



**Final Report:**

# **Evaluation of performance of tunnel ventilated layer housing**

**A report for the Rural Industries  
Research and Development  
Corporation**

by G A Runge

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# FOREWORD

Australian egg producers are experiencing difficult and competitive economic times. All are seeking ways of reducing the cost of egg production. Current housing performance is unable to provide the economic optimum temperatures required by layers in both winter and summer. Overseas information suggests that tunnel-ventilated houses are more efficient, more economic for egg production and more conducive to the bird's welfare than traditional, naturally-ventilated houses. Tunnel ventilation has been adopted by approximately 20 per cent of Australian chicken meat growers and the number is steadily increasing, but there are only nine tunnel ventilated layer sheds in Australia.

When an innovative egg producer constructed a tunnel ventilated layer house on the same property as existing traditional design layer houses, the opportunity was provided to monitor the performance of this new housing system. Because both systems were under the same management, the two styles of layer housing could be compared. The project is a field observation and not a designed experiment achieving statistically valid results. The information gained on performance, costs and management techniques will prove invaluable to egg producers.

The project aims are:

- To monitor the environmental, hen and economic performance achieved by tunnel ventilated housing and compare these with those achieved by naturally ventilated layer housing.
- To provide information which will allow egg producers to make a more informed decision when choosing shed type for housing layers.

RIRDC's involvement in this project is part of the Corporation's Egg Program which aims to improve sustainability and international competitiveness of egg production systems through research and development in flock health, welfare, management and nutrition.

**Peter Core**  
Managing Director  
Rural Industries Research and Development Corporation

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My sincere thanks to the owners and staff of the participating poultry farm for the untiring assistance given in providing information, help in implementing this field study and in resolving problems encountered in setting up the data logging equipment and recording all the information.

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# Contents

Foreword .....	<i>iii</i>
Acknowledgments .....	<i>iv</i>
About the author .....	<i>vii</i>
Executive summary .....	<i>ix</i>
<b>1. INTRODUCTION .....</b>	<b>1</b>
<b>2. METHODOLOGY .....</b>	<b>3</b>
<b>3. RESULTS</b>	
Age at housing .....	6
Feed management .....	7
Hen performance .....	8
Farm gate returns .....	11
Site climate .....	12
House temperature .....	13
Climate difference between the tunnel ventilated houses .....	17
House relative humidity .....	18
Cage temperature variation in the tunnel ventilated house .....	22
Air movement within the cages .....	24
Water consumption .....	24
House carbon dioxide level .....	29
<b>4. DISCUSSION OF RESULTS .....</b>	<b>32</b>
<b>5. CONCLUSIONS AND RECOMMENDATIONS .....</b>	<b>34</b>
<b>6. BIBLIOGRAPHY .....</b>	<b>35</b>



## ***About the author***

Geof Runge is a Senior Development Extension Officer, Intensive Livestock Industry Development Division, Department of Primary Industries, Caboolture Qld and is a member of the Queensland Poultry Research and Development Centre.

He has over thirty years experience in the poultry industry. During the last ten years he has worked in the area of housing and management for both meat chickens and egg layers.

He has investigated the feasibility of, and/or been instrumental in the adoption of, the following practices by the Australian poultry industry:

- The placement and management of stirring fans in naturally ventilated houses for both meat chickens and layers.
- Fogging systems for naturally ventilated housing for poultry.
- The suitability of tunnel ventilated housing for growing meat chickens in Australia.

He has also developed design guidelines for tunnel ventilated meat chicken housing including fan efficiency, placement of foggers, the use of deflectors to improve cooling performance, the use of cool pads and minimum ventilation.





## • Executive Summary

The hen production and environmental performance of tunnel ventilated and naturally ventilated laying housing were compared on a commercial egg farm in New South Wales.

The fully insulated tunnel ventilated house accommodated 20,000 hens in two rows of five-deck, vertically-tiered cages. Specially designed side wall and roof vent shutters provided minimum ventilation driven by natural ventilation instead of fans. A controller which responded to house temperature was used to manage the ventilation rate and keep the house temperature within two degrees of the target.

The naturally ventilated hirise house was of the standard style with 14,000 hens in three decks of cages on "A" frames. Sidewall curtains were used to control ventilation rate. Complete control over ventilation, particularly during winter, was not possible. Using reflective foil under the roof cladding reduced solar heat gain.

Single aged flocks of the same strain were placed in the sheds. All birds were reared on the same site in isolation, on an all-in all-out basis and subjected to similar management practices throughout the study.

Average hen housed egg production for 52 weeks from 5 per cent egg production was 20.8 eggs better in the tunnel ventilated house than in the hirise. On a hen day basis, it was 13.6 eggs better. Weekly egg production for the tunnel ventilated house was consistently better than for the hirise. This difference reflects the better house environment.

Eggs from the tunnel ventilated house were 0.75 grams lighter on average than the hirise. Better control over temperature was possible in the tunnel ventilated house. The tunnel ventilated house was run approximately 2<sup>o</sup>C warmer during the second year of the study in order to produce the smaller eggs demanded by the market.

Average feed consumption per hen was 10 grams per day higher in the hirise house than in the tunnel ventilated house. This reflects the diet differences and the lower temperatures achieved in the hirise house during winter. Slightly better quality diets were required in the tunnel ventilated houses to maintain production rate. It took 0.247kg of feed more in the hirise house to produce one kilogram of eggs. Most of this extra feed was used by the hens to keep warm during winter.

Based on farm gate costs the tunnel ventilated housing gave a net return of 8.52 cents per dozen more than the hirise house.

The breakeven point when feed plus pullet costs equals egg receipts was 7.1-8.6 cents per dozen less for the tunnel ventilated housing than for the hirise.

The trial demonstrated the ability of the tunnel ventilated house to maintain temperature within the range for efficient egg production (20-27<sup>o</sup>C). On hot summer days the maximum temperature in the tunnel ventilated housing was 27<sup>o</sup>C compared to 29-32<sup>o</sup>C in the hirise house.

During cold winter days the tunnel ventilated housing was able to maintain a temperature of 20-25<sup>0</sup>C compared to 9-18<sup>0</sup>C for the hirise shed. The outside temperature on these days was minus 2.4 to 10<sup>0</sup>C.

Temperature variation within the cages in the tunnel ventilated house was less than 4.5<sup>0</sup>C except in very cold weather when it rose to 9.0<sup>0</sup>C. This was caused by cold air entering the house through the tunnel ventilation inlet area due to poor sealing around the shutters. Fixing this leak will lower the variation to less than 4.5<sup>0</sup>C.

Water consumption for the hens in the tunnel ventilation house was 233mls per hen per day and 229mls for the hirise house. Water loss from leaking nipples in the hirise house during the night was estimated at 2220 litres per 1000 hens per year.

The carbon dioxide level detected in both houses was within the accepted levels for poultry. Levels of 0.04-0.26% and 0.04-0.12% were measured in the tunnel ventilated and hirise houses respectively. The highest levels were recorded on cold winters nights when ventilation rate was low. The lowest levels when high ventilation rates were being used in summer.

This project has demonstrated that by using well designed tunnel ventilated housing incorporating adequate insulation, a good ventilation system and good sealing against air leakage, it is possible to maintain temperature within the limits desired for efficient production. These results could not be achieved without paying attention to detail to both management of the house equipment and the layers and to installation of equipment.



# Introduction

Competitive economic conditions in the Eastern and Southern Australian egg industry have resulted in low profitability and the amalgamation of farms to improve viability. Egg producers are seeking methods to reduce the cost of egg production. Current housing design has proven unable to provide the economic optimum temperatures required by layers during winter and summer. Interest in new housing has increased since the introduction of the new Welfare Code.

Overseas information about tunnel ventilated housing suggests that:

- production units with 20,000 - 100,000 hen capacity using multi tiered cages with belt manure removal provide the cheapest housing on a per hen capacity basis.
- they are more energy efficient due to insulation, compactness and controlled fan ventilation.
- the new cage and house design and sophisticated ventilation system improves the hen's welfare by providing a better environment for the hen particularly during temperature extremes encountered in summer and winter. Cages comply with the Australian and overseas welfare standards.
- hens are able to produce eggs of larger or smaller size or mass (as required by the market) during seasonal extremes of climate.
- manure is drier, there is less ammonia within the house and less odour emitted from the house.

The construction of a tunnel ventilated layer house incorporating a natural ventilation system for cold weather ventilation on the southern tablelands of New South Wales provided the ideal opportunity to monitor the performance of the new housing system. The new house was close to an existing hirise naturally ventilated "A" frame cage house. The same feed source, strain of birds and management was used in each house on the farm. This provided the opportunity to compare the two styles of layer housing and to study tunnel ventilated housing under Australian conditions.

The project is a field study of the two systems and is not a designed experiment achieving a statistically valid result. The information generated on performance, costs and management techniques will prove invaluable to egg producers.

Tunnel ventilated layer housing incorporates four ventilation systems to provide optimum temperature and air quality environment for the individual hen. These systems are:

- Tunnel or hot weather ventilation
- Good weather ventilation
- Minimum or cold weather ventilation
- Manure drying system

Each system is used according to the requirement of the hens and the ambient weather conditions.

Tunnel ventilation is the use of more than half the available fans to ventilate the house when the outside temperature is greater than that required by hens, usually at least 1-2<sup>0</sup> C above. It uses wind chill effect to cool the hens and high air exchange rates to remove rapidly from the house the heat generated by the hens. If house temperature rises above 28<sup>0</sup>C-30<sup>0</sup>C additional evaporative cooling is required.

Good weather ventilation is used when the ambient or outside temperature is similar to that required by the hens. Either natural or fan ventilation is used.

With natural ventilation, curtains are fitted in both sidewalls and the amount of opening is controlled by a controller attached to winching devices or by manual adjustment of the winches.

The shed is operated in good weather mode when the outside temperature is 1-3<sup>0</sup> C below or 1-2<sup>0</sup>C above that required for the hens (ie. the target temperature).

If fans are used instead of natural ventilation the sidewalls can be solid with the house relying entirely on fans for ventilation. Backup generators and alarms are essential for this system. Up to two thirds of the tunnel ventilation fans are on and air is pulled in through the tunnel ventilation inlets. The number of fans on is dependent on the heat load in the house. This is related to density of hens. The decision as to whether natural ventilation or fans are used depends on the number of days per annum where the local climate is suitable for natural ventilation. The longer this is, the greater the saving in electricity usage.

Minimum or cold weather ventilation is used to maintain house air quality when the temperature outside is 1-2<sup>0</sup>C less than that required by the hens. The temperature difference between inside and outside is dependent on the heat produced by the hens. The ventilation rate must be sufficient to remove moisture, gases such as ammonia and carbon dioxide, maintain oxygen levels and yet keep enough of the hen body heat in to maintain house temperature. Either fans or natural ventilation can be used.

Where fans are used up to half of the tunnel ventilation fans are operated. The air is drawn in through special minimum ventilation inlets to ensure the cold air is mixed with warm shed air before coming in contact with the hens.

In a shed equipped for natural ventilation, roof vent and sidewall shutters are fitted. These are designed and operated in a way that ensures the cold incoming air is mixed with shed air before it comes in contact with the hens.

A manure drying system uses separate ventilation equipment which dries the manure by blowing air over it whilst it sits on the belts under each deck of cages. This reduces the ammonia and odour released from the manure and emissions from the shed. The air can be preheated if required. This equipment is optional. The manure is removed twice a week.

Tunnel ventilated houses incorporating natural ventilation can be no wider than the width required to house two decks of cages. If wider than this it is difficult to obtain an even temperature across the house when natural ventilation is used. With more than two decks of cages natural ventilation has insufficient force to adequately exchange air around the inner decks of cages. This results in hot spots in the inner decks.

## Objectives

- To demonstrate the environmental, hen and economic performance achieved by tunnel ventilated and naturally ventilated layer housing.
- To provide information allowing egg producers to make a more informed decision when choosing shed type for housing layers.

## Methodology

The hen production and environmental performance of a tunnel ventilated house incorporating a naturally ventilated driven cold and good weather system and a naturally ventilated hirise laying house were compared on an egg farm situated in the southern highlands of New South Wales. This area experiences very cold wet winters and hot dry summers.

The newly constructed tunnel ventilated house accommodates 20,000 hens in two rows of five-deck, tiered cages (Figure 1). Fifty millimetre sandwich panel is used in the walls and seventy-five millimetre panel in the roof for insulation. Six, forty-eight inch fans each with a flow rate of 39,850m<sup>3</sup>h providing airflow of 12m<sup>3</sup>h or 7 cfm per hen housed are fitted in one end wall. Cool pads and air inlets are fitted at the opposite end for hot weather ventilation and cooling. Specially designed side wall and roof vent shutters provide minimum ventilation during cold weather using stack effect to drive the natural ventilation system (Figures 2 and 3). A controller responding to house temperature is used to manage the ventilation rate and keep the house temperature within two degrees of the target. It controls the shutters, fans and cool pads.

This system works in three stages. (1) In cold weather when the ambient is less than 12°C opening the roof shutters ventilates the house. (2) As ambient temperature increases above 12°C the top sidewall shutter opens followed by the bottom two shutters at about 15-17°C. (3) The ventilation system switches to tunnel ventilation mode when the house temperature rises to one degree above target temperature. This usually occurs when the ambient is just below target temperature. The evaporative cooling is activated when the house temperature rises 2-3°C above target. Figure 4 shows the redesigned inlet that houses the cool pads.

The naturally ventilated hirise house is of the standard style with 14,000 hens in three decks of cages on "A" frames (Figure 5). Curtains on the sidewall from ground level to the eaves were used to control the ventilation rate. There is no shutter on the vent in the gable roof. Complete control over ventilation rate, particularly during winter, is not possible. Solar heat load is reduced using reflective foil under the roof cladding. Evaporative cooling is provided by a 600psi fogger system with 228 nozzles (flow rate of 4.9 litres per hour) in four lines. A controller responding to house temperature manages the opening and closing of the sidewall curtains and the activating of the fogger system.

A second tunnel ventilated house was built during the course of the project and the production from one flock was recorded in this house (flock TV2). The house temperature and relative humidity was compared with the first tunnel ventilated house.

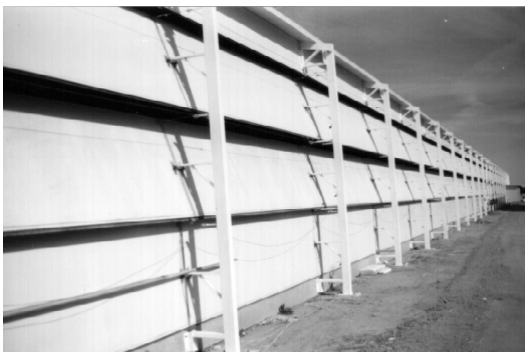
**Figure 1** The tunnel ventilated house



**Figure 2** The roof shutters



**Figure. 3** The sidewall shutters



**Figure 4.** The tunnel ventilation inlet



**Figure 5.** The hirise house



Five hens were housed per 500 x 500mm cage, 450mm high in the tunnel ventilated house in two decks, five tiers high. Three birds were housed per 500 x 300mm cage 430mm high in cages mounted on "A" frames in the hirise house. The side of the cages was of mesh.

Feed level was maintained in the feeding troughs by a travelling hopper in the tunnel ventilated house and by button cable in the hirise house.

Weekly feed consumption was estimated from feed deliveries. The feed delivery vehicle was weighed before and after delivery. Because feed on hand was estimated at each delivery there is some inaccuracy in the weekly consumption estimates. Total feed over the batch is accurate.



Nipple drinkers in both styles of house supplied water to the hens. The drinking water came from a town water supply. Water consumption was measured with meters placed on the inlet line to the drinking system in both houses.

Farm staff recorded mortality in each flock daily.

Single aged flocks of the same strain were placed in the test sheds. All birds were reared on the same site in isolation on an all-in all-out basis and subjected to similar management practices throughout the study.

The houses and flocks were monitored over a period of 34 months from October 1995 to August 1998. Detailed monitoring of the houses commenced in August 1996. The second tunnel ventilated house was monitored from May 1997 to August 1998.

