Nuffield Farming Scholarships Trust

A BEMB (R & E) Trust Award

Disease prevention in the chick embryo and young chick

Helen Houghton

July 2011

Contents

Executive Summary

Good chick quality is crucial to optimize performance in both egg laying and meat producing breeds of chicken. The quality of the layer or broiler chicks that a commercial farmer buys can determine the economic performance of that flock. Uniform flocks are easier to manage, convert feed more efficiently and grow to a uniform defined slaughter weight to fulfil a meat contract or become uniform pullets that will respond consistently throughout the flock to light stimulation, and come into lay to fulfil egg production contracts.

In the UK chick quality can be very variable, and is dependent upon the health and management of the parent breeder flock, the number of hatching eggs available, the incubation of the embryo and then management of the vital first days of a chick's life. I wanted to study how disease prevention in the chick embryo and young chick could help improve overall chick quality.

I wanted to visit poultry industries in countries where labour is expensive and automation and the role of technology is essential, such as in the USA and the Netherlands. I also wished to visit countries where labour is cheap and there is little or no automation to observe how good quality poultry can be produced through good management and attention to detail.

In the USA, India and China high levels of prophylactic antibiotics are routinely used and are viewed as a general management tool. Conversely in the Netherlands and UK, our aim is to reduce antibiotic usage to a therapeutic minimum due to concerns over development of antibiotic resistance. This reduction of antibiotic usage will be achieved through improved biosecurity, hygiene and general management of hatcheries and farms.

In the USA and the Netherlands I saw how well controlled incubation temperatures produced optimally developed mature chicks with optimal immune systems. Overheating embryos during incubation produces chicks that hatch out too early, are immature and smaller in size, with low relative body organ weights. The Bursa of Fabricious, which is the key organ for the active immune system, can be as much as 20% underdeveloped. Such chicks will always be more susceptible to disease and less able to respond to preventative measures such as vaccination. Single stage incubation and technologies for controlling airflow and temperatures can make incubation a much more uniform process.

In the USA I looked at *in ovo* delivery systems that can be used for mass vaccination of embryos at 18 days of incubation, enabling earlier protection against diseases a chick will encounter on farm. Giving probiotics *in ovo* could produce a day old chick with an established gut flora that has the potential to protect against colonisation by two bacterial species that are major causes of human food poisoning, *Salmonella* and Campylobacter.

In the Netherlands I learnt about early feeding systems where hatched chicks have immediate access to feed and water. Such systems prevent chick dehydration that can occur in chicks if there is a long time between hatching and arriving on farm. Day old chicks hatch with immature gut systems and the physical presence of feed in the gut

stimulates the maturation of the gut. Studies have shown that day old broiler chicks having immediate access to feed and water have produced birds that reach slaughter weight a day earlier when compared with conventional farming systems. Reducing the life of a broiler by one day will reduce costs of production and increase the potential number of crops of birds per house per year.

I saw how automation of day old vaccination coupled with infrared beak treatment reduced chick processing time, enabling chicks to be on farms sooner. Infrared beak treatment has now been accepted widely in the UK, but not in the USA where the technology was developed. USA farmers believe that a day old chick with a sore beak compromises that chick's ability to feed and drink. In the UK beak trimming at 10-13 days of age with a hot blade that cuts and cauterises the open wound is viewed as a welfare issue of continual pain and possible neuroma formation, and is now illegal. However, it is common practice for layer and breeder birds around the world to be beak trimmed by hot blade and this is not seen as a welfare issue.

In an Indian layer hatchery with very little automation, I saw how a high level of manual labour for chick take off, vent sexing and hand vaccination enabled chicks to be processed quickly and efficiently and placed on farm within a few hours.

In India and China I saw excellent quality chickens being raised on farms with a high ratio of staff to chickens, hand feeding, vaccines being delivered individually to birds and a great deal of care and attention paid to the birds.

To conclude, through my travels I learnt that attention to detail with good management is essential to produce excellent quality chicks through disease prevention in the parent breeder flock, the incubation of the embryo and then management of the vital first days of life.

1. Introduction

1.1 Personal

I am veterinarian working for Merial, a global animal health company, as the Avian Manager for the UK and Ireland responsible for all sales, marketing and technical aspects of the avian business.

In 2009 I joined the UK Nuffield Poultry Study Group on their trip to Northern France as a sponsor and organiser of a couple of farm visits. I learnt a huge amount from the Scholars and hope to continue to do so over the coming years.

I applied for a scholarship to learn more about disease prevention in the chick embryo and young chick and to understand how to produce excellent quality chicks.

1.2 Subject

Good chick quality is crucial to optimize performance in both layers and broiler breeds of chicken but, unfortunately, in the UK chick quality can be very variable. The quality of the chick is dependent upon the health and management of the parent breeder flock, the number of hatching eggs available, the incubation of the embryo and then management of the vital first days of life. I wanted to study how disease prevention in the chick embryo and young chick could help improve chick quality.

I wanted to visit countries where labour is expensive and automation and the role of technology is essential such as in the USA and the Netherlands. I also wished to visit countries where labour is cheap and there is little or no automation to observe how quality poultry can be produced through good management and attention to detail.

1.2 Key findings

- In the USA, India and China high levels of prophylactic antibiotics are routinely used and are viewed as a general management tool. Conversely in the Netherlands and UK, our aim is to reduce antibiotic usage to a therapeutic minimum due to concerns over development of antibiotic resistance. This reduction of antibiotic usage will be achieved through improved biosecurity, hygiene and general management of hatcheries and farms.

- In USA, Netherlands and India I saw how well controlled incubation temperatures produced optimally developed mature chicks with optimal immune systems. Over heating embryos during incubation produces chicks that hatch out too early, are immature and smaller in size, with low relative body organ weights. The Bursa of Fabricious, which is the key organ for the active immune system, can be as much as 20% underdeveloped. Such chicks will always be more susceptible to disease and less able to respond to preventative measures such as vaccination. Technology for controlling airflow and temperatures can make incubation a much more uniform process.

- In the USA I looked at *in ovo* delivery systems that can be used for mass vaccination of embryos at 18 days of incubation, enabling earlier protection against diseases a chick will encounter on farm. Giving probiotics *in ovo* could produce a day old chick with an established gut flora protecting against the colonisation of two bacteria that are the major causes of human food poisoning, *Salmonella* and Campylobacter.

- In the Netherlands I learnt about early feeding systems where hatched chicks have immediate access to feed and water. Such systems prevent chick dehydration that can occur in chicks if there is a long time between hatching and arrival on farm. Day old chicks hatch with immature gut systems and the physical presence of feed in the gut stimulates the maturation of the gut. Studies have shown that day old broiler chicks having immediate access to feed and water have produced birds that reach slaughter weight a day earlier when compared with conventional farming systems. Reducing the life a broiler by one day will reduce costs of production and increase the number of crops per house per year.

2. Background

2.1 Poultry Genetics

The poultry industry is a truly global industry with just a few genetics companies supplying a small number of breeds of broiler (meat bird) or layer (egg producing) birds all over the world. These birds then experience different climates and husbandry practices. With careful genetic selection of pedigree pure lines, it takes approximately five years to establish grandparents, parents, and through to the final commercial broiler or layer chick.

Part of the art of breeding poultry is in the prediction of growth or reproductive traits that will be required in 5 years' time. For example in the UK following the down turn in the economic climate, UK households which previously would have bought organic broilers have switched to buying free range birds and similarly households have switched from buying free range birds to buying standard broilers. All these different birds are expected to be supplied by the supermarkets and butchers in the quantities demanded by the consumer. The challenge for the industry as a whole is to provide what the consumer wants when the consumer wants it.

With rapid changes in market requirements, broiler and layer companies may therefore suffer from shortages or surpluses of parent or commercial hatching eggs.

2.2 Chick Quality Issues

For both the meat and egg production sectors the quality of the chick that will be grown for meat or to lay eggs, is vital. Good chick quality is crucial to optimise performance. Good chick quality has been defined as chicks that have developed optimally during incubation and show a good performance such as daily growth, breast meat yield, eggs or liveability in the field. (Molenaar, R et al 2009).

The quality of the chick is dependent upon the health and management of the parent breeder flock, the incubation of the embryo and then management of the vital first days of life. Get these factors right and the chick will have the ability to fulfil its genetic potential for which it has been carefully selected and bred over the previous five years.

Due to the length of time it takes to produce a commercial chick that reflects the current market's needs, hatching eggs are often scarce and from 24 weeks of age all eggs produced from a breeder flock are incubated (often including dirty eggs collected from the floor). Automation of egg collection has also reduced control over the quality of eggs set, where hand collection allowed visual inspection and the discarding of eggs before they even arrived at the hatchery.

Breeder flocks are generally between 24-60 weeks of age when they produce eggs. The ideal age of a breeder flock for production of commercial chicks is between 35-45 weeks of age. Younger breeder flocks that are less than 35 weeks of age produce small eggs and hence small chicks with little passive immunity from maternally derived antibodies. Older flocks over 45 weeks of age produce bigger eggs with larger embryos, but also have reduced passive immunity.

It is common practice for the commercial farmer to receive, all on the same day, either chicks from different parent flocks of varying ages, or for that same chick order to have been made up through the course of a week. Often mixtures of small and larger more mature chicks are housed together and managed as one uneven flock, which is less than ideal for broiler or layer bird production.

Minimal variation between chicks within a flock is critical to achieve a good flock performance. It enables ease of management such as feed conversion control, uniformity of layer pullets' body weights vital for responding to light stimulation to bring them into lay, or for uniformity of broilers' body weight at slaughter to fulfil meat contracts. Uniformity in maturity of immune systems and consistency in levels of both active and passive immunity aids the prevention of disease. Parental flock age has a direct effect on when to administer vaccines and achieve the optimum immune response.

Uneven flocks are hard to manage due to the individual chicks' differing needs. It is, therefore, essential to try to understand what causes the variations in chicks and how to change their management accordingly.

2.3 Countries Visited

When choosing countries to visit for my study I wanted to visit countries where both poultry meat and eggs are consumed, but with different economic climates. As in the UK, labour costs in America and the Netherlands are high and automation is essential.

In contrast I also visited two countries where, when most of the world was going into recession their economic growth continued i.e. India and China. In both of these countries labour costs are low but, with massive populations to feed, poultry meat and eggs are an essential and accessible source of protein and will continue to be important in the future.

3. USA

3.1 Broilers in the USA

I started my trip by visiting the southern state of Georgia commonly known not only for being part of the Bible Belt of America, but also part of the Broiler Belt of America producing 10 billion broilers a year. The state of Georgia alone produces 1.4 billion broilers per year. The Ross 708 bird is grown for the USA's processed meat market, rather than the whole bird market. Chicken wings are a speciality in the USA along with white meat portions. However some white meat is exported to Mexico and chicken feet are exported to China. Brown meat is currently exported to Russia although Russia is looking to cease all USA imports by 2016.

In the USA all poultry meat is chilled by water immersion rather than air chilling and rinsed in chlorine to kill surface contaminating bacteria such as Campylobacter and *Salmonella*, both major causes of human food poisoning. Both these processes are banned in the EU, preventing imports of poultry meat from the USA.

