/hour), adjustment possibilities, noise and their consumption of electric power per 1000 m^3 air removal. Fans are usually adjustable by changing the number of revolutions/minute from a minimum to maximum and vice versa.

19.6 Relative humidity

The RH is another important climate factor. It is closely related to the ambient temperature. Therefore the RH may be very low at the start of the growing period, because of the warming up of the air inside. It may even be too low, particularly when the young chicks are deprived of water or have been hatched at too high temperatures and therefore may be extra sensitive to lack of water. However, soon after the start of the growing period the RH increases due to the water vapour production from the chickens. The RH may range from 50 to 80%. The critical period for RH control is between 3 and 5 weeks of age. During this period the RH should not exceed 70%, particularly in hot seasons. In most cases the applied ventilation will be sufficient to keep the RH at an acceptable level. Experiments have shown that at 20 °C the RH level is of little importance, but in warm climates it may only make things worse.

19.7 Air composition

As far as the gaseous content of the house is concerned the ammonia (NH_3) level could cause some problems; particularly when ventilation is minimal, the NH_3 content may rise to unacceptable levels. Generally the ammonia level should not exceed 25 ppm. Every 10 ppm ammonia level is said to depress the body weight by 1%. A noticeable eye and nose irritation by humans indicates 25 ppm ammonia being present and would reduce body weight by 2.5%.
Too high NH_3 concentrations cause keratoconjunctivitis, a higher susceptibility to diseases of the respiratory tract, reduced growth rate and skin lesions.

Computerised climate control is coming into use particularly in the broiler sector. In its most ‘simple’ form temperature and humidity can be controlled automatically to maintain a given situation as programmed. With more sophisticated regulation the computer also registers changes in the environment.

19.8 Feeding systems

In modern broiler houses the feed is distributed by automatic feeders. Hand filled tube feeders are also possible. Whatever system is used it is always necessary to give the chickens sufficient feeder space (cm/bird). Insufficient space will cause differences in growth rate and thereby a less uniform flock. Mechanical feeders should be run several times a day.
Feed efficiency can suffer by a too high percentage of wasted feed. Wastage can be prevented by keeping the feed level in the feeders as low as possible and by installing a grill in the feeder.
Feed consumption of broilers must be stimulated in order to enable them to grow according to their genetic potential. Therefore the feed is provided in pellet form or as crumbs. Moreover, the energy level of the feed should be high: usually 3100 to 3200 kcal per kg or even more, with a crude protein content of 22 and 18% for a broiler starter and finisher respectively.

19.9 Water supply

Broilers must be provided with clean and cool drinking water. The birds must have access to the water system at all times. Generally this means that the birds should not have to walk more than 3 m to reach the watering device. Adequate distribution of drinkers throughout the house is of utmost importance.

For the young chickens so-called mini drinkers or founts should be used: 1 for every 50 birds. As the birds grow older these founts can be gradually withdrawn. In litter systems round drinkers are commonly used: 1 for every 150 birds if the diameter is about 30 cm.

The litter must be kept friable; this means not capped (i.e. hard topping or coating) by too much moisture and greasiness. High inclusions of soya and/or manioc or excessive salt may cause wet droppings and thus wet litter. Greasy litter can be caused by a high dietary level of fat, which young chickens cannot digest completely. Hard capped litter causes skin burns and breast blisters. Litter moisture content should not exceed 45 %. Poor ventilation, too high housing density and poor control of the drinkers may be the causes of capped litter.

Under these circumstances bell shaped drinkers should be replaced by small cup drinkers or nipple and cup/nipple drinkers. These give less rise to wet litter and the water is always fresh and less contaminated. However, if they lead to less water consumption, they may not be suitable in hot climates.

19.10 Lighting

Lighting of broilers, being young birds, will not have any effect on the hormonal system. It merely helps the birds find the feed and water during the first days. Later too much light would only give rise to pecking and cannibalism, so light intensity should be kept as low as possible. Rest promotes growth rate. In open houses a high light intensity cannot be avoided, but activity will already be limited due to the high temperatures. In closed houses dimming is necessary, either electronically or by replacing bulbs with a lower intensity.

The lighting system most often used in broilers is continuous lighting during the whole day, or 23 hours per day, the latter in order to get the chickens acquainted with darkness, in case light is lost due to a power cut. Also in open houses dim artificial light could be provided during the dark hours, again with the exception of 1 hour.

Lighting in the cool morning hours and/or evening will stimulate feed intake.

However, from various experiments we have learnt that systems with alternating short light and dark periods, the so called IL patterns, could give better results. The system most often used provides light for 1 hour and darkness for 3 hours. Such a scheme, indicated as 1L:3D, would save electricity, causes less leg problems and gives a better feed conversion. It should not start too early. One must be sure that the birds are able to find feed and water and there must be sufficient feeding and drinking space. During the light period the activity of the birds increases, causing a favourable effect on the development of the legs (‘jogging effect’).

The only disadvantage is that the birds at the end of the growing period are difficult to catch. It seems that the temperature in the dark period should be somewhat (may be 3 °C) higher. Although a higher temperature generally leads to a better feed conversion, it should not be overdone, because then the effect disappears.

Light intensity should not exceed 3 lux. Brighter light gives rise to cannibalism and depresses growth rate.

19.11 Measures at delivery time

Broilers should be taken off feed approximately 6 hours before slaughtering. So if catching, transport and waiting time at the slaughter house will take two hours, as a rule of thumb a fasting period of 4 hours before catching is sufficient. This procedure guarantees both minimal contamination at the slaughter house and an efficient feed conversion.

However, full access to clean drinking water remains important.

Catch and transport broilers only during cool hours.
Adjust crate densities; for example not more than 16 kg per m^2.
Losses by downgrading may occur if careful catching is not carried out.

19.12 Record keeping

Use standards to compare your results. In the Netherlands some technical standards used for broiler cost calculations are:

Weight at delivery 1.8 kg
Feed conversion 1.9
Mortality % 4.8

These traits can be combined in a so-called ‘productivity index’ being: daily growth rate × percentage of survivors / feed conversion.

The most used standard of judgement is the margin/m^2/day.
Recorded are:

- the growing period (days, including starting day, excluding delivery day),
- the period the house is being cleaned and left empty (days),
- housing density (number of chickens per m^2),
- mortality (%),
- live weight at delivery (kg total/ number of delivered chickens),
- growth/bird/day (total kg delivered/ number of bird days),
- price at delivery,
- feed conversion (kg/kg),
- feed price,
- chicken price,
- feed costs,
- margin of yield minus feed costs and chicken costs,
- costs of heating,
- costs of medicine (medical treatment + disinfection),
- delivery costs (costs of catching and loading, weighing),
- litter costs,
- total direct costs, that is: all costs, except feed costs, chicken costs, housing costs, general costs and labour costs; general costs are often forgotten: insurance, car costs, accountancy, telephone costs, meetings and excursions, contribution to an association, subscription costs, etc.
- margin of yield minus feed costs, chicken costs and total direct costs,
- labour income,
- margin per m^2/day, being: labour income + housing costs/m^2/day.

Calculation of housing costs:
Calculate costs per m^2 broiler house and equipment, separately!
Then calculate total interest, depreciation and maintenance:

Table 25:

	Average interest	Depreciation	Maintenance	Total
House	5	5	1	11
Equipment	5	10	2	17

The sum of these would be the total costs per m^2 per year. Divided by 365 it will give the total costs per day per m^2.

The quality of meat is becoming more and more important. Tenderness is much appreciated, fat content should not increase. The taste of the meat is improved in older birds. Nutrition affects taste; fish meal and milo produce adverse effects, oats and wheat positive effects. In the near future data concerning the composition of the carcass will also be available. Todate the proportion of breast fillet has increased, from 20% to 22% or more. Processing also has a great influence on meat quality.

