Environmental influences on laying hens production

Cavalchini L.G., Cerolini S., Mariani R.

in

Sauveur B. (ed.).
L'aviculture en Méditerranée

Montpellier : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 7

1990
pages 153-172

Environmental influences on laying hens production

Luigi G. CAVALCHINI, Silvia CEROLINI, R. MARIANI
Istituto de Zootechnia, Facultá di Medecina Veterinaria, Universitá degli Studi di Milano (Italy)

I. – Introduction

In the Mediterranean region poultry are raised in a climate in which the summer temperatures are rather high and the winter temperatures are more or less severe, depending on the distance from the sea and the exposure of the site to the wind. Environmental pollution is also often a problem.

The type of final product desired is greatly influenced by the eating habits and the age-old traditions of this region. Obviously, the requirements are more specific and more numerous for meat. For eggs, the only requirements are for a particular shell colour and for the weight of the egg.

Both the environment and breeders have interacted in the selection of animals over time so as to obtain strains that are adapted to particular conditions. The strains typical of the Mediterranean area are usually resistant to high temperature and to changes in temperature, are resistant to diseases and have few specific nutritional requirements.

In Italy there are local strains of chicken that have satisfied human needs for millenia. One of these is the "Livornese" whose genetic inheritance has been partly introduced into almost all the commerical hybrids used today for egg production.

However, in recent decades the breeding situation has been totally transformed. Local strains have almost completely disappeared or are on the way to extinction, and throughout the world there are only four or five commercial hybrids for industrial production of eggs. Most of these hybrids are quite similar in their characteristics. This change has been paralleled by unification and standardization of environmental conditions. At present, the buildings, equipment and technologies for breeding and feeding are almost the same in all parts of the world.

Therefore, I will try to summarize the many different environmental influences that can affect animal production, including immediate consequences and long-term accumulation effects. It is easy to see the immediate effects and to determine their cause, but the delayed effects are much more difficult to identify ***(Scheme 1).***

II. – Effects of light

1. Photoperiod

Light is of fundamental importance in the reproducton of birds, both during the rearing and the laying time. In the 1960s, many studies were done by Morris and his co-workers on the effects of different photoperiods on reproductive activity. Many other investigators looked into the effects of alternative and traditional light programmes. (Cavalchini *et al.*, 1983 ; Shanawany, 1982, 1983 ; Ernst *et al.*, 1987 ; Rowland, 1985).

By now the best quantitative and qualitative characteristics of the photoperiod for modern use have been established for the different types of shelter available. Two different situations can be identified :

a) in which closed sheds and artificial light are used, and
b) in which the sheds have windows, and natural light is available.

During the rearing period (0-18 weeks), the most convenient light programme can be used in situation A: a constant 8 hours of light and 16 hours of dark (8L:16D) for the entire period (**Figure 1**). It is also possible to use 6 hours of constant light as described in the King system (1959), or even 10 hours, without making any great difference. In situation B, there are two phenomena :

1°– Chicks born more or less between April 1 and September 15, are in the best situation (in the northern hemisphere) since they have a decreasing photoperiod and it is not necessary to modify the number of hours of natural light ;

2°– Chicks born between September 16 and March 31 are worse-off because the natural photoperiod is increasing and this can lead to premature laying.

To avoid this, two alternative systems can be used : calculate the longest photoperiod between the Ist and the 18th week and maintain the light for this length of time throughout rearing by using artificial light partly in the morning and partly in the evening, or determine the number of hours of light that there will be in the 18th week and then add from 4h15' to 6h of artificial light on the 3rd day of life and then decrease by 15-20 minutes per week until the 18th week.

According to Shanawany (1983), the best age for the hen to reach sexual maturity is 150-160 days, and this is the condition for producing the largest number of eggs with the best alimentary conversion index (ACI). However, feed intake does not seem to be affected by when oviposition begins.

Continuous selection of animals that grow ever more rapidly has produced hens that are of laying size at an early age. Light has been used for early induction of sexual maturity in these animals with early mrophological development to mature size.

When the number of hours of light is increased from 8L:16D to 14L:10D by the 15th to 18th weeks of life instead of the 21st, there is an increase in the number of eggs produced, but they weigh less (Leeson and Summers, 1980). If the increased photostimulation is applied even earlier, at 10 to 12 weeks fewer eggs are produced (Leeson and Summers, 1985b).

Therefore, it is generally advised to start a progressive increase in light during the 18th week of life, with the daily increases suitable for stimulating sexual maturity and with it the initiation of oviposition at the best time. The hens begin to lay about 4 weeks after the start of photostimulation. The increase is usually gradual, to avoid early peak and to maintain deposition (**Figure 1**).

A photoperiod of 10L:14D is sufficient for stimulating oviposition and 14L:10D provides the maximal production. Further increases to 17L:7D do not consistently increase production and if the exposure to light is even greater than this, production decreases. Rowland (1982) compared 18L:6D with 15L:9D and found a larger percentage of breakage of the shell in the oviduct, 6.4 % vs 2.4 %, and a worsening of the specific gravity of the shell with the longer light exposure.

2. Quality of the light

Except for the first week, in which intense light is needed to stimulate the chicks to eat, the intensity of the light should be lower than natural light. Different studies with the hen (Cavalchini *et al.*, 1976 ; Morris, 1968) found that for good reproductive activity there should be at least 10 lux of light. The light requirements of the pullets are less well known.

There is a strict linear correlation between the intensity of light and body activity. As one increase light from 1 to 120 lux, the motor activity of the animals increases, and as a consequence, so does the energy expenditure measured as heat production. This correlation is the basis of the observation that in birds, as well as in mammals in general, there is a correlation between intensity of light and perception of light (Boshouwers and Nicaise, 1987).

It is a useful rule to avoid excessive differences in intensity and colour of the light between the phase of growth and that of oviposition. For this purpose, pullets that have been reared under artificial light are maintained under the same type of light after they begin to lay eggs, or may become excessively excitable. It is even more necessary to continue keeping pullets under natural light if they have been raised under natural light.

Several studies of the influence of the colour of light (Benoît *et al.*, 1950 ; Harrison, 1972 ; Mc Ginnis *et al.*, 1966 ; Morris, 1968 ; Oishi and Lauber, 1973) have shown that birds are more sensitive to wave-lengths toward orange and red and less sensitive to blue, green or yellow. The optimal wave-lengths are between 600 and 750 nm. From a practical point of view, it has been proposed that fluorescent lamps of suitable colour can be substituted for incandescent lamps, reducing the energy expenditure to 1/3 to 1/4. It has been shown, in studies that if monochromatic light is used, sexual maturity is shifted from day 131 to day 124 of life, and also that the quality of the light affects the body weight and the abdominal fat deposits (Pryzak *et al.*, 1986).