3.2 Cagel's Hatchery, Dalton, Georgia.

I visited Cagel's commercial broiler hatchery to look at their *in ovo* vaccination technology. The company has an integrated system of producing broilers in that they own one "complex" consisting of parent stock, hatchery, broiler farms, a feed mill, and 2 processing plants.

The hatchery produces 2.5million broiler chicks a week. All embryos (whilst inside the egg) are vaccinated against Marek's disease using ¼ dose of HVT Marek's vaccine with Gentamycin antibiotic added. The hatchery operates 3 *in ovo* machines 4 days a week.

The eggs are not candled (using a light to check for infertile eggs) as this involves extra labour costs in handling and removing infertile eggs. However, bacterial contamination of the hatchery from infertile eggs or dead embryos could be high, which can result in reduced hatchability or an increased incidence of bacterial yolk sac infections in the hatched chicks, each of which has economic consequences.

In ovo administration of vaccine and antibiotic is common practice in the USA, with over 90% of broiler hatcheries vaccinating embryos. Routine on farm prophylactic antibiotic usage is common too, which is very different from the UK and parts of Europe where there is a drive to reduce antibiotic usage. In USA cephalosporin and fluoroquinalone antibiotics are banned by the FDA in food producing animals, but other antibiotics are freely used.

In ovo vaccination is not used in commercial layer hatcheries as only female chicks are required and vaccinating unwanted male chicks represents an unnecessary expense. The *in ovo* machines are capable of delivering accurate doses of vaccine (and antibiotic) to over 50,000 eggs per hour enabling uniform vaccination of a flock.
Eggs are injected at approximately 18 days of incubation. A small hole is punched into the egg shell and a needle passes through the hole, through the air sac, membranes and into the amniotic fluid surrounding the embryo. Vaccine in the

amniotic fluid is swallowed by the embryo and "breathed" into the respiratory system in the final days of incubation. It is not intended to vaccinate directly into the embryo as this can cause damage and trauma which may result in the death of the embryo. Marek's vaccines placed into the air sac or allantoic sac in the egg are ineffective, so there is a science to vaccinating embryos at the correct stage of incubation and having eggs positioned correctly for injection. Marek's disease HVT virus will start replicating in the embryo before hatching, giving earlier protection than vaccinating a day old chick.

After vaccination the egg punch and needle are retracted out of the egg and are then rinsed with a detergent, which also falls onto the egg shell to reduce contamination of the egg with microorganisms.

The eggs are then transferred to the hatcher trays and placed back inside the incubator to continue the final 3 days of incubation. Chicks are hatched as normal and, as they have already received their vaccination, chick processing time and hatch day labour costs are reduced. Placement of chicks onto farms can occur sooner, reducing the time chicks have feed and water withheld.

3.3 Poultry Disease and Research Centre (PDRC), Georgia University

I enjoyed a tour of facilities with Dr John Glissen, Head of the PDRC. Dr Glissen is famous for discovering a strain of Newcastle disease (ND) virus, suitable for a very efficacious ND vaccine used on a global scale. At PDRC poultry diseases ranging from coccidiosis, viral diseases such as Infectious Bursal Disease (IBD) Marek's disease (MD) as well as bacterial infections caused by *Salmonella* and Camplylobacter, are studied.

I met with Dr Margie Lee whose group researches chickens' gut flora. Her research challenges the conventional understanding that birds acquire their intestinal bacteria from the environment and that newly hatched chicks are devoid of intestinal micro-organisms. (Pedroso A.A. 2009a). It is well established that vertical transmission of pathogens such as *Salmonella*, E coli, Mycoplasma and Campylobacter pass from the breeder to the chick. Microorganisms can enter the egg before the formation of the shell, passing into the yolk and then enter the embryonic chick's gastrointestinal tract during early development, or through ingestion of amniotic fluid, or when the yolk sac is internalised into the chick on the 18th day of incubation. It is also known that microorganisms on the shell surface penetrate into the albumen (egg white) and yolk, through damaged shell cuticles or through normal shell pores when eggs are wet, such as when the egg comes into contact with chicken faeces when the egg is laid. (Berrange M.E. et al 1999).

Dr Lee explained how her research has been to take hatching eggs, sterilise the outer egg shell and aseptically remove the chick embryo to study the microflora of the embryo's gut. Her studies using molecular approaches rather than culturing bacteria have shown that bacteria are present in a chick's intestines on day 16 of incubation. It has also been shown that a day old chick's intestine may be already colonised with Clostridia and Bacteroides bacteria, the amounts of which and strains present change as the bird matures. This is reflected on broiler farms, when large changes in small intestinal microflora between 14 and 21 days of age occur and is seen as the time when many gut problems appear.

So, following the discovery that chicks can hatch with bacteria already in their intestines, the idea of establishing an intestinal community of healthy bacteria during incubation to make it more difficult for pathogens to establish themselves and cause disease and affect chicken growth rates could be considered. Probiotics administered in the hatchery resulted in lowered rates of *Salmonella* carriage and improved intestinal development.

Probiotics can be defined as "non-pathogenic organisms which can exert a positive effect on the host". (Pedroso A.A. 2010). Probiotics work in different ways to adhere to the intestinal lumen interface, compete with pathogens for nutrients, block receptor binding sites and colonisation of the gut, enhance mucosal barrier function, promote innate and adaptive immune responses and modulate epithelial cell kinetics via altering the proliferation/cell death rates. The probiotics that are commercially available for poultry are bacterial cultures originally derived from a healthy chicken's gut content (i.e. caecal contents). The bacterial populations in probiotics are often undefined, but are rigorously screened for known chicken pathogens. A suspension of probiotics can be administered in the hatchery as a spray onto eggs inside the incubator or onto newly hatched chicks. However, if a chick's gut flora is already established before hatching, spraying day old chicks could be too late. Probiotics cultures are exceedingly odorous and spraying them within a hatchery would be very unpleasant.

In order to promote early and beneficial intestinal colonisation, probiotics can be given at 18 days of incubation by injection directly into the egg using the *in ovo* delivery system currently used for administering Marek's disease vaccines. Dose rates for probiotics such as Aviguard have been established for day old chicks. Dr Lee's research group has reduced the dose down to an efficacious and safe level to administer to embryos. (Pedroso A.A. 2009b). When administered *in ovo*, the day old chick dose had such high levels of bacteria that the embryos died and the eggs exploded in much the same way as infertile "bangers" do in the hatchery.

Further compatibility studies are required for probiotics to be given with Marek's disease vaccines currently administered at 18 days of incubation.

The concept of early *in ovo* administration of probiotics would greatly help gut health in both broilers and layers, to reduce antibiotic usage, promote improved bird health and reduce economic human health diseases such as *Salmonella* and Campylobacter infections.

3.4 Fieldale Farms – Dr John Smith DVM

I visited Fieldale Farms with their vet Dr John Smith. Fieldale Farms produce 3.2million broilers per week. Fieldale Farms own 3 hatcheries, 2 feed mills, 2 slaughter plants, 1 cooking and 2 rendering plants, employing a total of 4500 people. Fieldale are unusual as they produce 100% drug free birds (this excludes vaccines) which gain a premium price in the USA. These birds would not be classified as organic in the USA since they are given GMO feed.

Dr John Smith discussed different vaccination programme for broilers in the USA. All broilers (standard and longer growing broilers) receive Marek's HVT vaccines via *in ovo* vaccination at 18 days of incubation. The dose of vaccine used varies between 1/8 of a full dose per bird in the summer months when ventilation is at a maximum, to a ¼ of a dose in the winter months when Marek's disease is perceived to be a bigger problem. Slower growing breeds and roosters that are grown to 70 days of age receive a 1/3 dose HVT + SB1 Marek's disease vaccines. The increase in quantity of vaccine and "strength" of the vaccine is again due to the perceived increased risk of disease. Tumours in broilers from Marek's disease are thought to be rare in the USA but, at the slaughter plant, birds are rejected for human consumption due to folliculititis.

At the hatchery chicks receive IB and ND vaccines which are repeated on farm at 16 – 20 days by spray application. Avian metapneumovirus (TRT) is not perceived to be a problem in the USA. IBD is not viewed as a major disease risk (unlike in the UK) and only a third of broilers in the USA receive any IBD vaccines, but the practice of placing chicks on "dirty" litter re-used from the previous flock of broilers may be a way of "vaccinating" birds with mild local strains.

Broiler breeder birds receive a full dose of Marek's HVT + SB1 vaccine *in ovo* (along with antibiotics), and some chicks will also receive an IBD vaccine *in ovo* or at day old by subcutaneous injection, along with Reo virus and Fowl Pox virus vaccines. Combined ND + IB, and IBD vaccines with increasing levels of virulence, are given every 2 weeks during rear. Infectious Layngotracheitis vaccines are given by eye drop and a combined AE and fowl pox vaccine via a wing web "stab". Some birds will also receive live Pasteurella and Chick Anaemia Virus vaccines. At 16 weeks the birds are injected into the muscle with inactivated IB, Reo, ND, IBV and IBD vaccines. Broiler breeders may also be injected with inactivated *Salmonella* vaccines on transfer to the laying farms at 21 weeks.

I visited one of Fieldale Farm's hatcheries at Lavonia and Dr John Smith, with hatchery manager Joe Colee, was keen to show me their single stage HatchTech incubators. Large investments had been made in technology to improve their uniformity of hatch and to produce chicks of the very best quality.

Hatching eggs need to be stored at temperatures below that required for morphological development: ideally at 16-18^{o}C if the eggs have been laid for less than 7 days or at 10-12^{o}C if the eggs are older than 7 days. Ideally eggs approximately 4 days old should be incubated for maximum hatchability. Hatchability is increased if eggs are slowly pre-warmed over a period of 24 hours before starting incubation to a temperature of 25^{o}C, just as in nature where a hen lays a new egg each day to form a clutch of eggs in a nest. When all the eggs in the clutch have been laid, then the hen will begin the 21 days' incubation of those eggs. It is important not to let embryos physically develop too far before the start of incubation as this reduces hatchability. The hatching eggs are taken from the egg storage room and pre-incubation warming conditions are delivered to the eggs inside the incubator. The HatchTech incubators use an Optimal Preheat Control system which enables eggs to be uniformly and gradually pre-warmed to an internal egg temperature of 37.8^{o}C ready for incubation. The benefits of such a controlled system are a uniform embryo starting incubation, reduced embryonic mortality, reduced abnormal embryonic development, reduced contamination by pathogenic microorganisms caused by condensation of water on egg shells and an overall improved uniformity of hatching and chick quality. As an automated device it saves labour costs as eggs are just moved from the egg storage room to the incubator, rather than being handled twice as eggs are moved from the egg storage room to somewhere warmer in the hatchery, before being placed in an incubator.

During incubation uniform internal egg temperature is essential throughout all the eggs in the incubator. How hot or cold an embryo is determines the rate of development of that embryo and resulting hatching chick quality. However embryonic temperatures can only be measured by killing the embryos, so external egg shell temperatures are monitored instead.

During the first 9 days of incubation, embryonic heat production is very low and the eggs lose water by evaporation which cools the embryo, so initially air temperature must be maintained above 37.8^{o}C to transfer heat to the embryos.

