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Understanding Immunity and Vaccines

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INSIDE

Introduction

We all realize that diseases cost both companies and growers and they both strive to avoid the consequences of disease. Diseases can be caused by microbes (viruses, bacteria, fungi or protozoa), internal or external parasites, genetic disorders or by nutrient deficiencies. Modern poultry production methods have virtually eliminated nutrient deficiencies and are addressing genetic disorders. However, both companies and growers continue to battle against microbes and parasites. Since fewer and fewer antibiotics are being used in poultry feeds, growers and companies are depending more heavily on the immunity provided by vaccines. While important, this article will not address parasite issues, but will provide some understanding of microbial disease, immunity and vaccines.

Understanding Immunity

Immunity can be described as the ability of the body to recognize the presence of material normally within the body (“self”), and to eliminate foreign (“non-self”) materials. When a disease organism invades, the bird’s body usually produces antibodies and specific cells whose purpose is to engulf (or eat) and destroy foreign substances. Substances that are identified by the bird’s body as foreign are known as antigens. In other words, antigens are substances that cause the immune system to develop a defense against an invading organism (an immune response). However, it is important to realize that antigens are chemical substances that modern science has often been able to identify and separate from or weaken in the disease causing microbes so that the bird’s body becomes immune without getting the disease. Some proteins are good antigens that are easily recognized by the immune system and will produce an effective immune response. Other materials, such as carbohydrates are less effective antigens, and the immune response may not provide good protection (Varela, 2007). Once a bird’s immune system has responded to an antigen (either from the microbe or a vaccine) antibodies circulate in body fluids. If the bird is exposed again to that microbe, it responds very quickly because it “remembers” the microbe (Cutler, 2002). The quick response of the immune system prevents the disease from happening or shortens its duration and severity.

Disease Processes

When a bird is exposed to a disease microbe, there is one of three outcomes, either:

- The bird gets the disease,
- The bird is protected by immunity from hens or
- The bird is protected by immunity from vaccines.

Getting a disease

For most poultry diseases the progression is the same. This progression has three steps or phases: infection, development of immunity and recovery (Cutler, 2002).

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When birds are not immune to a given disease, infection may easily occur, allowing the microbe to attack various parts of the body producing sickness in the bird. Depending on the disease, some or all of the birds may die from the infection. However, the performance of even those birds that do not die is reduced by the infection.

Those birds that do not die from the infection usually become immune to the disease. However, the development of immunity in this fashion is risky because the disease may irreparably damage tissues (such as the intestine) in the bird's body. Such immune responses are also expensive because they require nutrients that cannot be used for growth or production (Klasing, 1998).

Those birds that survive the disease have an active immunity that allows their body to rapidly respond to future invasions of the same or similar microbes. While performance may return during recovery from the disease, the performance lost during exposure is often never regained, particularly if the challenge occurred early in the life of the bird.

Immunity from Hens

As the embryo develops within the egg it has no immunity of its own, but antibodies from the breeder hen are absorbed; protecting the chick from diseases. This immunity (called maternal or passive immunity) protects the young bird from diseases, but prevents the bird's body from mounting an immune response and is short lived. At 3 days of age about half of the passive immunity is lost. Very little passive immunity is present at 2 weeks and at 3 weeks it is completely gone (Cutler, 2002).

Vaccine-induced immunity

Vaccines trigger the bird's body to think that it's being invaded by a specific organism, and the immune system goes to work to destroy the invader and prevent it from infecting the bird again. If the bird is exposed to a disease for which it had been vaccinated, the invading germs are met by antibodies that will destroy them. The immunity the bird develops following vaccination is similar to the immunity acquired from natural infection.

Understanding Vaccines

Today, modern large scale animal agriculture has vaccines against most major pathogens and are continually creating new ones. However, vaccines come in a bewildering array of forms including: live or killed vaccines, recombinant-vector vaccines and DNA vaccines.

Live or Killed Vaccines

Several vaccines (i.e. Gumboro Disease, Newcastle Disease, Infectious Bronchitis and others) come in live or killed (inactivated) forms. While both live and killed products produce results, it is important to realize the advantages and disadvantages of both types.

It should be obvious that if birds are given the disease causing microbe (the pathogen), they will develop the disease we are trying to prevent. However, if birds are given a weakened (or attenuated) and diluted form of the pathogen they will develop immunity, but not develop the disease. This is the concept behind live attenuated (weakened) vaccines (Okonek and Peters, 1997). Attenuated or modified live vaccines are created by weakening the disease microbe, usually by culturing the pathogen in the laboratory until it loses or reduces its ability to produce disease and then providing a small dose of the organism during vaccination (Varela, 2007). However, to be effective the live attenuated organism must stimulate an immune response by growing within the bird; usually causing brief, mild symptoms (a vaccine reaction).