3. Manipulations of the photoperiod and ahemeral cycles

In the last few decades most of the research into the effects of light has been carried out to determine the possibility of using intermittent light programmes or circadian cycles longer or shorter than 24 hours, called ahemeral cycles. The initial interest in such photopériods was to save considerable amounts of electricity, but the results have turned out to be of interest principally for the effects on the quality of the eggs.

Shanawanuy wrote a review in 1982 in which he summarized the effects of **circadian cycles** that were not 24 hours on both total egg production and the weight of the eggs. He calculated from the data of many trials that shortening circadian cycles to less than 24 hours decreased egg laying more or less linearly, down to 21 hours.

When cycles were prolonged above 24 hours, there was no change in production at 25 hours, but from 25 to 33 hours there was again a progressive decrease as the cycle was lengthened. The weight of the egg increased by 5% for each hour of change in the cycle, either above or below 24 hours. The quality of the shell was better in the 27 hour cycles (6-8% thicker) and the 28 hour cycles (8-10% thicker) and the number of deformed or shell-less eggs was decreases by 4%. Nordstrom (1982) obtained a better quality of shell, as g/cmq, with a photoperiod of 27 hours after only one week of treatment and after 3 weeks the weight of the eggs had increased significantly. Feed consumption decreased when a photoperiod of 28 hours was used (Leeson and Summers, 1985a). The ACI showed the same pattern with cycles of 26 or 27 hours (Nordstrom, 1982) (**Table 1**).

Recently it has been suggested that the period of darkness be changed to a period of very low intensity light so that the various operations required for breeding can be carried out at the most convenient times, whatever the time of the dark period. The experimental results have been good. Hens on this type of photoperiod still recognize the light stimulus and the pattern of egg-laying is the same as when the "darkness" is total (Rose *et al.*, 1985 ; Waters *et al.*, 1987). A 5:1 ratio of the intensity of the "daylight" to the "dark" is sufficient for stimulating egg laying, but the results are better if the ratio is 30:1 (Waters *et al.*, 1987).

Breaking up the periods of light in either circadian or ahemeral cycles into short light-dark cycles is usually called intermittent light programming. Rowland (1985) divided these into two types. In type 1, the light-dark cycles are repeated without change although they can be of equal duration (3L:3D) × 4 or different duration (1.5L:4.5D) × 4. In type 2, the light-dark periods are not repeated symmetrically (6L:2D:6L:10D). When the programme is of type 1, oviposition is distributed over the 24 hours without any particular pattern. When it is of type 2, there is the same circadian oviposition cycles as there is in continuous light (**Figure 2**).

This is because the hen kept under conditions of type 2 cyles again distinguishes a "day-time" and a "night-time" and the laying cycle is adjusted to this. The "day" period interpreted by the hen under intermittent light is called "subjective day" and it must last at the most for 16 hours to be recognized.

The light programme affect oviposition both quantitatively and qualitatively. The production of eggs tends to decrease markedly when the intermittent (Sauveur and Mongin, 1983 ; Van Tienhoven *et al.*, 1984 ; Leeson *et al.*, 1982) or ahemeral 28 hour lighting programmes (Leeson and Summers, 1985a) are administered from the start of the productive cycle. If, instead, the cycles are changed near the end of the hen's egg-laying activity, no marked differences occur (Nordstrom and Ousterhout, 1983 ; Skoglund and Wittaker, 1980) (**Table 1**). To maintain the production at a level similar to that obtained with a photoperiod of 16L:8D, intermittent light must be administered at least 10 hours (Nordstrom and Ousterhout, 1983), but some investigators say that as little as 4 hours is sufficent (Van Tienhoven *et al.*, 1984).

Egg weight is always heavier when light is administered in either intermittent cycles (Skoglund and Whittaker, 1980 ; Nys and Mongin, 1980 ; Sauveur and Mongin, 1983) or ahemeral cycles (Van Tinhoven *et al.*, 1984 ; Nordstrom and Ouserhout, 1983 ; Leeson and Summers, 1985a) (**Table 2**). The quality of the shell is also improved, as agreed by several investigators (see the review by Sauveur and Picard, 1987). Both the total weight of the shell (Nordstrom and Ousterhout, 1983 ; Nordstrom, 1982) and its resistance to breakage (Nys and Mongin, 1981 ; Sauveur and Mongin, 1983 ; Van Tienhoven *et al.*, 1984) are greater. However, Lesson *et al.* (1982) found no differences in total egg weight or in the quality of the shell when they applied an intermittent schedule of 17L:7D (**Table 2**).

As already underlined by Sauveur and Picard (1987), the better shell quality, measured as thickness and resistance, appeared to be due to the longer interval between the laying of one egg and the next, with the egg remaining in the oviduct. In addition, under intermittent light, feed consumption is distributed more uniformly over the day (Nys and Mongin, 1981).

If intermittent light of 3L:3D is used when rearing the chicks, sexual maturity does not seem to be delayed, but egg production is decreased by 5% (Sauveur and Mongin, 1983).

During the major period of egg production, the traditional photoperiod is thus still the best, but ahemeral or intermittent photoperiods can be used toward the end of the productive period of the hen to improve the quality of the egg shell. Before we can confirm the effects of their use during the period of maximal production or of rearing, further studies must be done, especially with large numbers of animals, such as those found in actual production.

III. – Effects of temperature

Hens are usually housed in cages containing 3-5 birds and without any possibility of moving or choosing and so they must survive the cryptoclimate of the room.

The principal mechanisms available to the chicken for maintaining a normal temperature have been divided by Meltzer (1987) into two groups. The first group includes physical mechanisms, such as standing in a certain way, increasing the respiration rate (tachypnea) which increases respiratory evaporation or changing the angles of the feathers so as to retain or disperse more heat (however, it must be kept in mind that when hens are towards the end of their reproductive period, they lose many of their feathers and therefore have less thermal protection). The second group includes chemical or metabolic mechanisms, such as changing the amount of feed consumed or the activity of some endocrine glands (hypophysis, thyroid, adrenals and pancreas).

Therefore, it is easy to understand why it is so important to maintain an optimal microclimate that provides a thermoneutral zone in which the hen stays well. This zone is usually between 20° and 25°C. The response to environmental temperature varies considerably in different genetic strains and the adaptation process varies accordingly (Arad *et al.*, 1981).

Figure 3, taken from Van Kampen (1981), shows how heat production decreases as the environmental temperature is increased to 35°C (for non-acclimatized animals the upper limit is 33°C) and then rapidly increases.

Usually the body temperature is maintained up to 26°-27°C environmental temperature. At higher temperatures the animal needs to call into play effective thermoregulatory mechanisms, such as an increased respiratory rate (Sykes and Fataftah, 1886a). By 32°C the respiratory rate is 5-6 times the 30-35mn that occur between 2° and 18°C (Arieli *et al.*, 1980). At about 35°-38°C the animal pants and develops alkalosis, which continues to worsen up to 41°C, with the pH of the blood going from 7.5 to 7.6 (El Hadi and Sykes, 1982) because of the decrease in the partial pressure of CO2 (PCO2) in the arterial blood and the increased concentration of HCO3 (El Hadi and Sykes, 1982 ; Staten and Harrison, 1984 ; Koelkebeck and Odom, 1985).