With the help of a computer a better surveyable records administration can be kept. Moreover, by the use of special programmes a quick calculation can be made of the results.
It is necessary to record daily the mortality, feed and water consumption and temperature. A sample of birds should be weighed weekly in order to calculate the feed conversion. At the end of the growing period it should be possible to calculate the daily growth, the feed conversion and the total mortality. Comparisons can be made with the results of former flocks and, if possible, with the results of other broiler farms.

20 Disease prevention: hygiene

All existing poultry diseases will, sooner or later, be found all over the world, due to the wide distribution of breeding stock. Wherever poultry is kept, disease prevention is one of the most important issues in poultry operations; this applies also in the tropics. Prevention is cheaper than cure.
Hygiene is the most important factor in preventing diseases. Vaccinations are also effective preventive measures.

20.1 Hygiene

Areas with high poultry density may easily give rise to transmission of infections. Dry, dusty conditions, for example, promote the dissemination of airborne pathogenic organisms (Marek virus). Therefore the farm should be located as far away as possible from other poultry farms.
Man is often the carrier of pathogenic germs from one farm to another. Fences should protect the farm against any intruder, man or animal. No visitors should be allowed to enter the farm. If inevitable, access should not be possible without proper disinfection, including changing clothes and disinfection of shoes or boots. Used boots should be thoroughly cleaned (water, brush, grill), then dipped into a container with disinfectant and dried on a rack. This process of disinfecting should be repeated everytime the boots are used. Refill regularly (every 2-3 days). Chlorine based disinfectants are effective only as long as the pH of the contents is neutral.
In a sanitary room at the entrance of the poultry house you can install a foot bath with a disinfectant, a wash-basin, a coat rack with special clothes, foot wear only to be used at entering the poultry house concerned, and finally a disinfectant containing second foot bath at the entrance of the pen. It should have a concrete floor sloping to a drain.
All materials entering the farm should be controlled, including feeds and feed trucks. As birds can be carriers of disease, try to make the ventilation inlets and other openings bird proof. Combat penetration of vermin as much as possible.
Workers on the farm should not have any poultry of their own.

Once all the precautions at farm level have been taken hygiene within the farm must be given attention. One of the major hygienic issues is the all in-all out system: only one age of one kind of poultry on one farm. Multiple ages are still a major obstacle to good bird health. Single ages are a must.

20.2 Cleaning and disinfection of the house

Every time a flock has arrived at the end of its production period the house must be cleaned and disinfected for the next flock. Remaining birds, equipment that can be put elsewhere, and litter, are removed. The litter must be deposited far from the house or used immediately as a fertilizer, to prevent reinfection after cleaning. Then dry, loose dirt is removed, working from top to floor, for example with a vacuum cleaner. The equipment should be soaked in a tank containing disinfectant or be otherwise disinfected.
Water is the best disinfectant. Although this may seem to be an overstatement, it is a fact that the use of large quantities of water at the start of the cleaning operation will remove many potentially pathogenic micro-organisms. The wet cleaning should start by soaking house and equipment. If only water is used, soaking time should be at least 3 hours. If a detergent is also included to loosen the dirt, then soaking is only necessary for ½ to 1 hour. Clean the equipment with a high pressure sprayer. Then reinstall it and let the house dry up. After drying the house can be disinfected. The watering system should be drained and repeatedly flushed to remove blocking material. Thereafter it can also be disinfected and then flushed again with clean water.

Not all disinfectants are equally effective against all pathogenic germs. If many germs are killed we call it a disinfectant with a broad spectrum activity. A disinfectant should be stable in the atmosphere and during storage, readily soluble in water for ease of application, non corrosive for equipment and tools, readily available, have no objectionable odours and be relatively safe for men and animals, without residual toxicity.

Acids and alkalies do kill many microbes, but they are irritating and corrosive. Only sodium hydroxide (NaOH), in a 2-3% solution, is sometimes used because it is very active, even in a dirty environment.
Quaternary ammonium compounds (e.g. Farmquat) are very active against bacteria and viruses and remain active in organic material. They are most suitable on smooth surfaces.
Some chlorine based disinfectants are rather popular (e.g. Halamid). They kill nearly all bacteria and viruses in a relatively short time, are soluble in water, non toxic and not expensive. In organic material, however, they loose their activity rather rapidly and they corrode metals. Therefore as much organic material as possible should be removed beforehand. Chloramine is used in ½ or 1% solution.
Phenol derivatives are more active in organic material, but their disinfecting activity is not so strong, especially against viruses. Sometimes a so-called pine oil disinfectant is used, belonging to the phenolic group. It is not toxic, non irritant and has a pleasant colour and odour. It is favoured for hatcheries.

Formaldehyde gas, a very effective disinfectant, can be applied in various ways. A 10% solution of formalin (containing 40% formaldehyde) can be used to disinfect surfaces (1-2 litres per 10 m^2, depending on their porosity). It is not corrosive, but it is irritant and it should be applied very carefully due to its toxicity. Its action is strongly affected by temperature; the warmer the better, so it is a preferred disinfectant in hot climates.
Formaldehyde can also be used for fumigating. For this purpose either a 40% solution or paraformaldehyde in powder form or chips is heated in an electric pan. One pan per 1.000 m^3 is used, taking about 4 g of chips per m^3. After 1 hour of heating the gas will evaporate for 3-4 hours. The heating of the paraformaldehyde must be started by remote control.
The disinfectant can also be evaporated from formalin by pouring it onto potassium permanganate ($KMnO_4$). The heat of the chemical reaction is considerable. This way of disinfecting with formalin is largely used for disinfecting hatching eggs (30 ml formalin and 20 g $KMnO_4$ per m^3).
Fumigation with formaldehyde must be carried out in fully closed houses, which are kept closed for one night. Then it takes 2 days of ventilation, before the new stock can arrive. Formalin fumigation is unpleasant for the worker. The use of a gas mask is strongly advised. Protect hands with gloves.
After disinfection the house should stay empty for a while. Such a resting period, preferably 14 days, will reduce germ activity.

20.3 Some important poultry diseases and disorders caused by parasites

An elaborate discussion of all the diseases and disorders occurring in the poultry industry would take the size of a handbook and such handbooks are already published.
We ourselves would like to refer our readers to the other AGROMISA guide on chicken farming **(the 'basics' text)** which has a chapter on infectious diseases and their prevention (about 30 pages text) and a chapter on disorders caused by parasites (about 20 pages).

Name	Cause	Symptoms	Prevention	Treatment
New Castle Disease (NCD)	Virus	Respiratory troubles, nervous signs, green diarrhoea, egg drop	Vaccination	None

Infectious bronchitis (IB)	Virus	Respiratory troubles, egg drop, misshapen eggs	Vaccination	None
Infectious laryngo-tracheitis (ILT)	Virus	Respiratory problems	Vaccination	None
Fowl pox (avian pox)	Virus	Lesions on comb, wattles and face, yellow membranes in mouth cavity	Vaccination	None
Egg drop syndrome (EDS)	Adeno-virus	Egg drop and weak shells	Vaccination	None
Lymphoid leucosis (LL)	Virus, horizontally and egg transmitted	Large liver	Strict sanitation, LL-free stock	None
Marek disease	Virus, herpes type	Nervous disorders, paralysis	Vaccination	None
Avian encephala myelitis (Epidemic tremor, AE)	Virus, egg trans-mitted	Paralysis, nervous tremors, paralysis	Vaccination	None
Infectious bursal disease (Gumboro disease)	Virus	Watery diarrhoea	Vaccination	None
Malabsorption syndrome (MAS)	Virus	‘Helicopter chickens’, leg problems	Strict sanitation	None
Fowl cholera	Bacterium: Pasteurella multocida	Swollen joints and wattles, darkened heads	Sanitation	Antibiotics, sulfa drugs
Fowl Typhoid	Bacterium: Salmonella	White diarrhoea, mortality	Sanitation, blood monitoring	Sulfa drugs, antibiotics
Coli bacillosis	Bacterium: E.Coli	Diarrhoea	Sanitation	Antibiotics