Egg production was recorded daily for the first flocks in both houses, and changed for subsequent batches to four days per week due to reorganisation of farm labour to handle the extra work load from the second tunnel ventilation house. Where eggs from two days were recorded on the one day the production was averaged over the two days.

Eggs from one hundred hens in each flock were weighed once a week. The hens were housed in one section of cages selected at random.

The environment was monitored over two consecutive flocks in both the hirise house and the original tunnel ventilated house. Egg production, egg mass, mortality, and feed and water consumption were recorded for these flocks. Due to a delay in construction of new rearing facilities to cater for the increased hen numbers the first flock in the tunnel ventilated house was rested to extend the laying period until the next pullets were ready.

Temperature, relative humidity, carbon dioxide level, and water consumption were monitored for each shed using sixteen-channel loggers. The ambient temperature and humidity were also monitored. The loggers scanned each sensor and meter every ten minutes on a 24 hour basis.

The house temperature was measured on sensors placed next to the three sensors that the controller used to monitor house conditions. In the tunnel ventilated house the sensors were placed at positions 7, 8 and 9 in the centre aisle level with the top tier of cages (Figure 7). Temperature was also measured at the same positions in the second tunnel house. In the hirise house the sensors were placed at positions 1, 2 and 3 as shown in Figure 6. They were fitted level with the second top tier of cages and in the free space under the top tier.

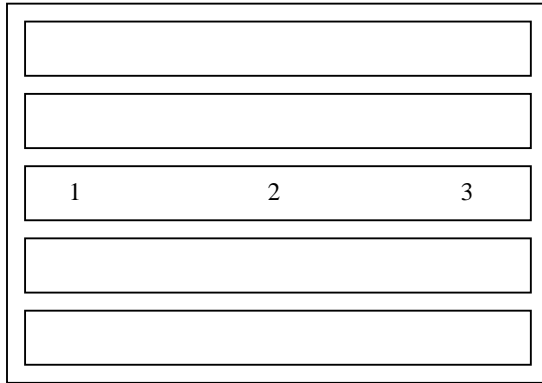
Relative humidity was measured near both ends of each house in positions 7 and 9 in both tunnel ventilated houses and at positions 1 and 3 in the hirise house.

These temperature and relative humidity sensors were placed adjacent to the sensors used by the controller to monitor house conditions to enable tracking of the controllers ability to provide the desired conditions in the tunnel ventilated house.

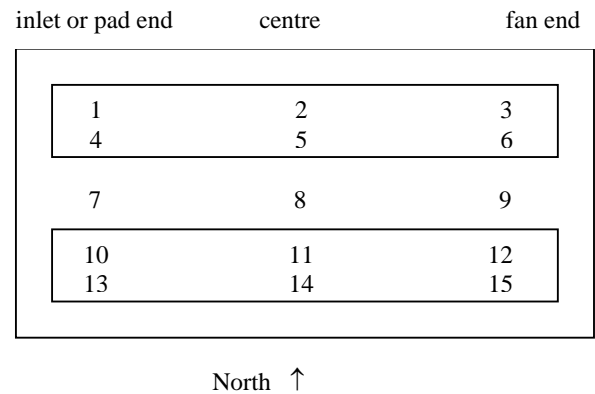
In order to measure the evenness of temperature throughout the cages in the tunnel ventilated house additional temperature sensors were placed in the top and bottom tiers of cages of each deck at positions 1-6 and 10-15 (Figure 7).

A carbon dioxide sensor was placed in each house to give a indication of air quality. The sensor in the tunnel ventilated house was at position 8 level with the top of the third tier of cages. In the hirise house the sensor was at position 2 at a level similar to the other sensors.

**Figure 6** Sensor layout in the hirise house



**Figure 7** Sensor layout in the tunnel ventilated house



During the first seven months of the study errors occurred in temperature data for the tunnel ventilated house during the two hours of egg collection each day. It was caused by electromagnetic fields generated by a faulty power inverter in the egg collection equipment. The errors were corrected manually using averaging techniques.

## Results

The performance from five flocks of hens and the climate in both houses was recorded during the project.

### Age at Housing and start of egg production

Age at housing was approximately 16 weeks for all flocks except for Tunnel Ventilated 1 (TV1) flock, which was 19.4 weeks of age. Housing of this flock was delayed until the completion of the house. Hirise 1 and TV1 flocks were reared 10 weeks apart. The age difference between subsequent flocks was 16-21 weeks. TV1 and TV3 were housed in the first tunnel ventilated house, TV2 in the second house. More information is presented in Table 1.

The pullets reached 5% egg production between 16.6 and 19 weeks age.

Table 1 Date and age birds were housed in laying facilities and at 5% egg production.

Flock	Housed		5% Egg Production	
	Date	Age (weeks)	Age (weeks)	Date
Hirise 1	16 Oct 1995	16.0	17.0	23 Oct 1995
Tunnel Ventilated 1 (TV1)	5 Jan 1996	19.4	19.0	1 Jan 1996
Hirise 2	4 Jan 1997	16.5	19.2	22 Jan 1997
Tunnel Ventilated 2 (TV2)	7 May 1997	15.3	16.6	18 May 1997
Tunnel Ventilated 3 (TV3)	23 Aug 1997	16.0	18.2	11 Sep 1997

## Feed Management

Egg production rate and egg size was used to gauge if diets were adequate and when diets were changed. The changes were made to maximise returns so that the difference between the cost of maintaining egg production rate and feed cost was maximised. As an example; if the difference in cost between Layer 1 and Peak Layer was \$5.00 per tonne and changing from Peak Layer to Layer 1 resulted in a loss of more than 60 eggs per 8,000 hens (0.75%), it was better to leave the hens on Peak Layer. It was assumed that eggs were \$1.00 per dozen at the farm gate and feed consumption was 125g per hen per day.

The age at which the pullets were placed on each diet is presented in Table 2. The energy, methionine and lysine levels in each diet fed during the project are presented in Table 3.

**Table 2** Age in weeks when diet was changed.

	Hirise 1	Hirise 2	TV1	TV2	TV3
Prelayer	16.0	15.0	16.0	15.0	15.4
Layer 1	22.0	20.2	20.4	17.5	18.2
Peak Layer		22.0		19.2	20.0
Layer 3	29.0				
Layer 4	62.4		56.4		
Layer 3			62.6		
Layer 1		37.0		40.4	65.3

When the first flock, TV1, went into the tunnel ventilated house, the diets used were based on previous knowledge and experience gained on the farm. The change from Prelayer diet to Layer 1 was made when the pullets showed signs of egg production. ie as soon as practical after 5 % eggs. Flock Hirise 1 was changed to a layer diet later than the following flocks. Observation of the hen performance from flocks Hirise 1 and TV1 suggested that diets Layer 1, 3 and 4 did not enable the hens to lay at their full potential. Peak Layer was formulated and Layer diets 3 and 4 were not used in subsequent flocks.

At 56.4 weeks flock TV1 was placed on Layer 4 diet. This resulted in a slight egg production drop and the hens were changed back to Layer 3 diet at 62.6 weeks.

In flock TV2 the change from Peak Layer to Layer 1 was made at 40.4 weeks of age. Observations of the performance of the flock suggested that the hens in the tunnel ventilated houses should be left on Peak Layer until 65 weeks of age (flock TV3). The effect of the

climate on the hens in the hirise shed constrained the hens from reaching their potential performance and did not warrant keeping flock Hirise 2 on the Peak layer diet longer.

**Table 3** Energy, Methionine and Lysine levels of the diets.

<b>Diet</b>	<b>Energy MJ</b>	<b>Methionine %</b>	<b>Lysine %</b>
Prelayer	11.11	0.305	0.686
Layer 1	11.50	0.361	0.773
Peak Layer	11.72	0.418	0.786
Layer 3	11.42	0.305	0.686
Layer 4	11.30	0.350	0.729

### Hen Performance

Average hen housed egg production from 5 per cent eggs for 52 weeks lay was 20.8 eggs better in the tunnel ventilated houses than in the hirise house (see Table 4). On a hen day basis, it was 13.6 eggs better.

There are significant differences between the tunnel ventilated houses and the hirise house for egg numbers per hen housed and per hen day, egg numbers percent hen housed and percent hen day, and feed consumption in grams per day ( $P < 0.05$ ).

The feed conversion ratio (kg feed per kg egg) for the flocks in the second tunnel ventilated house (flock TV2) was higher than the feed conversion ratio for the flocks in the original tunnel ventilated house (flocks TV1 and TV3).

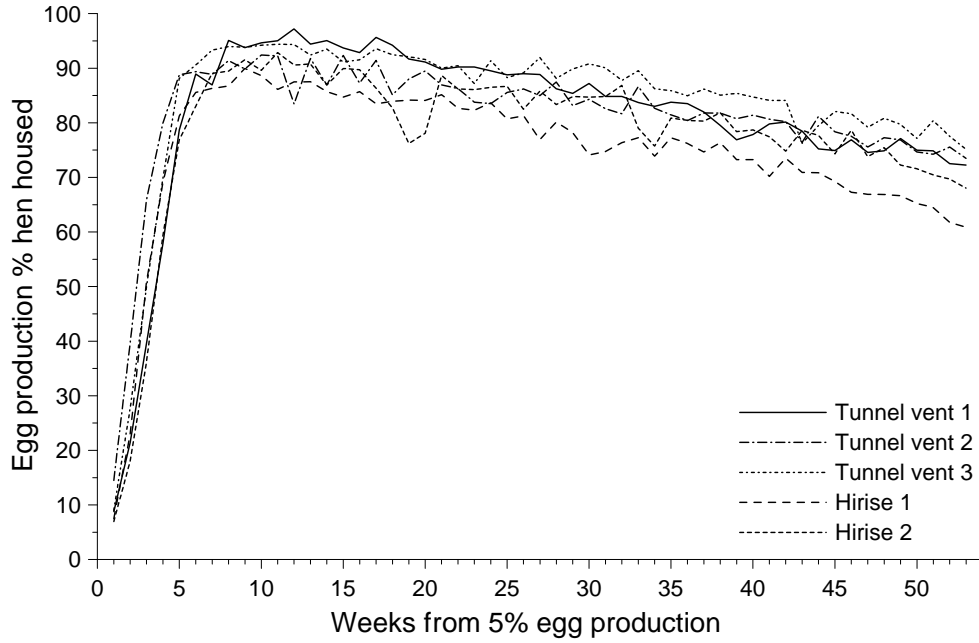
Average mortality was 4.2% higher in the hirise house than in the tunnel ventilated houses. (See Table 4). This was mainly due to the high mortality in flock hirise 1.

**Table 4** Egg production rate, average egg weight, feed consumption, feed conversion ratio and mortality for each flock.

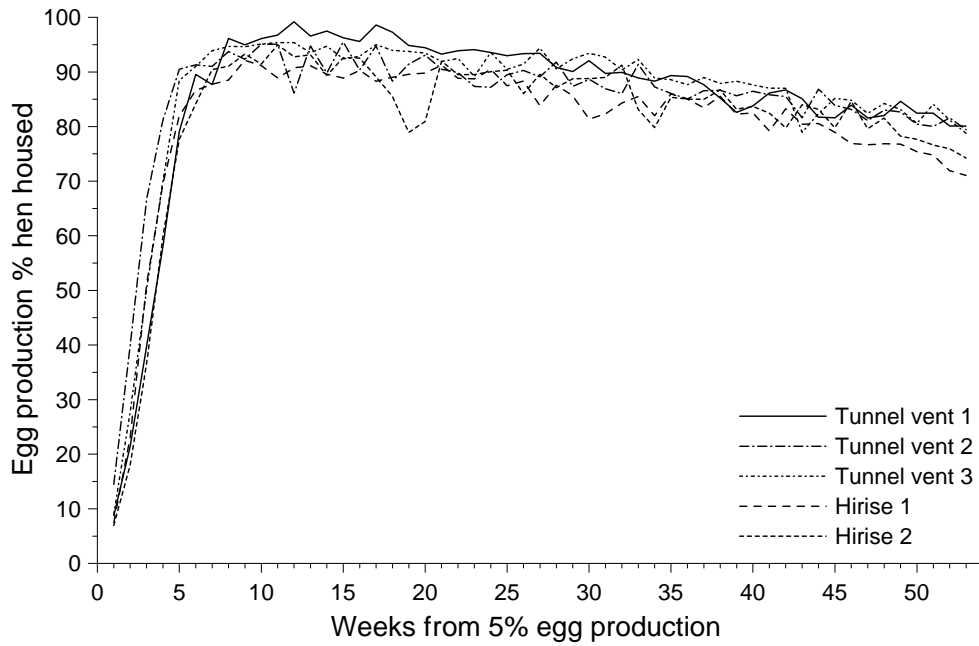
	<b>Hen Housed Eggs</b>	<b>Hen Housed %</b>	<b>Hen Day Eggs</b>	<b>Hen Day %</b>	<b>Average Egg Weight</b>	<b>Feed Conversion Ratio</b>	<b>Feed g/day/hen</b>	<b>Mortality %</b>
Hirise 1	273.6	75.18	301.5	82.84	62.83	2.470	128.5	14.60
Hirise 2	286.1	78.60	304.4	83.63	64.16	2.500	134.2	8.55
TV1	297.1	81.62	311.8	85.67	65.86	2.189	123.5	9.88
TV2	296.7	81.52	316.4	86.94	60.09	2.334	121.9	7.67
TV3	308.0	84.63	321.6	88.34	61.10	2.197	118.6	4.64
Hirise average	279.8	76.86	303.0	83.23	63.50	2.485	131.4	11.63
TV average	300.6	82.58	316.6	86.98	62.34	2.238	121.3	7.41

A comparison of hen housed and hen day production for each flock is presented in Graphs 1 and 2 respectively. Egg production for the tunnel ventilated house was consistently better than the hirise (Graphs 1 to 4).