These changes in PCO2 and the alkalosis they cause have a negative effect on egg shell formation that is inevitably reflected in the quality of the shell.

The increase in environmental temperature is usually accompanied by an increase in respiratory evaporation (Arieli *et al.*, 1980), because the adaptation to the high temperature seems to be due to increased loss of heat as well as a simultaneous decrease in heat production (Meltze, 1987).

Above certain limits, increasing the environmental temperature leads to a progressive increase in body temperature, whether the animals had or had not been adapted to cold or hot environments (Arieli *et al.*, 1980). At an environmental temperature of 41°C, the body temperature is 44°C (El Hadi and Sykes, 1982). **Figure 4** shows the daily patterns of body production as a function of the high environmental temperatures that can occur in tropical climates.

The qualitative and quantitative effects of environmental temperature on the reproductive capacity of the laying hen have been reviewed by Deaton (1983).

It is useful at this point to note that optimal production efficiency means to combine the lowest ACI with the maximum production of eggs, in terms of total weight. Usually when the temperature is increased there is a decrease in feed consumption (Deaton *et al.*, 1981 ; Tanor *et al.*, 1984) and, above a certain limit, also in egg weight (Tanor *et al.*, 1984 ; Peguri and Coon, 1985; Magruder, 1982), whether the animals are maintained under constant or variable temperatures (Emery *et al.*, 1984).

The interval between 24° and 27°C is usually considered to be that in which the ACI is lowest (**Table 3**).

The maximal values for percentage production are generally obtained at temperatures from 16 ° to 25°C, although with a suitable diet this can be raised to 29°C. With higher temperatures, it is necessary to increase the concentration of feed so as to maintain the daily protein consumption.

The literature often gives different and variable temperatures that are considered to provide the best egg production, because increasing environmental temperature does not always correspond with any significant differences in production (Grover and Anderson, 1980 ; Magruder and Coune, 1980 ; Deaton *et al.*, 1981, 1982 ; Emery *et al.*, 1984 ; Peguri and Coon, 1985) (**Tables 5, 6**).

It has been observed that the production of eggs by adult hens between 170 and 236 days of life, whatever the environmental temperature (21°C constantly, Co, or 21°-28°C cyclically, Cy), is significantly affected by the temperature to which they were exposed as pullets (Cowan and Michie, 1983).

The thickness of the shell usually decreases as the temperature raises (Deaton *et al.*, 1981 ; Tanor *et al.*, 1984), but not always significantly (Grover and Anderson, 1980) (**Table 6**).

Further studies have shown that for equal mean environmental temperatures, whether the temperature is variable or constant can sometimes cause differences, with variable temperatures giving the best results (Emery *et al.*, 1984), but again the differences are not always significant (Deaton *et al.*, 1982).

As already indicated, changes in temperature, humidity and ventilation change the amount of feed intake, as a function of its energy content, and it should be remembered that larger feed intake makes the resistance to heat worse (Sykes and Salih, 1986 ; Sykcs and Fataftah, 1986b).

It must always be kept in mind, however, that when energy consumption falls below a certain level, first the body weight and then egg production decrease. From this, we can conclude that any factor that can modify metabolic activity can affect the resistance to heat (Sykes and Salib, 1986).

The decrease in feed consumption is probably connected to the loss in live weight at high temperatures observed by many investigators (Deaton *et al.*, 1981 ; Tanor *et al.*, 1984 ; Peguri and Coon, 1985), although this is not a constant finding (Sloan and Harms, 1984) and weight loss is not always significant (Arad *et al.*, 1981).

For equal mean temperatures, it does not seem to matter for body weight whether the temperature is constant or variable (Deaton *et al.*, 1982), though one sometimes sees a greater initial loss of weight in animals exposed to variable temperatures, but this tendency inverts at 275 to 336 days of age (Emery *et al.*, 1984).

Exposure to 30°C when the animals are pullets results in significantly lower weights in the laying hens than the weight of hens reared at 15°C, regardless of the temperature at which the adult hens are kept (21°C Co or 21°-28°C Cy) (Cowan and Michie, 1983) (**Table 5**).

Even if there is no absolute loss of weight, environmental temperature of 21°-24°C can lead to slower growth in the first 12 weeks of laying than temperatures of 15°-18° but this does not affect the live weight of the animals (Grover and Anderson, 1980).

In parallel with reduced feed consumption, there is a change in the amount of water intake. Increased temperatures notably increase water consumption (Lesson, 1986). In some cases, even when there is ample water available, many hens still go into negative water balance (Sykes and Fataftah, 1986a).

It is also interesting to see how the effects of environmental temperature vary with the photoperiod. If the animals are on a photoperiod of 16L:8D and with cyclically varying temperatures from 21° to 35°C, the best performance is obtained when the highest temperature occurs during the hours of light. Not only that, if the high temperatures occur during the hours of dark there is a negative effect on the deposition of calcium in the 62-week-old hens and in younger animals there is an effect on ovulation (Nasser *et al.*, 1985).

From what we have summarized so far, we can conclude that environmental temperature does affect laying performance and that every time hens are kept outside the zone of thermoneutrality, negative effects occur. In order to avoid production loss because of anomalous temperatures, which can occur at any time because of mechanical breakdowns or exceptional weather conditions (Deaton *et al.*, 1982), it may be ueful to acclimate the animals. This is especially true for the adults, because at all ages thermal stress has negative effects, but in laying hens the combination of this with calcium metabolism aggravates the situation (Leeson, 1986).

It has been found that exposure of the animals on several days to 38°C for 4 hours a day at a relative humidity of 26% increased their resistance to climatic conditions that had been lethal without this acclimatization (Sykes and Fataftah, 1986a).

There are very few data in the literature about the influence of relative humidity (RH), which should however be taken into consideration. It is well to remember that excessively high RH makes adaptation to extremes of temperature more difficult. An increase in RH decrease the loss of heat by evaporation at high temperature and decreases the thermal isolation of the animal at low temperatures.

The success of the adaptation depends on following some rules based on the fact that constantly high temperatures cause more damage than variably high temperatures (Leeson, 1986). This was shown in an experiment with two groups of animals subjected to 39°C. The hens acclimated with constant temperature produced significantly less than the others (Deaton *et al.*, 1982).

It has also been shown that if animals reared at 30°C are placed just before being subjected to thermal stress in a room at 20°C they are no longer able to react effectively to the high temperatures, having lost their heat resistance (Sykes and Fataftah, 1986b). This phenomenon appears to be due to the increased metabolic activity and increased heat production caused by the lowering of the temperature counteracting the decrease in heat production induced by the thermal stress. The first mechanism outweighs the second and makes the animals more sensitive to heat (Sykes and Fataftah, 1986b).