After 9 days of incubation embryonic heat production increases exponentially and the embryos require cooling to maintain a temperature of 37.8^{o}C. If multi age incubators are used younger embryos will be cooler and older embryos will be producing more heat causing unevenness of temperatures within an incubator, so there will be hot spots and cold spots. It takes a very experienced incubation technician to manage such incubators. Other incubation systems that are single egg age can also suffer from hot and cold spots if the air flow within the incubator is incorrectly managed due to poor cooling or inappropriate air velocity over the eggs.

Embryos that are too cold will not develop properly and heat stress also has a very serious effect on the developing embryo. Egg shell temperatures greater than 37.8^{o}C in the second half of incubation result in shorter incubation times and chicks hatch out too early. (Lourens A. et al 2007). Signs of overheating in an incubator include panting and noisy chicks and chicks with red hocks and beaks as they struggle to hatch out of their shell due to malpositioning of the embryo within the egg shell. Reduced incubation times result in small chicks with unhealed navels due to large un-retracted residual yolk sacs with reduced nutrient uptake from the egg. Very importantly, embryonic development is reduced; chicks have reduced yolk free body masses and reduced relative organ weight in both layers and broilers. Heat stress has caused relative heart weights to be reduced by as much as 18% in broilers and 22% in layers compared with eggs incubated at 37.8^{o}C. Compromised cardiovascular systems can result in sudden deaths or ascites. (Leksrisompong, N et al 2007).

Relative Bursa of Fabricius weights can be reduced by as much as 20% due to heat stress of the embryo. (Molenaar R. et al 2009). The bursa is essential for the development of a healthy bird's immune system. An under developed bursa can seriously immunocompromise a bird for the rest of its life resulting in poorer responses to vaccination and reducing a bird's ability to fight disease.

When the time to remove chicks from an incubator is fixed, such as by shift patterns in a hatchery, the heat stressed embryos will hatch out first and will start to dehydrate due to loss of water by evaporation. The effect of heat stress during incubation can be continued throughout a bird's life resulting in broilers with lower slaughter weights and increased FCR. (Hulet R. et al 2007).

Fieldale Farms' hatchery had invested heavily in HatchTech Incubators with laminar airflow technology. The airflow over the incubating eggs flows horizontally, created by pressure differentials within the environment and the perforated radiators that act as the walls within the incubator before and after every setter trolley. The laminar airflow eliminates variations in embryo temperatures, eliminating hot and cold spots within an incubator and thus ensuring a uniform hatch and uniform chick quality. The uniform air flow ensures that the optimal combination of air temperature, air velocity and relative humidity are achieved for every egg in the incubator.

I visited two Fieldale broiler farms on the South Carolina border. Each farm housed 27,000 birds per house on dirt floors. Unlike in the UK, in the USA only the pure line stock, great grand parents and grandparents birds are housed on concrete floors. Houses with dirt floors are impossible to clean and disinfect so residual disease challenge is carried over from one crop of birds to the next. The litter is re-used for 3-6 crops and the houses are cleaned out only once or twice a year. The litter was friable and warm which was very pleasant for placement of day old chicks when compared with the UK where chicks can sometimes be placed onto clean litter which is put on top of wet, cold concrete floors (when turn around times between crops of birds is short). The live, unattenuated coccidiosis vaccines recycle in the re-used litter, other bacteria and viruses remain within the houses infecting young chicks.

Often in the USA broiler chicks are not vaccinated with live IBD vaccines. It is possible that mild field IBD viruses circulate and infect the chicks acting like live attenuated IBD vaccines. By re-using litter, chicks can be exposed to potentially high levels of pathogens shed by the previous flock's older birds, causing disease in young chicks with immature immune systems. There can also be a build up of ammonia in the house which affects the corneas of the chicks causing painful blindness. The practice of re-using poultry litter in the USA is due to the costs involved of disposing of litter. In the past poultry litter has polluted waterways and now most litter is either composted or burnt in power stations.

In the NL and UK new broiler houses with under floor heating are being built which provides the direct floor heat that is ideal for day old chicks, combined with the ability to completely clean and disinfect whole houses between crops enabling better disease control.

Fieldale Farms operate an all-in all-out policy with no multi age sites, so making disease easier to control. They do not "thin" the birds (a process in which birds suffer from feed and water restriction whilst a proportion of the birds in a house are removed for slaughter and then the remaining birds grown on for longer) in USA, which reduces stress for birds.

3.5 Aviagen, Huntsville, Alabama

I visited Dr Gregorio Rosales DVM, the Vice President of Aviagen's Veterinary Services Aviagen, to learn about the breeding company that supplies 48% of the world's broiler parent stock. Their breeding stock birds are split between North

America, Scotland and Brazil so that if diseases such as Avian Influenza cause birds to be slaughtered or exports restricted, then supply can be continued from a different area. Aviagen produce 3 main breed lines: Ross, Arbor Acres and Indian River.

In the USA the most popular bird is the Ross 708 which is a heavier bird more suitable for the de-boning industry, whereas globally the Ross 308 is the most popular breed.

3.6 Layers in the USA

The USA has 280 million layers, of which the majority is white birds producing white eggs. All shell eggs are washed and 50% go into the liquid egg market for baking etc. Moulting by restricting feed is common practice in the white egg layer breeds. Moulting extends the life of a flock by producing more eggs per bird without the problems of producing unwanted large eggs that occur in the brown egg breeds. Moulting is illegal in the UK due to the welfare issues of withholding feed and water.

3.7 Hy-line, Dallas County

I visited one of the world's largest layer genetics companies in Dallas County, Iowa. Hy-line supplies layer parent birds all over the world. Its biggest market is China, followed by USA, Mexico, Japan, Brazil and France. Hy-line has a sister company Hy-vac supplying SPF eggs for vaccine production. I wanted to learn about poultry genetics and the ability to breed a bird that was resistant to certain diseases.

Dr Ian Rubinoff DVM, Hy-Line's Technical manager, and I discussed the disease situation of layers in the USA. Commercial birds are vaccinated against Marek's disease (with gentamycin antibiotic), Fowl Pox, E coli, IBD, ND and IB in rear. All layer pullets receive inactivated vaccine at 16 weeks. Spent hens (birds that have come to the end of their egg laying life) that have received inactivated vaccine containing an oil adjuvant are often refused by meat processing plants because such meat is banned in schools in the USA. This is due to the perceived human health risk of any residual oil that can persist in birds approximately 60 weeks post vaccination.

Dr Petek Settar, Hy-line's geneticist in charge of the selection of the pure line birds, is interested in developing the commercial traits that are required in the final layer bird. She explained to me how the pure lines are free of Avian leucosis, Mycoplasma gallinarum, Mycoplasma synoviae and *Salmonella* Enteritidis. All pure line birds are regularly tested for such pathogens.

One of the most important production traits is egg quality. The very first 3 eggs laid by the pure line birds plus eggs produced at 26 and 42 weeks are monitored for an array of quality standards. Egg shell colour is recorded. Brown eggs with speckled egg shells are not acceptable and these birds are removed from the breeding lines. Brown eggs with speckled egg shells are not acceptable in Asia as the egg shells appear to be covered with fly faeces. Egg shell strength, albumen height, weight of yolk and colour of yolk are measured. If any blood spots in the egg contents are present, again the parent birds are taken out of the selection process as blood spots are unacceptable in most societies.

Dr Neil O'Sullivan, Hy-line's Research and Development Geneticist, discussed how different genetic traits are selected by birds housed in research farms and then further selection occurs when commercial birds are grown in "field" conditions. Such selection processes have been carried out by Hy-line for over 25 years. The commercial layer birds are grown in 4 different field locations in open sided houses in the tropics in Asia and closed sided houses in UK, Brazil, Mexico, USA and Canada to see how the birds perform under different management and disease situations. In the USA moulting of hens is common practice so the breeds are moulted to see how well they perform.

The ability to breed a bird that has all the desired production traits and is resistant to Marek's disease is still a far off goal. Hy-Line have a Marek's disease resistance testing programme aimed at trying to overcome the devastating effect of high mortality caused by this disease.

Other traits covering liveability, feather cover (important for regulation of body temperature), social behaviour such as feather pecking, nesting behaviour, sexual maturity, fertility, mating ability, peak egg production, rate of decay of egg production curve, feed efficiency, wetness of manure are all recorded. Genetics companies aim to add 2-3 eggs per hen housed, per year, using less feed.

Dr Janet Fulton, Hy-Line's Molecular Geneticist, explained that currently all genetic selection is based upon looking at phenotypic performance of the pure lines for certain traits such as number of eggs produced in a laying hen's lifetime, egg weight, eggshell quality etc The chicken genome was sequenced in 2004 and now, in an attempt to speed up selection, Hy-Line are trying to find genetic markers relating to different phenotypic traits. Therefore, in the future, pure lines can be selected or rejected based upon a blood test result rather than waiting until birds are 20 weeks to lay eggs to be tested. An important genetic marker on chromosome 13 gives some resistance to Marek's disease.

The genetic marker research continues alongside the classical phenotypic selection procedure with all birds being blood sampled and their genome investigated for possible markers. However the genotyping is expensive and many samples are being stored until such time that technological advances bring cheaper techniques. Hy-line now hold sera from 13 generations of birds in their DNA bank, matched with the all important phenotypic data.

3.8 Nova-Tech Engineering

I travelled to Willmar, Minnesota where I met with Jim Sieben, General Manager, and Ernie Van Gulijt, Technical Manager, of Nova-Tech Engineering. I wanted to learn about automated day old subcutaneous vaccination of poultry. Such automation is essential in countries where labour is expensive and I was interested to learn if automation would remove some of the human error that can occur when large numbers of chicks are to be vaccinated and vaccinators begin to tire.

CEO Mark Warrence started Nova-Tech Engineering in 1992 after working for the Willmar Poultry Group and began looking at automation of certain procedures in poultry hatcheries. A common procedure was the cutting off of the rear toe in turkeys with a hot blade and then gluing the area to stop any haemorrhaging. Mark Warrence designed a microwave system that was applied locally to the turkey toe causing the tissue to die and the toe to drop off. He also looked at beak trimming in turkeys which is carried out to prevent pecking and cannibalism. He automated this procedure by applying infra-red radiation (IR) to the top beak causing the tissue to die.

Beak trimming is a routine husbandry procedure in layer chicks to prevent feather pecking and aggressive pecking which can often lead to cannibalism. Traditionally, part of the upper and lower beak is removed with a hot blade to cut and cauterise the beak tissue of a chick between 1 and 13 days of age. However, it is believed that hot blade treatment may cause acute and chronic pain in adult birds with neuroma formation. (Dennis R.L. et al 2009).

Mark Warrence adapted his turkey IR beak treatment to layer chicks. The chicks are placed on the Nova Tech machine and are immobilised by a head restraint. The infrared energy is focused on the area of beak that requires trimming. High intensity heat penetrates down through the corneum layer of the beak to the corneum-generating basal tissue and inhibits further germ layer growth. After treatment the corneum layer remains intact until 7 to 10 days post trimming, after which the tip of the beak begins to soften and erode away with use. The advantages of IR beak treatment are that there are no open wounds which can readily become infected, changes in beak length and shape occurs gradually over a 2 week period (allowing chicks to feed) and the resulting beaks are not as short as after hot blade treatments. The treatment is precise and reliable minimising operator error and inconsistency. Fewer behavioural changes and reduction in feed intake have been reported when compared with hot blade beak trimmed birds. It is this system for IR beak treatment that has been widely accepted in the UK by Freedom Food standards and replaced hot blade treatments that were made illegal on 01/01/2011.