**Graph 1** Comparison of Hen Housed percent egg production between flocks.

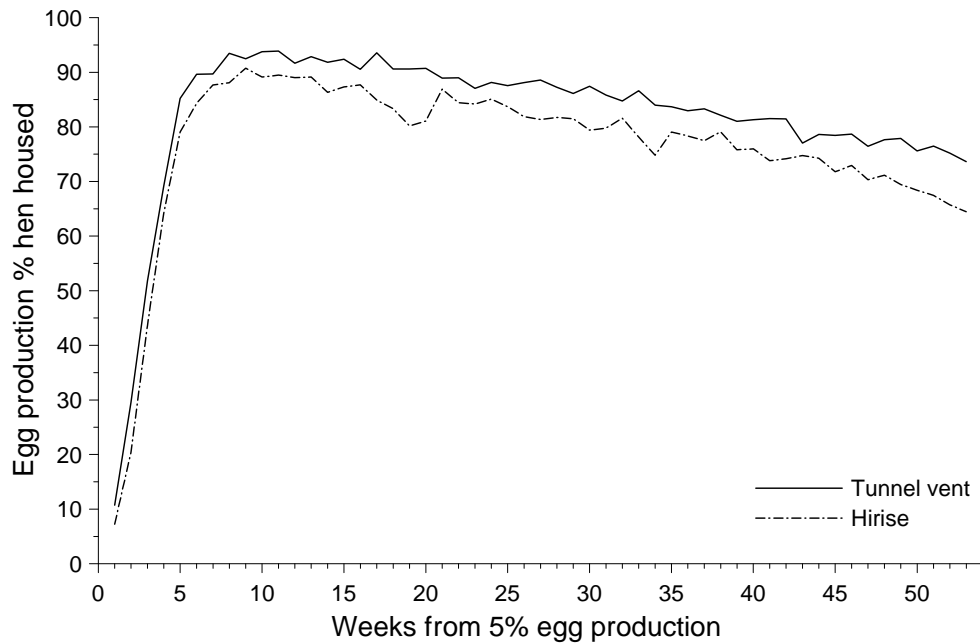


**Graph 2** Comparison of percent Hen Day egg production between flocks.

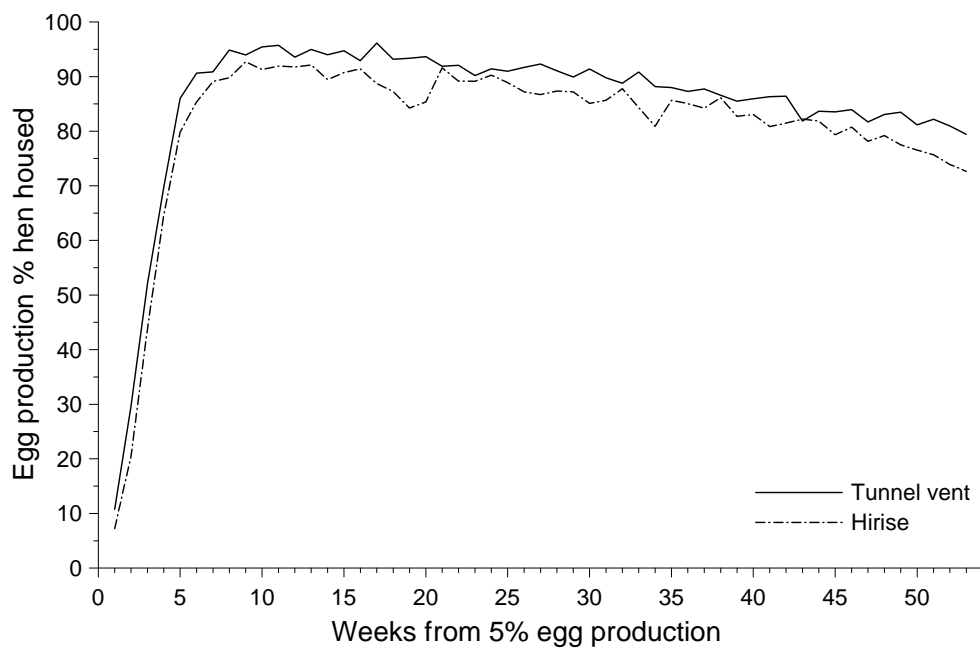


Eggs from the tunnel ventilated houses were 0.75 grams lighter on average from the tunnel ventilated house than the hirise. In order to produce eggs of a weight closer to market needs steps were taken to reduce egg size in flocks TV2 and TV3. This was done by increasing house temperature.

**Graph 3** Comparison of average Hen Housed egg production (%) between house types.



**Graph 4** Comparison of average Hen Day egg production (%) between house types.



Average feed consumption for the hens in the hirise was 10 grams per day higher than the tunnel ventilated houses. This reflects diet differences and the lower temperatures in the hirise house during winter. It took 0.247 kg of feed more in the hirise house to produce a kilogram of eggs.

## Farm Gate Returns

Net returns from each flock were compared using farm gate income and costs. After deducting feed and pullet costs from egg sales, the tunnel ventilated houses have an excess income over the hirise house of \$2,773 per 1,000 hens housed. Average egg price of \$1.23 per dozen, feed at \$293 per tonne and pullets at \$7.00 each was used (see table 5). No allowance has been made for differences in the extra cost in running the tunnel ventilation fans in summer.

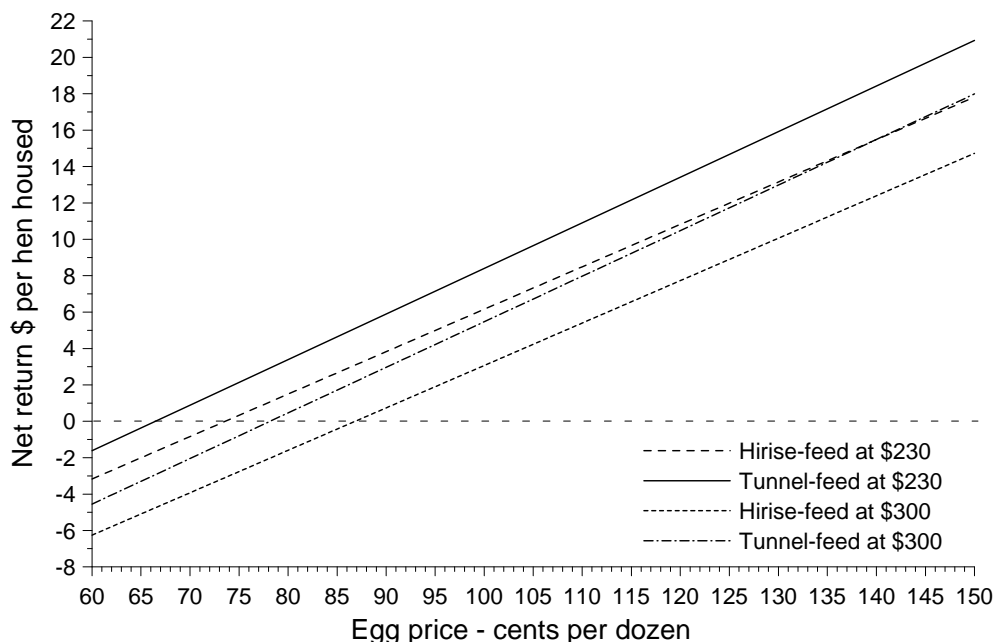
Based on farm gate costs the tunnel ventilated housing gave a net return 8.52 cents per dozen more than the hirise house.

**Table 5** Costs and return comparison between house types.

	Feed Cost	Pullet Cost cents per dozen eggs	Net Return
Hirise 1	54.55	30.70	37.75
Hirise 2	56.41	29.36	37.23
TV1	50.69	28.27	44.03
TV2	49.30	28.31	45.39
TV3	47.30	27.27	48.54
Hirise average	55.48	30.03	37.49
TV average	49.05	27.95	46.01

The effect of varying egg price and feed price on returns was investigated. Graph 5 shows that the breakeven point (when feed plus pullet costs equals egg receipts) for the tunnel house was 66.5 cents per dozen and 73.6 cents for the hirise when feed price was \$230 per tonne. If feed increased to \$300 per tonne the breakeven price was 78.3 cents per dozen for the tunnel house and 86.9 cents for the hirise (See Graph 5). The breakeven point for the tunnel house is 7.1-8.6 cents per dozen less than the hirise.

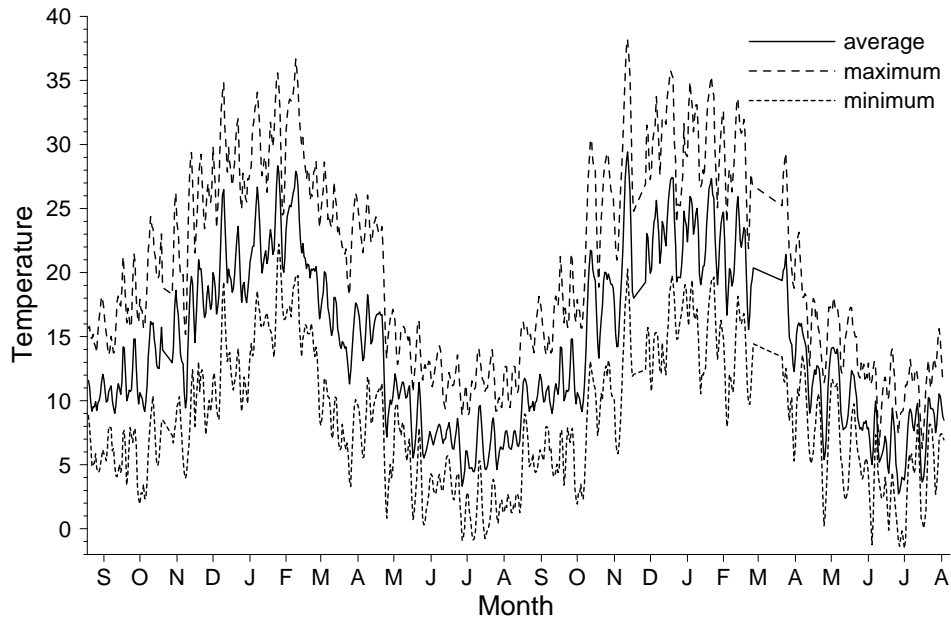
**Graph 5** Comparison of net return per hen housed between house types according to egg price and feed cost.



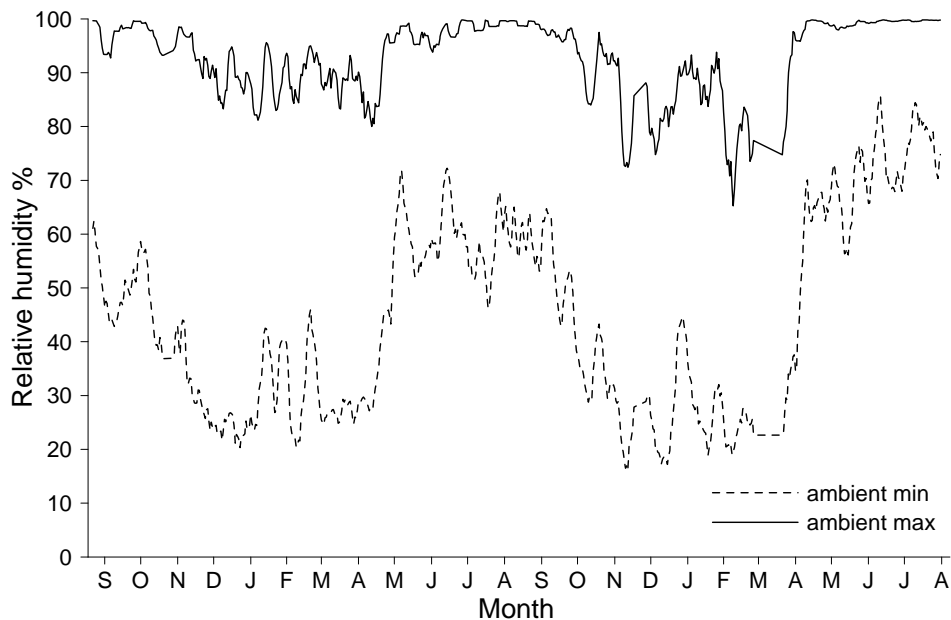
## Site Climate

The external environment on the site was measured. This information is presented in Graphs 6 and 7. The average temperature over the study period was 14.34°C. However the range was -2.4 to 39.8°C. The relative humidity reflects the seasonal conditions experienced in the area. Winters are wet and summers are dry. The relative humidity was lower in summer than in winter.

**Graph 6** The daily average, maximum and minimum ambient temperature. Sept 96-Aug 98.



**Graph 7** The daily maximum and minimum ambient relative humidity. Sept 96 – Aug 98.





## House Temperature

The average daily temperatures and the range at the site weather station and in the houses for the period of the study was -

	Average mean temperature °C	Temperature Range °C
- Site weather station	14.3	-2.4 to 39.8
- Hirise house	19.9	8 to 33
- Tunnel ventilated No 1	23.5	20 to 27

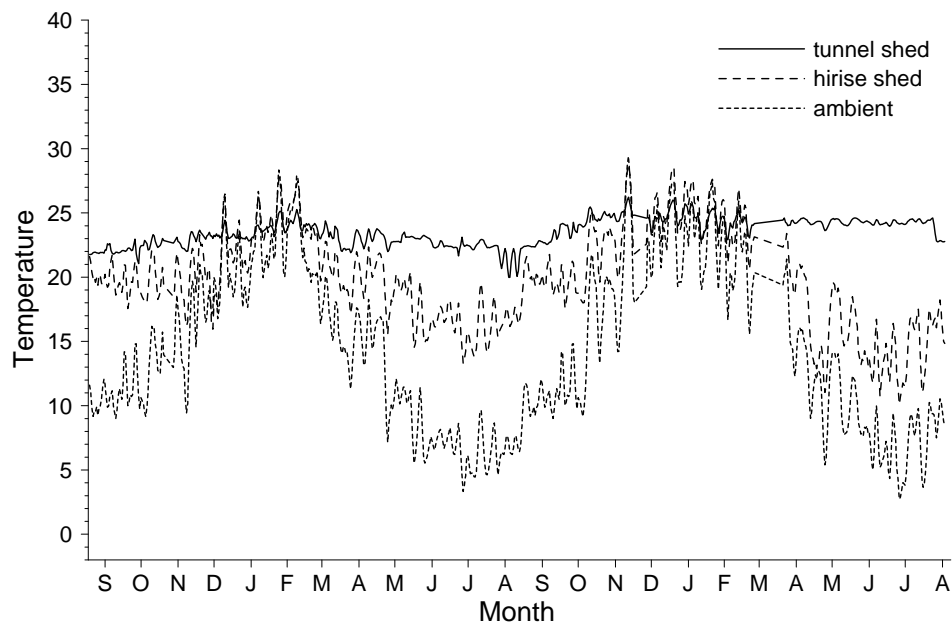
The tunnel ventilated house maintained house temperature within the range for efficient egg production. (Graphs 8 and 9). The average daily tunnel ventilated house temperature was maintained within a range of 20-27°C over the period of the study.

Initially the target temperature on the controller was set at 21°C. This was increased to 23°C as the behaviour of the control and ventilation system was understood better. During the second year it was increased further to 25°C. This is reflected in the tunnel ventilated house temperature plot in Graph 8.

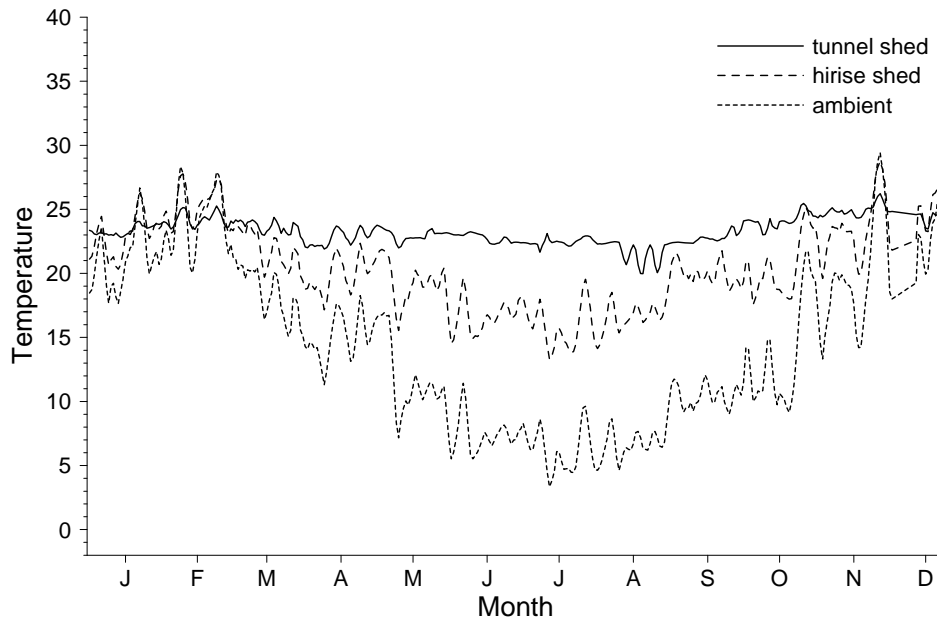
The average temperature in the hirise house tended to follow the seasonal variation. It almost reached the peaks of the average daily ambient temperature in summer. In winter it was about ten degrees above the average daily ambient temperature (Graph 9).

Graphs 8 and 9 show a comparison of the mean daily tunnel ventilated and hirise house temperature with the ambient temperature for the period of the study and for 52 weeks respectively.

**Graph 8** Comparison of average daily ambient, tunnel ventilated and hirise house temperature. Sept 96 – Aug 98.



**Graph 9** Comparison of average daily ambient, tunnel and hirise house temperature Jan – Dec 97.



On a cold winter day the tunnel house was able to maintain a temperature of 20-24°C compared to 9-18°C for the hirise shed. The ambient temperature range for the day was minus 1.5-8°C.

On a hot summer day the maximum temperature achieved in the tunnel ventilated house was 26.5°C compared to 29-32°C in the hirise house.

