

Modelling of a poultry shed

NRM/Tegel Ltd

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Tegel Foods is New Zealand's leading producer and supplier of poultry products, providing an extensive range of quality poultry products to New Zealanders for over thirty years. Tegel is part of the Heinz-Wattie group of companies, owned by multinational food producer HJ Heinz Co. Tegel Foods began operations as a department of General Foods Corporation in 1966 and now employs approximately 1700 people at its sites throughout New Zealand.

Tegel Foods is a fully integrated poultry producer involved in breeding, hatching, feeding, growing, processing and marketing of chicken and turkey in New Zealand. Its product range includes fresh, frozen and cooked whole chickens and fresh and frozen chicken portions. NRM New Zealand markets all feed and animal health products that are sold externally.

The problem presented by Tegel was specifically to model the energy exchange between the chickens and their shed environment in order to better understand and control the shed climate and thereby maximize growth rate.

A typical shed has chickens placed as day-old chicks at a stocking density of about 21 birds per square metre. They are reared on a concrete floor (about 15 cm thick), with a 5 cm layer of dry wood shavings spread as 'litter'. This litter remains with flock for the duration of the batch, 'composting' down to a friable litter material consistent with '50% sawdust mixed with 50% dry garden soil'. The sheds are of 'controlled environment' type, and the birds are grown within a specific temperature profile as they get older. The shed temperature control starts at 32 C at the day of placement, reducing down about 0.4 per day to 20C by the time the birds reach final processing age (average 37 days). The chickens have unlimited access to feed and water, and grow to a specific growth profile with target weight-for-age expectations. Specific air exchange requirements are necessary to maintain a shed environment acceptable

for animal welfare and performance parameters. Water generated into vapour/humidity, through evaporation, and CO₂ are the predominant waste products which must be removed.

The moisture content of the dry wood shavings prior to placing the chicks is close to 5%. By the end of the growing cycle the litter moisture is ideally no more than 20%. Water accumulation in the litter is insignificant compared to total water throughput during the run. The air exchange is determined by total biomass within the shed and therefore increases throughout the life of the flock. Failure to remove sufficient waste air leads to ‘wet litter’ which causes welfare problems as well as performance depression expressed by low feed intakes, low weight gains and poorer feed conversion.

As the birds grow, progressively generating their own body heat, the supplementary heat requirement in the shed decreases and the need to remove heat from the shed starts to overlap. This transition from a heating to a cooling mode is strongly influenced by the weather conditions outside the shed, combined with insulation values of the shed, weight for the age of the flock and target shed environment temperature.

These daily shed temperature targets are based on achieving the optimum ‘comfort’ of the birds at every stage. However as the biomass increases and the influence of heat build-up occurs at floor level, then cooling requirements become harder to formulate on a mathematical basis. Daily temperature monitoring normally measures ‘ambient’ air temperature 30cm above the birds’ heads. This temperature is therefore not an accurate temperature requirement but an assumption based on visual flock behaviour. This temperature ‘perceived’ by the birds is a combination of ambient shed temperature, relative humidity, air flow, metabolic heat production and litter temperature.

The modelling of the shed environment’s inputs and outputs will be particularly valuable for assessing three fundamental inputs of economic importance: feed nutrient density in terms of energy formulation, heating in terms of gas/power usage, and heat removal via extraction fans. Optimisation of liveweight gain and feed conversion potential are the end targets.

The important variables needing careful consideration include:

- The temperature and relative humidity outside the shed.

- Supplementary heating into the shed.
- Energy and nutrient density of feed consumed by the chickens.
- Increase in biomass within the shed.
- Heat accumulation and ‘storage’ in the litter and floor under the chickens from biomass heat generation.
- Heat generated by composting effect of litter bed.
- Increase in insulating effect of birds on litter heat from increasing biomass.
- Effect of air flow on heat transfer.

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The MISG group found that Tegel’s farmers raise their chickens in sheds of rough size 15 wide, 80 m long and 3.5 m high. Between 30,000 and 40,000 one-day-old chickens are introduced to the shed where they are kept with unrestricted access to food and water for between 30 and 40 days, at which time they are between 2 and 3 kg in weight.

The shed’s floor is concrete. On this is the litter, which is initially wood shavings which then gets mixed with chicken manure, a good deal of which is excreted water which must be removed by ventilation. The shed’s ceiling and walls are well insulated. When the chicks are under about 2 weeks old the shed is heated to between 30 and 35°C, with minimal ventilation. After that time the chickens are weaned off the heat, and the shed may be intensively ventilated, depending on the interior and exterior climatic conditions.

A field trip to one of Tegel’s sheds convinced us that the shed could be treated fairly accurately as a homogeneous structure; the air seemed to be well-mixed and the chickens and litter were spread evenly across the shed floor. Therefore the model of the situation consisted of stratified layers: at the bottom was the soil below the shed, then the concrete and then the litter; above that was the ‘chicken layer’, then the internal air, the shell of the shed, and finally the external air.

Our model of the situation included the temperature of the external air, the internal air, the chickens, the litter, the concrete floor and the underlying soil. It also included the relative humidity (RH) of the external air, the internal air and the moisture content of the litter.

The main input of heat into the system was through the metabolism of the chickens. Experimental data suggested that a sufficiently precise model for a chicken was that its heat and moisture output was proportional to the surface area of its lung. A typical 2 kg bird produces roughly 10 W of sensible heat, and respire 0.28 kg of water per day. For a shed of 30,000 birds, this is about 8 tonnes/day, or 0.1 kg/s.

The heat from the chicken passes into the air, but is also used to evaporate moisture from the litter. Much of this is usually vaporised because of the heat input from the chickens and the high water activity of the droppings, but occasionally, if the shed is inadequately ventilated, the water builds up and the litter becomes uncomfortably saturated.

Heat also passes through to the concrete and the underlying soil. Since the shed is virtually in thermal equilibrium at all times, a simple calculation revealed that roughly 1W per chicken is conducted through to the ground. Similarly, in climatic conditions typical of Auckland, roughly 1W per chicken is conducted through the shed's wall and roof. This leaves about 8 W per bird, or a total of about 240 kW of heat to be removed by ventilation.

The group made a sample calculation based on an air speed of 1 m/s provided by the ventilation fans. With ambient (outside) air conditions of 20 C and a relative humidity of 60%, the expelled air was calculated to be at 20 C with a RH of 70%. This provided a water uptake of 0.1 kg/s and a heat gain of 235 kW, which matched the sample data closely (see above). This was very encouraging, as it showed that a simulation of the thermodynamics and psychrometry of the shed environment produced feasible results.

The rate of food and water intake was also investigated using Tegel's data. We found that the chicken's intake was proportional to their surface area, assuming that they were spherical-remarkably, this latter assumption appears to be fairly good! The rate of growth appeared to be quadratic with age. A model for the heat production and water respiration rate of a typical chicken was developed, based on physical principles. Perusal of actual data on chicken weight vs feed and water intake led to some initial simple models for growth rate as a function of mass. These will be refined for the final write-up.

Industry representative John Foulds said that the models developed by the team confirmed Tegel's thoughts about important parameters, but

he was impressed by the way the group attacked the problem and how the members insisted on ensuring that everything was accounted for.