In the USA hot blade beak trimming at 7 days is common practice as this is included in the contracts of specialised companies providing chick placement, vaccine administration, depopulation of birds and on farm cleaning and disinfection. The USA farmers widely believe that at 7 days the chicks have already found feed and water and that growth is reduced (due to lack of feed intake) for only a few days following beak trimming. After IR treatment at the hatchery the chicks required careful management. Feed needs to be piled up high to encourage chicks to eat as their beaks are sore and pecking feeders will discourage chicks to feed. Water pressures should be high so that chicks do not need to tap the drinker nipples hard to release the water; any discouragement in drinking will result in dehydration and chick deaths. For these reasons most USA farmers do not want IR beak treated chicks resulting in only 15 – 20% of USA pullets being beak trimmed using the IR treatment.

The same machine that delivers the IR beak treatment also has a subcutaneous (sc) injection system. This automated system has completely replaced hand vaccination in USA hatcheries. The chicks are held by the head in neck clamps and move around a carrousel for IR beak treatment and then for sc injection into the back of the neck, before being released into a chute down to the chick counter. Every few chicks the needles are sanitised with alcohol. It is widely used across the USA for vaccinating day old layers, layer breeders, broiler breeders and turkey poults. All chicks receive vaccine with an antibiotic or, in the case of the turkey poults, no vaccine was injected, just antibiotic alone.

The injection system can be more efficient than hand vaccinating, especially when large numbers of chicks are required to be vaccinated and vaccinators tire towards the end of a shift. However, the machines require careful management to make sure all needles and syringes are working well, with correct volumes of vaccines being administered and careful cleaning of the machines to prevent bacteria being injected into day old chicks.

3.9 Key Observations from the USA

- **Breeding companies.**
  Breeding programmes aim to produce birds that have both genetic resistance to diseases such as Marek's disease and also that can adapt to particular husbandry conditions that may pre-dispose to disease.

- **Incubation technology**
  Incubation systems with prewarming and laminar air flow systems to create uniform controlled incubation environments are essential to produce maximally developed chicks

- **Automated applications of vaccines**
  In ovo administration of vaccines (with antibiotics) in broiler hatcheries is very widely practised. Large number of eggs can be injected in a short period of time, while chick processing time on hatch days is much reduced allowing chicks to be delivered sooner to farms.

  Automation of subcutaneous injections of day old chicks and turkey poults with vaccines and antibiotics has revolutionised mass day old administrations, reducing human operator error and reducing chick processing time.

- ***In ovo* application of Probiotics**
  Early administration of probiotics to 18 day old chick embryos may help gut maturation, improve gut health and help to prevent pathogens such as Salmonella and Campylobacter establishing in the gut in chicks.

- **IR Beak treatment**
  IR treatments have dramatically cut the hot blade beak trimming of layer birds in the UK, although this application of the technology is still not widely used in the USA as on farm hot blade beak trimming at 7 days is favoured.

- **Litter re-use and disease risk**
  Although warm friable litter is an ideal environment for day old chicks, the risk of disease carry over from adult birds to chicks with immature immune systems can be a disaster; although the antibiotics received at the hatchery and on farm may help to overcome bacterial diseases or secondary bacterial infections in birds suffering from viral or coccidial diseases.

4. Netherlands

I travelled to the Netherlands to see a poultry industry where labour costs are high, as are investments into new technologies. The Dutch describe themselves as a Nation of Traders; it is certainly true for their poultry industry as they export 70% of the eggs and chicken meat that they produce.

4.1 Marchel Boereboom DVM, "Pluimreeprktyk" Poultry Practice.

I met with poultry vet Marchel Boeredom DVM, who runs the poultry practice "Pluimreeprktyk", De Achterhoek, Ruurlo, near the Dutch/German border. The poultry practice has existed for 15 years and its work is divided between the Netherlands (85%) and Germany (15%).

The Dutch national flock consists of approximately 34 million layer birds of which 55% are brown egg laying birds and 45% are white egg laying birds. 44% of birds are caged, 41% in barn systems and 15% are Free Range. Approximately 600,000 tonnes of shell eggs are produced each year, of which 390,000 are exported to Germany (an increase since the banning of conventional cages in Germany in 2009, resulting in a shortage of shell eggs). The Dutch also import 138 tonnes of shell eggs, and export liquid eggs and dried egg products.

The layer industry is integrated with companies buying parent stock from the large genetics companies, and then hatcheries selling point of lay pullets rather than day old layer chicks. The major companies are: Verbeek (selling Lohmann pullets), Tet Heents and Hat Ankaer (selling 100% Hendrix pullets).

The broiler industry is less integrated with a national flock size of 5 million broiler breeders and 250 million broilers. Broiler parent stocks are kept in Germany and day old broiler chicks exported to the Netherlands. 95% of broilers are grown to 40 days and much of the meat is exported to Germany, the remaining 5% being slow growing/organic birds. The Dutch only consume the breast meat and there is no whole bird market in the Netherlands. Additional poultry meat is imported from Brazil.

With so much poultry movement between the Netherlands and Germany one of the most severe disease threats is of Avian Influenza, which has decimated the national flock in previous years.

In the NL there is much concern regarding antibiotic usage in poultry production and potential links to MRSA and ESBLs (Extended Spectrum Beta-Lactamases) in humans. ESBLs are enzymes carried by certain bacteria which render them resistant to many antibiotics.

Much lobbying has occurred from medics, general public, government and animal welfare organisations to reduce the overall use of antibiotics in farm animals and in humans to protect against the development of antibiotic resistance. For animals, all prophylactic antibiotics in feed have been banned and antibiotics are only allowed for therapeutic use when antibiotic sensitivity has been demonstrated. Targets have been set of reducing antibiotic usage in poultry by 20% in 2011 and by 50% in the following 3 years. However, the mechanisms of monitoring such reductions have not been established. Cephalosporin antibiotics have been banned in NL (due to a lack of minimum residue data), but the antibiotic is still administered in breeding stock (outside NL) and then those birds are imported into NL.

4.2 G D Deventer

I met with vet Teun Fabri DVM, Poultry Health specialist at G D Deventer, a privately owned diagnostic laboratory for ruminants, pigs and poultry. G D Deventer is licensed for detection of notifiable diseases such as Newcastle Disease, Avian Influenza and Mg testing. *Salmonella* testing occurs in other laboratories.

All field vets receive regular emails regarding poultry disease outbreaks in the NL which, due to the level of poultry trade with other countries, can pose significant threats to the global industry. At the time I visited in 2010 there were concerns regarding Coryza infections in layer birds that had been imported from Germany. The vets were trying to contain such outbreaks and vaccinate birds in affected areas. Infectious Bronchitis QX-like strains were isolated in the Netherlands 4-5 years ago but, unlike in the UK, Dutch vets are not concerned about the virus's impact on the broiler and layer industries as experience has shown that existing Massachusetts and 793B variant vaccine combinations can provide adequate cross protection.

4.3 Isa Hendrix, Boxmeer.

I met with vet Bart Stokvis DVM, from Isa Hendrix, a layer genetics company that has a large market share in the Netherlands with their ISA Brown bird. All breeders are tested to ensure they are free from all *Salmonella*, MG, Ms, ILT, EDS, and Avian leucosis. Grandparent stocks are vaccinated for TRT. IBD infection pressures are deemed to be very low and often maternally derived antibodies to IBD are very low, which can be a problem for progeny transported to areas where IBD causes clinical disease. Breeders are vaccinated against CAV and tested for Avian Influenza every 4 weeks. Breeder birds are tested for Mg and Ms every 2 weeks as 70 80% of the national flock is positive for Ms.

4.4 The Pluimveebedriff Schapendijk.

With vet Harry Arts I visited a Cobb broiler breeder farm. The birds are tested for *Salmonella* at 1 day, 7 days, 4 weeks, 12 weeks, and every 2 weeks thereafter. The farmer was paid on the uniformity of the birds, as uniform birds lay more uniform eggs leading to uniform hatching. All of this uniformity simplifies the management of the broiler flocks. The farmer was also paid based on the number of fertile eggs at 18 day incubation.

4.5 FarmArts Probroed, Meppel

I visited a highly automated broiler hatchery producing 1.2 million broiler chicks per week, most of which are exported to Germany. All eggs are candled and non-embryonated eggs discarded. Some customers require sexed chicks and all are spray vaccinated with IB, ND vaccines and a probiotic to help establish healthy gut flora and exclude unwanted gut flora such as *Salmonella* or Campylobacter. No Marek's vaccines or antibiotics were administered.

4.6 Unibroed hatchery, Langenboom

I had a very interesting visit to Unibroed Hatchery where Pieter Van Noord, Technical Manager showed me around his unique hatchery. The Unibroed hatchery is the only one in the world that sells Ross 308 broiler chicks at 3 different ages.

The chicks they sell are as follows:

- i) day old broilers hatched from eggs weighing more than 50g
- ii) 1.5 day old broilers from eggs weighing 40-50g
- iii) 4 day old broilers from eggs weighing 40-50g

Egg storage, incubation and brooding of chicks all occurs in one hatchery.

The hatchery has contracts to receive unwanted small hatching eggs. This is highly cost effective as eggs from breeder flocks 24 weeks old and younger are often discarded and companies charged for disposal. Eggs are candled at 18 days of incubation to remove infertile eggs, and bacterial content in such eggs is measured. Similarly bacterial load of dead embryos at 21 days is also measured and the information is passed back to the breeder flocks, for them to look at their hygiene and farm disease situations.

The hatchery routinely records chick quality at day old as a measure of determining the success of incubation and for predicting chick performance. Day old chick quality has been shown to be directly related to field performance as a maximally developed chick has the potential for better growth, breast meat yield, better egg production and better liveability in the field.

Evaluating chick quality by chick body weight can be misleading as a heavy chick does not necessarily indicate a well developed chick. The chick may have a heavy residual yolk mass and a low yolk free body mass. Yolk free body masses are a more accurate assessment of chick quality and development, but as this involves euthanasia of the chicks it is not a practical method.

HatchTech (whose incubators I saw in the USA) have researched Chick Length as a marker of chick quality. Chick length has been shown to be related to Yolk Free Body Mass and can be a good predictor of subsequent performance, correlating well with body weight at a later stage. (Molenaar R. et al 2008). The more efficiently an embryo utilises the available energy and nutrients within the egg, the more advanced the chick's development is and this corresponds to longer chick length. Measurements are made from the tip of the beak to the end of middle toe (minus the nail length).

Research in broilers has shown that a 1cm chick length advantage on the day of hatch has resulted in 264g more bodyweight with 45g more breast meat at 38 days. Hence an optimally developed chick will have a better feed conversion ratio and lead to an increased profit. (www.hatchtech.nl).

Chick length is also a reflection of incubation practices. If it is too hot within the incubator then a chick's energy is used in cooling down instead of growing. Also the smaller the residual yolk (as the embryo has used it to grow) the lower the risk of yolk sac infections post hatch. The ideal chick length is 22cm and chicks can gain another 0.5cm in the Hatchbrood brooding system in the Unibroed hatchery.