Infectious coryza	Bacterium: Haemophilus gallinarum	Mucous discharges from nostrils	Sanitation, MG control	Antibiotics, sulfa drugs
Spiro-chaetosis (tick fever)	Bacterium: Borrelia	Greenish diarrhoea, lameness	Combat ticks	None
Chronic respiratory disease (CRD)	Myco-plasma (MG)	Respiratory signs	Sanitation, monitoring, use of MG-free flocks and vaccinations	Antibiotics
Coccidiosis	Protozoa (Eimeria)	Diarrhoea	Sanitation, dry litter, coccidiostats	Sulfa drugs
Worm infections	Various kinds of worms	Diarrhoea	Sanitation fresh litter, avoid exposure and overcrowding	Various anti-worm drugs
Ascites	Inadequate oxygen supply, due to inadequate management or altitude	Low hatching results and performance, water belly	Higher ventilation rate	None
Fatty liver syndrome (FLS)	Too high energy intake	Excessive fat accumu-lation in liver	Reduction energy intake	Change diet, adding of vitamins

The first signs of a disease outbreak are a decrease in water and/or feed intake and less activity of the birds. Remember: an early diagnosis contributes to the possibility to take measures in time. Medication through the drinking water is presumably more attractive than medicated feed, because it can immediately be applied in any dosage. However, the water must be clean and a dosage device must be available. The total live weight and the daily water intake must be known in order to get the right prescribed amount of medicine to be administered. Calculate the size of the tank which is needed in order to know which concentration is achieved. This concentration should not be too high, because in that case the birds would not drink the water because of the taste. Moreover, they might take the medicine in a too short period.

20.4 Vaccination

Most of the vaccinations are given against viral diseases as they cannot be therapeutically healed. Amongst them there are respiratory diseases, such as NCD, IB, ILT and Fowl Pox (FP), but also

Gumboro disease, Marek disease, AE and EDS. Vaccinations are also applied against some bacterial diseases and attempts are made to do so even against coccidiosis.

Immunity against diseases can be built up either actively or passively. The passive immunity is received from antibodies passed on through the hatching egg from the mother hen to the chick (maternal immunity). Immunity built up by the bird after a natural or an artificial infection (vaccination) is called active immunity. Since the passive immunity does not last long - generally not much longer than a week - vaccination must protect the birds against diseases.
Vaccines contain either living or killed pathogenic organisms, which are administered to incite the formation of antibodies in causing either a gentle degree of the disease involved or no disease at all. Live vaccines can be derived from untreated natural or from attenuated infectious matter (lentogenic or mesogenic, depending on its activity). When a severe reaction is produced the natural microorganism must be weakened, which is realized by passing it through several infected tissue cultures or other objects of infection. Although vaccines should be rather mild to avoid severe negative effects, they should be strong enough to stimulate the formation of antibodies.
Dead or so called inactive vaccines have a high concentration of pathogenic organisms on an oil basis, which is retained in the tissue for a long time, thus allowing a slow release of the organism and providing a long lasting protection.
Sometimes birds have to be pre-immunized with live vaccines to obtain an optimum effect from the dead vaccine. This is advantageous in case of high levels of maternal immunity from vaccinated parents. However, vaccination with inactive oil based vaccines is a time consuming work, as an individual injection is necessary. On the other hand the time of administration is flexible, so that it can be done when the birds are being handled for other reasons.
Live vaccines should be stored in a dark place at 4 °C. Vaccine bottles should be opened by immersion of the bottle in a small quantity of water. This concentrate should then be thoroughly mixed into the final water volume. Opened bottles must be used within 2 hours. Dead vaccines can be stored under normal conditions.

Vaccination procedures

Live vaccines can be administered by injection - either into the leg muscle or under the skin at the base of the neck (Marek) - through the eye drop method or intranasal (ILT), through the drinking water (ND,IB and Gumboro), or through the wing web or follicular route.

Vaccination via the drinking water is done most frequently. Yet immunity from vaccination by this way may vary. Important is the time of water consumption (2 hours). Ensure adequate drinking water space. Drinkers should be clean and free from disinfectants and antibiotics. The birds should have no water for 1-3 hours before vaccination, depending on the age of the birds and the temperature level. Enough water space should be provided to such an extent that at least 2/3 of the birds can drink at one time. Adding of 2.5 g of skim milk powder per litre water before the addition of a virus vaccine can improve the results. In hot climates vaccination should be carried out during cool hours, preferably in the early morning.

Spray vaccination has become popular because it needs less labour. It is a quick and effective method for vaccinating a large group of birds. Droplet size is important. If too small, they penetrate too deeply into the lungs and may cause pneumonia; if too large they do not penetrate deeply enough. A droplet size of 3-10 microns is recommended. The older the bird the finer the droplets should be. Only spraying against Gumboro should always be done with a coarse spray.
When spraying all air movement in the house must be avoided, by closing the windows and/or curtains or by shutting off the fans for one half or three quarters of an hour. Personnel doing the vaccination must wear goggles, a face mask and protective clothing. As long as the ventilation system is turned off, they should monitor the birds' behaviour, particularly in hot weather.

In the wing web method the needle, filled with the vaccination solution, should be inserted from beneath. For the follicular vaccination the birds should be at least 10 weeks old, because only these have sufficiently developed feather follicles. At least 15 feathers from the front side of the shank are removed and the follicles are to be rubbed into with the vaccine solution.

Inactivated vaccines must always be injected individually, usually into the leg muscle, sometimes into the breast or subcutaneous, midway between the base of the skull and the body.
Attempts are made to vaccinate village chickens against NCD by means of an oral vaccination with feed treated with a vaccine.

During the post-vaccination period stress must be avoided, as it may strengthen possible negative reactions and even could lower the bird's immune response, which can be measured by assessing the height of blood titers.
Always follow the manufacturer's instructions carefully. Records should be kept of the vaccine manufacturer, the batch number, the date used, the birds' number and their reaction.

Vaccination schemes

As several vaccinations have to take place generally a vaccination scheme is followed. Important factors are:

1 Kinds and types of vaccines that are available.
2 Presence of diseases.
3 Age at vaccination. Young birds may not respond as well as older birds due to maternal immunity or because their immune system has not yet fully developed (first 3 weeks).
4 Differences in response, caused by different strains of pathogens involved.
5 The health status at the moment of vaccination. Healthy birds respond better.

Generally the first vaccinations will not take place before 7-14 days, when the maternal antibodies no longer interfere with the vaccine. From then on the active immunity is taking over from the passive maternal immunity. As a rule there should be at least 10, preferably 14 days in between vaccinations with live vaccines and at least 4 weeks between vaccinations against the same disease.
However, there are exceptions to this rule. Against IB and NCD a combined vaccination on the first day of broilers is possible now.
Against the Marek disease and IB a day-old vaccination is given at the hatchery. But then the immunity status of the day-old chick should be known. In the Netherlands even a day-old vaccination against NCD is possible.

Spraying at 7 days is better than at 12 days, because at that age the maternal immunity is higher and thus less multiplication of the vaccine and less reactions take place. Use a spraying device with a not too high pressure (max. 2 atm.), and large openings. If the reaction is too severe than vaccinate at 1st day.
Spraying against IB is done at 1st day at the hatchery with × 120. This gives local immunity. Then at 8 weeks spray with D 274 and than D 1466 eye dropped at 10 weeks. Followed by inactivated vaccine at 16-18 weeks.
Early vaccination may be a higher risk due to the higher sensitivity of the young chickens. Moreover, the bird's immune system only reaches its maximum level of productivity at 4-5 weeks of age. But the responses are reasonably effective at 7-10 days of age.
Many vaccinations are repeated to give a booster effect. However, also in this respect measuring of the antibody levels would be the best way to decide whether or not this should be done.