The animals also temporarily loose acquired resistance to heat when tested in groups of two or three ; this appears to be due to greater physical activity rather than limitation imposed by the crowding or the adoption of particular postures (Sykes and Fataftah, 1986a).

When the animals are exposed to 39°C for 16 hours, the type of acclimation (25°C Co or 5.6°-35°C Cy) does not seem to affect egg weight, but the percentage of oviposition is significantly lower for the group acclimated at the constant temperature (Deaton *et al.* 1982).

Finally, we must realize that there are two or three levels of heat stress to which the animals respond differently, just as there are differences in response according to the strain or breed studied (Leeson, 1986).

Resistance to heat also depends on the age, the climate of the zone in which the animals are reared, and the diet they are given. Generally light birds resist better than heavy birds (Meltzer, 1987).

Strains that are native to hot climates, such as Sinai breed, when gradually acclimated to high temperatures, are able to increase egg-laying to 38°-40°C and even a ♂ Sinai × ♀ Leghorn hybrid has better qualitative and quantitative performance at high temperatures than the acclimated Leghorn (Arad *et al.*, 1981).

We can suppose from this that local strains are both physiologically and genetically adapted to high temperatures. This should enable us to select animals particularly resistant to heat and able to maintain satisfactory production levels (Arad *et al.*, 1981).

IV. – Conclusion

To obtain better climate control and increase the performance of laying hens in Italy, we are transforming laying houses.

Up to a few years ago, the classic housing structure was a shed open on two sides that could be closed with plastic curtains, with a poor thermal isolation. The concentration of animals was not very high because most the cages were on two or three levels.

This type of structure has been replaced with closed sheds that have forced-air ventilation, cooling units and controlled light. This has provided better control of the microclimate, which is particularly advantageous because it means that in the summer the negative effects of excessively high temperature on egg production can be avoided and in the winter feed consumption is lower.

The concentration of animals has been considerably increased. We now use batteries on 4 levels, with 4-5 hens per cages, which greatly increases the number of hens per unit of surface.

It has been possible to increase the concentration of the hens because the ventilation systems have been greatly improved. We no longer use a large number of small ventilators but a few ventilators of large capacity, which saves a great deal of electricity.

These constantly updated structures make it necessary to continuously update the technology and to control both the environmental conditions and the general conditions of the hens. It is important to record throughout the entire cycle not only the production, such as number of eggs/day, weight of the eggs and mortality, but also data on the microclimatic conditions, temperature, humidity and photoperiod.

Once a week it is useful to weigh individual animals, so as to see whether the diet is satisfactory for nutrition and production of the hen. At the same time, notes should be made about the general condition and health of the hen. It is a good rule to always weigh the same hens and to weigh a large enough number of animals to be representative of the building. Variability of weights in different parts of the building is often rather large, and inter-individual differences are considerable. The body weight of the laying hen increases notably up to 32-34 weeks of age and then tends to stabilize.

Another control that can be made systematically and that reflects the physiological conditions of the hens is the analysis of the metabolic profile (Cerolini *et al.*, 1987). Blood biochemical parameters can reveal negative effects provoked by unsuitable environmental conditions (Verga *et al.*, 1984 ; Cerolini *et al.*, 1986).

The strains that are widely used commercially are the results of intense genetic selection. The individuals produced are potentially able to provide very high production performance as they grow faster and produce large numbers of eggs over their productive span.

However, these animals are more sensitive to unsuitable housing conditions and must be maintained under specific and well-controlled environmental conditions. In addition to light and temperature, other environmental factors play important roles. These are listed in **Scheme 1** and include nutrition, management, health, etc.. All these factors can have immediate consequences and/or long-term impacts on animal production.

References

• ARAD, Z., MARDER J. and SOLLER M., 1981.- Effect of gradual acclimatization to temperature up to 44°C on productive performance of the desert Bedouin fowl, the commercial white Leghorn and the two crossbreds.- In: *Br. Poult. Sci.*, **22**, pp. 511-520.

• ARRIELI A., MELTZER M. and BERMAN A., 1980.- The thermoneutral temperature zone and seasonal acclimatisation in the hen.- In : *Br. Poult. Sci.*, **21**, pp. 471-478.

• BENOIT J., WALTER F.X., ASSENMACHER I., 1950.- Nouvelles recherches relatives à l'action de lumières de différentes longueurs d'onde sur la gonadostimulation du canard mâle impubère.- In : *Compt. Rnd. Soc. Biol.*, **144**, pp. 1206-1211.

• BOSHOUWERS F.M.G., NICAISE E., 1987.- Physical activity and energy expenditure of laying hens as affected by energy light intensity.- In : *Br. Poult. Sci.*, **28**, pp. 155-163.

• CAVALCHINI G.L., PIGNATELLI, P. SARTORE G., 1976.- L'influenza della luce sulle galline ovaiole.- In : *Zootec. Vet.*, **2**, pp. 159-162.

• CAVALCHINI G.L., CEROLINI S., GIARDINI A., 1983.- La luce nell'allevamento della pollastra leggera.- In : *Avicoltura*, **6**, pp. 13-17.

• CEROLINI S., CAVALCHINI L.G., BALDI A., MARIANI P., 1986.- Pullets in cages vs. floor : effect on laying performance. *7th European poultry conference.*-Paris, vol. 2, pp. 800-804.

• CEROLINI S., BALDI A., CAVALCHINI L., 1987.- Il profilo metabolico nella gallina ovaiola. Simposio internazionale di zootecnia.- Milano (In press).

• COWAN P.J., MICHIE W., 1983.- Raised environmental temperature and food rationing as means of restricting growth of replacement pullet.- In : *Br. Poult. Sci.*, **24**, pp. 11-29.

• DEATON J.W., REECE F. N., McNAUGHTON J.L., LOTT B.D., REECE F. N..- 1982.- Effect of heat stress on laying hens acclimated to cyclic vs. constant temperature.- In : *Poultry Sci.*, **61**, pp. 875-878.

• EL HADI H., SYKES A.H., 1982.- Thermal panting and respiratory alkalosis in the laying hen.- In : *Br. Poult. Sci.*, **23**, pp. 49-57.

• EMERY D.A., VOHRA P., ERNST R.A., 1984.- The effect of cyclic and constant ambient temperatures on feed consumption, egg production, egg weight, and shell thickness of hens.- In : *Poultry Sci.*, **63**, pp. 2027-2035.

• ERNST R.A., MILLAM J.R., MATHER F.B., 1987.- Review of life-history lighting programs for commercial laying fowls. In : *World's Poult. Sci. J.*, **43**, pp. 45-55.

• GROVER R.M., ANDERSON D.L., 1980.- The influence of environmental temperature and intermittent watering on resource conservation in the management of brown egg type hens in wire cages.- In : *Poultry Sci.*, **59**, pp. 961-965.