The first 5 days of brooding are critical in a bird's life as a correct brooding can increase the possibility of a bird to reach its true genetic potential. A chicken can multiply its body weight up to 4 times compared with its body weight at day old, and any growth that is missed in those first 5 days will not be regained later in life. Careful brooding is essential as, when a chick hatches, it is anatomically complete but its digestive, immune and thermoregulatory systems are not fully developed, so leaving the chick vulnerable to extremes in environmental temperature, feed changes and disease.

In the Hatchbrood system day old chicks are hatched as in any other hatchery and undergo normal chick processing such as IB vaccination, but then they are transferred directly into the brooding room connected to the chick processing area. 50 chicks are placed in each crate or "cradle" and the chicks have immediate access to feed and water. Hatchbrood use their own special chick starter diet containing a probiotic and high levels of sugar amongst other nutrients. The manure falls through onto a plastic tray inserted between each crate to keep the chicks clean. The same laminar airflow system that is used in the HatchTech incubators keeps the brooding temperatures very uniform and can be easily controlled. The sections are illuminated by LED lighting allowing lighting patterns to be adjusted as required.

When small eggs (40-50g) are hatched and sold as day old chicks, these small chicks require higher environmental temperatures (floor temperatures of 31^{o}C) and easy access to feed and water. When the same small chicks are brooded in the Hatchbrood for 1.5 days they can be sold as 80-100g chicks, which can then be managed in the same way as a 3 day old chick reared on floor temperatures of 26^{o}C. When chicks are transported from the Unibroed hatchery to a farm they may be in transit for 5-6 hours so the same feed is always included in the chick boxes to allow continued feeding and tipped with the chicks on farm to help with the transition in feed.

Economically, the cost of a 4 day old chick is €0.06 more expensive than a day old chick, but the farmers see an €0.08 advantage due to reduced feed and fuel costs in those first 4 days, plus an increased number of crops/year/house.

4.7 Vencomatic, Eseel

I next visited Vencomatic, a company that has been producing egg handling systems for hatching and commercial eggs, nest box systems, and a heat exchanger system "Agrosupply" for reducing heating costs on farms.

I was interested in learning about a new brooding system that they have developed for broiler chicks allowing immediate access to feed and water, called The Patio system. Lotte Van Deven researched the Patio System idea when she was studying at Wageningen University and now works for Vencomatic and she showed me around.

In conventional systems, broiler chicks spend approximately 5% of their lives in the hatchery before placement on farms.

At the hatchery correct, uniform incubation temperatures are essential to produce optimum quality chicks. The time between hatching and ingesting feed and water in chicks is critical as a chick can loose up to 8% of its initial body weight in the first 24 hours. Feeding stimulates intestinal development of the villi thereby increasing the surface area available for absorption of nutrients. (Noy, Y. and Skalan, D. 2002). As young chicks are unable to control their body temperatures, it is important that the chicks are not chilled during chick processing, transportation to the farm or by being placed on cold concrete floors in brooding houses.

Vencomatic have developed a tier system where fertile broiler eggs are moved to the farm at 18 days (after candling) in the setter trays and the last 3 days of incubation occur within a climate controlled broiler house. The chicks hatch out of the setter trays and fall approximately 45cm directly onto the litter where they have immediate access to feed and water. The broilers then stay in the tier system for their entire life, until they are caught for slaughter.

I visited the 100,000 bird purpose-built house containing 2 columns of 6 tiers with a central passageway to allow airflow. Initially the house is heated to 35^{o}C when the 18 day old eggs are placed. Each tier has a conveyor belt which reduces labour costs by enabling the egg setter trays to be passed into each tier. The litter is placed on the conveyor belt. Running the belt removes the manure and at depletion the belt is run to collect the birds.

Vaccinations can be applied either through the drinker lines or a spray system that moves to cover all the birds. Cleaning between flocks will be more complicated, but birds can be inspected without walking between them, thus reducing the risk of spreading disease.

The Patio system has achieved 96-97% hatchability of fertile eggs candled at 18 days, demonstrating that it is possible to hatch eggs in an environment where relative humidity is not so strictly controlled as in an incubator and with a temperature 3^{o}C lower than in a normal incubator. However, there is no grading of chicks in the Patio system (unlike in a hatchery) so the hatchability figures will include second grade chicks. At slaughter the birds are 70-90g heavier for their age as the chicks have immediate access to feed and water and so start growing a day earlier than conventional on farm brooding of broilers. Traceability is excellent as eggs are stamped and placed directly into the setter trays, transported to the Patio system where they hatch out and remain for the whole of their life.

The Patio system uses highly automated processes, essential where labour costs are high and, as the birds are raised in tiers, this enables a 2.8 x more efficient land use than that for conventional floor reared broilers.

Advantages of up to 1.5% increased hatchability (but with the inclusion of 2nd grade chicks), controlled thermoregulation with a 50% reduction in energy used for heating (due to the use of the heat exchanger) during hatching and brooding, immediate access to feed and water all go to produce chicks with optimum digestive and immune systems enabling optimum performance. (Van den Ven L. J.F. et al 2009).

Two purpose built Patio systems have been set up in Russia and the systems have been run successfully at different stocking densities.

I visited Vencomatic's Rondeel system consisting of free range layer accommodation with a covered ranging area. This enables the whole area to be enclosed and birds would still be able to range in the event of an Avian Influenza outbreak when all birds must be kept indoors. The "Rondeel egg" is marketed as a brand priced between organic and free range egg levels.

4.8 Hatchery Verbeek

Vet Marcel Berendsen DVM showed me around the hatchery of Verbeek, a company that owns layer breeders, hatcheries and rearing farms. Verbeek sell 16 week old pullets, rather than day old pullet chicks. The hatchery produces 100,000 female chicks per day from 7 different breeds. 60% of chicks are for the Netherlands and 40% for export to Germany, Italy, Spain, Belgium and Oman. All chicks were vaccinated for IB by spray and then, when dry, vaccinated for Marek's disease by hand by intramuscular injection into the leg. Infrared beak treatment was given via a Novatech machine, but the same machine was not used for vaccinations.

4.9 Key Observations from the Netherlands

- **Transfer of birds between Germany and the Netherlands**
  The poultry industries are very much co-dependent and so the risk of spread of disease between the two countries is much increased. This was seen especially so during outbreaks of avian influenza.

- **Rondeel system**
  This is a novel management system that allows ranging of layer birds even in the event of an outbreak of Avian Influenza when all birds must be housed. The Rondeel Egg brand has been successfully marketed.

- **Early feeding of newly hatched chicks**
  2 companies have addressed the issue of delays in access to feed and water for day old broiler chicks, by brooding at the hatchery for 4 days before movement to farm or by hatching directly on farm, starting a chick's growth as soon as possible. Desired slaughter weight was achieved a day earlier than under conventional systems.

- **Hatching broilers from small eggs from young breeder flocks**
  Unibroed hatchery has a business buying small eggs (45g) from young breeder flocks (that would otherwise often be thrown away) and the young chicks brooded in the hatchery before placement on farms in a highly cost effective operation.

- **Placing chicks according to parent flock/chick size**

By placing chicks from the same parent flock, chicks of a similar size can be put together in one house. This rules out an initial unevenness and improves the ease of management.

5. China

5.1 The Chinese poultry industry

I travelled to China to visit a country which has a vast population with cheap labour and where poultry as a source of protein is a very important. China produces 4000 million white broilers per year and 4000 million yellow chickens for the home market. The national flock of 1400 million layers is all in cages and split between 80% brown eggs and 20% white eggs, although duck eggs account for 20% of all eggs consumed in China. The majority of eggs produced is for the home shell egg market which is 100% self sufficient and only 0.3% of shell eggs are exported. The export of liquid or dried egg products has fallen following the melamine in milk powder scandal. Eggs in China are bought in the markets and supermarkets and can be fresh or preserved in mud, salt, vac-packed boiled tea eggs, and the famous 100 day old egg!

5.2 Piess Layers, Beijing

I visited the Piess layers company, which is the biggest parent stock layer company in China, producing 50 million parent stock in the Herbe province. Most table eggs in China are brown, but the “pink egg” produced from a white bird crossed with a brown bird is popular in Northern China.

Marek’s disease, Newcastle disease, and Avian influenza are the prominent avian diseases in China causing high mortality, especially during the winter months when ventilation is reduced in an attempt to keep fuel costs down. IB viruses do cause disease and birds are vaccinated against Massachusetts and 793B strains. No TRT is reported and only occasionally Infectious Laryngotracheitis.

Unfortunately, due to biosecurity I was not allowed to see any of the birds, but was allowed to walk through the walled compound looking at the gardens, poultry houses and the noodle trolley providing a hot lunch for the workers.

5.3 Yukou Poultry, Beijing

Yukou Poultry have owned their own parent lines since 1998 producing commercial day old layer chicks. They produce 90% brown layers. The company has 1.6 million breeders and the farm I visited produces 300,000 birds/year. All parent stock is fertilised by artificial insemination, giving them 3% higher fertility than in natural mating with their breed of bird. So, although it is labour intensive, it is productive for their breeds. One male is placed with 10-12 females in natural mating systems, whereas one male’s sperm is given to 50 females via artificial insemination. All the hatching eggs are sold in China, but the company would like to export to SE Asia.

Salmonella, as a zoonotic disease, was not considered an issue for eggs produced for the home market (only for export) and birds were not vaccinated. I was told that Chinese people are immune to *Salmonella*, unlike “white” people. However, there are published reports from Chinese hospitals on Salmonellosis cases due to infections with *Salmonella* Entererititidis and *Salmonella* Typhimurium. (Cui S et al 2008). I think that, because of the traditional Chinese diet, where eggs and poultry meat are very fresh and well-cooked when consumed, Salmonellosis is rare. In contrast with the EU where many cases arise when people eat products such as mayonnaise containing raw eggs, these types of products are not common in China.

5.4 Hadud Foodstuff, Luanping town in Hebei Province

I headed north of Beijing to visit the Hebei Luanping broiler company near the Simatai part of the Great Wall of China. My first sight of the Great Wall was impressive as was the road cut through the rock and we travelled under the Great Wall. The large integrated broiler business, consisting of Cobb parent stock, hatcheries, feed mills, broiler farms and a processing factory was an amazing operation. A new processing factory was being built next to the large blocks of flats that housed the workers.

Away from the company offices and buildings, I visited a delightful family run farm with 6 houses on the farm each housing 6000 birds. Over each house doorway a duvet hung over the door to help insulation. Two people per house looked after the birds which were placed on table height netting as the floors are too cold in winter, where temperatures regularly drop to minus 26^{o}C, to house broilers. The houses were heated by coal fired stoves and the hot air piped around the houses (wild mushrooms were being dried in the houses next to the birds) and in the summer (30^{o}C) air conditioning units cool the houses.

The faeces fell through the netting onto concrete floors and were swept away daily. The birds were hand fed and were individually vaccinated against ND, IB and AI with an oil inactivated vaccine at day old, followed by ND and IB at 10, 14 and 20 days of age, again individually vaccinated by eye drop. Mortality was 3% over the whole crop. I suspected routine antibiotic use too.