Live vaccines are the most effective type of vaccine for a rapid, strong, long lasting immune response. Live vaccines also tend to be less expensive and are less likely to cause allergic reactions than other types of vaccines. (Whiting, 2005) They can be administered by injection, spray/ fog, in the water or by eye drops (intraorbitally). However, live vaccines come with their own problems. Because they contain living organisms, they must be handled with care. Excessive heat, sunlight, freezing, chlorinated water and other conditions can kill off live organisms, rendering them useless. Live vaccines can also cause severe reactions in animals that have weakened immune systems or are infected with other disease organisms. In addition, if live vaccines are not handled with proper biosecurity, the organism may spread to numerous other avian species, causing (sometimes severe) reactions. Finally, while rare, the organism could revert back to the "wild" form, causing the disease.

Killed (or inactivated) vaccines are an alternative to live vaccines. Killed vaccines contain no living organisms, eliminating the potential of reversion to a "wild," disease-causing form. Killed vaccines are also safer than live vaccines for weak or immune compromised animals. In addition, killed vaccines are more stable in storage than live vaccines. However, killed vaccines produce a much weaker, more unstable immunity than live vaccines and multiple doses may be required to maintain protection. Killed vaccines are also more likely than live vaccines to cause allergic reactions in birds. Finally, giving killed vaccines is much more labor intensive since they must be administered by injection.

Recombinant-vector vaccines

Recombinant-vector vaccines are made by removing the genes from the pathogen that direct cells to produce antigens and then put these genes (recombine them) into the DNA of a non-pathogenic microbe (called a vector). The newly engineered vector is then used to infect the host, where the vector will replicate and express the antigens of the virulent pathogen resulting in an immune response (Prescott et al., 2005). The biggest advantage to this vaccine type is that the newly created vector is live, so that it can be used in a similar manner to other live vaccines, but usually producing milder symptoms following vaccination. The fowl pox virus is one microbe that is used as a vector. One commercial recombinant-vector vaccine combines fowl pox and Marek's Disease. The vaccine protects birds from fowl pox as a live virus, but also contains genes (DNA) from Marek's Disease Virus so that birds are protected from both diseases.

DNA vaccines

DNA vaccines produce what is sometimes called genetic or DNA immunization. DNA vaccines are made by isolating the genes (the DNA) that direct the pathogen cell to make antigens. This DNA is then injected directly into muscle tissue. The DNA is then incorporated into the cells within the animal's body, allowing the animal cells themselves to produce antigens and in turn immunity against the disease (Babiuk, 2007). At present there are no commercial available DNA vaccines for poultry. However, testing suggests the following advantages DNA vaccines: 1. They provide long- lived immunity with a single injection; 2. DNA from several pathogens could be combined so that animals could be protected from multiple diseases with a single injection and 3. DNA vaccines are extremely stable, eliminating the need for refrigeration or special handling (Henahan, 1997). However, many unknowns remain about the practicality of these vaccines in field situations, so it remains to be seen if DNA vaccines against poultry diseases will appear.

Summary

In summary, immunity is the ability of the bird's body to recognize its own tissues (self) and to eliminate foreign (non-self) materials in an immune response. Substances that cause immune responses are called antigens. Since disease outbreaks are expensive, it is important to prevent them and vaccination provides such protection. Live vaccines use altered or diluted microbes to produce long-lasting immunity with a single exposure, but produce symptoms in the bird (vaccine reactions). Killed vaccines do not produce vaccine reactions, but offer much less protection and may require multiple injections. Recombinant-vector vaccines are made by isolating the DNA that encode for antigen production in the pathogen and then placing that DNA in a non-pathogenic, which allows that organism to produce the antigen as it grows in the animal's body. At present, the use of DNA vaccines seems to hold the potential to help fight most diseases, but questions remain about how these vaccines will perform under field conditions.

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Applied Broiler Research Farm Report: Propane and Electricity Usage One Year After Renovations

Through our integrator, we purchased a hand-held ammonia sensor that clips to your belt; and it has proven to be an extremely useful tool in managing house ammonia levels.

Introduction

A year has passed since the Applied Broiler Research Farm (ABRF) underwent major renovations necessary to remain up to date with current poultry industry standards for broiler production facilities. This report details some of what we have seen in terms of electricity and propane usage and cost at 1 year after the renovations. Propane and electricity usage and costs are reported on both a farm basis and also for each of the 4 individual 40 x 400 ft broiler houses. With regards to electricity usage, we are able to sub-meter total electricity usage. Therefore, for each individual house, we are able to measure not only the total amount of electricity used, but also the portion of total electricity used for lights and the portion used for fans.