• HARRISON P.C., 1972.- Extraretinal photocontrol of reproductive response of Leghorn hens to photoperiods of different length and spectrum.- In : *Poultry Sci.*, **51**, pp. 2060-2064.

• KING D.F., 1959.- *Artificial light for growing and laying birds.* Alabama Agric. Exp. Stn. Prog. Rep. Res. 72.

• KOELKEBECK, K.W., ODOM T.W., 1985.- Effect of 1.5% ambient CO2 on plasma electrolytes, enzymes, and acid-base balance in laying hens subjected to acute heat stress.- In : *Poultry Sci.*, **64**, pp. 130. Abstract.

• KOELKEBECK K.W., BIELLER H.V., 1986.- Effect of shemeral light-dark cycles on production and egg quality of laying-hens.- In : *Poultry Sci.*, **65**, pp. 874-880.

• LEESON S., 1986.- Nutritional considerations of poultry during heat stress.- In : *World's Poult. Sc. J.*, **42**, pp. 69-81.

• LEESON S., SUMMERS J.D., 1980.- Effect of early light treatment and diet self-selection on laying performance.- In : *Poultry Sci.*, **59**, pp. 11-15.

• LEESON S., SUMMERS J.D., 1985a.- Early application of conventional or ahemeral photoperiods in an attempt to improve egg size.- In : *Poultry Sci.*, **64**, pp. 2020-2026.

• LEESON S., SUMMERS J.D., 1985b.- Response of growing Leghorn pullets to long or increasing photoperiods.- In : *Poultry Sci.*, **64**, pp. 1617-1622.

• LEESON S., WALKER J.P., SUMMERS J.D., 1982.- Performance of laying hens subjected to intermittent lighting initiated at 24 weeks of age.- In : *Poultry Sci.*, **61**, pp. 567-568.

• MAGRUDER N.D., 1982.- Effect of four pullet growing programs, two breeds and two environments on subsequent laying performance.- In : *Poultry Sci.*, **61**, pp. 1504. Abstract.

• McGINNIS J., RAMIREZ H., BOYD J., LAUBER J.K., 1986.- Effect of using coloured light during the rearing and laying periods on performance of hens.- In : *Poultry Sci.*, **45**, pp. 1104. Abstract.

• MELTZER A. 1987.- Acclimatization to ambient temperature and its nutritional consequences.- In : *World's Poult. Sci. J.*, **43**, pp. 33-44.

• MORRIS T.R., 198.- Light requirement of the fowl.- In : *Environmental control in poultry production.-* Edinburg: T.C Carter ed. Oliver & Boyd, pp. 15-39.

• NASSER Y.A., BECK M.M., DESHAZER J.A., 1985.- Laying hen performance as affected by two cyclic temperature patterns.- In : *Poultry Sci.*, **64**, p. 152. Abstract.

• NORDSTROM J.O., 1982.- Shell quality of eggs from hens exposed to 26- and 27-hour light-dark cycles from 56 to 76 weeks of age.- In : *Poultry Sci.*, **61**, pp. 804-812.

• NORDSTROM J.O., OUSTERHOUT L.E., 1983.- Ahemeral light cycles and protein levels for older laying hens.- In : *Poultry Sci.*, **62**, pp. 525-531.

• NYS Y., MONGIN P., 1981.- The effect of 6- and 8-hour light-dark cycles on egg production and pattern of ovipositions.- In : *Br. Poult. Sci.*, **22**, pp. 391-397.

• OISHI T., LAUBER J.K., 1973.- Photoreception in photosexual response of quail. II. Effects of intensity and wavelength. In : *Amer. J. Physiol.*, **225**, pp. 880-886.

• PEGURI A., COON C., 1985.- The effect of temperature and dietary energy on layer performance.- In : *Poultry Sci.*, **64**, p. 160. Abstract.

• PYRZAK R., SNAPIR N., GOODMAN G., ARNON E., PEREK M., 1986.- The influence of light quality on initiation of egg laying by hens.- In : *Poultry Sci.*, **65**, pp. 190-193.

• ROLAND D.A. sr., 1982.- Relationship of body-checked eggs to photoperiod and breaking strength.- In : *Poultry Sci.*, **61**, pp. 2338-2343.

• ROSE S.P., BELL M., MICHIE W., 1985.- Comparison of artificial light sources and lighting programmes for laying hens on long ahemeral light cycles.- In : *Br. Poult. Sci.*, **26**, pp. 357-365.

• ROWLAND K.W., 1985.- Intermittent lighting for laying fowls. A review.- In : *World's Poult. Sci. J.*, **41**, pp. 5-19.

• SAUVEUR B., MONGIN P., 1983.- Performance of layers reared and/or kept under different 6-hour light-dark cycles.- In : *Br. Poult. Sci.*, **24**, pp. 405-416.

• SAUVEUR B., PICARD M., 1987.- Environmental effects on egg quality in the laying hen.- In : *Egg quality Current problems and recent advances*.- London : R.G. Wells and C.G. Belyavin eds., Butterwoods, pp. 219-234.

• SHANAWANY M.M., 1982.- The effect of ahemeral light and dark cycles on the performance of laying hens. A review.- In : *World's Poult. Sci. J.*, **38**, pp. 120-127.

• SHANAWANY M.M., 1983.- Sexual maturity and subsequent laying performance of fowls under normal photoperiods. A review 1950-1975.- In : *World's Poult. Sci. J.*, **39**, pp. 38-46.

• SKOGLUND W.C. WHITTAKER D., 1980.- Interrupted lighting programs for brown egg breeds.- In : *Poultry Sci.*, **59**, pp. 2397-2399.

• SLOAN D.R., HARMS R.H., 1984.- The effects of temperature on feed consumption and egg size in commercial layer houses.- In : *Poultry Sci.*, **63**, pp. 38. Abstract.

• STATEN F.E., HARRISON P.C., 1984.- Renal compensation for high environmental temperature induced acid-base disturbances in SCWL hens.- In : *Poultry Sci.*, **63**, pp. 188. Abstract.

• SYKES A.H., FATAFTAH A.R.A., 1986a.- Acclimatization of the fowl to intermittent acute heat stress.- In : *Br. Poult. Sci.*, **27**, pp. 289-300.

• SYKES A.H., FATAFTAH A.R.A., 1986b.- Effect of change in environmental temperature on heat tolerance in laying fowl.- In : *Br. Poult. Sci.*, **27**, pp. 307-316.

• SYKES A.H., SALIH F.I.M., 1986.- Effect of changes in dietary energy intake and environmental temperature on heat tolerance in the fowl.- In : *Br. Poult. Sci.*, **27**, pp. 687-693.

• TANOR M.A., LEESON S., SUMMERS J.D., 1984.- Effect of heat stress and diet composition on performance of White Leghorn hens.- In : *Poultry Sci.*, **63**, pp. 304-310.