The birds were in fantastic condition and were treated more like pets. They were well feathered with bright white feathers with no evidence of scratches or pododermatitis.
The birds were caught for slaughter by hand during the day as they are so used to human contact and handling does not cause them any stress. Two days were allowed for turnaround before the next birds were placed but, with no litter to remove and only plastic netting to wash and with very little "equipment" in the house, this was easily achieved.

Figure 1. Hand fed broiler chickens at Huadu Foodstuff

Most of the Huadu chicken is

sold as cooked (no fresh or frozen chicken meat is exported) and then exported to Japan. Huadu proudly supplied fresh and frozen chicken to the Beijing Olympics.

5.5 DQY Ecological Farms

Outside Beijing on a 240 acre site, DQY Ecological Farm was set up in 2004 and has expanded to house 3 million layer birds. Hy-line brown day old chicks are placed in 13 pullet rearing houses, and 700,000 birds are transferred at 17 weeks into 19 layer houses each accommodating 100,000 birds. Mortality rates of 0.02% were reported. The company have their own egg packing plant and feed mill.

The company’s ethos is based upon sustainable agriculture for which it won the IEC ecological award in 2008. On site they have a Biogas power plant utilising the chicken manure and the plant supplies the farm and surrounding villages with electricity. DQY also has an organic farm producing fruit and vegetables. DQY has 3 other farms run along similar lines in other provinces in China.

Unfortunately I was not allowed to see the birds, but toured the egg packing plant where eggs are washed, exposed to UV disinfection and stamped. Compared to packing stations in the UK, very few of the processes were automated. I discussed disease prevention with DQY Farms’ Chief Veterinary Officer Xiaohua Li. The chicks are vaccinated for Marek’s disease at the hatchery and in rear receive multiple IB, ND vaccinations all by eye drop, which is a highly efficacious way of administration but very labour intensive. The birds receive IBD vaccines via drinking water and 3 inactivated ND vaccines, again a very labour intensive process.

After previous discussions regarding Salmonellosis in China, I asked about *Salmonella* vaccines. DYK will start vaccinating as a government funded trial in 2011 and again Xiaohua Li spoke about Salmonellosis in humans having never been reported in China.

5.6 Shenyang Huamei Livestock and Poultry Company

I travelled to Shenyang, north of North Korea, to see the Huamei Livestock and Poultry Company. The company is owned by Cheng Changhai, a vet who had previously worked as a distributor for pharmaceutical companies and had travelled widely within and outside of China. Initial impressions showed that he was very conscious of biosecurity. The whole farm was surrounded by brick walls with shards of glass on the top, changes of clothing were required, foot dips and a large wheel dip for lorries to drive through were present and with disinfectant in both!

The company buys in broiler breeder chicks from Aviagen and hatch their own broiler chicks. All birds are reared in cages and fed a maize based diet grown locally. The broiler breeders are mated by artificial insemination, a very labour intensive process.

The farm was a mixed ages site and the broiler chicks were grown in cages due to it being too cold during the winters to produce floor reared birds. The houses were heated by coal fires heating large tanks of water and the hot water then circulated. Two people work per house to look after the birds (hand feeding and faeces collection) and to keep the heating boilers fed with coal. The birds were slaughtered at 42-45 days.

Newcastle Disease is a major disease problem in China causing high mortality. The birds received 4 live ND hot La Sota vaccinations via eye drop and 1 killed ND vaccine, 2 Infectious Bronchitis vaccines via eye drop and 1 IBD vaccine through the drinker lines. Water sanitation and priming drinker lines were routinely carried out, something that has never been discussed by the other companies I visited. Another subject I managed to discuss was the use of antibiotics which according to Cheng Changhai are routinely used by poultry companies. In retrospect I think that the use of antibiotics is just part of normal Chinese poultry management, so nothing “special” to talk about, whereas vaccines are expensive and directly linked to disease management in the minds of the producers. On Cheng Changhai’s farms antibiotics are routinely given to the birds at 1-4days, 14-18days (to help the bird cope with any secondary bacterial infections following hot IBD vaccination) 20-25days to help with ND live vaccine reactions and again at 28-31 days.

Mortality was approximately 5%; higher mortality is seen during the winter months when ventilation is reduced.

5.7 Villages in China

After Beijing and Shenyang I headed south to Taishan to see part of rural China consisting of 275,000 villages where 80% of China’s population are subsistence farmers. Each farmer has an allowance of 1/3 acre that is reallocated by the Chinese Government every 8-10 years, so any improvement that a farmer makes to his piece of land will benefit one of his neighbours on reallocation. Conversely one may receive very poor land which has had few or no improvements. There are 2 rice harvests a year and one harvest used to go the Government as tax for the land (abolished in 2005), while the second harvest would feed the family for a year. The farmers live rent free in houses in villages that belong to Government.

Strict population control laws are in evidence in China, where the legal age for marriage is 20 for men and 22 for women and any children born out of wedlock cannot be registered and so cannot go to school (there is no free schooling in China), have no entitlement for land, and cannot have a paid job. Married couples can only have one child, unless the parents have certain educational achievements or are prepared to pay vast sums of money per extra child. In a village a second child is permitted if the first child is a girl. The countryside is full of older people and young children, as many young adults will work in the cities where wages are high and send money home to the family.

In the villages indigenous chickens are seen around the houses. The birds will lay a few eggs and the meat will be eaten too.

Amazing wet markets take place 7 days a week, where local people will buy and sell fresh vegetables, eggs and live geese, ducks, chickens and pigs. Chinese food is always very fresh. Produce will be bought from the market every day and cooked and eaten on the same day. Most Chinese do not own a fridge and do not see the need for one as fresh food is the ideal. The birds in the markets are in cages or hobbled (legs tied together) and are either sold live and taken home, or killed at the market and dressed ready to take home to be cooked. Many of the chicken carcasses seen in the markets had very little meat on them, but had large egg follicles – apparently a delicacy. Any produce not sold will be taken home and brought to the market on another day. These wet markets with the mix of live water fowl and poultry are at the crux of China's Avian Influenza (AI) problem as water fowl can carry AI with no ill effects and pass the virus to poultry. Any unsold or purchased birds are taken home to mix with home flocks and so diseases can be easily spread.

The close proximity of people and their pigs and poultry in rural China also provides an opportunity for different influenza viruses to recombine and produce new strains that may be lethal to the human population, such as the unfortunately named "Swine Flu" epidemic of 2009/2010.

Figure 2. Freshly slaughtered chickens for sale in a Chinese wet market

5.8 Key Observations from China

- **Poultry is a very important source of protein**
  In China where 80% of its vast population live in rural communities, indigenous species providing a few eggs and meat, or buying live broilers and eggs is a fresh, essential and cheap protein to supplement a mostly vegetarian diet.

- **Diseases such as virulent strains of ND, AI and IB can spread easily with devastating effects**
  Good biosecurity, and the application of vaccines are essential to help prevent disease outbreaks. AI is particularly easy to spread in the wet markets where live water fowl and poultry mix on a daily basis.

- **Labour is cheap with little automation**
  In the large poultry companies, and when attention to detail is paid to good husbandry and vaccination, great poultry can be produced.

6. India

6.1 The Indian Poultry Industry

I visited India with the UK Nuffield Poultry Study Group to gain an understanding of the Indian poultry and egg industry. India has a population of 1.18 billion, 42% of which are Hindu vegetarians and the rest are omnivores, but there are now some “eggetarians” (vegetarians that eat eggs) where Indians are beginning to eat eggs in baking products. India has a fresh bird and egg market that is not yet self sufficient and there are no poultry imports. The majority of Indian poultry production is in the South whilst the majority of the egg consumption is in the North. Poor transport and roads hamper the distribution of poultry products. Despite not meeting the egg demand in the home market, egg products are exported and India is the third largest supplier of yolk powder into the UK.

6.2 Meeting with British High Commission in Delhi

Tanisha Thiara, Senior Trade and Investment Advisor for the British Trade Office, gave an overview of the Indian Poultry Industry and the Indian social and economic situation. India has 26 states, 627,000 villages and 62% of the population lives in hamlets with populations of less than 2000 people. Indians consume 45 eggs per capita per annum and there is more demand than supply, but egg imports are prohibitively expensive.

India’s poultry industry has changed from mostly egg production in the 1970s, to broiler production in the 1980s with an increase in automation seen in the 1990s. From 2010 onwards the emphasis will be on processing and packaging.

India has 5 major layer companies producing 250million layers/year. 3.2 million tonnes of poultry meat is produced per year, costing 150-200 rupees (£2.50)/kg meat. Rural consumption of poultry meat is 0.25Kg per capita annually and 1.25Kg per capita in urban areas.

Retail in India is through small road side stalls and shops, and 97% of poultry meat is sold as live birds. The Indian Government has a policy to prevent major supermarkets coming in and dominating small businesses. 48 billion eggs and 2.5 million tonnes poultry meat is sold per year through small businesses.

The group travelled to Hyderabad and were hosted by Venky’s to see different aspects of their poultry meat and egg business.

6.3 Anurag Poultry Layer Farm, Hyderabad.

Mr Srinivasa Rao showed us around the multi-aged caged unit of 300,000 birds, 2 rearing, open sided houses of 50,000 birds, and 4 laying houses. The BV300 breed is owned by Venky’s and is a Bovan breed genetically selected to cope with India’s climate (47^{o}C in the summer) and husbandry conditions. The birds produce 315-320 white eggs per crop over 72-76 weeks and there is no moulting of birds unless egg prices drop or feed prices increase. All commercial laying birds are housed in cages with a stocking density of 387sqcm/hen and 7 birds/cage. An average of 4-5% mortality in rear up to 20 weeks, and 6-8% mortality in lay, is achieved.

The chicks are vaccinated with Marek's HVT+SB1 at the hatchery (there are no Rispens Marek's vaccines available in India), IBD, IB, Coryza, ND, Pasteurella and Fowl Pox on farm. The birds are severely beak trimmed with a hot blade at 13 days. There are apparently no red mites in India.

The eggs are collected by hand and excellent egg shell quality was seen. Eggs are not graded and sold as collected; however transportation of eggs accounts for 0.5-1% breakages due to the poor roads in India.

6.4 National Egg Co-ordination Committee: their slogan is: "My egg, my price, my life……"

I visited the National Egg Co-ordination Committee (NECC) to discuss how eggs are marketed and a fair price reached for farmers. The NECC is paid for by a non-compulsory levy of 1 rupee per chick (layer chick price is 20 rupees). The NECC aims to increase egg production and promote the benefits of eating eggs as a valuable source of protein in India.

6.5 Dr G L Jain, Managing Director of Venco

Dr G L Jain gave a talk about the genetic selection programmes used to produce the Venky's own breed of broilers "Venco" and layers "VRB".

The Venky company was set up by Dr B V Rao in 1971 to provide "total poultry support" for the Indian poultry industry and is now the largest company in India with aspirations to become a global company. (Venky's also owns Blackburn Rovers Football Club in the UK).

Dr B V Rao saw that India required its own breeds of birds to deal with high (45^{o}C) temperatures during the summer in open sided houses with no environmental control such as fans or foggers, because electricity in India is expensive and supply irregular with most electricity being available at night.