In regions with a rather homogeneous pattern of farm management vaccination schemes are useful. But special circumstances may give reason to deviate from such a general advice.
Examples of vaccination schemes in the Netherlands:

For pullets:
1st day Marek intramuscular injection
IB (H 120) spray in the hatchery
1-10 days NCD spray in the house
2 weeks Gumboro drinking water
26-38 days NCD spray
12-14 weeks combined ILT eye drop method
Fowl pox follicular method or wing web
AE orally (3%) or drinking water
14-16 weeks IB (H52) eye drop or spray
16-18 weeks NCD spray or injection
if necessary, also an injection against EDS
Against Coryza or Mycoplasma could be vaccinated at ± 14 weeks.

The schedule for parent stock does not deviate very much from this, but due to the later start of production more time is available. So the schedule is the same until 12 weeks; at that moment blood control can take place to know when to vaccinate against NCD. Vaccination against ILT and Fowl Pox follow then in week 13 and in week 16 IB, NCD and Reo (Gumboro) injections can be given.
If the parent stock has been vaccinated with dead vaccine against Gumboro the chickens should be vaccinated at 2-3 weeks; if not then at 1-2 weeks. Also the drinking water method is used here and there.
A combination of NCD and IB on the 1st day should not be made, as the birds would react too severely.

For broilers the following schedule is given:
1st day IB spray or: 1st day NCD spray
7-12 days NCD spray
8-14 days Gumboro drinking water
14-17 days IB spray

Sometimes unexpected outbreaks occur, although vaccinations have been carried out. In many cases this is caused by a new virus strain (field virus) within one disease. NCD viruses still belong to one serotype, but IB viruses show a great variety, so that sometimes more vaccines are necessary. Outbreaks may also occur due to variable levels of maternal immunity, unfavourable housing conditions, improper handling and administration of vaccines, etc.

20.5 Organized disease prevention

Mycoplasmoses, such as Mycoplasma gallisepticum (MG) and Mycoplasma synoviae (MS), are as much as possible prevented by control programmes. MG is transmitted both horizontally and vertically. The egg transmission is broken by egg treatment. Thereafter thorough sanitation programmes must follow. Ask first for MG-free stock. If from blood testing at 4 weeks and before delivery of eggs it appears that the flock is not MG-free, the hatching egg can be dipped in an antibiotic containing solution by which the pathogenic germs are killed.
Bacterial diseases, such as Infectious Coryza, must be prevented by sanitation (all in - all out, etc.). More bacterial contamination is to be expected in dry dusty climates.
Coli bacillosis is often causing a lot of problems. The pathogenic Coliform bacteria, which are normal inhabitants of the digestive tract, are abundant in the poultry environment. Infection takes place very easily, either by direct contamination or through the drinking water. Respiratory problems and/or enteritis are the result.
Use clean water. The water can be chlorinated or treated with broad spectrum antibiotics. Minimise stress factors, such as cold and high ammonia levels.
Aspergillosis should be prevented by sanitation, air quality and litter management.

Mycotoxicosis is mostly caused by high levels of aflatoxin in the feed, for example in groundnut meal. It damages the liver and the immune system. Laying hens can withstand higher levels than broilers. Raw materials must be tested for the presence of aflatoxin. Mixing with safe sources of protein may keep levels under control.

20.6 Ectoparasites

There are 5 main sorts of ectoparasites, but the most persistent of external parasites is the red blood mite. They are yellow, but sucked with blood brownish red. They cause a lot of unrest in the flock, wasting energy, and may even lead to a serious form of anaemia. The parasites reproduce easily under warm conditions and can stay for a long time without food. Try to wipe out their hiding places in very narrow openings in walls etc. Several sprays are available. Treat their hiding places, not the laying hens, by spraying. Avoid used egg trays.
Other parasites are meal mites, flees, Sarcoptes mites and ticks, against which also sprays are used.
All sorts of worms can be dealt with effectively by adding anthelmics to the feed during 7 days.
Coccidiosis is still one of the most difficult diseases to cope with. Coccidiostats are increasingly less effective due to resistance building by the parasite. So called 'shuttle programmes', consisting of an alternate use of different coccidiostats may be of help, but nowadays also medicines are available against all sorts of coccidiosis, to be supplied through the drinking water, also preventive.

20.7 Control of flies and other vermin

The favourable conditions in poultry houses with abundant manure quantities encourage the rapid expansion of house fly populations. The insects develop fast in moist places and especially under warm conditions. So drying of manure in the poultry house may partly prevent fly development, but, as they carry many pathogenic germs you should try to get them more definitely under control. That is not easy. House flies have a live span of 2-4 weeks, but in this short time they can multiply fast. Eggs become larvae in 1 day. The larvae become pupae in 4-10 days and 3-6 days later they mature and new adult flies originate, which again start to lay eggs within 1-2 days. From egg to egg a complete life cycle can occur in less than 2 weeks, even in 10 days in a humid warm environment.

For an effective fly control hygiene is a first requirement. The house fly is a product of filth and poor sanitation. Moisture levels should be kept low. Leaking nipples, for example, may give masses of larvae. Manure removal and proper disposal are the most important steps to start with in an effective control programme. If possible the manure should be removed daily, whereas the manure pits should be regularly disinfected. Keeping the surroundings free of dead birds, rotting feed and broken eggs, all being favourable spots for flies to lay their eggs, is important, but accumulating manure is usually the major source of the problem. Therefore the best approach is to break the breeding cycle in the larval phase in the manure.

The flies breed in many different places. Consequently the first step in control is to survey the area in order to learn where the flies are breeding and to see where they are abundantly present.
Where the infestation is severe it is increasingly becoming clear that the conventional insecticides are not effective any more, either because the flies are so numerous that killed insects are easily replaced by new adults, or that they have become resistant to the insecticides being used. Even spraying of an effective larvicide at the breeding sites may fail due to the development of resistance. Resistance building in the flies may be prevented by using various means. There are chemical means, containing organic phosphor compounds, to smear on surfaces (1-5 m^2 per 100 m^2 floor, dependent on the seriousness of the problem), being effective during 4-6 weeks, other organic phosphor compounds, which should be added to the manure, active during 10-14 days, and sprays, active during 4 weeks. Especially with the last ones resistance building is possible, so change means regularly.
A new method involves the use of an insect growth regulator, blended in very small amounts into the feed, as long as a fly problem exists. The active chemical in the feed passes through to the manure,

where it kills the fly larvae, thereby eliminating the major source of the fly problem. In combination with proper sanitation and good management such an approach has already appeared to be very successful.
Some fly killing chemicals may flavour meat and eggs. So be careful in choosing the right ones.

Rats and mice eat poultry food, cause damage to and contaminate the surroundings. Ready mixed poison baits can be used at well spread places (at least one per 10-20 m^2) on the floors and other places the vermin is regularly visiting. Use not too few baits and do not remove them too soon, i.e. after several weeks. Also boxes with baits can be very effective.

21 Waste management

In this chapter we will discuss the management of waste disposal from poultry farms and from poultry processing plants. Waste from poultry farms consists mainly of the excrements of the birds and the used litter. Dead birds may also cause disposal problems. Several types of waste originate from poultry slaughtering houses and hatcheries.

There are four ways to deal with poultry manure:
1 utilization as a fertilizer,
2 utilization as an ingredient in ruminant feeds,
3 use it for aquatic bioconversion (fertilising fish ponds),
4 convert it into biogas.

Laying hens produce on average about 50-60 kg of fresh droppings per year, with a dry matter content of approximately 20-25 %, so they have a dry matter production of 10 to 15 kg per bird per year. Both the total weight and the dry matter content of the droppings vary considerably, due to differences in type of feed, feed and water intake, and climate conditions.

21.1 Manure as fertilizer

The traditional and still the most commonest method of disposal of poultry manure is the utilization as a fertilizer for crops. However, in regions where high concentrations of poultry farms are found, problems arise when the manure is dumped on the land, because of overfertilization, resulting in pollution of water and soil.
Fortunately, in most of the countries in hot climate zones, poultry manure is still an important means to supply poor arable land with the highly necessary minerals for plant growth. Under these circumstances poultry waste management should be concentrated on the most suitable ways of storage, removal, and transport of the manure.