• VAN TIENHOVEN, OSTRANDER C.E., GEHLE M., 1984.- Response of different commercial strains of laying hens to short total photoperiods in interrupted night experiments during days of 24 and 28 hours.- In : *Poultry Sci.*, **63**, pp. 2318-2330.

• VAN KAMPEN M., 1981.- Thermal influences on poultry. In : *Environmental aspects of housing for animal production*.- London : J.A. Clark ed., Butterworths, pp. 131-147.

• VERGA M., CAVALCHINI L.G., CARENZI C., BONETTI F., 1984.- Performances, behavioural reactions and blood plasma parameters of laying hens in cages versus floor. Proceedings and abstract of the World's Poultry Congress-Helsinki, pp. 467-468.

• WATERS C.J., ROSE S.P., BAMPTON P.R., 1987.- Production responses of laying hens to 28 H bright : DIM light cycles using different light intensity ratios and a 24H temperature regimen.- In : *Br. Poult. Sci.*, **28**, pp. 207-212.

Scheme 1: Environmental factors that affect optimization of laying performance

- 1 -	PRODUCTION STRATEGY	Productive programme	Farm dimension	*Farm programme*		
- 2 -	MICROCLIMATE	Sea distance Altitude Ventilation Radiation Raininess	MICROCLIMATE	*Light*	Photoperiod Intensity Wave-length	
				Temp. humidity	Mean and extremes	
				Air	Quantity Quality Direction	
- 3 -	ENGINEERING	*Housing*	*Equipment*			
- 4 -	MANAGEMENT	Technology	Staff training and incentive	Labor efficiency	Equipment maintenance	
- 5 -	NUTRITION	Protein/energy of the diet	Ingredients quality	Vitamin-mineral supplements	Feeding system	Feed efficiency
- 6 -	HEALTH	Bird susceptibility Level of infection Interaction with points 1-2-3-4-5 Welfare				

Figure 1: Standard light regime recommended for egg-type strains

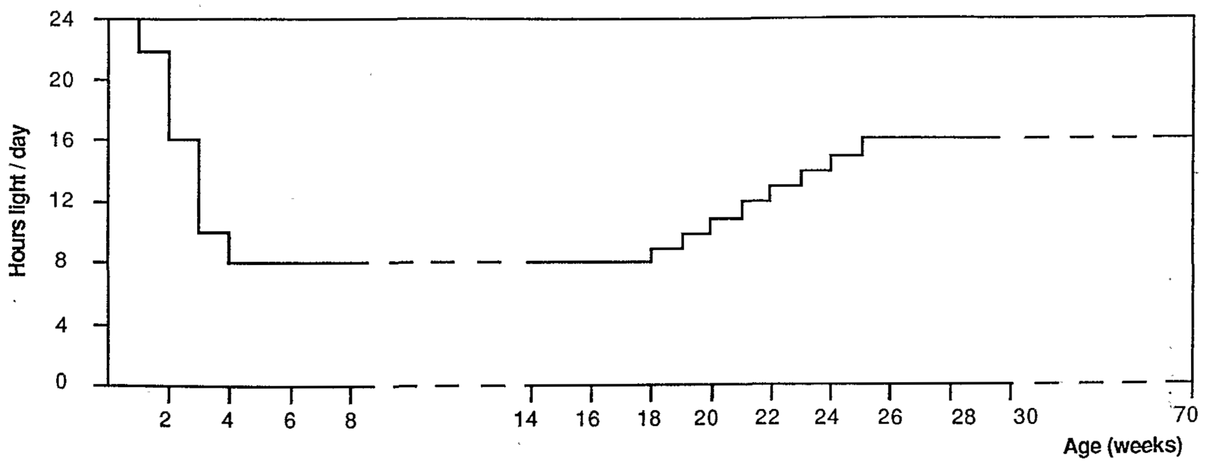

Figure 2: Distribution of oviposition times of hens under lighting schedules of 3L:3D
(adapted from Sauveur and Mongin, 1983)
and 6L:2D:6L:10D
(adapted from Naito *et al.*, 1982) (Rowland, 1985).

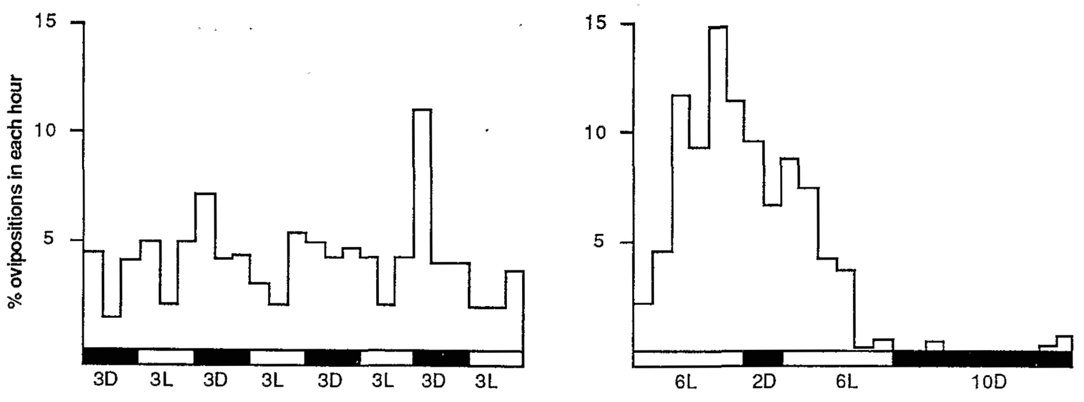

Figure 3: Schematic diagram showing the relationship between ME intake, heat production, evaporative heat loss and body temperature in the fowl. (Tb. body temp; HP, heat production; Et, Er and Ec, Total respiratory and cutaneous evaporative heat loss)

(after Van Kampen, 1976) (Van Kampen, 1981)