Venky's have owned the pure lines for BV300 layer bird with Isa Babcock since 1980. The BV300 was developed to suit the Indian market and husbandry practices. Compared with imported Bovans they produce 330 eggs in 72 weeks, with much reduced feed consumption and thus reduced feed production costs such as fertilisers etc. Venky's BV300 breed dominates the Indian market share by 85%. Others include 8% Bovan, 3% Hy-Line and 3% Lohmann. Eggs are sold without grading and high egg weights are not required.

Venky's have owned the pure lines for the broiler VenCobb with Cobb (from Arboacre stocks) since 1980. The VenCobb bird is grown to 2kg body weight at 40 days, averaging 5.65% mortality and FCR of 1.76. The broiler breeders are all kept in cages and are mated by artificial insemination.

Poultry meat in India is bought as whole live birds weighing1.2kg at 26 days of age. Chicks are placed as hatched and the males are identified first by eye and removed, then the females grow on a little and are sold later. In 2009 1.85 billion Vencobb broilers were placed and have a 75% market share.

The Pure lines are tested for *Salmonella*, and have no *Salmonella* Gallinarum or Pullorum. This is probably due to the disease not being present in the pure line stock received years ago. Mg or Ms is not seen in the pure lines, but is seen in the breeder and commercial stocks on the multi age farms.

After experiencing problems with supply, Specific Pathogen Free (SPF) eggs have been produced by Venky's for their own vaccine production business.

Other businesses that Venky's own are all partnered with major non-Indian companies. These include:

- VR equipment with James Way incubators, Roxal Belgium feeding and watering systems
- Venky's feed producing pelleted feed and BV Feed Supplements
- Biosecurity systems with Biocentury USA
- Poultry vaccine production plant with a USA company started in 1970 (now wishing to expand into cattle and human vaccines)
- Egg powder production business producing yellow and white powders
- Poultry meat processing business producing chicken nuggets and sausages
- Bromark consisting of co-operative shops selling broilers either as live or as hygienically killed and dressed.

Other interests include:

- Dr B V Rao's Institute for training students in poultry management
- the NECC
- Venky's Poultry Diagnostic and Research Centre offering Veterinary, Microbiology, Serology, and hatchery hygiene testing services.

It was clear to see how Venky's poultry business has grown to provide every aspect of poultry production from birds, feed, housing, equipment and vaccines.

6.6 Factory of M/s Sneha Farms at Medchal

I visited a feed mill and feed analysis lab. The main diets include home grown maize from 2 harvests a year, with maize husk bi-product used as litter for broilers, and non GM soya.

6.7 Chicken Processing Plant of M/s Gold Chick Hatcheries, Humnabad

Dr Prasad, Managing Director, and Mr Hari Krishna, Director, gave an overview of their plant. Only 17 processing plants exist in India as 95% of poultry meat is bought as fresh live whole birds from local retailers. The remaining 5% of poultry meat is processed for MacDonalds (87 restaurants) and KFC Chicken (70 stores) which moved into India in 1995. Evisceration of the carcasses was the only automated part of the processing chain. The factory operated 6 days a week and only runs at night as the birds are easier to handle in the dark. There are problems with processing as most Indian broilers are 2kg or less in weight producing approximately 0.6kg breast meat compared with the much large USA broilers bred for processing, with a much larger percentage of breast meat .

6.8 Venkateshwara Layer Hatchery, Papireddy Guda

I visited the Venkateshwara layer hatchery where hatching eggs are disinfected on farm and then stored at the hatchery for a maximum of 3 days before setting. The eggs are disinfected with formaldehyde at the hatchery. High fertility is achieved by the artificial insemination of breeder birds.

Multi age setters and hatchers are run fully stocked with manual transfer and eggs are candled at 4 days and again at 18 days, a highly labour intensive process with no automation. The eggs are hatched in metal boxes with no papers to line them.

An impressive 93% hatchability of fertile eggs was achieved. Chick quality looked very good and, although equipment was either antiquated or non existent, attention to detail produced very good chicks.

The chicks were manually placed into cardboard boxes with coconut husks as bedding (80 chicks per box in winter, 60 per box in summer) and as all chicks produced are yellow they are vent sexed at a rate of 1000 chicks per hour, another highly labour intensive process compared with the UK's utilisation of coloured sexed breeds.

Every female is manually vaccinated with Marek's vaccine subcutaneously at the back of the neck with HVT+SB1 vaccines, and is sold for 20 rupees per chick. The unwanted male chicks may be collected and grown for meat or drowned at the hatchery. In November 2010 India's broiler chicks were more expensive than layer chicks at 25 rupees per chick. 16–18 staff were employed by the hatchery for 4 days hatch to produce 100,000 female chicks per week.

6.9 Egg Processing Division of Venky's

Dr Zakir Hussain gave on overview of the egg processing business and a tour of the plant. Four products were produced:

- pasteurised whole egg powder
- pasteurised yolk powder
- de-sugared white powder
- egg shell flakes (providing calcium for poultry feed). These egg shell flakes would be illegal in the UK as it involves feeding a chicken product back to a chicken.

The egg processing plant is not run when the shell egg price is high. 95% of egg powder is exported to 26 countries (including the UK). The BV300 eggs have a high dry matter content, essential for an egg processing plant. Every 5th bag of egg powder is tested for nutritional content, microbiology, pesticides and antibiotics. Colour is monitored by spectrophotometry and product graded accordingly. Egg powder products are produced to Halal standards and cannot use any ingredient that is forbidden such as alcohol or any product that originates from Israel

6.10 Key Observations from India

- **India has a vast population, but has a very small egg and poultry meat consumption per capita.**
  Although many Indians are vegetarian there is an increase in the consumption of eggs. Poor roads and transport hamper distribution of eggs and broilers.

  95% of poultry meat is bought as whole live 1.2kg broiler birds in small outlets, and some will be killed and dressed by the retailer.

- **Breeds of birds are adapted to India's climate and husbandry conditions.**
  All breeders and layers are produced in open sided cages and all broilers on dirt floor systems. Ventilation can be an issue in the winter and increased levels of respiratory diseases are seen. Birds are vaccinated with locally produced vaccines against Marek's, IBD, IB, Coryza, ND, Pasteurella, and Fowl Pox.

- **Hot Blade beak trimming at 13 days**
  Severe beak trimming at 13 days will probably cause a drop in body weight, but it is not regarded as a welfare issue.

- **Cheap labour**
  Costs of feed are on a par with the UK, but labour is cheap and although very little automation exists, where attention to detail is good quality meat and eggs are produced.

- **Potential for growth**
  The Indian poultry industry has enormous potential for growth not only in terms of home consumption but it is also is looking to become a significant player in the global poultry market.

7. Conclusions

After completing my study "Disease prevention in the chick embryo and young chick" I have drawn the following conclusions:

1. Breeders

Poultry breeds are either globally tested in different parts of the world to see if they can cope with different husbandry and disease situations or they can be local breeds developed to meet local needs for meat or eggs (or both). At this level many diseases have been eradicated through breeding or controlled by vaccination.

Good quality vaccination of healthy breeders produces high levels of maternally derived antibodies that can pass to their progeny to protect them in the first weeks of life against various diseases.

In countries where labour is cheap, artificial insemination can help to produce higher fertility from fewer birds (especially if there is a mating issue involving the male bird).

2. Incubation

Incubation has a major effect on chick quality and a chick's immune system. Clean eggs, candling and removal of infertile eggs either manually or automated, reduces bacterial contamination in hatcheries and thus reduces infections in chicks - often seen as yolk sac infections - and mortality during the first week of life.

High incubator temperatures during the second half of incubation produce immature chicks that hatch out early. These chicks have low body weights, high residual yolks and low relative organ weights (such as the bursas being 20% smaller). These small bursa directly compromise a chick's immune system and its ability to resist disease. Uniform, highly controlled incubation temperatures and ventilation produce more uniform chicks with shorter hatch windows improving ease of management of a flock.

3. *In ovo* treatments

Automated, mass vaccination at approximately 18 days of incubation can provide early protection against diseases such as Marek's disease. Uniform protection levels are essential for reducing disease pressure in any population and for preventing a disease challenge taking hold in a flock.

The hatchery represents one control point for disease control and many more vaccines are being produced for *in ovo* administration such as IBD or ILT, and vaccines for other diseases such as ND will revolutionise disease control on a global scale.

In ovo administration of probiotics may enable a chick's gut to mature earlier and help promote overall chick development, especially in chicks from young breeder flocks where the yolk size may be reduced. The addition of probiotics may also help to colonise a chick's gut with healthy bacteria before hatch and so aid in the prevention of colonisation by pathogens such as *Salmonella*, E Coli and Campylobacter when the chick is placed on a farm.

In ovo vaccination reduces chick processing time at the hatchery when compared with day old subcutaneous vaccination. Shorter chick processing time reduces the stress undergone by a day old chick by allowing chicks to arrive on farm earlier and start feeding and drinking earlier. This reduces the potential for chick dehydration.

4. Chick processing at the hatchery

Post hatch vaccination is important for administering vaccines before a chick arrives on farm, which can either be by injection or by spray when the vaccine is taken by oral and ocular routes during preening. Traditionally vaccinations have been administered “by hand”, but now technology exists for automated vaccination and, if machines are set up and managed correctly, the chance of human error and chicks not being vaccinated is much reduced. This enables a more uniform vaccination of a flock. The machines are also used around the world for the administration of antibiotics which may compensate to some extent for poor hatchery practice or poor on farm hygiene and are an excellent method of halting vertical transmission of pathogens such as Mycoplasmas.

Hatchery and on farm hot blade beak trimming can now be replaced with Infrared beak treatment, which has proved to be an equally effective, but less painful and more welfare friendly, system of preventing pecking in breeders and layers. The lack of an open wound has led to reduced infections in the beak. However, this technology has not been adapted worldwide.

5. Brooding

The management of the first 5 days of a chick’s life is critical while a chick’s immature gut, immune and thermoregulatory systems fully develop.

Early feeding via brooding at the hatchery, hatching directly on farm, or via hatchling diets placed with the chicks during transport, allows the period between hatching and first feeding and drinking to be reduced. The physical act of feeding stimulates the maturation of the gut and improves future utilisation of food. Early feeding can produce desired slaughter weights a day earlier in broilers, reducing housing costs, fuel and feed and increasing the possible number of crops of birds per year on a farm.
The addition of probiotics or competitive exclusion products in chick diets can greatly help with protection against unwanted bacteria such as *Salmonella* and Campylobacter. Probiotics can be given in hatchling diets at the hatchery or on farm.

Placement of chicks according to parent flock/chick size prevents a lack of uniformity from the start. Different parent flocks will pass on differing levels of maternally derived antibodies, making it very difficult to vaccinate a flock when all chicks are receptive to the vaccine on one occasion. Uniform flocks at the start of a crop, allows easier management and a more uniform broiler or layer bird to be produced.

As day old chicks are unable to control their body temperature, correct brooding temperatures are essential and placing chicks onto cold concrete floors will only reduce growth. Smaller more immature chicks will require more heat than larger more mature chicks. Chilling chicks in cold holding rooms and lorries with poor temperature control will slow or even halt growth altogether.