Caged layers' manure in most cases simply accumulates under the cage rows, either in pits or directly on the floor of the house. It is important to provide a watertight floor under the cages to avoid infiltration of manure liquid into the ground. In order to prevent fly problems it is always advisable to store the manure as dry as possible. In this respect care must be taken to avoid leakage of water troughs or other kinds of drinkers. Certainly the warm environment is a favourable factor in keeping the stored manure in a dry state. If this is not the case it can be useful to stimulate the drying process by extra ventilation over the surface of the heaped droppings.
Storing for a long time under hot climate conditions will cause unwanted nitrogen losses. Therefore it is advisable to remove the manure from under the cages regularly. Frequent cleaning out will also prevent favourable conditions for the development of fly populations.

Taking aside losses caused by improper storage, poultry droppings have a high value as a fertilizer compared to the excrement of other kinds of domestic animals. Given favourable conditions the nitrogen content is especially high in poultry manure.
The composition of manure is influenced by the storage, type of litter used and bacterial decomposition but the following is a general guide:

Table 26: Mineral composition of poultry manure

	Fresh droppings	Partially dried	Dry manure
Water (%)	75	50	25
Nitrogen (%)	1	2	3
Phosphorus (%)	0.6	1.1	1.7
Potassium (%)	0.6	1.1	1.7

The excrements in a dropping pit under a slatted floor in floor system houses will easily dry out until a dry matter content of 50 % or more is reached. This is due to evaporation and also as a consequence of decomposition by fermentation.
When the droppings are absorbed in litter, as it is the case in deep litter laying houses and in broiler houses, the microbial decomposition continues, resulting in production of large amounts of ammonia. Naturally the manure from litter houses is much easier to handle, and is therefore nearly always used as a fertilizer.
The manure value can be enriched by adding super phosphate, which binds the nitrogen. Addition of hydrated lime powder is also possible, but is not necessary in the case of laying hen manure, which already naturally contains a reasonable amount of calcium.
The amounts of manure supply per hectare vary according to the dry matter and to the kind of crop. Sugar cane reportedly uses more than maize or rice.

If not enough land is available to utilise manure directly as a fertilizer, an alternative way of disposal might be to convert it into more stable products such as dried manure in pellet form. Such a product can be easily transported to other regions e.g. for utilization as a fertilizer in horticulture.
Composting, by adding a carbon (C) source, e.g. in the form of plant waste, to the manure, can also increase the value of this waste.

21.2 Use of poultry manure in ruminant feeds

If, in a warm climate area, manure surplus problems arise, recycling through animals, by using treated manure as an ingredient in animal feed, can be a welcome solution. In the literature it has been stated by many investigators that poultry manure has more monetary value as a feed source than as a fertilizer. It is well known that poultry waste has nutritional value, especially for ruminant feeds. At least part of the energy of the ration left in the excreted droppings is still available for animals, whereas it is of no value to plants. Moreover, manure, being the undigested remainder of the ingested feed, naturally contains a high amount of fibre, which can be efficiently utilised by ruminants.

Table 27: Nutritional value of poultry manure, in percentages of dry matter

	Dehydrated cage layer waste	**Broiler litter**
Crude protein	28	31.3
Digestible protein	14.4	23.3
Crude fibre	12.7	16.8
Calcium (Ca)	8.8	2.4
Phosphorus (P)	2.5	1.8
Magnesium (Mg)	0.7	0.4
Sodium (Na)	0.9	0.5
Potassium (K)	2.3	1.8

The crude protein content of poultry droppings varies considerably. Approximately 40 to 50 % of the nitrogen is present in the form of protein. The main non-protein constituent is uric acid, a component of the urine which is excreted as a part of the droppings.
Uric acid can be efficiently utilised through the microbial fermentation processes in the rumen of the ruminants. This is also the case with the fibre which is left in the droppings.
Generally we must remember that the nutritional composition of poultry manure varies with the level and type of nutrition of the birds involved and with the waste management system applied.
Storing for a longer time, for example, results in nitrogen losses, the size of which is also determined by other factors such as temperature and moisture content.

Replacing certain ingredients in rations for ruminants by used poultry litter and also by dehydrated poultry excrements is already applied on a large scale in the United States. In a large number of experiments it has been demonstrated that such an application can be successful, provided the waste is rendered free from pathogenic organisms, such as E.coli and salmonella bacteria.

This can be done by heating, or by chemical treatment or by a combination of both. Direct heating at temperatures of around 200 °C for a couple of hours will be quite effective, but perhaps less advisable because of the complications and the costs. Therefore a better method may be deep stacking of litter in heaps in which the temperature will rise automatically through bacterial fermentation. Chemical treatment consists of the addition of 3% NaOH.
Utilization of poultry manure in poultry rations has, until now, only been investigated in experiments with broiler feeds. It has been done with positive results, but we must keep in mind that the energy content of the added waste is low.

Use of excrements in feed can have a detrimental effect when these excrements contain residues of feed additives or medical drugs. Possible negative effects of these residues in the litter feed can be prevented if the feed is withheld for a short period e.g. 5 days. That means that such litter is not fed during 5 days before slaughter. However, until now no evidence of pesticide accumulation has been reported.

21.3 Aquatic bioconversion

A widespread method of waste utilization, with a great nutrient recycling potential, is the aquatic bioconversion of waste, in the form of fertilization of fish ponds. This alternative is of special economic importance in tropical and subtropical countries. Part of the faecal matter is consumed directly by the fish (carp or other kind of cultivated fish), but most of the fish production originates from the aquatic food chains in the ponds, consisting of microscopic aquatic organisms (algae, bacteria etc.). The processes involved are strongly dependent on the ambient temperature, which is of a favourable level in hot climate zones. These food chains in ponds greatly benefit from manure application.

For pond fish production in the tropics, see the AGROMISA guide **Fish Farming in Tropical Fresh Water Ponds** and **Integrated Fish Farming in the Tropics.**

21.4 Conversion into biogas

A well known method of disposal, again of special importance in tropical areas, is the bioconversion of waste into methane gas by anaerobic digestion. For this type of waste utilization we need a mixing device, a digester tank and a pump to transport the slurry to the digester. Three types of products are generated: biogas, a liquid effluent and solid material.
The gas is produced by microbial organisms under anaerobic conditions, provided the right operating temperature is maintained. The best results are achieved at 40-60 °C. Furthermore the duration of the process influences the gas production.
A continuous supply of manure, with a simultaneous stirring of the fermenting mass, seems to give the best results.
From observations under practical conditions it has been concluded, that at 30 °C the gas production varies from 20 to 40 m^3 per m^3 manure, depending on the dry matter content of the slurry supplied.
The produced gas can be trapped by an inverted drumlike structure, covering the surface of the liquid and therefore rising as the amount of gas increases, thus acting as a gas storage chamber or a gas holder.
There are also so-called fixed top generators. Here the gas holder is of fixed dimensions, with separate gas outlets. Mobile gas digesters are also in use.
The trapped gas contains 50 to 80% methane, the remainder consisting mainly of carbon dioxide (CO_2). The methane can be used for heating purposes and for generating electricity. The liquid effluent can be utilised as a fertilizer in a fish pond. Finally the solid sludge can be dried and then utilised as a fertilizer on crop land or in fish pond. A second possibility is to utilise the dried sludge as a feed ingredient with a high level of proteins and minerals and some vitamin B12.