The ability of both houses to manage temperature at various ambient temperatures is presented in Graphs 10 – 14.

*Cold Winter Day* - Graph 10 - The tunnel ventilated house maintained a temperature of 23°C ± 1 degree whereas the hirise house temperature followed the ambient and was about 8-10°C above it.

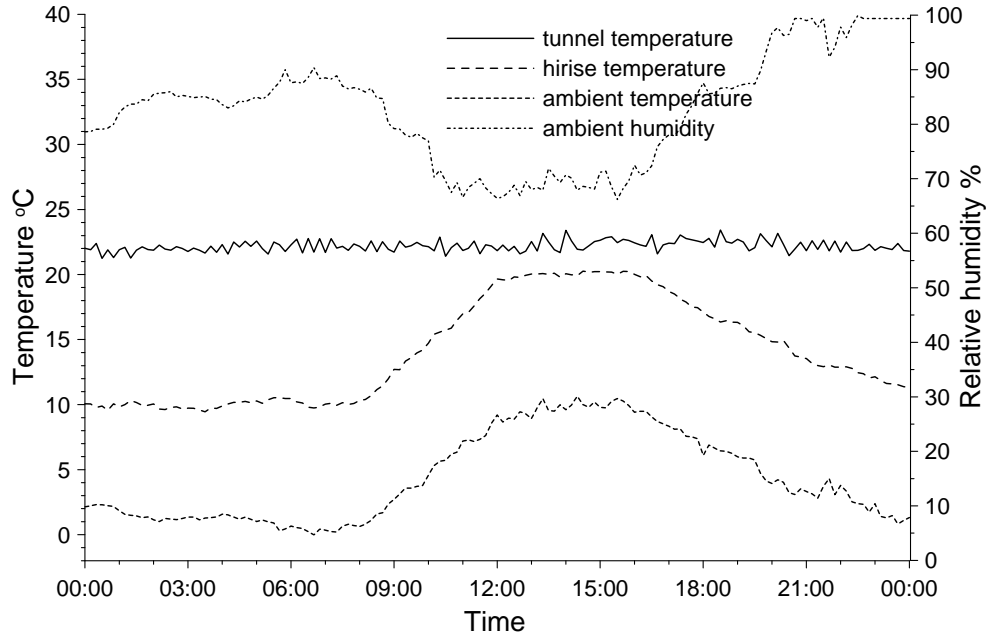
*Warm Winter Day* - Graph 11 - The tunnel ventilated house maintained a temperature of 22°C ± 1 degree. The hirise maintained a temperature of approximately 6°C above the ambient. The differences between the temperature of 8-10°C and 6°C shown in Graphs 10 and 11 is due to the effect of wind on the house internal air movement patterns.

*Spring/Autumn Day* - Graph 12 - The tunnel ventilated house maintained house temperature at 22-23°C until ambient temperature rose above 24°C. At this point (about 0930 hours), the ventilation system switched from natural to tunnel ventilated mode. The number of fans operating varied with house temperature. At about 1800hrs the system reverted to natural ventilation. The evaporative cooling system did not operate because the shed temperature did not rise above 27°C.

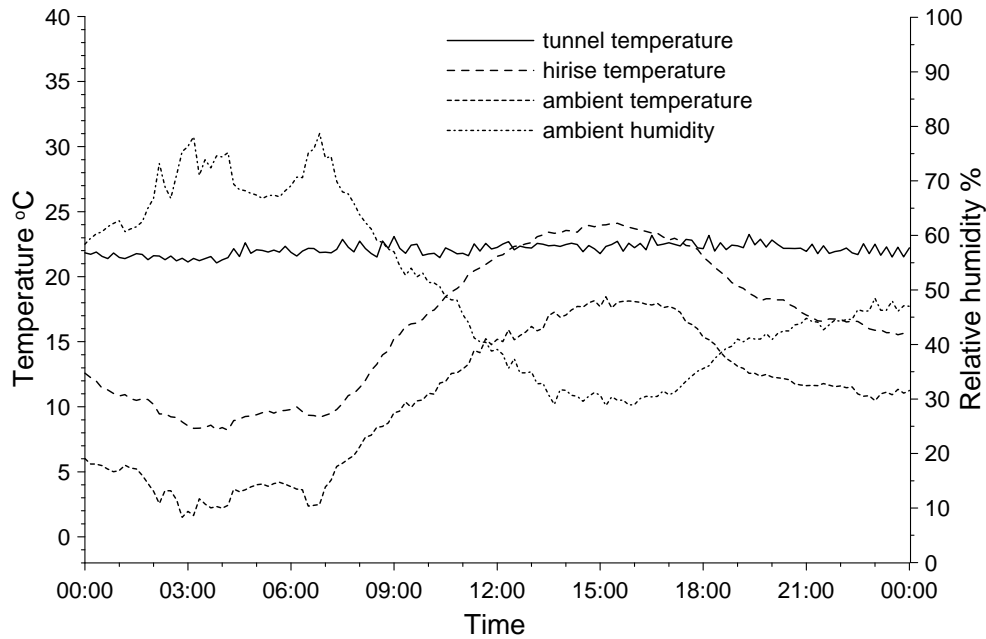
The hirise house maintained a temperature of 6°C above ambient until sunrise and after sunset. During daylight it was less than 2°C above ambient. The hirise house temperature was slightly

higher than that in the tunnel ventilated house. The curtains were opened/shut by a controller in response to higher house temperature.

**Graph 10** Temperature comparison between houses on a typical cold winter day.



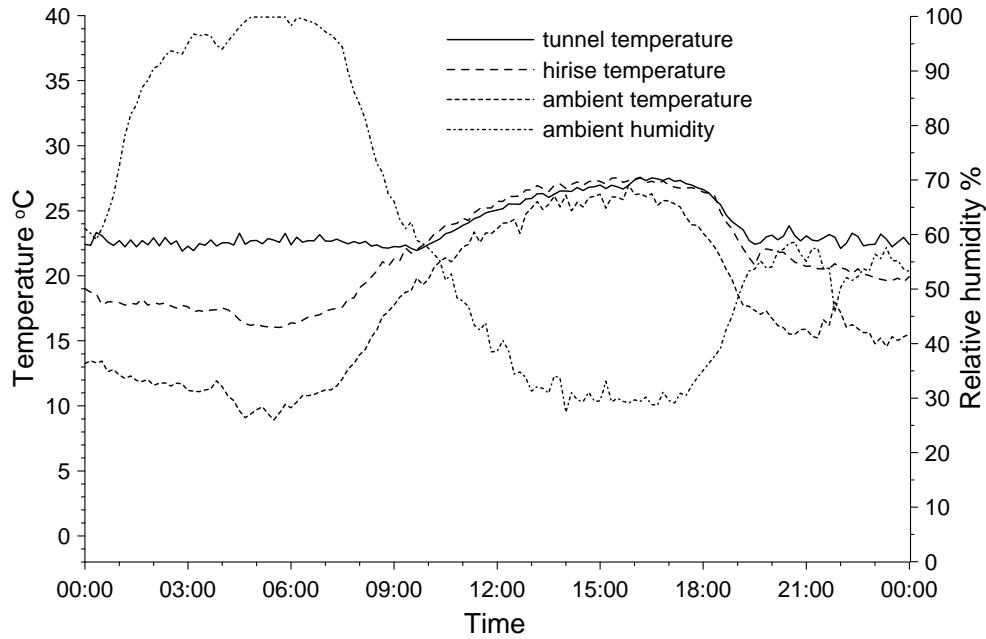
**Graph 11** Temperature comparison between houses on a typical warm winter day.



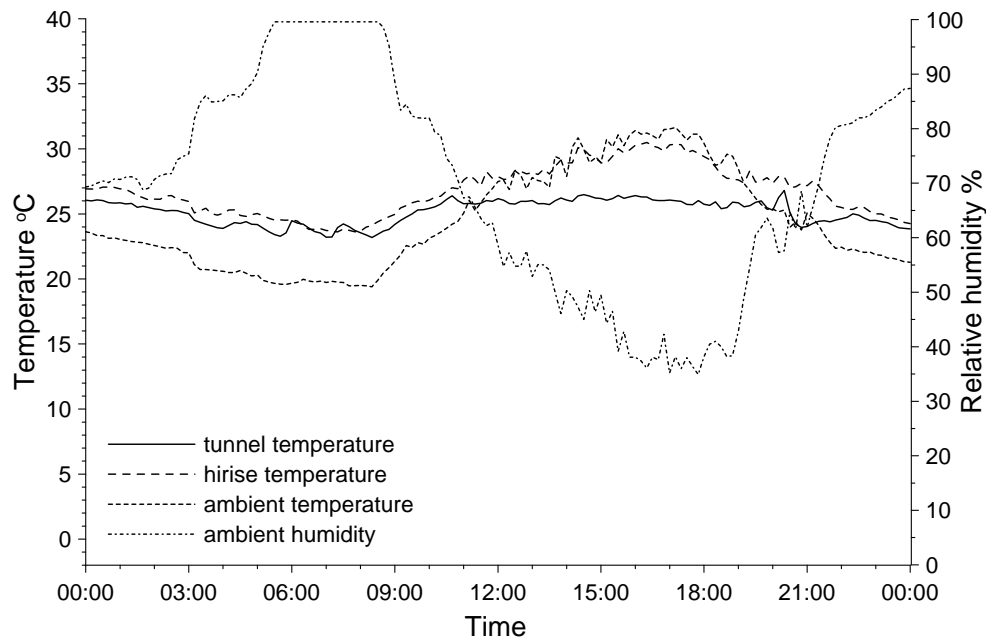
*Warm Summer Day* - Graph 13 - The ambient temperature range was 19-32°C. The temperature range in the tunnel ventilated house over the 24 hour period was 23-27°C and 23.5 – 31°C for the hirise house. The hirise house relied on adjustment of the sidewall curtains

for ventilation and fogging for cooling. The cool pads were activated at a lower temperature on this day compared to Graph 12. The fans operated in the tunnel ventilated house all the time except in the early morning between 0300 and 0900hrs when the shed switched to the natural ventilation system. The cool pads operated between 1030 and 2000 hours and for a short period at about 2100hrs (following a small peak in house temperature).

**Graph 12** Temperature comparison between houses on a typical spring/autumn day.



**Graph 13** Temperature comparison between houses on a typical warm summer day.

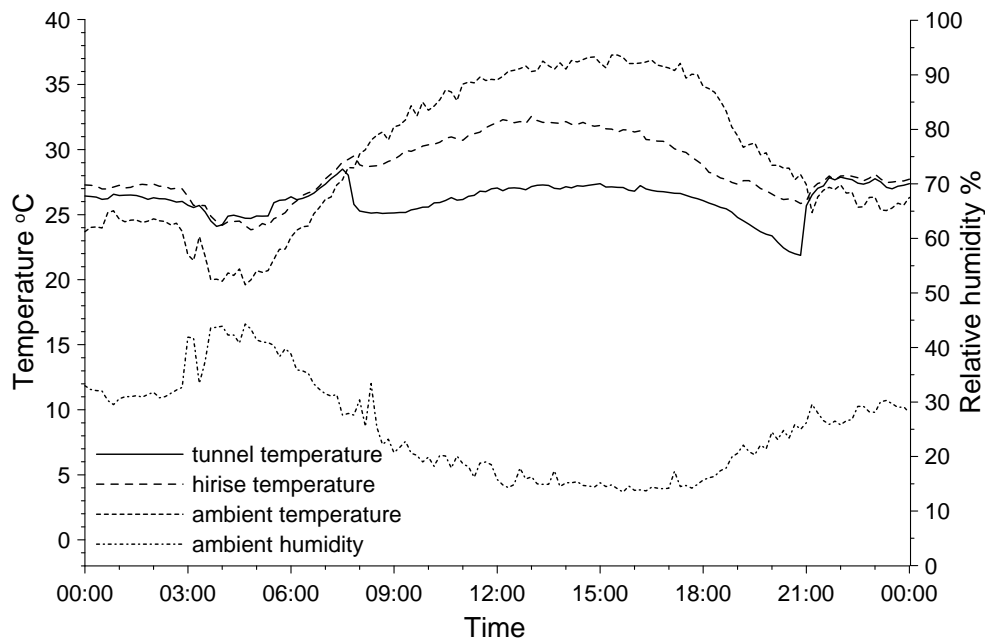


*Hot Summer Day* - Graph 14 – The ambient temperature range was 20-38°C. The tunnel ventilated house maintained temperature within the range of 21-28°C and the hirise within

23.5–32.0°C. The cool pads in the tunnel ventilated house dropped house temperature by 10°C and the foggers in the hirise by 6°C below the ambient temperature. On hotter days the cool pads were able to drop the temperature by 11-12°C. The better cooling is due to the high cooling efficiency of the cool pads. The temperature peak in the tunnel ventilated house at 0715hrs occurred when the cool pads switched on. The rise at 2100 hours occurred when the pads switched off. These peaks can be lowered by reducing air flow through turning off one or two of the fans.

The cool pads achieved less cooling on the day shown in Graph 13 compared to the day shown in Graph 14 because ambient temperature was lower and relative humidity higher. On the day shown in Graph 14 the set point for activating the cool pads was 28°C, higher than in Graph 13.

**Graph 14** Temperature comparison between houses on a typical hot summer day.



### Climate Differences Between Both Tunnel Ventilated Houses

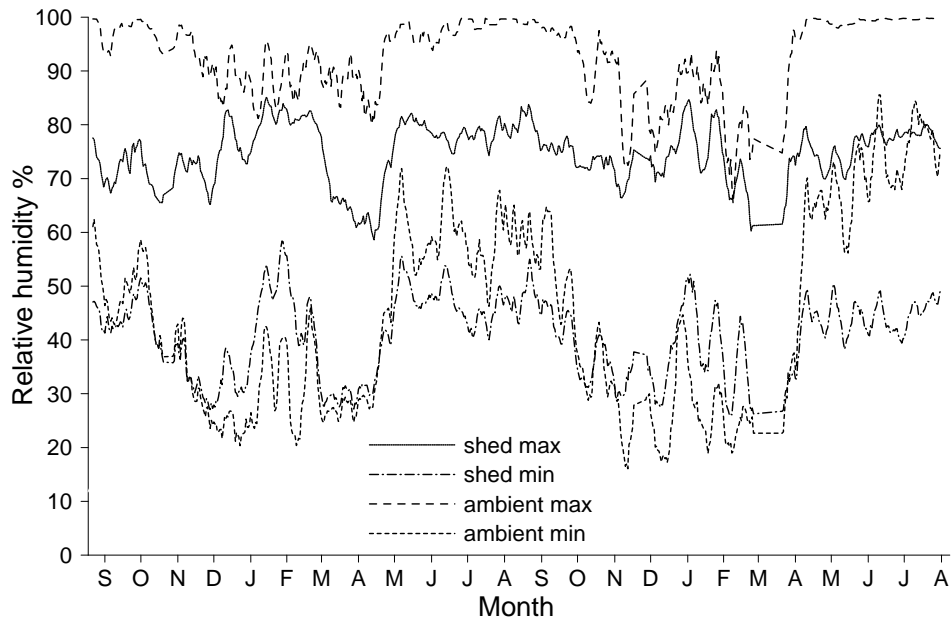
The temperature and relative humidity in the second tunnel ventilated house was similar to the first except on cold days in winter.

Better sealing around the tunnel ventilation inlets in the second house reduced the effect of cold winds on the inlet end of the house resulting in acceptable variation in temperature between ends in this shed in winter.