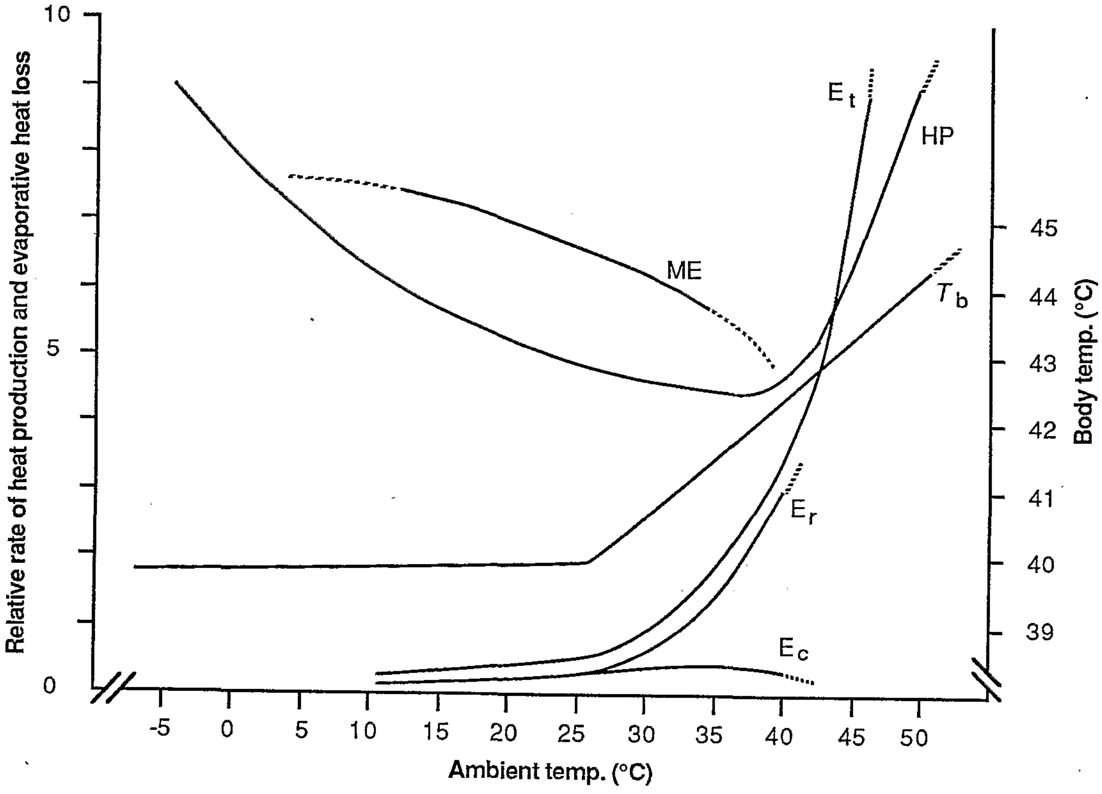

Figure 4: Mean heat production of six single White Leghorn hens during a simulated "tropical day"

(adapted from Van Kampen, 1977) (Van Kampen, 1981)

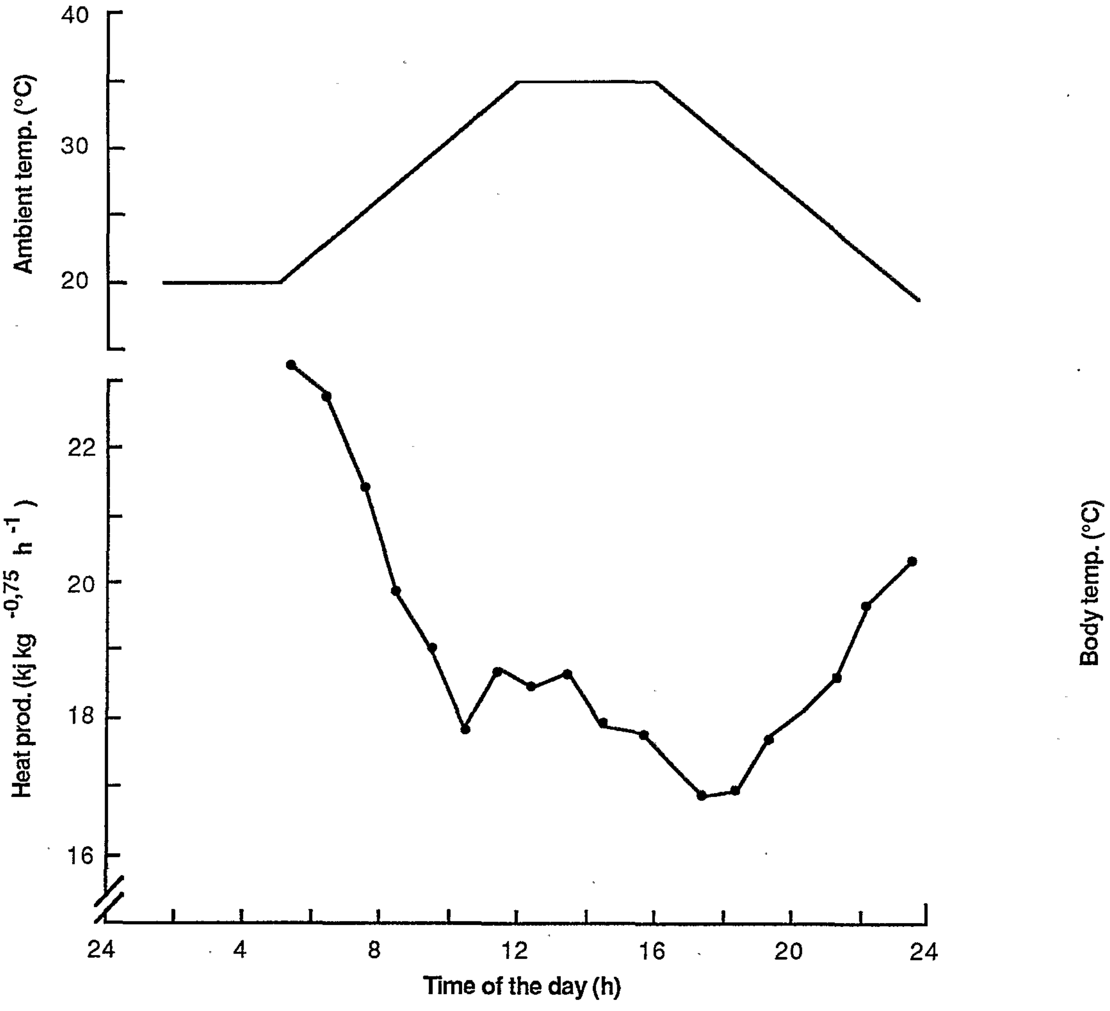

Table 1: The effects of photoperiod on percent hen-production and feed intake

PHOTOPERIOD	AGE weeks	PROD/HEN/D %	FEED INTAKE g/d	REFERENCE
3L:3D	39	84.2	130.9	NYS and MONGIN, 1981
4L:4D	39	86	129.8	
3L:3D	20-55	79.6	121.7	SAUVEUR and MONGIN, 1983
1.5L:4.5D	20-55	78.7	126.2	
18L:8D	67-82	65		NORDSTROM and OUSTERHOUT, 1983
16L:10D	67-82	65.6		
20L:8D	67-82	66.1		
16L:12D	67-82	65.9		
12L:16D	18-66	73.1		VAN THIENHOVEN *et al.*, 1984
16L:8D	18-66	77.9		
2L:6D:2L:18D	18-66	72		
16L:8D	76	57.2	3.14*	NORDSTROM, 1982
16L:10D	76	57.1	3.12*	
16L:11D	76	61.5	2.89*	
14L:10D	15-67	70.4	105.6	LEESON and SUMMERS, 1985a
14L:14D	15-67	66	102.6	
17L:7D	15-67		78.3	
17L:7D	24-76	77.4	114.6	LEESON *et al.*, 1982
17L:7D**	24-76	72.9	110.2	
13L:15D	72-83	72.5	126.9	ROSE *et al.*, 1985
24-hr LDC	22-70	83.2		KOELKEBECK and BIELLIER, 1986
23-hr LDC	22-70	83.2		
26/23-hr LDC	22-70	81.1		

* Feed efficiency (g FEED/g EGG).