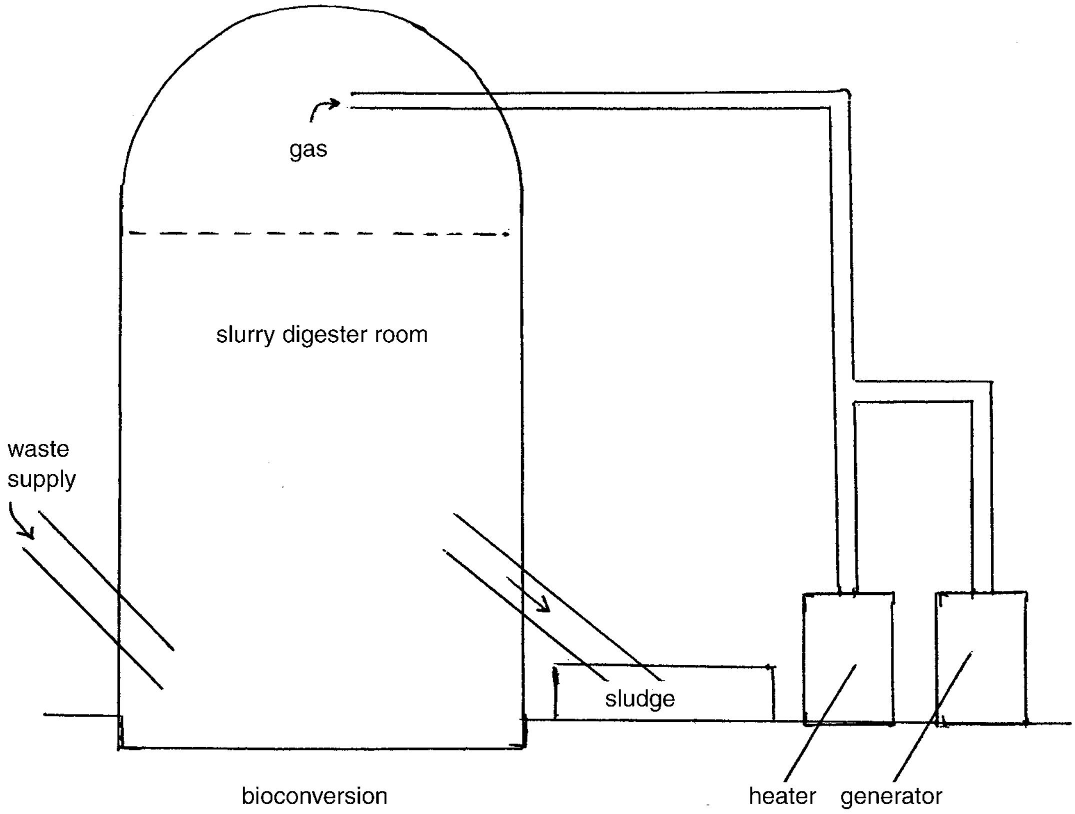


Figure 19: Bioconversion schematically

In European countries none of the foregoing solutions may be applicable, because of concentration problems and/or too low ambient temperatures, leading to serious pollution problems here and there. Therefore research in these areas is strongly directed to developing methods of disposal which, in the future, may lead to a more transportable product, for use elsewhere.

21.5 Disposal of dead birds

Dead birds can be disposed of by burying, incineration or dry pit disposal. The last method may be the simplest one, but the decomposition of the carcasses is highly dependent on the ambient temperature. Burying cannot be a good solution for large enterprises. Incinerators are definitely the best tools to dispose of dead poultry.

21.6 Waste from processing plants

Poultry slaughter houses produce a lot of offal, such as feet and heads, feathers and intestines. All this offal can be recycled through rendering plants into valuable byproducts, such as feed ingredients (blood and meat meal, hydrolysed feathers) and fertilizers.
The waste water from slaughter houses contains large amounts of proteins and minerals. These ingredients can be valorised as feed ingredients after flocculation and flotation of the waste water.
Egg breaking plants and hatcheries produce rejected eggs and hatching eggs, including infertile eggs, cracks, dead embryos, etc. All these waste products can be used in poultry feeds, substituting for soybean meal, meat and bone meal, wheat bran and ground lime stone.
However, in recent years there is considerable public concern about the use of slaughterhouse waste as ingredient in the feed for farm animals.

22 Nutritive value of eggs and poultry meat

22.1 Eggs

Depending on the egg's weight the **composition of a normal egg** is roughly as follows:

Shell	5-7 g	± 12%
Egg white	34-35 g	± 57%
Yolk	18-19 g	± 31%

The egg contains highly valuable nutrients in a concentrated and very easily digestible form. The nutritive values of egg white and egg yolk differ considerably, the yolk being rich in protein and fat and also in minerals and vitamins, whereas the white mainly consists of water and protein.

Table 28: Example

	total egg	white	yolk
water	65.5 %	88 %	49 %
protein	12	10.5	16.5
fat	10.5	-	32.5
carbohydrate	1	1	1
minerals	11	0.5	1

Proteins are present both in the white and the yolk, but fat is almost entirely deposited in the yolk. The main fatty acids in the yolk fat are: linoleic acid (± 14%), oleic acid (± 43%), palmitin acid (± 26%) and stearic acid (± 8%).

Nutrient composition in 100 g edible egg (modified from US Department of Agriculture data):

Water	76 g	Energy	150 kcal
Protein	12.5 g		
Fats	10.0 g		
Carbohydrates	1.2 g		

Amino acids:

glutamic acid	1.6 g	arginine	0.75 g	proline	0.5 g
aspartic acid	1.3 g	alanine	0.7 g	glycine	0.4 g
leucine	1.1 g	isoleucine	0.7 g	methionine	0.4 g
serine	0.9 g	phenylalanine	0.65 g	histidine	0.3 g
lysine	0.9 g	threonine	0.6 g	cystine	0.3 g
valine	0.8 g	tyrosine	0.5 g	tryptophan	0.15 g

Fatty acids:

saturated	3.1 g
unsaturated	5.2 g
cholesterol	426 mg (so ± 255 mg in an egg of 60 g)

Minerals:	P	0.18 g	Cl	0.18 g
	Na	0.12 g	K	0.12 g
	Ca	0.05 g		

traces of Mg, Fe, Zn, Mn and Cu

Vitamins:

pantothenic acid	1.3 mg	E	740 mcg
riboflavin	0.5 mg	B2	310 mcg

B 6	0.14 mg	A	220 mcg
niacin	0.07 mg	folacin	46 mcg
thiamin	0.06 mg	B12	1 mcg
traces of D			

From a nutritional point of view the ratio of saturated and unsaturated fatty acids within the fat content is important. A high percentage of saturated fatty acids, together with a high cholesterol content, in the human diet is considered to be risky in connection with the occurrence of heart diseases. However, the proportion of unsaturated fats in eggs is higher than the saturated ones. About two thirds of the fat is of the beneficial unsaturated type.
The discussion about the role of cholesterol in the human diet, and the possible consequences for human health, is still going on. Normally an egg contains on average 250 mg cholesterol.
In countries with an abundant food supply, eating too much (animal) fat, and thereby too much cholesterol, is considered to be harmful for those people who are sensitive to such a diet, but there is enormous individual variation in the response to this food component.

Probably the most relevant factor is the question to what extent eggs, in a normal diet, do increase the blood plasma level of cholesterol. Dietary cholesterol - 80% of the cholesterol is manufactured by the body itself! - is the third and least important dietary factor contributing to a high cholesterol level in the blood. Cholesterol plays an important role in the human metabolism. It is transported through the blood vessels by so called Low Density Lipoproteins (LDL) to the cells. When these LDL are not removed from the blood they may block the vessels. However, so-called High Density Lipoproteins (HDL) normally transport the cholesterol away from the vessels to the liver. So the ratio HDL/LDL is much more important than the cholesterol level itself. Cholesterol is not the main cause of disorders, but the HDL/LDL ratio. In those people, who are not able to control the cholesterol metabolism, a high dietary cholesterol intake can lead to an undesirably high increase of blood cholesterol.
Obviously the composition of the diet as a whole is also of primary importance. Replacement of fat containing components in the diet by eggs, and variation of the menu, can lower the risks to a minimum for those who are sensitive to this food component. Research has clearly demonstrated that for most people (± 75%), thanks to the normal compensatory mechanism, there is no harm in eating 1-2 eggs a day.