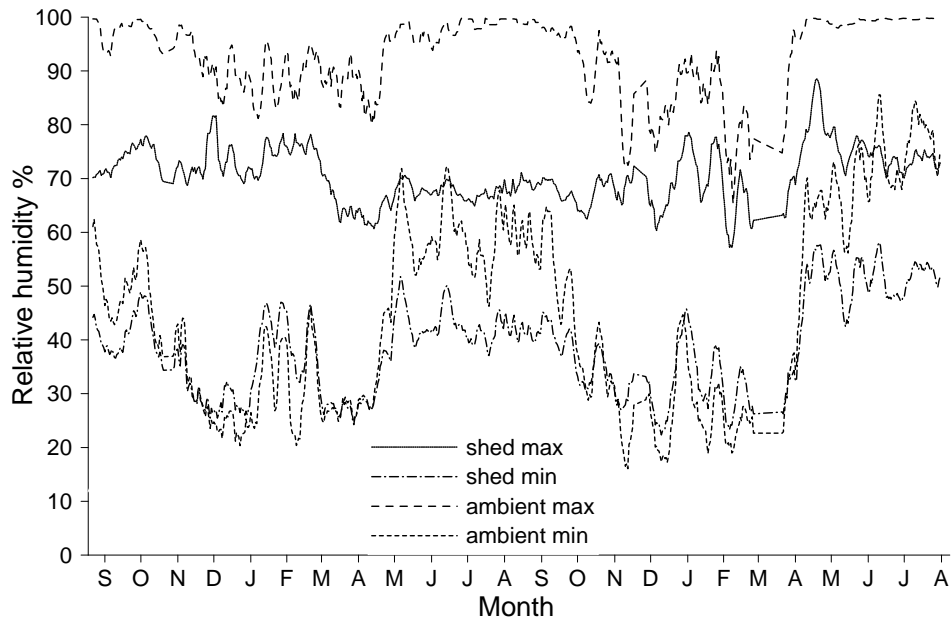
## House Relative Humidity

The tunnel ventilated house ran at a slightly higher relative humidity than the hirise house. In the tunnel ventilated house the relative humidity was within the range of 30-85% and in the hirise it was 25-80%. (Graphs 15 and 16).

**Graph 15** Maximum and minimum relative humidity comparison of ambient with the tunnel ventilated house. Sept 96 – Aug 98.

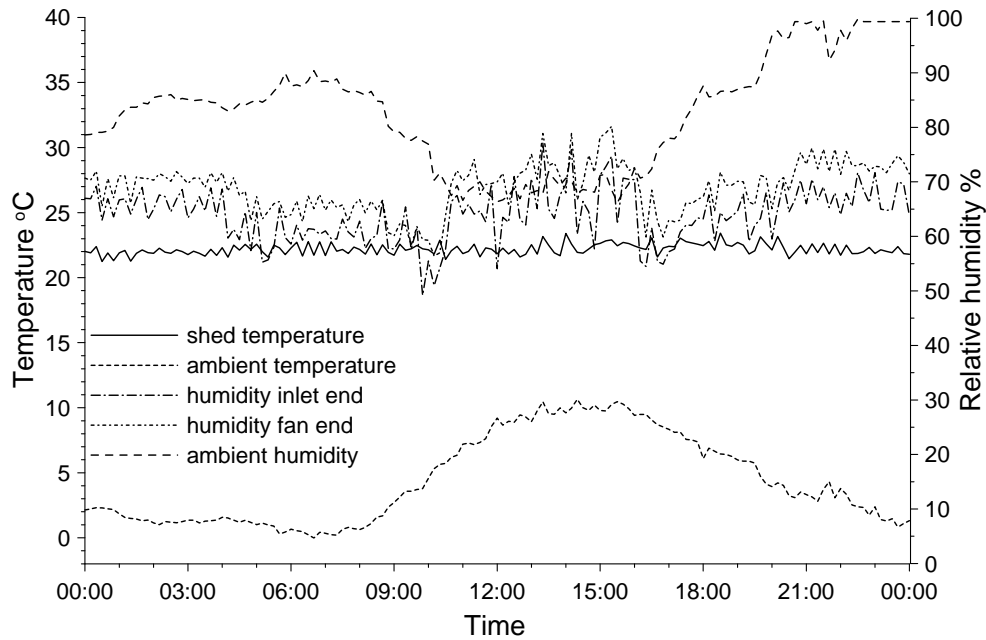


**Graph 16** Maximum and minimum relative humidity comparison of ambient with the hirise. Sept 96 – Aug 98.

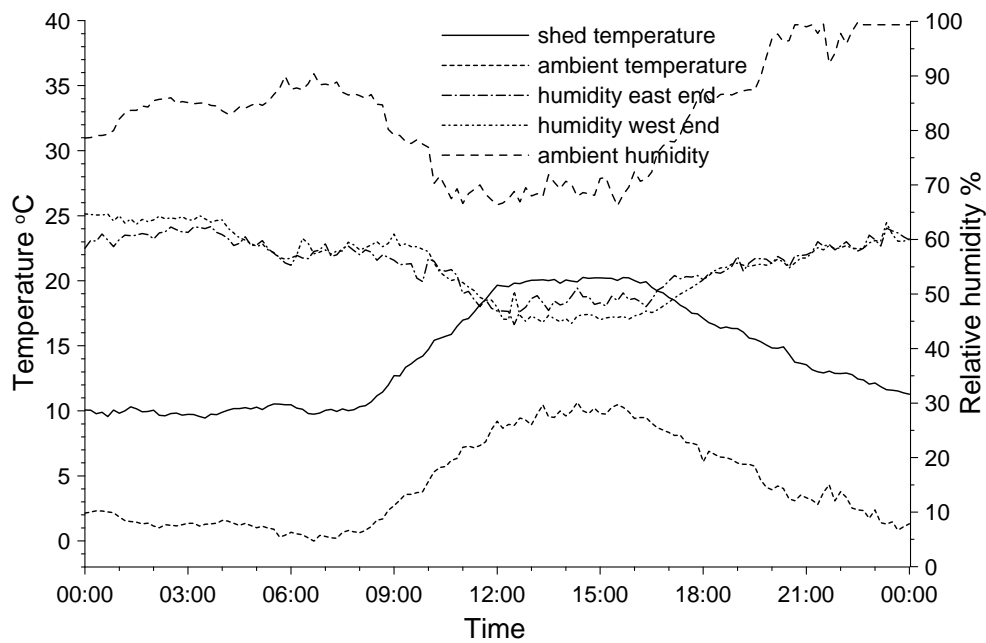


The relative humidity in the hirise house followed the ambient relative humidity more closely than did the tunnel ventilated house except when evaporative cooling was used in summer. (See Graphs 17-20).

**Graph 17** Temperature and humidity comparison of ambient with the tunnel house on a cold winter day.

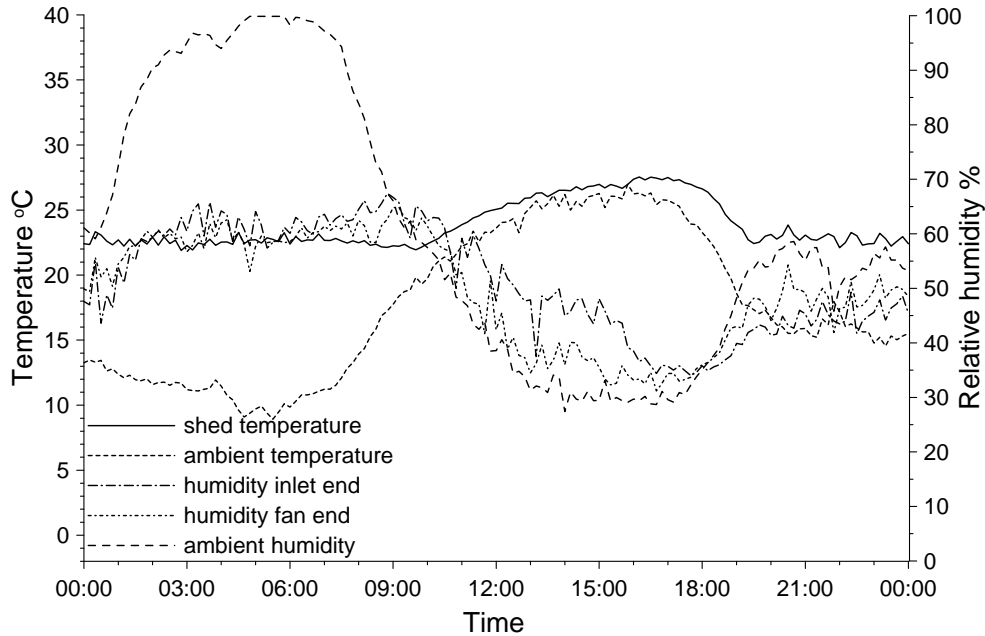


**Graph 18** Temperature and relative humidity comparison of ambient with the hirise house on a typical cold winter day.

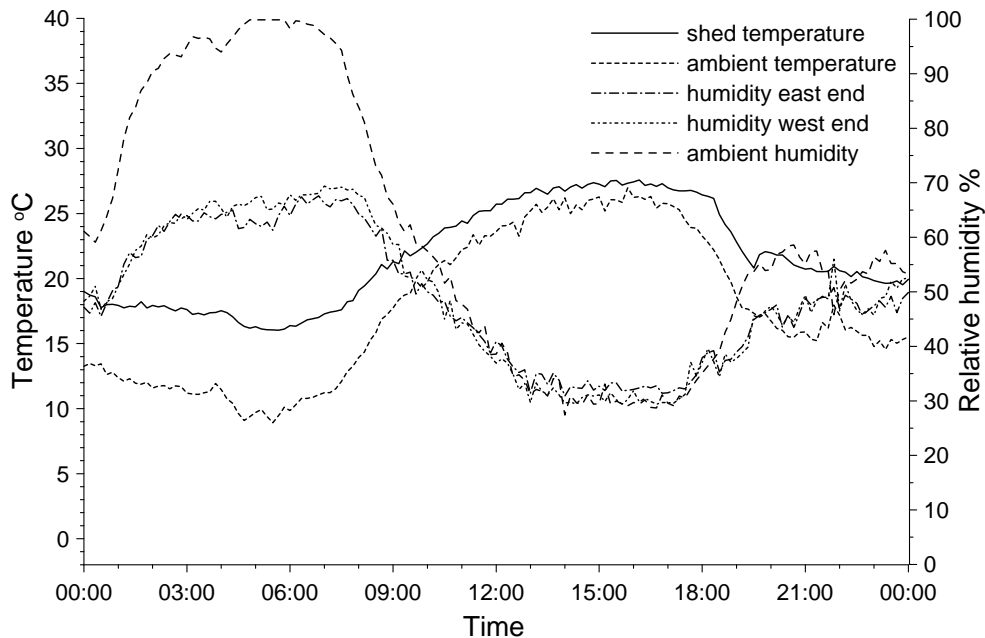


As cold weather ventilation rate increased in response to higher ambient temperatures the ambient and tunnel ventilated house relative humidities moved closer together. (Graphs 17 and 19).

**Graph 19** Temperature and relative humidity in the tunnel ventilated house on a typical spring/autumn day.



**Graph 20** Temperature and relative humidity in the hirise house on a typical spring/autumn day.



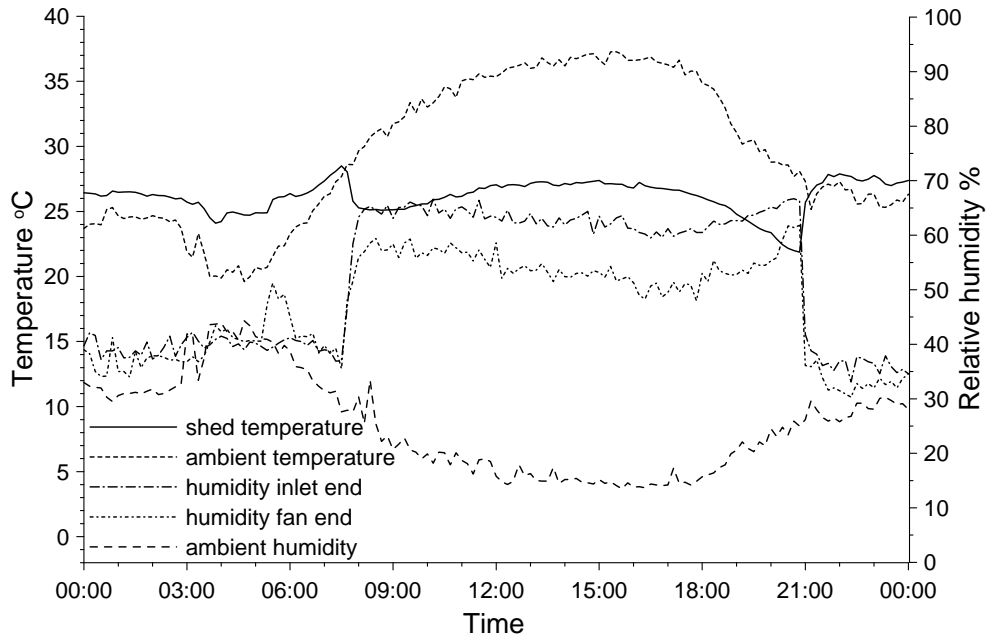
On a typical hot summer day when the fans and cool pads were operating (between 0730 and 2100hrs in Graph 21) in the tunnel ventilated house the increase in the shed relative humidity was 40-50% above the ambient. The relative humidity at the fan end was lower than that at the inlet end because the air warmed up as it moved down the house absorbing heat from the hens



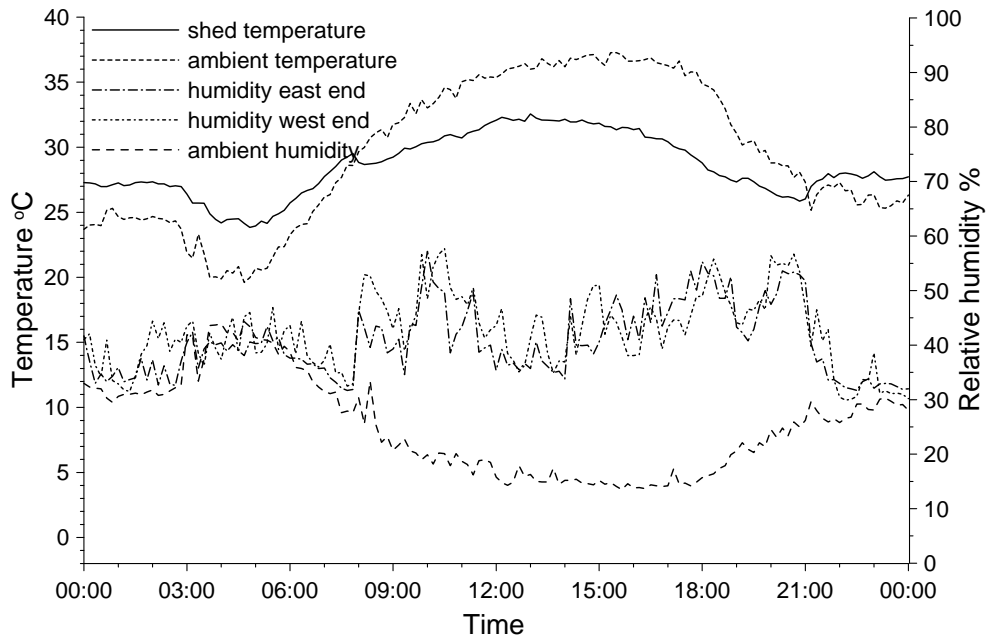
(see Graph 21). As the air warms it expands. This dilutes the amount of moisture in a cubic metre of air, hence the lower humidity.

On the same summer day the relative humidity increased by 20-35% in the hirise house when the foggers were operating between 0800 and 2100hrs (Graph 22). This increase was not as great as in the tunnel ventilated house.