Providing a clean environment for day old chicks where environmental challenge is at a minimum is essential for chick health. Placing chicks on litter from the previous flock may help with recycling of low levels of coccidiosis vaccines and mild IBD strains, but problems of circulating virulent disease shed from older birds and high ammonia content of the litter can cause real welfare issues. Under floor heating systems seen in the UK and NL provide clean warm, ideal temperatures for starting chicks, with good ventilation not affecting temperatures at chick height. However, problems can arise when birds are older and producing more body heat as floors may not be cooled quickly enough resulting in hot birds that do not feed or grow.

6. Biosecurity

In every stage of a bird's life biosecurity is essential to prevent disease. Clean breeder farms with clean nest areas ensure clean eggs reducing bacterial contamination in hatcheries which can affect hatchability. In many countries eggs are washed and bacteria can track through the pores in the shell into the egg. Cleaning eggs by abrasive scrubbing damages the protective egg shell cuticle and this allows potentially harmful bacteria to enter the egg.

Good biosecurity at the hatchery, foot dips, changes of clothes and good hatchery hygiene are all essential for fertile eggs to hatch.

Placement of chicks onto clean farms is vital as a chick's immune system is still relatively immature. *Salmonella* contamination is greatly reduced on clean farms, with active rodent control.

Avian Influenza is major risk to the global poultry industry. Reducing traffic on farms and keeping wild birds out of poultry housing is essential to reduce chances of infection. Mixing of water fowl and poultry can be a disaster (as water fowl can carry AI without appearing sick) and aids greatly in the spread of AI as seen in China. The covered ranging system for layer birds demonstrated in the NL allows excellent biosecurity with layers ranging without coming into contact with wild birds and other poultry. In the event of an AI outbreak, birds can continue to range in a completely covered area.

7. Management

Good management and attention to detail is essential for disease prevention in breeders, hatcheries and on farm. Cheap labour costs can mean more staff per bird, but, if attention to detail is not paid, then this extra labour is wasted. Highly automated systems can work well, where again attention to detail is essential to make sure that machines work correctly and that incubation, vaccination, thermoregulation, ventilation or feeding failures do not occur.

8. Recommendations

1. Prediction of the market

Planning of numbers of breeder flocks usually involves a 3 - 5 year projection. It is a true skill to predict what the market need will be and to plan the number of broilers or layers on the ground to fulfil those future market needs.

2. Breeder flock management

Uniform breeders produce uniform eggs which in turn produce uniform chicks. Good quality breeder nutrition is essential (which may be hard in times when feed costs are the major production cost) to produce good fertile birds and thus the number of commercial birds for the market. Attention to detail for vaccination is important to prevent disease in the breeder flock and also to produce high levels of maternally derived antibodies to pass to chicks to protect them against disease in the first days of life. Strict biosecurity, cleaning and disinfection are essential in reducing disease risk.

3. Hatchery management

Setting eggs of similar size together in one incubator helps to produce a uniform heat during incubation, enabling a uniform hatch. A way to encourage farmers to produce more uniform hatching eggs, would be to pay a bonus based upon uniformity of egg weight. Uniform incubation temperatures are vital. Over-heating embryos results in early hatching and immature chicks with lower relative organ weights which can affect a bird for the rest of its life.

Candling eggs and removing infertile eggs reduces overall bacterial contamination in the hatchery and associated risk of infections in chicks.

In ovo vaccination can reduce chick processing time, starts the immunisation process before hatch and the administration of probiotics could potentially colonise the gut with beneficial bacteria to prevent colonisation of the gut with pathogens such as *Salmonella*, E Coli and Campylobacter.

Reduction of the hatch window reduces potential dehydration of the earliest hatched chicks as they are transported to the farm before being given access to food and water. Early feeding to stimulate maturation of the gut, encourages a bird to grow from day one, (compensatory growth in chickens does not occur) and can reduce time to slaughter by one day for broilers. Feeding can start in the hatchery by the use of hatchling diets or by hatching directly on the farm.

4. Brooding management

To allow placement on farm to be according to chick size, chicks should be sent out of the hatchery labelled with the parent flock code and age of parents. Starting with a uniform flock can only make management easier for temperature regulation, feed, drinker heights and timing of vaccinations.

Chicks should be placed in thoroughly cleaned and disinfected houses, to reduce the exposure of day old chicks with immature immune systems to infections carried over from adult birds from the previous flock.

Good biosecurity is essential, involving changes of clothes, foot dips with adequate disinfectant in them, hand sanitizers and consideration of farms visited previously.

Attention to detail of the needs of the birds is essential as true stock management is an art that requires time and effort and should not become secondary to computerised management of the bird’s feed and environment.

9. After My Study Tour

Following my study tour I now understand how important the incubation process is to producing a maximally mature chick. A skilled incubationist managing different incubators in a hatchery can determine the chick quality of a hatch. I now look at incubation processes when investigating poor chick quality.

In the UK where labour is expensive, automation is essential in hatcheries. My study has enabled me to understand the technology used more and more for day old subcutaneous vaccination in layer and breeder hatcheries and IR beak treatment. Being able to "trouble shoot" when observing vaccination is essential.

In ovo vaccination is gaining in popularity in the UK broiler hatcheries as new vaccines are being developed to give even earlier protection against diseases for which previously only "on farm" vaccines were available. Earlier vaccination means earlier protection and better flock health. I have been working with broiler hatcheries and learning how to be able to deliver vaccines *in ovo* without the use of antibiotics. This is unlike other countries where antibiotics are always given with vaccines via *in ovo* administration and previously, *in ovo* vaccination without antibiotics was thought to be impossible without having a dramatic effect on overall hatchability. Looking at egg shell quality, overall hatchery hygiene and reducing contamination of injected eggs has been the key to the success of *in ovo* vaccination.

In ovo administration of probiotics is an exciting prospect. Compatibility studies with licensed vaccines are required and I have been discussing such projects with a UK probiotics producing company.

Reducing chick processing time and feeding chicks as early as possible is vital to help an immature gut develop and to reduce chick dehydration. Feeding hatchling diets does occur in the UK, but on farm hatching or brooding in hatcheries has yet to occur in the UK.

To conclude, through my travels I learnt that attention to detail with good stock management is essential to produce excellent quality chicks through disease prevention in the parent breeder flock, the incubation of the embryo, and then management of the vital first days of life.

Through my Nuffield Study Tour I have experienced unique opportunities to visit poultry companies that are usually closed to the public eye and made many new friends and contacts who were willing to openly discuss their businesses. I have a better understanding of the truly global nature of the Poultry Industry and of the importance of poultry in feeding the world's growing population.

10. Thanks and Acknowledgements

I am very grateful to the people who have helped and supported me throughout my Nuffield Scholarship.

- My Sponsors, The British Egg Marketing Board (R & E) Trust for allowing me to study both broilers and layers. A special thanks goes to Aled Griffiths for all his enthusiasm and encouragement before and during my Nuffield Studies and to Anne and Alan Beckett for their interest and support.

- The Nuffield Director, John Stones for preparation and guidance for my study tour and study report.

- My husband Steve, who encouraged me to apply for a Nuffield Scholarship, encouraged me throughout my travels, and continues to support my involvement with the UK Nuffield Poultry Study Group.

- Merial Animal Health Ltd, for allowing me the time to travel for my Nuffield Scholarship and for supporting my involvement with the UK Nuffield Poultry Study Group.

- My Merial colleagues Dr David Smith, Joey Johnston, Johan Ratsma, Michel Lee and Dr Enrique Montiel for helping set up meetings and enabling visits that would otherwise be closed to foreigners.

- UK Nuffield Poultry Study Group for their encouragement, ideas and suggestions for my study tour and report.

- Dr Neil O'Sullivan at Hyline USA for his generous hospitality and helping me think about layer poultry on a global scale.

- Dr Harry Arts DVM in the Netherlands for his great enthusiasm, organising some great visits (including a rabbit farm) and encouraging my education in poultry.

Helen Houghton BSc BVetMed CertLAS MRCVS NSch
Coles Cottage
7 Plum Park Lane
Paulerspury
Towcester
Northants
NN12 7NN

Tele: 01327 811170
Mob: 07917 507018
Email: helen.houghton@merial.com

11. Appendices

11.1 Glossary

AE – Avian Encephalitis
AI – Avian Influenza
CAV – Chick Anaemia Virus
FP – Fowl Pox
IB – Infectious Bronchitis
IBD – Infectious Bursal Disease, sometimes also known as Gumboro Disease
ILT – Infectious Laryngotracheitis
MD – Marek's Disease
Mg – Mycoplasma Gallinarum
Ms – Mycoplasma Synoviae
ND – Newcastle Disease
TRT – Turkey Rhinotrachietis, now known as Avian Metapnemovirus

11.2 References

Berrange M.E, Cox N.A., Frank J.F. and Buhr R.J. "Bacterial penetration of the eggshell and shell membranes of the chicken hatching egg: A review" Applied Poultry Research 8:499-504

Cui S, Li J, Sun Z, Hu C, Jin S, Guo Y, et al. "Ciprofloxacin resistant *Salmonella enterica* serotype Typhimurium, China". Emerging Infectious Diseases. March 2008

Dennis R.L., Fahey A.G. and Cheng. H. W. "Infrared beak treatment method compared with conventional hot-blade trimming in laying hens" Poultry Science 88:38-43. 2009

Hulet R., Galdys G., Hill R., Meijerhof R. and El-Shiekh T. "Influence of egg shell embryonic incubation temperature and broiler breeder flock age on post hatch growth performance and carcass characteristics." Poultry Science. 86:408-412. 2007

Leksrisompong, N,H, Romero-Sanchez, P. W., Plumstead, Ke, E. Brannan and Brake. J. " Effect of elevated temperature during late incubation on body weight and organs of chick". Poultry Science 86:2685-2691. 2007

Lourens A., Van den Brand H., Heetkamp M. J. W., Meijerhof R. and Kemp B. "Effects of eggshell temperature and oxygen concentration on embryo growth and metabolism during incubation". Poultry Science. 86:2194-2199. 2007

Molenaar, R., Meijerhof R., Kemp. B., Hulte R. and Van den Brand H. „High eggshell temperatures: A matter of life and death importance?" Proceedings of IFRG meeting, Norwich, Norfolk, UK 2009

Molenaar, R., Reijrink, I., Meijerhof R. and Van den Brand H. "Relationship between hatchling length and weight on later productive performance in broilers" World's Poultry Science Journal 64:599-603. 2008

Noy Y. and Skalan D. "Nutrient use in chicks during the first week post-hatch". Poultry Science 81:391-399. 2002

Pedroso A.A. (a) "Which came first? The egg or it's microbiota?" The Poultry Informed Professional. Issue 107 July/August 2009.

Pedroso A.A. (b) "Could *in ovo* probiotics be beneficial to chicks?" The Poultry Informed Professional. Issue 109 November/December 2009.

Pedroso A.A. "Do probiotics need to be alive?" The Poultry Informed Professional. Issue 114 September/October 2010

Van den Ven L. J.F, van Wagenberg A. V., Groot Koerkamp P.W.G., Kemp B. and van den Brand H. "Effects of a combined hatching and brooding system on hatchability, chick weight and mortality in broilers" Poultry Science 88:2273-2279. 2009