Positive nutritional factors in eggs are the high quality proteins, with great biological value through the presence of many essential amino acids. Moreover, eggs contain vitamins A and E and, although in minor quantities, vitamin B. Furthermore there are a large number of minerals, among which are many trace elements.

The freshness of an egg can be judged by the firmness of the thick white: the higher the layer of white the better the quality. This so-called inner quality is, as we have seen, mainly determined by how the egg is stored and its age.

Consumers prefer eggs with a yolk colour ranging from golden yellow to orange. Pale, but also orange-red yolks, are not appreciated. Basically the yolk colour is influenced by the genotype and the rate of egg production, but in practice the feed composition is the decisive factor. Both natural and synthetic sources in pigmenting egg yolks are in use. Stabilization with antioxidants and vitamin E in the feed improves the pigmenting quality of the natural carotenoids.

22.2 Poultry meat

Poultry meat is generally considered as a healthy food everywhere. Its dry matter consists mainly of protein. The average water content of chicken meat is 70%, varying from 65 to 75%, and the average protein content is 20%, varying from 17 to 23%. The high nutritive value of chicken meat is derived of course from the relatively high protein content. It is lean meat. On average it contains 7.5% fat in

total, divided over the skin and the abdominal cavity. The low fat content makes chicken meat very attractive for those consumers who do not want too much fat in their diet. The ratio of saturated fatty acids to unsaturated fatty acids is also better, namely about 40:60.
However, in the last 10 years the broiler fat content appears to have increased, mainly due to an increase of the abdominal fat of up to 3-4%. Generally this increases with age and is higher in female birds than in male birds. Feeding also has an effect on the total amount of carcass fat. Additional dietary energy increases the carcass fat and therefore much attention should be paid to the protein/energy ratio of the diet. The amount of abdominal fat also varies with strains. Selection of broiler strains on better feed conversion improves the genetic basis for leaner birds, whereas a proper protein/energy ratio in the diet can do the rest.
Relatively large amounts of fat are especially observed in broilers with a large live weight, so the trend to grow the birds to a larger body weight has increased the problem.
Too much fat is a detrimental factor. It has to be removed, causing weight losses; if it is not removed, it is generally not appreciated. However, the problem might be not as serious in tropical zones as it might be in the temperate climate zones. High ambient temperatures, and probably also the feed composition in general, will prevent a too large deposition of fat.

The so-called organoleptic quality is very important, these are the characteristics based on which the consumer gives his/her judgement.
Poultry meat characteristics are: taste (flavour), odour, colour and tenderness (juiciness). This aspect of quality is strongly influenced by the age at slaughtering. Tenderness and/or juiciness decrease with increasing age, whereas flavour intensity generally increases in older birds. Presumably this is the reason why the locally produced village poultry is often more appreciated by the local consumer. Modern producers can easily meet this preference by extending the growth period e.g. through a low protein diet. However, the longer use of the housing facilities will increase the costs and it is certainly advisable to explore thoroughly the market possibilities for such a product.

For the processing industry the processing efficiency is becoming important: output/input × 100%, and above all the hygiene of the slaughtering process. During processing cross contamination should be avoided. Modern equipment has improved the processing.

During the last few years there has been a tendency to purchase fresh (0 °C) instead of frozen products (-18 °C). The processing of fresh products involves, amongst other things, a different way of chilling after the removal of feathers, namely in cold air instead of cold water.

23 Poultry industry as an agribusiness

Compared to other livestock sectors the poultry industry is showing a characteristic tendency to a rapid application of advanced technologies. This is not difficult to understand. There are some clear differences between poultry husbandry and animal husbandry in general, which can explain the rapid development of the poultry industry, such as:
1 a high rate of reproduction,
2 a quick return on invested capital,
3 the absence of the necessity to own large areas of land.

Rapid growth, together with the application of modern husbandry methods, is also taking place in many countries in hot climate zones. This is not surprising. The technical knowledge and experience necessary to run modern poultry units is now internationally available and the management methods are more and more the same all over the world.
Modern poultry breeds, for example, are fairly well capable of adapting themselves to tropical circumstances, certainly better than exotic breeds of other types of livestock. If problems arise, e.g. in the form of heat stress, there are solutions available, especially through effective climate control.

However, the possibilities to control the situation are not always used. Moreover there are problems which are not easy to solve, e.g. heat stress problems in heavy broiler breeder flocks. Generally the main constraints are: health problems, lack of feed resources, poor feed quality and failing climate control. The consequences are: low efficiency in the use of stock, feed and housing facilities. Under these circumstances adequate management, as described in this manual, is of utmost importance.

23.1 Integrated enterprises or not?

The present structure of the poultry industry as an agribusiness is the result of structural developments, which have taken place during the last decades. It is only 50 years ago that poultry was usually kept in small units as part of a mixed family farm. Large poultry units were exceptional at that time.
With the introduction of factory manufactured feed, keeping poultry was no longer restricted to arable land, either owned or rented by the farmer. The size of the poultry units could grow unhampered. Simultaneously tremendous technical developments took place, for the greater part designed for labour saving purposes, so that poultry units could grow larger and larger. Eventually poultry was kept mainly on large specialised units, definitely disjoined from the ancient type of farms.
Of course this briefly described development has taken place gradually. That means that in many places of the world both larger and smaller units still exist together in the same region, but the economy of scale is continuing to change the picture in favour of large poultry enterprises.
In western countries the question is still valid as to whether the large poultry farms should specialise in one category of birds, within the total chain of production or keep more than one category of birds, representing more than one link in the production chain. In the laying sector many poultry men do not restrict themselves to laying hens only. They rear their own replacement pullets. However, this is not yet a common rule. In the broiler sector differentiation prevails. There are specialised broiler farms and there are hatching egg supply farms.
This picture, however, is not complete. In many European countries most of the poultry farmers have chosen to be an independent specialised farm. On the other hand they have nearly always voluntarily entered into a contract with other participants in the sector involved. Such a group of poultry farmers, participating in one organization, is called an integration group. The planning and organization is done by one company (the integrator), usually a feed company.
Against this background the question again arises whether it is wise to have more or less production links in one hand, i.e. owned by one integrated company? Apart from the high capital investment needed for this form of enterprise, there is something to say in favour of it. In an integrated poultry

enterprise the margins of every single link merge together to one common margin at the end of the chain. This margin is less sensitive to price fluctuations of the end product than the smaller margins for every single product within the production line. Therefore the price risk for an integrated company is smaller. On the other hand contracts have proved to be an excellent means of combating price fluctuations.

It is remarkable to see that the integrated form of farming prevails in many developing countries. The reason might be that maintaining contract conditions is not always easy to do. Moreover the system requires a controllable and reliable feed industry. This is often difficult to organise, so that a completely integrated organization, in the hands of one company, with its own feed manufacturing, is often considered as the only option left. Contracting small farmers within an integrated group, as is usually done in Europe and the USA, is now also becoming common practice in several countries in South East Asia.

23.2 How to set up a modern poultry unit?

Modern poultry farms cannot give satisfactory results without an adequate infrastructure, in the wide sense of the word. Roads and well functioning telephone connections and other means of communication are necessary, in order to be able to buy and supply feed, equipment and other inputs, and to sell and transport farm products.
Furthermore there must be an adequate water supply. Regular feed supply is not enough, unless its quality is guaranteed. The availability of a nutritionist within the firm, together with laboratory facilities, can be of great help. Regular testing of feed ingredients at the point of manufacture will prevent a lot of serious problems.
Power supply is always necessary and if, in an exceptional case, it might fail, we ought to have the protection of a stand-by electricity generator. In this respect an alarm installation is essential, in order to warn us of a power cut, or if extreme environmental conditions occur.
Veterinary services must also be available locally - or at least available immediately after calling the service. Diagnosing ability, supported by laboratory and post-mortem facilities, is also necessary.
Another service needed is the expertise to ensure that all the equipment works at full capacity.
Measures must be taken for regular disposal of all waste, both solids (manure) and effluents.
Last but not least: no success can be expected without the help of knowledgeable, experienced and dedicated personnel!