**Graph 21** Temperature and humidity in the tunnel ventilated house on a typical hot summer day.



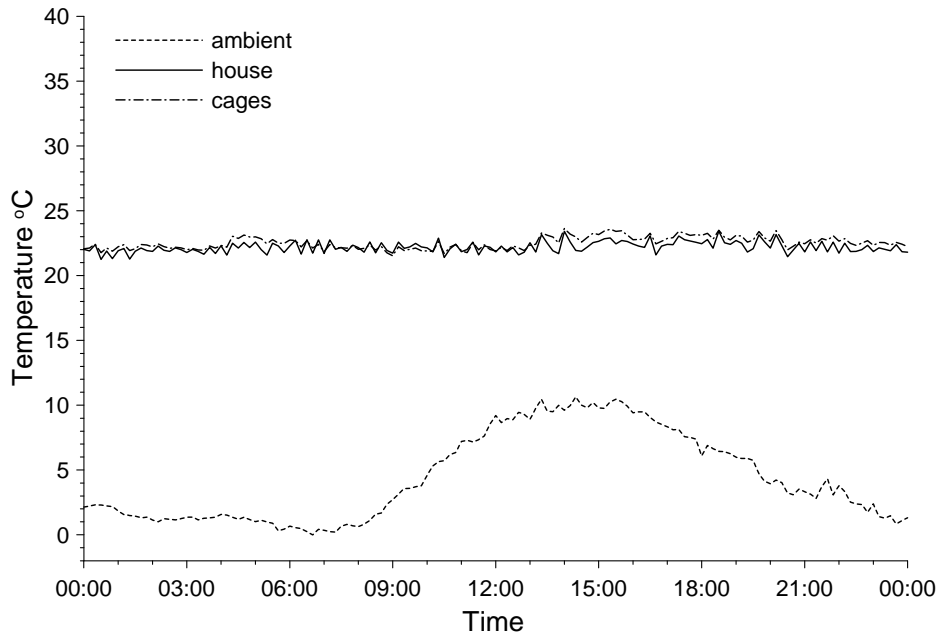
**Graph 22** Temperature and humidity in the hirise house on a typical hot summer day.



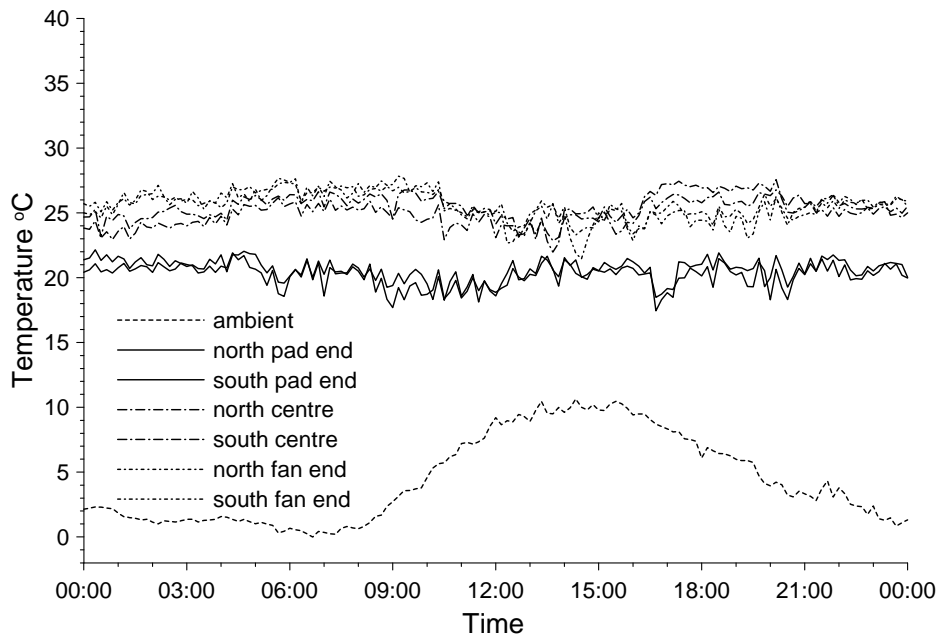
## Cage Temperature Variation in the Tunnel Ventilated House

The average temperature in the cages was within 2°C of the average house temperature (Graph 23). Temperature difference between cages in both cage decks on the same level and the same section of the house was less than 2°C (Graph 24). In cold weather the top tier of cages in the same section was up to 4°C warmer than the bottom tier. In summer the difference was 1°C.

**Graph 23** Average cage and house temperature on a winters day.



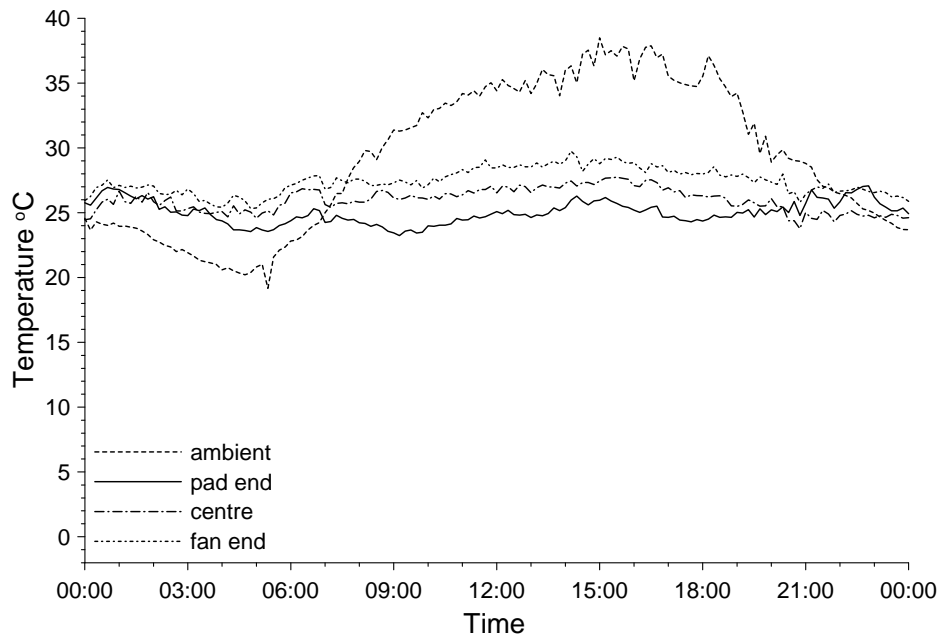
**Graph 24** Temperatures in various cage sections on a cold winters day.



In cold weather the temperature of the inlet or pad end section was 6.5–9.0°C lower than the other cage sections in both decks of cages. Graph 24 highlights this. The centre and the fan end sections differed from each other by 3.0–4.5°C. Poor sealing of the inlet area caused the problem at the inlet end. This allowed cold air to enter the building in winter. Wind exacerbated the problem. It was fixed in the second house built by redesigning the inlet so that it was airtight. This reduced the difference to less than 4°C.

In warmer weather when the ambient temperature was less than that required in the house the variation was 2–4°C between the top and bottom cage tiers in both decks.

**Graph 25** The temperature in the bottom cages on a typical hot summer day.

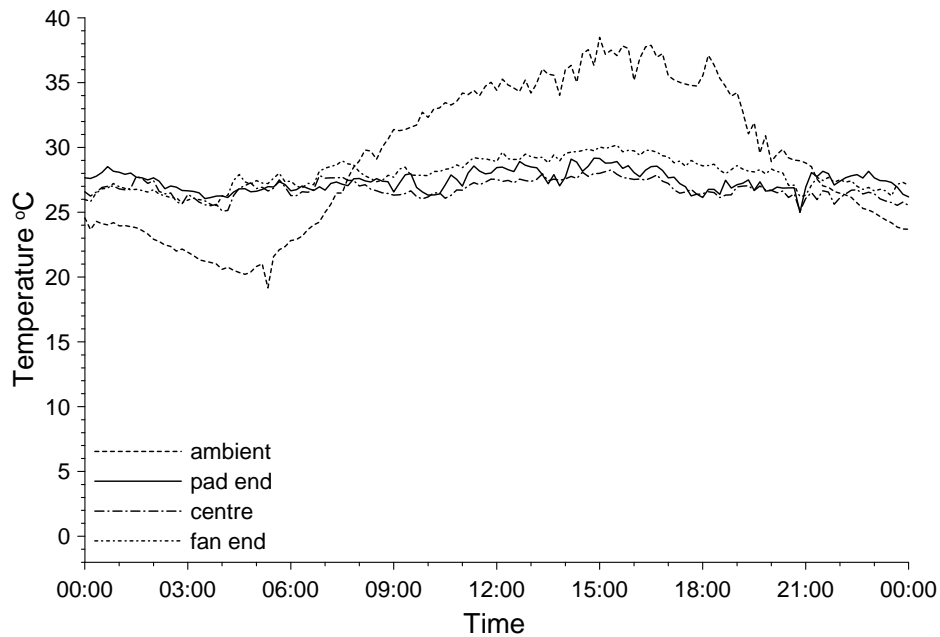


In summer when the tunnel ventilation system, including the cool pads, was used the difference between the inlet and the fan end sections of the bottom cage tier was up to 4°C (Graph 25). In the top cages it was up to 2°C (Graph 26). The temperatures in the top cage tier at the inlet end were equal to or higher than those recorded in the centre section. This effect was caused by the building structure. The large volume of space between the top of the cages and the roof allowed the inlet air to rise above the cages instead of being forced through the cages or around the end of the decks of cages into the centre aisle. Placing deflectors across the house in the airspace above the cages will reduce this problem.

In this mode the cool pads cool air as it enters the house. The air is warmer as it exits through the fan end since it gains heat given off by the hens as it moves down the length of the house. This is depicted in Graphs 25 and 26. The evaporative cooling pads turned on at 0700 hours and off at 2200 hours.

Water flow to the pads was pulsing on and off between 2030 and 2200 hours causing fluctuations in house temperature. As the pads dried out after the water was turned off there was still cooling of the air passing through the pads until about 2300 hours.

**Graph 26** The temperature in the top cages on a typical hot summer day.



### **Air Movement within the Cages**

When the house was operating in tunnel ventilation mode with all fans on, air movement of 0.2-0.4 m/s was recorded in the cages. Using smoke provided by a smoke generator, it was seen that there was a continuous movement of air within the cages. There was a mixing of air from the aisle with the air contained by the cage and a drift of air down the tiers of cages towards the fan end. This movement to the fan end was particularly evident in the clear space between the cage floor and the manure belt. There was also mixing of air between cages across the 140mm gap between the V trough formed in the duct carrying the manure ventilation air and the roof of the cages. Observations of hen behaviour (panting) also supported these observations that there was adequate mixing and exchange of air in the cages with that in the aisle.

### **Water consumption**

Average water consumption for the tunnel ventilated house was 233mls per hen per day and 229mls per hen per day for the hirise shed.

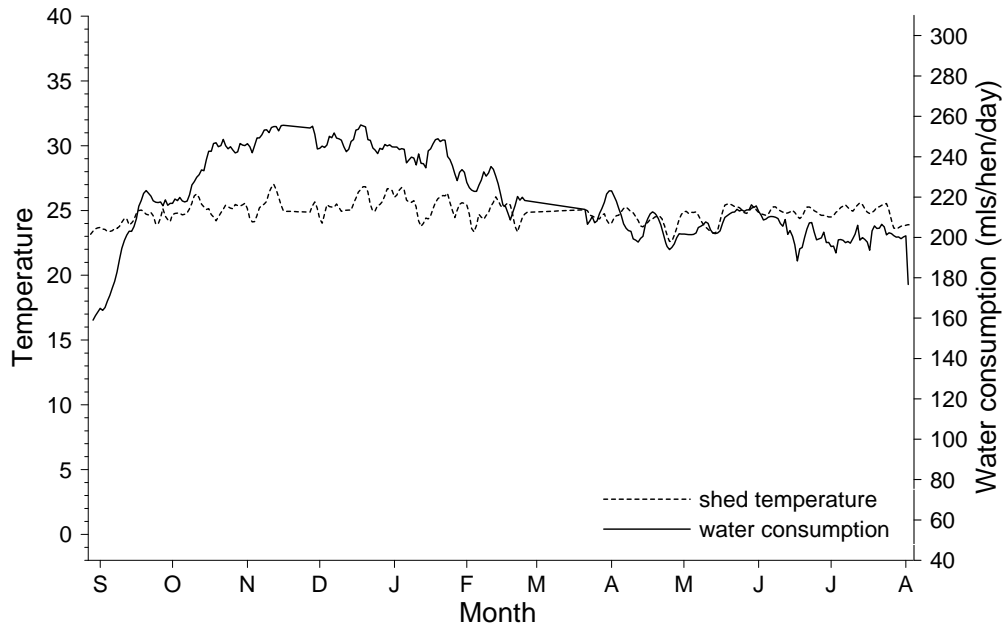
About 2.5% (5-7mls per hen per day) of the water consumption in the hirise house occurred at night when the lights were off. This was water lost from leaking nipples and amounts to 575 litres per week per flock or 2220 litres per 1000 hens lost per year. This loss increases the average hirise consumption to 235mls per hen per day. How much water loss occurred during light periods is unknown.

On bright moonlit nights the hens in the hirise house drank up to 5mls each during the lights out period of eight hours. Sufficient light entered the house through the sidewall curtains and

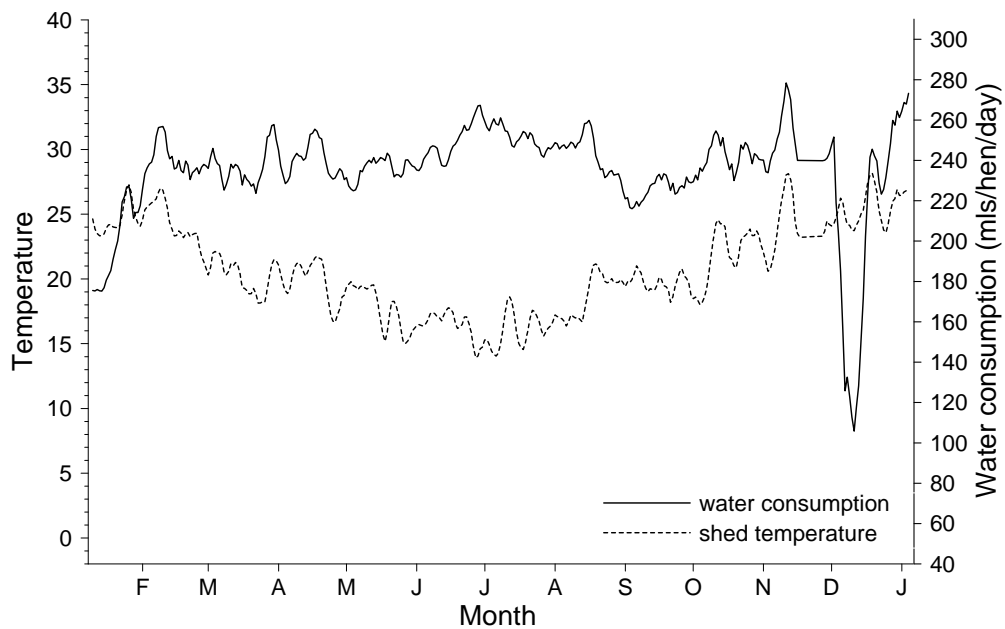
curtain openings to cause the hens to be active. There was no such behaviour in the tunnel ventilated house. Its design did not allow sufficient moonlight in.

In the tunnel ventilated house, water consumption followed production rate peaking at approximately 250mls per hen per day and falling to approximately 200mls at end of twelve months lay. There is a slight increase in water consumption on hot days (Graph 27).