** Intermittent light.

Table 2 : The effects of photoperiod on egg weight, egg shell weight and egg shell quality

PHOTOPERIOD	AGE weeks	EGG W. g	SHELL W. g	E. SHELL QUALITY	REFERENCE
3L:3D	39	65.05		2891c	NYS and MONGIN, 1981
4L:4D	39	86		2880c	
3L:3D	20-55	79.6		2529c	SAUVEUR and MONGIN, 1983
1.5L:4.5D	20-55	78.7		2594c	
18L:8D	67-82	64.6	5.29		NORDSTROM and OUSTERHOUT, 1983
16L:10D	67-82	64.9	5.54		
20L:8D	67-82	66	5.64		
16L:12D	67-82	66.6	5.66		
12L:16D	18-66	65		4110c	VAN THIENHOVEN *et al.*, 1984
16L:8D	18-66	61.3		3410c	
2L:6D:2L:18D	18-66	64.9		4110c	
16L:8D	76	64	5.73		NORDSTROM, 1982
16L:10D	76	64.5	5.82		
16L:11D	76	65.3	5.95		
14L:10D	15-67	58.4			LEESON and SUMMERS, 1985a
14L:14D	15-67	59.3			
17L:7D	19-31	49.3		23.2b	
17L:7D	24-76	56.8		25.7b	LEESON *et al.*, 1982
17L:7D**	24-76	56.8		25.3b	
13L:15D	72-83	68.28			ROSE *et al.*, 1985
24-hr LDC	22-70	61.6		1.087a	KOELKEBECK and BIELLIER, 1986
23-hr LDC	22-70	62.6		1.087a	
26/23-hr LDC	22-70	62		1.087a	

a) Specific gravity - b) Shell deformation (µm) - c) Egg shell breaking strength (g).
** Intermittent light.

Table 3: Results of trial measurements of egg size and egg production by White Leghorns at various ambient temperature (van Kampen, 1981)

REFERENCE	TEMPERATURE °C*	EGG SIZE g	LAYING % **
AL-SOUDI and AL-JEBOURI, 1979	± 10	56.0	44.0
	± 45	51.7	45.0
BRAY and GERSELL, 1961	5.6	58.0	88.3
	24.4	56.9	86.5
	30.0	52.9	87.8
DAVIS, HASSAN and SYKES, 1972	7	54.7	92.0
	35	53.7	89.5
DAVIS, HASSAN and SYKES, 1973	7.2	64.9	76.2
	15.6	59.3	86.3
	23.9	59.6	85.1
	29.4	60.1	82.1
	35.0	58.5	79.2
MOWBRAY and SYKES, 1971	± 12.5 (10-15)	56.0	88
	± 22.2 (13-35)	53.8	85
	± 23.0 (18-30)	54.5	88
	30	54.0	87
PAYNE, 1966	18	57.3	78.1
	± 20.8 (15-24)	56.3	81.9
	± 22.5 (18-30)	56.0	82.6
	24	55.9	81.4
	± 25.5 (18-30)	55.6	84.4
	30	55.8	84.2
WILSON, ITOH ans SIOPES, 1972	10	61.3	70.2
	23	60.0	65.8
	36	48.3	62.0

* A plus-or-minus sign indicates the mean of a fluctuating temperature ; temperature limits within brackets.
** Laying percentage is the number of eggs laid per day by 100 birds.

Table 4: The effects of environmental temperatures on percent hen-day production, body-weight, feed efficiency

TEMPERATURE °C*	AGE weeks	PROD/EN/D g	BODY WEIGHT g	FEED EFFICIENCY g feed / g egg mass	REFERENCE
15.5°-18	22-70	71.9		1.97@	GROVER and ANDERSON, 1980
21°-24	22-70	71.8		1.90@	
15.6°-35°	60-64	54	+ 31	3.3	DEATON *et al.*, 1981
21.1°-35°	60-64	58	- 61	3.0	
26.7°-35°	60-64	47	- 42	3.6	
15.5°-35°	28-44	72	- 3	2.6	
21.1°-35°	28-44	69	- 18	2.7	
26.7°-35°	28-44	73	- 43	2.4	
21°	25-92	74.8	+ 179		COWAN and MICHIE, 1983
21°-28°	25-92	74.7	+ 298		
21°	25-92	62.4	+ 346		
21-28°	25-92	61.1	+ 379		
23.9°	36-45	77.5	- .1 + 1.1**	1.90	EMERY *et al.*, 1984
26.7° ±	36-45	74.9	- 1.8 + .4**	2.14	
29.4° ±	36-45	81.7	- 2.0 + .8**	1.85	
23.9°	45-49	79.4	+ .8	2.10	
26.7° ±	45-49	75.6	+ 1.2	2.19	
29.4° ±	45-49	77.6	+ .3	2.02	

** 243-275 and 275-308 days of age.

* A plus-or-minus sign indicates the mean of fluctuating temperature @ Kg/doz.

Table 5: The effects of environmental temperatures on egg weight and egg shell thickness

TEMPERATURE °C*	AGE weeks	EGG W. g	THICKNESS mm	REFERENCE
15.6°-35°	60-64	58	.323	DEATON *et al.*, 1981
21.1°-35°	60-64	58	.325	
26.7°-35°	60-64	57	.314	
15.6°-35°	28-44	57	.319	
21.1°-35°	28-44	56	.316	
26.7°-35°	28-44	55	.305	
23.9°	35-45	58.4	.357	EMERY *et al.*, 1984
26.7° ±	35-45	56.7	.333	
29.4° ±	35-45	55	.339	
23.9°	45-49	59.1	.357	
26.7° ±	45-49	57.8	.354	
29.4° ±	45-49	54.7	.338	

* A plus-or-minus sign indicates the mean of a fluctuating temperature.

Table 6: The influence of ambient temperature on layer performance

(after Zimmerman and Snetsinger, 1975) (van Kampen, 1981)

MEAN TEMP.* °C	RELATIVE PRODUCTION %	RELATIVE EGG SIZE %	RELATIVE FOOD REQUIRED/EGG %	RELATIVE FOOD REQUIRED PER UNIT OF EGG MASS %
16	100	100	100	100
18	100	100	95	95
21	100	100	91	91
24	100	99	88	89
27	99-100	96	86	89
29	97-100	93	85	91
32	94-100	86	84	98

* The daily temperature range was 4.7-7.1 K