Once all the foregoing conditions are fulfilled, the definite set up of the enterprise can be chosen.
The first condition to satisfy is that a given poultry unit must be of the right size. The question what is this to be exactly, is not easy to answer. Technically speaking there is an optimum size per house, mainly determined by the running capacity of the feed supply equipment. Another measure to use is the number of birds that one person can take care of, because of hygienic considerations. The answer to this depends, of course, on the applied degree of mechanization.
The poultry units as a whole, individually owned or part of an integrated company, should be large enough to obtain the advantage of discounts in prices of inputs, and/or extra charges to be paid for the off-farm products.
Within an integrated enterprise the unit sizes must be attuned to the planning and set up of the enterprise as a whole. For example: for every rearing unit there must be three laying units of the same size, to be sure that all the houses are completely utilised.
The question whether mechanization should be applied or not, is first of all a matter of labour costs, but the availability and skill of the labourers can also play a role in this decision.
Finally the lay-out of the farm should be such that the all in-all out principle can be maintained. That means only one age at one location! The labour organization must also be adapted to this aim.

23.3 Marketing of eggs and poultry meat

No viable enterprise is possible without good marketing prospects. Marketing is the most determining factor for the success of an enterprise. It is of utmost importance to have a good insight in the marketing conditions before the business is started, through a preliminary market survey, but later on it is still necessary to follow the market developments, even when the enterprise is in full operation.
However, marketing means more than selling and market research should imply more than just collecting government statistics about production and consumption.

Fluctuations in supply and demand

At all times it is necessary to know how supply and demand develops over a long period of time in the area involved. As far as demand is concerned, population growth, and especially buying power and disposable income developments, determine the marketing chances for the future.
Apart from long term developments the production size in a given country is seldom stable for long periods of time. First of all climatic changes may affect productivity, either seasonally or incidentally, e.g. by suddenly occurring hot periods. However, in many cases economic factors are responsible for changes in the size of production. Availability of feedstuffs and the level of feed prices can fluctuate considerably.
On the other hand the size of demand also fluctuates over the course of time. In this respect we must think of differences in availability and price level of alternative food protein sources such as fish and red meat, and seasonal changes in eating habits.
Even in the absence of direct influences from outside, a cyclic pattern of prices can usually be observed. When the prices are high, many producers will react by expanding their production. This in turn will cause a temporary overproduction, with lower prices, eventually below the cost of production, which again will give rise to producers decreasing the size of their output. As soon as the supply does not meet the demand, the whole story will repeat itself again, resulting in the same cyclic movement as before.
Once we know how the market as a whole is functioning, it is recommended to find out how our own products find their way to the market, compared to those of our colleagues and how to improve our marketing procedures.

Marketing channels

There are two major marketing channels:
1 direct sales to the consumers or consumer centres, such as hotels and retail shops,
2 marketing through middlemen.

Generally speaking large poultry enterprises are nearly always found near urban population conglomerations, obviously because there is a ready market for eggs and meat. Consequently feed manufacturing factories are also usually found near these populated centres.
Whatever marketing channel is chosen, there must always be an adequate infrastructure to enable us to market our products in the most efficient way. Well kept roads and efficient means of communication, such as properly functioning telephone connections, are a necessity for an effective transport and distribution.
Seasonal changes in supply and/or demand and consequently in price level, may partly be met by the availability of storage facilities, but the costs of such provisions should not be underestimated. There may be a chance to cope with these fluctuations by establishing egg breaking plants.

Sales promotion

The usual form of sales promotion consists of advertising and merchandising in order to draw the attention of the consumer to the products. In some cases it may be wise to support our sales outlets by providing them with special storage equipment, such as refrigerators and deep freezers.
However, the best sales promoting activity is to ensure a regular supply, excellent quality and an attractive presentation.

In order to realise a fairly constant supply throughout the year, it is necessary to have proper planning and to avoid production disturbances. Some minor fluctuations in size of production may be unavoidable, but climate control and hygiene measures must be of such a level that climate disturbances and serious outbreaks of diseases, causing mortality and drop of production, can be prevented.

The quality of our products must be adapted to the wishes of the consumers, both in terms of quality itself and in presentation. The times that eggs were sold in baskets, filled with straw, or in cardboard fillers, is definitely over. In modern, large laying units, eggs are graded into weight classes and candled in order to sort out the cracks and eggs with blood and meat spots. These quality graded eggs are sold in trays, containing 30 eggs, or in boxes with 360 eggs. However, more and more transparent plastic packs with 10 eggs or cardboard packs with 6 eggs are used. Although the latter may cost more, they certainly meet the wishes of the consumers and therefore increase our sales.

Eggs from smaller units are often sold ungraded and unpacked to wholesalers. These middlemen transfer the eggs to the retailers. Such a marketing situation is less favourable to the producers. When prices are going up, a larger proportion may go to the wholesaler, whereas, when prices go down, a large part of the decline will be born by the producers. Monopolistic situations in which a few traders may dominate the market, should be prevented.

Apart from grading and packing necessities there may be other consumer preferences, such as a choice of brown eggs instead of white eggs, or, in the case of broilers, white coloured skin instead of yellow. Of course we must always meet these wishes.

Quite often there is a preference for ‘village produced eggs and/or meat’, as a consequence of the belief that they taste better. If this is true for eggs, it is the intensive industry which is to blame, as naturally there should be no difference. If the intensively produced eggs taste worse, it is a matter of wrong feedstuffs such as too much or poor quality fish meal.

Above all the customer wants fresh and unspoiled products. Storage and packing are the most important factors in this respect.

Eggs should be stored in a cold environment. In smaller shops storage conditions may be poor, but an increasing number of retail shops, especially larger supermarkets, are giving much more attention to suitable storage conditions.

Eggs should not be stored too long, especially in hot climate zones. Delivering should take place at least once a week, or preferably more often.

23.4 Marketing of poultry meat

In the chicken meat market a choice must be made between marketing birds alive or slaughtered. Selling live broilers is of course a certain way of providing the customer with a fresh product, and therefore this method of marketing is preferred in many countries. The consumer or client has the opportunity to choose the bird of his/her preference and to take it away for slaughtering. The practice of slaughtering the bird at point of sale under more or less hygienic conditions is also possible.

Public slaughter houses provide chilled fresh chicken meat, either as a whole chicken or cut up in portions (chicken portions). When this method is chosen, the way of packing is of great importance. The wrapping should be not only attractive and colourful on the outside, but it must also contribute to the freshness and cleanliness of the packed meat inside the package. Wrapping in polyethylene bags does not prevent microbial spoilage, because this material has a high oxygen permeability.

Impermeable wrapping is better. Under these circumstances build up of carbon dioxide (CO_2) occurs, which inhibits the activity of aerobic micro-organisms, thus prolonging proper conditions for the wrapped meat. Unfortunately this kind of packaging material may still be too expensive. A well presented table bird has an obvious advantage on the market.

All poultry are potential carriers of micro-organisms. Microbial spoilage usually occurs 4 to 10 days after slaughtering, depending on how the broilers have been handled at the processing plant, and the type of micro-organisms involved. Even when the meat is kept at refrigeration temperatures from 0 to 4 °C, microbial spoilage goes on, albeit it at a slower rate. The storage temperature should be around 0 °C or lower.

Adding value to the primary product will certainly contribute to an easier way of marketing. Fast food, cooked or fried chicken snacks can increase consumption and thus improve the marketing possibilities of chicken meat. Always keep in mind that the image of the product and of the producing company are determining factors for our chances in the market.