**Graph 27** Water consumption and temperature for flock TV3. Sept 97 – Aug 98.



**Graph 28** Water consumption and temperature for flock hirise 2. Feb 97 – Jan 98.

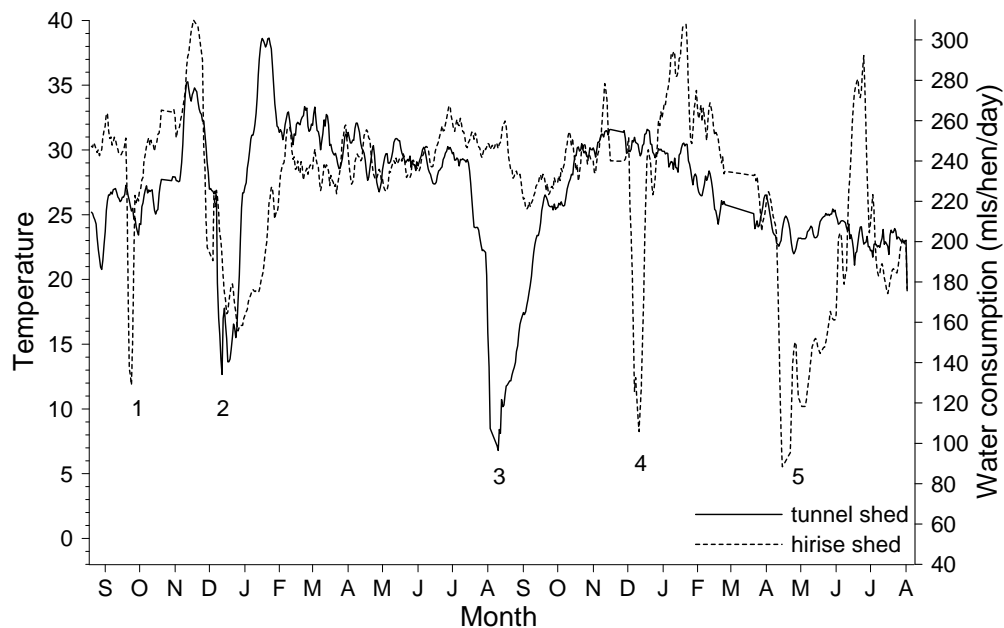


There was no obvious pattern in the hirise house. Maximum water consumption occurred in hot weather where it peaked at 285-300 millilitres per hen per day (Graph 28).

Graph 29 compares the daily water consumption for the hens housed in both houses over the length of the study. The dips in consumption are due either to new flocks entering the house or problems with the watering system as indicated below –

1. Temporary loss of water supply in the hirise house.
2. New batch of pullets placed in hirise house or hens in the tunnel ventilated house were rested.
3. New batch placed in the tunnel ventilated house.
4. Blockages in the hirise house watering system.
5. New batch placed in the hirise house.

**Graph 29** Comparison of water consumption between the tunnel ventilated and hirise houses Sept 96–Aug 98.



Water consumption commenced at the onset of lights each morning. There was increased consumption in both sheds at each run of the feeder system. This is not as well defined in the tunnel ventilated house as in the hirise house possibly because of the number of times the feeder was run each day (Graphs 30-33). The tunnel ventilated house feeders were run twelve times and the hirise house six times. Feeder run times are presented in Table 6.

**Table 6** The daily feeder run times in hours

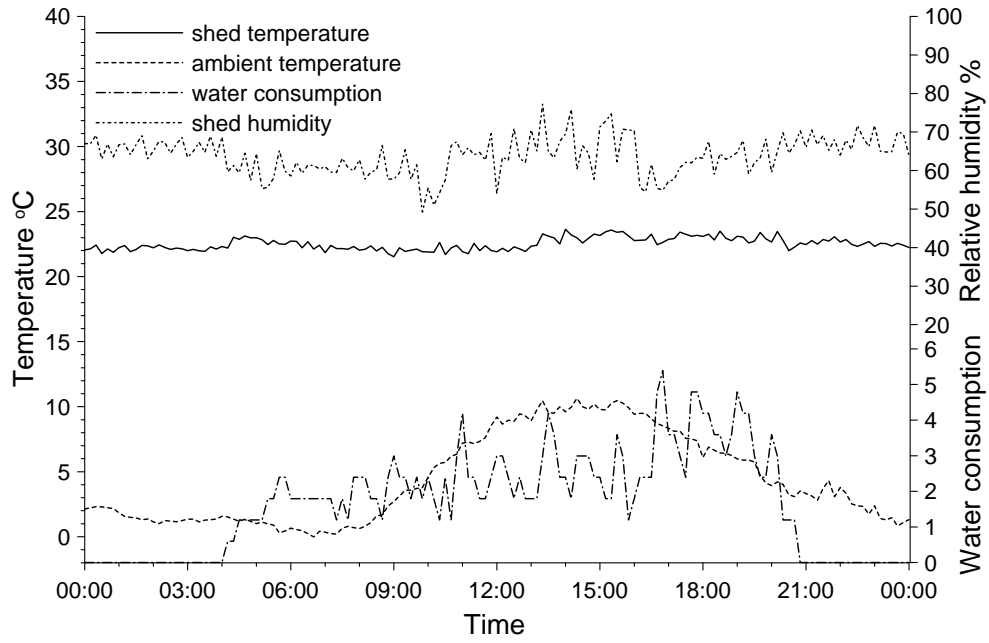
Tunnel house		Hirise house
0400	1300	0430
0515	1430	0830
0645	1615	1145
0800	1715	1415
1000	1830	1600
1115	1930	1845

Over the trial period these times were adjusted slightly according to hen eating habits.

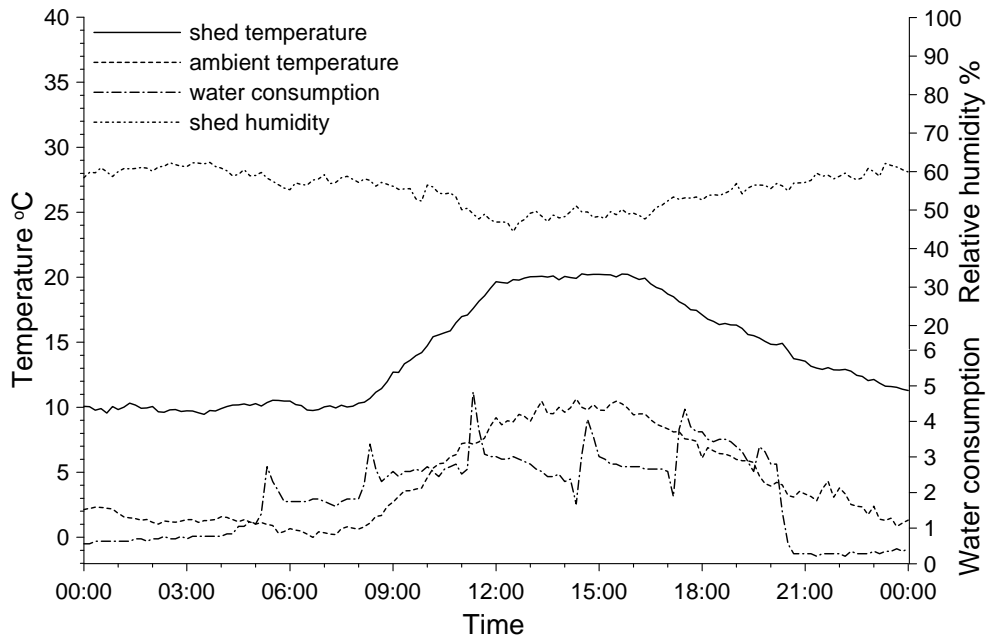
A sixteen hour lighting program was used. Lights were on from 0400 to 2000hrs.

The graphs show that maximum water consumption was in the late afternoon to early evening between 1600 and 2000hrs.

**Graph 30** Water consumption in the tunnel ventilated house on a typical cold winter day. (mls/hen/10 mins.)

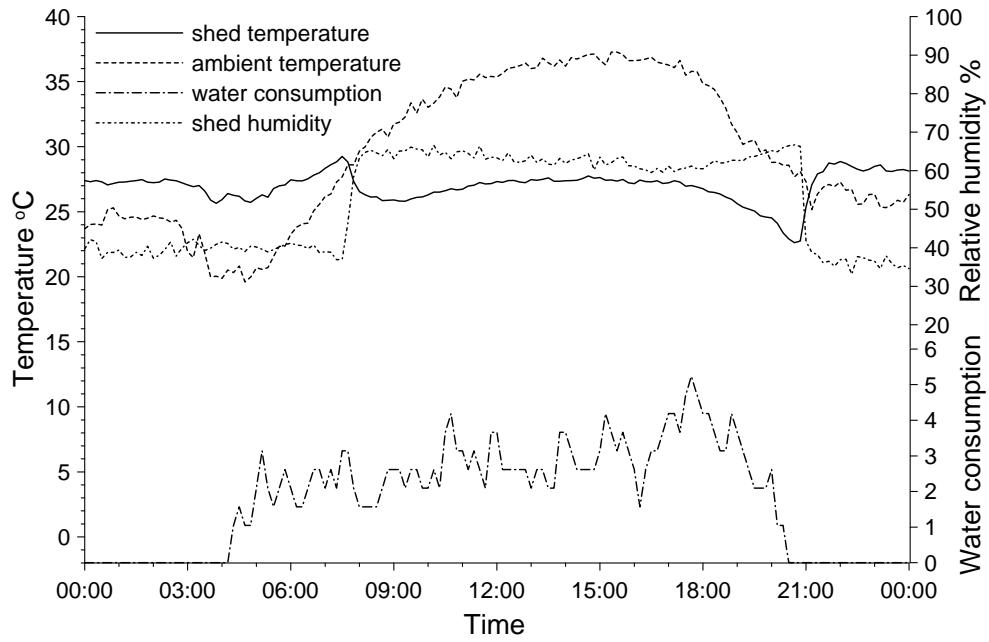


**Graph 31** Water consumption in the hirise house on a typical cold winter day. (mls/hen/10 mins.)

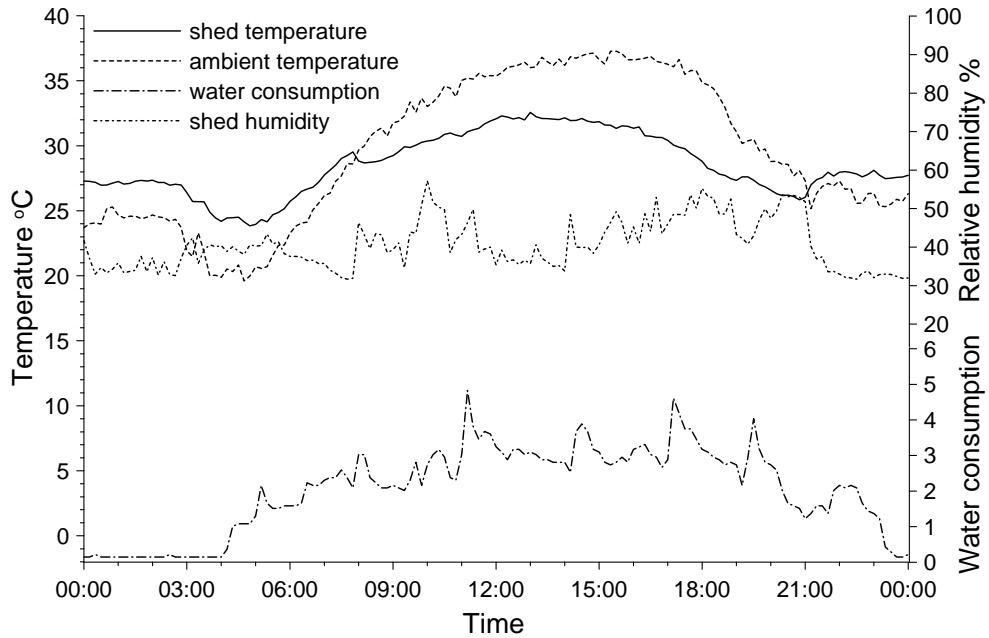


On hot days the lights were left on until midnight in the hirise house to give the hens more feeding and drinking time. This practice helped to maintain egg production in hot weather (Graph 33).

**Graph 32** Water consumption in the tunnel house on a typical hot summer day. (mls/hen/10 mins.)



**Graph 33** Water consumption in the hirise house a hot summer day. (mls/hen/10 mins.)

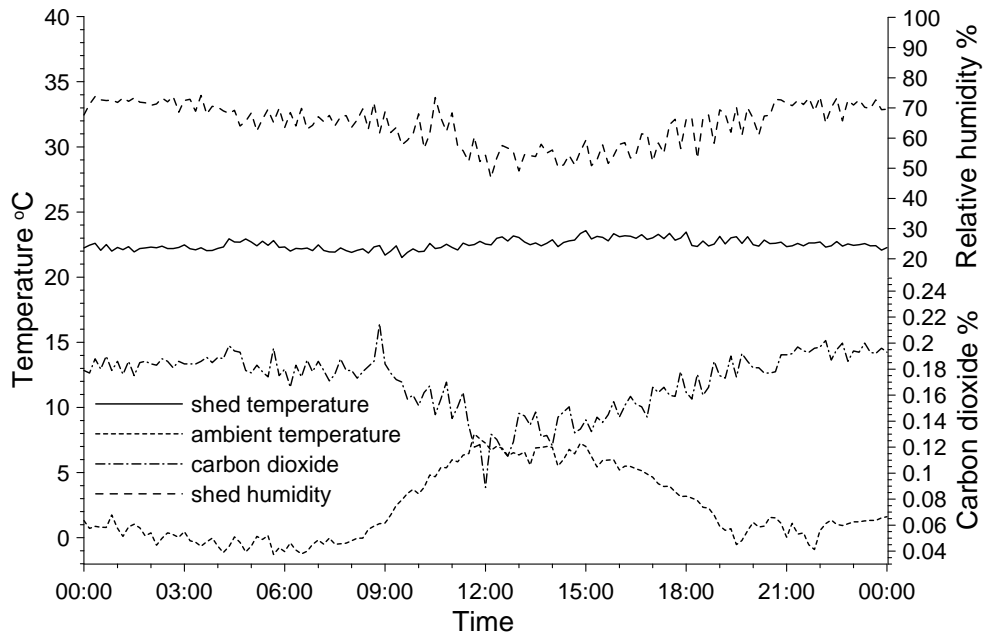




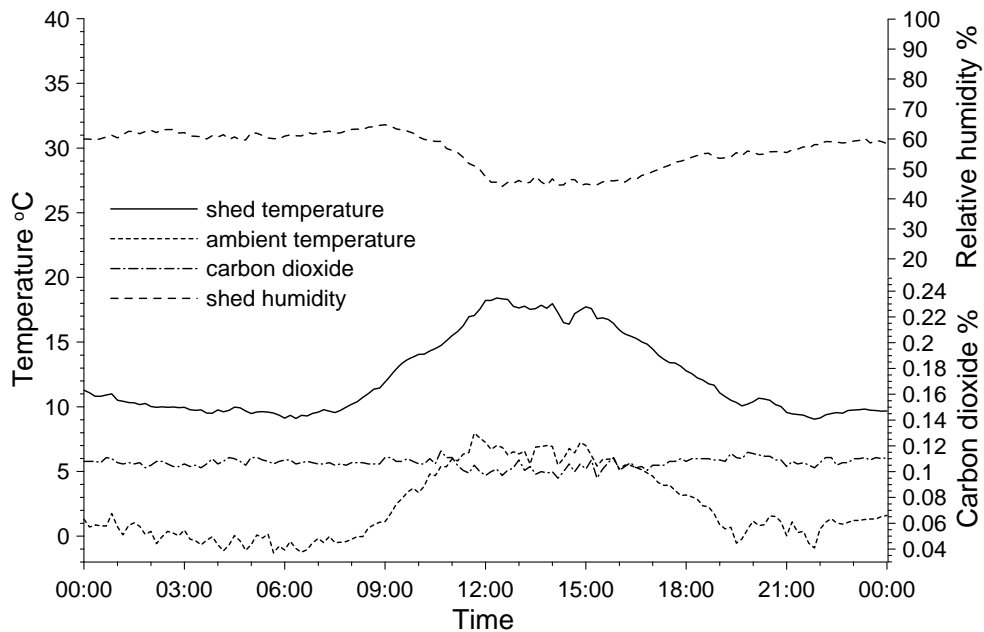
## Carbon Dioxide

The maximum carbon dioxide level measured in the tunnel ventilated house was 0.26% and 0.12% in the hirise. In Graph 34 the peak is 0.22% for the tunnel ventilated house. These high levels occurred during very cold winter weather. The maximum continuous level of 0.20% lasted 13 hours in the tunnel ventilated house (Graph 34). The highest continuous level measured in the hirise house was 0.11% for a period of 24 hours (Graph 35).

**Graph 34** Carbon dioxide, temperature and relative humidity in the tunnel ventilated house on a typical cold day.

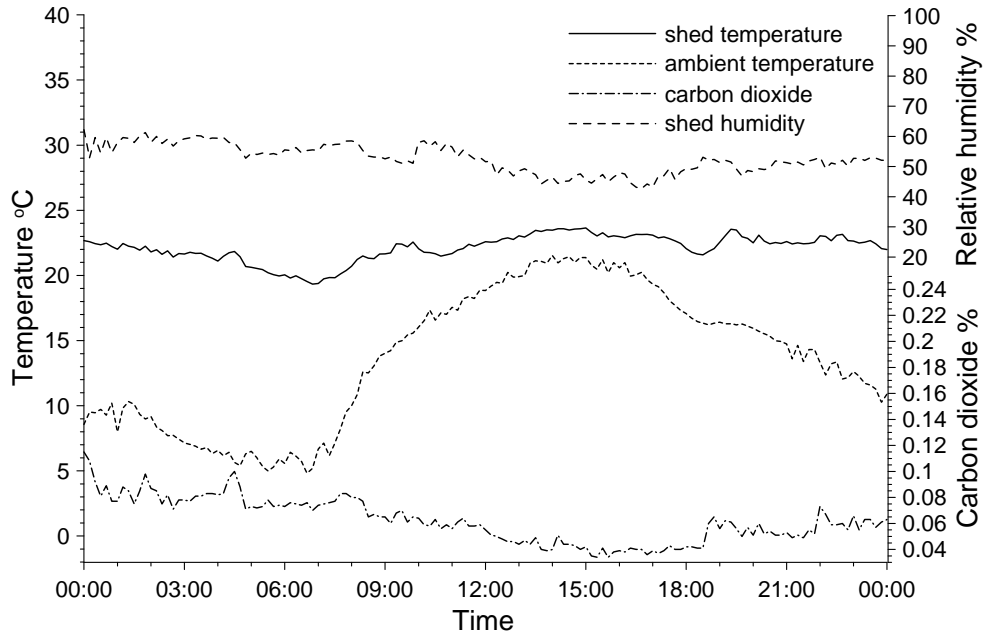


**Graph 35** Carbon dioxide, temperature and relative humidity in the hirise house on a typical cold day.

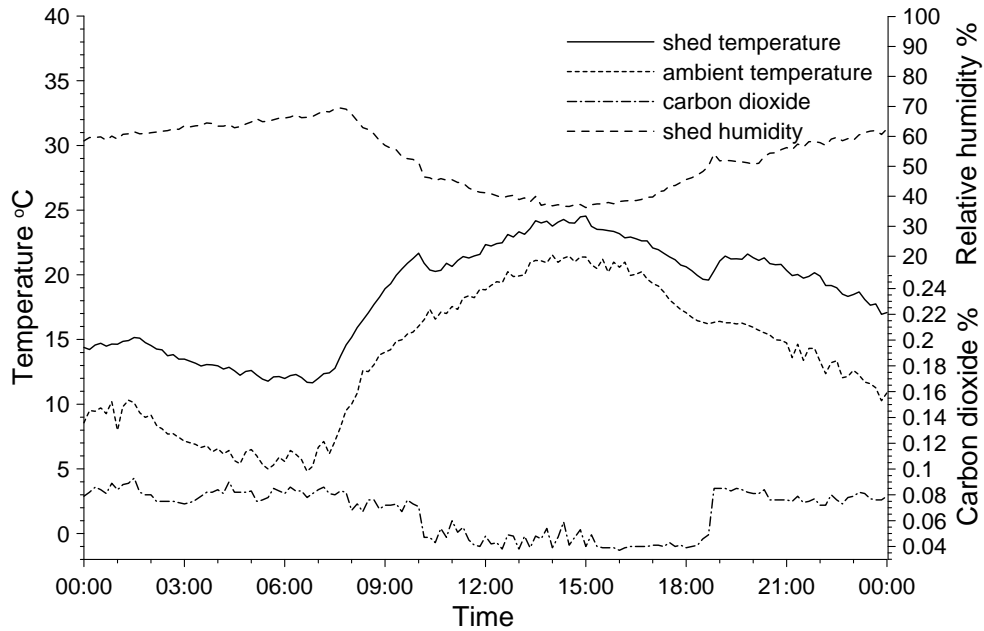


On a typical cold day the level in the tunnel ventilated house fell from 0.22% to 0.09% around 1200hrs as ambient temperature peaked (Graph 34). This coincides with maximum daily ventilation rate. In the hirise house carbon dioxide varied by about 0.01% during the day reflecting an almost constant ventilation rate irrespective of the ambient temperature (Graph 35).

**Graph 36** Carbon dioxide, temperature and relative humidity in the tunnel ventilated house on a typical spring day.



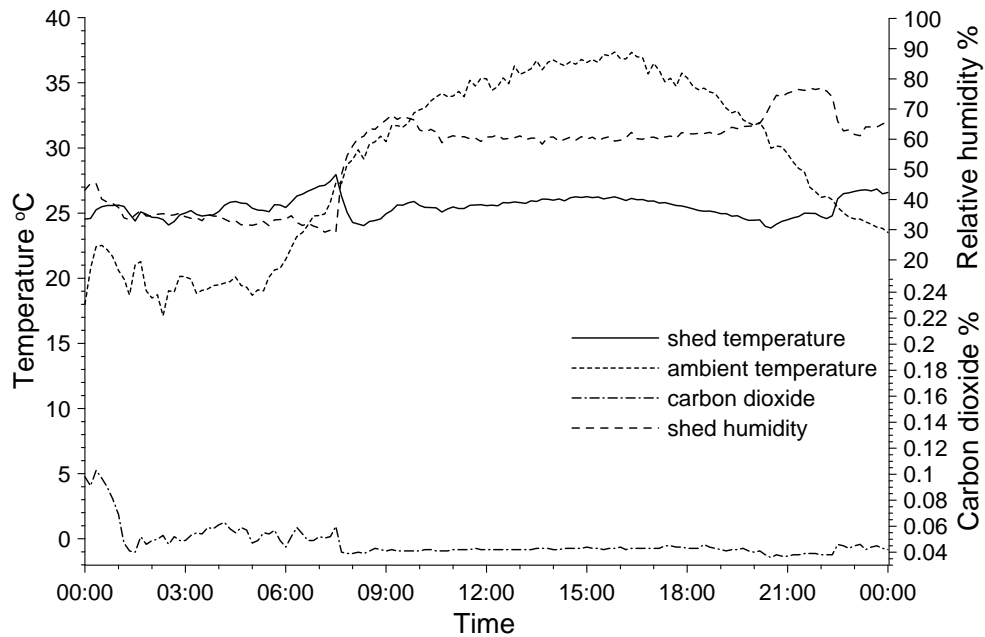
**Graph 37** Carbon dioxide, temperature and relative humidity in the hirise house on a typical spring day.



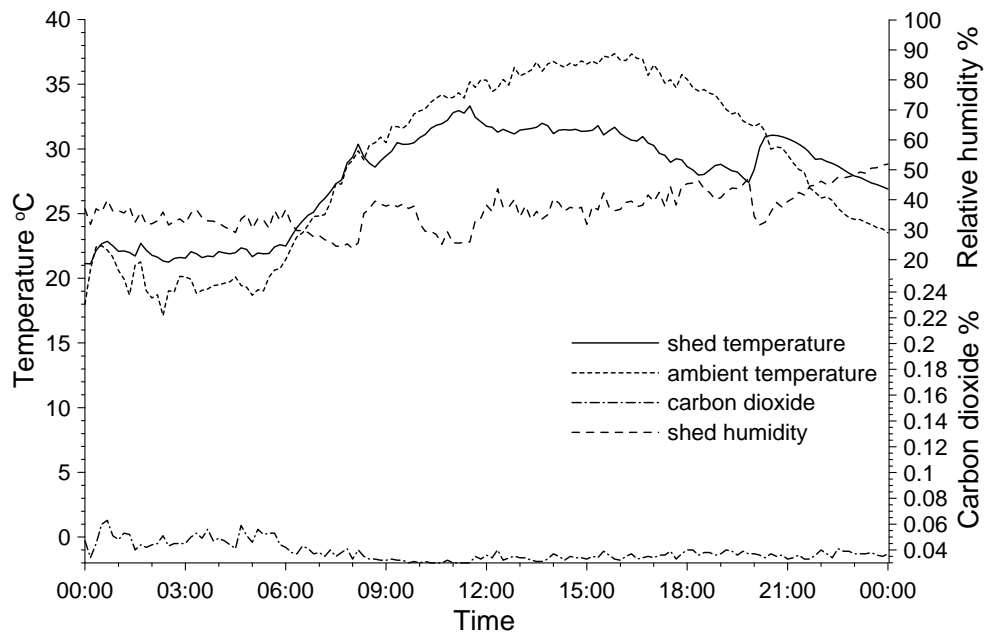
On a typical spring/autumn day the level in both houses dropped from the night time highs to about 0.04% during the warmest part of the day when ventilation was at a maximum (Graphs 36 and 37).

During hot weather when maximum ventilation rate was being used to remove heat from both houses the carbon dioxide level was about 0.04%. This occurred between about 0800 and 2400hrs when the temperature was above 25°C in Graphs 38 and 39. Between 2400 and 0800hrs the ambient temperature was about 20°C, house ventilation rate was lower and the carbon dioxide level was above 0.04%.

**Graph 38** Carbon dioxide, temperature and relative humidity in the tunnel ventilated house on a typical hot summer day.



**Graph 39** Carbon dioxide, temperature and relative humidity in the hirise house on a typical hot summer day



## Discussion of Results

Hen housed egg production for 52 weeks from 5 percent egg production was significantly 20.8 eggs better in the tunnel ventilated house than in the hirise house. On a hen day basis, it was 13.6 eggs better. Weekly egg production for the tunnel ventilated house was consistently better than for the hirise house.

The harsher conditions in the hirise house may have contributed to the higher average mortality of 4.2%, which occurred in that house.

Eggs from the tunnel ventilated house were 0.75 grams lighter on average than the hirise house. This was not significant ( $P>0.05$ ). Management practices were modified in the tunnel ventilated housing for the second and third flocks placed. The house temperature was lifted 2°C to reduce egg size slightly to meet market requirements.

Feed consumption per hen in the hirise house was on average 10 grams per day higher than in the tunnel ventilated houses. This difference was significant ( $P<0.05$ ) and reflects the lower temperature experienced in the hirise house during winter. Differences in diets may have also been a contributing factor. Slightly better quality diets were required in the tunnel ventilated houses to maintain egg production rate.

It took 0.247kg of feed more in the hirise house to produce one kilogram of eggs. The hens to keep warm during winter used most of this extra feed.

The feed conversion ratio (kg feed per kg egg) for flocks in the second tunnel ventilated house (flock TV2) was higher than the feed conversion ratio in the original tunnel ventilated house (flocks TV1 and TV3). The temperature differences between the inlet and the fan ends in TV2 were less than in the first tunnel ventilated house during cold weather because of poor sealing of the inlet area. A different feeding regime was used for flock TV2 in the second tunnel ventilated house compared with flocks TV1 and TV3.

The average net return based on farm gate costs from the tunnel ventilated housing was 8.52 cents per dozen more than the hirise house.

The breakeven point where feed plus pullet costs equals egg receipts was 7.1-8.6 cents per dozen less for the tunnel ventilated housing than the hirise. This reflects the efficiencies achievable with improved housing. It gives an advantage to farms using better housing and a high standard of management particularly when egg prices are low.

The tunnel ventilated house was able to maintain the house temperature within the range of 20-27°C compared to 8-33°C for the hirise house. Over the period of the field study the average temperature in the original tunnel house was 23.5°C and 19.9°C in the hirise house.

With modification to the winching gear used to adjust the shutters, improving the seal on the roof shutters and the tunnel ventilation inlet for air tightness in the first tunnel ventilated house built it should be possible to run the house within a 5°C temperature range.

The temperature in the hirise house followed the ambient temperature except in hot weather when the evaporative cooling system cooled the house. The tunnel house stayed within  $\pm 2$  to

3°C of the target temperature set on the controller. On a cold winter day the hirise maintained a temperature of 8-10°C above ambient.

The evaporative cool pads used in the tunnel ventilated house were more effective in lowering house temperatures than the foggers in the hirise house. The cool pads reducing the ambient temperature by 10-12°C compared to 6-7°C for the fogging system.

The average temperature measured in the cages in the tunnel ventilated house was within 2°C of the average house temperature. As the house temperature was measured at the same point as the sensors attached to the controller, this result suggests that the control sensors were placed in the correct position in the house.

The relative humidity range in the hirise house was 25-80% compared to 30-85% for the tunnel ventilated house. This is a reflection of the differences in control over the ventilation rate. The relative humidity in the hirise house followed the ambient relative humidity more closely than did the tunnel ventilated house except when evaporative cooling was used in summer.

The relative humidity increased in both houses in hot weather when the evaporative cooling system was used. In the tunnel ventilated house the increase was 40-50% and 20-35% in the hirise. This reflects the difference in cooling efficiency between cool pads and a fogging system. The cool pads are more efficient.

When hens are housed in rows of tiered cages in a house it is essential that temperature is within acceptable limits within each block of cages. There was less than 2°C difference between cages on the same level and in the same section of the house. In winter the top tier of cages in the same section was up to 4°C warmer than the bottom tier. In warm and hot weather the difference was 1°C. The cold weather variation was due to the air movement patterns in the house associated with the way that the cold air entered the house. This variation is acceptable.

Of concern was the temperature variation between the inlet end section and the other cage sections. This was 6.5-9.0°C. The variation between the centre and the fan end section was 3.0-4.5°C, which is acceptable. Poor sealing of the inlet area caused the problem at the inlet end. This allowed cold air to enter the building in winter. Wind exacerbated the problem. It was rectified in the second house built by redesigning the inlet so that it was airtight and it is planned to rebuild the inlet on the original house.

In summer when the tunnel ventilation system was used the temperature difference between the inlet and the fan end sections of cages was up to 4°C. The top cages in the inlet section were warmer than the bottom cages. This is due to the way air flowed into the house from the inlets. The large volume of space between the top of the cages and the roof allows the inlet air to rise above the cages instead of being forced through the cages or around the end of the decks of cages into the centre aisle.

Average water consumption for the tunnel ventilated house was 233mls per hen per day and 229mls for the hirise house. Leaking nipples in the hirise house caused a water loss during darkness of 6mls per hen per day. Any loss that occurred during the day was unable to be measured. This loss increases the consumption per hen to 235mls per day. The water consumption rates and drinking pattern observed reflect those reported in the literature and by producers.

The level of carbon dioxide is an indicator of ventilation rate and air quality in the poultry house. There are recommended exposure levels for both humans and poultry. The United Kingdom human occupational long term exposure limit for carbon dioxide is 0.5% or 5000ppm. The recommended maximum continuous exposure level for poultry is 0.3% or 3000ppm. Fresh air contains 0.035%.

The levels of carbon dioxide measured were within the current suggested levels for poultry and humans. Maximum levels of 0.26 and 0.12% were recorded in the tunnel ventilated and hirise respectively during very cold weather when ventilation rate was at its lowest. These levels dropped to about 0.04% when maximum ventilation rates were being used to remove heat in warm to hot weather.

Continuous levels of 0.22% and 0.12% for more than nine hours duration were recorded in the tunnel ventilated and hirise houses respectively. Where hirise houses are fitted with roof insulation and roof vent shutters to give tighter control over ventilation then carbon dioxide levels will be higher.

The carbon dioxide levels measured in both houses suggest that the ventilation systems are effective in maintaining good air quality.

## **Implications**

The results of this field study suggest that by using well designed housing incorporating adequate insulation, a good ventilation system and good sealing against air leakage it is possible to maintain house temperature within the limits for efficient egg production. These results could not be achieved without the high standard of management applied on the participating farm.

Potential benefits to the industry are improvements in production efficiency. These can be achieved through increased eggs per hens housed, a reduction in feed consumption per hen and an improvement in feed conversion.

Based on farm gate costs there is a possible saving of 8.52 cents per dozen eggs or \$2,770 per 1000 hens housed. If this is applied by the Australian egg industry there is an annual saving of \$28,115,500.

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