Farm Totals

Table 1 lists usage and cost figures for propane at the ABRF for the period April 2006 - April 2007. Six flocks were grown during this period with placement months of April, June, August, October, and December 2006 and February 2007. Propane usage for the year was 25,476 gals at total cost of $34,228. The December flock used 12,622 gals (almost half the total for the year). This was due, in part, to very cold weather conditions during the December-placed flock and the fact that for much of the flock we allowed the controllers to automatically ramp the minimum ventilation run time as they would during warm weather. This did provide excellent air quality in the houses and excellent litter conditions (perhaps the best I can remember for a winter-time flock). However, it also resulted in a gas bill that was roughly two-thirds of the chicken check. Therefore, before harvest, we began to decrease the minimum ventilation run time to a more manageable winter-time program while keeping the ammonia level at less than 25 ppm. Through our integrator, we purchased a hand-held ammonia sensor that clips to your belt; and it has proven to be an extremely useful tool in managing house ammonia levels. I carry it when I am working in the houses. It is pre-set to sound an alarm if the ammonia level is over 25 ppm. It has become an important part of my management program, especially when the birds are small and any time we are using minimum ventilation.

Table 1. Propane usage and cost at the Applied Broiler Research Farm (ABRF) one year after renovations (2006-07).

Month Placed	Propane (gals)	Propane Cost
April	2,576	$3,918
June	635	$860
August	176	$243
October	4,856	$6,361
December	12,622	$16,663
February	4,611	$6,183
YEARLY TOTALS	**25,476**	**$34,228**

Electricity usage and cost for the farm is reported in Table 2. A total of 125,040 kilowatt hours were used on the farm at a cost of $7,502. Fan and light electricity do not sum to total because feed line, cross auger, and fill auger motors along with service and convenience outlets, etc., are also included in total. However, fan and light electricity usage always accounted for ≥90% of the total per flock electricity usage. Notice that the cost to operate the lights was within $550 of the cost to operate the fans for the year ($3,252 for lights vs. $3,802 for fans). Solid sidewall housing has greatly increased electricity required for lighting because natural light is no longer available. As a result, lighting is now an area that may offer potential monetary savings for tunnel ventilated houses through use of more energy efficient bulbs. We are currently investigating 2 types of cold cathode bulbs (that are easily dimmable and work with light dimmers) as an alternative to incandescent lighting.

Table 2. Electricity usage and cost at the ABRF one year after renovations (2006-07).

Month Placed	Electricity usage (kwh) and cost ($)					
	Fan	Cost	Light	Cost	Total	Cost
April	5,971	$358	9,209	$553	16,067	$964
June	13,303	$798	9,480	$569	23,607	$1,417
August	17,764	$1,066	10,000	$600	28,964	$1,738
October	11,471	$688	9,037	$542	22,300	$1,338
December	5,386	$323	6,414	$385	13,133	$787
February	9,475	$569	10,052	$603	20,969	$1,258
Yearly Totals	**63,370**	**$3,802**	**54,192**	**$3,252**	**125,040**	**$7,502**

Propane Usage and Cost

Table 3 lists propane usage and costs for each house during the 6 flocks. As all producers know, most propane used to raise chickens is consumed from October through April, with only a small portion consumed from April through October. In that respect, the ABRF is no different than any other broiler farm. The December-placed flock used the most propane, followed by the October- and February-placed flocks. There were differences in propane use among the 4 houses with House 1 using the most at 7,026 gals ($9,425), followed by House 3 at 6,320 gals ($8,487), House 2 at 6,167 gals ($8,286), and House 4 at 5,693 gals ($8,030). Part of this difference was due to litter conditions within the houses that forced us to change the minimum ventilation rates necessary to maintain ammonia levels at 25 ppm or less. House orientation may also play a part, although this is less of a factor now with solid sidewalls than before renovations when the houses were curtain-sided. Nevertheless, shifts in the ceiling insulation caused by strong winds from the south just prior to the completion of renovation may have also contributed to elevated propane usage in house 1. At the ABRF, House 1 is the southernmost house while House 4 is the northernmost house.

Table 3. Propane usage and cost at the ABRF one year after renovations (2006-07).

Month Placed	Propane usage (gals) and cost ($)							
	House 1	Cost	House 2	Cost	House 3	Cost	House 4	Cost
April	638	$970	611	$929	634	$964	693	$1,053
June	154	$211	164	$225	136	$186	181	$248
August	72	$99	68	$93	18	$25	18	$25
October	1,327	$1,738	1,107	$1,450	1,222	$1,601	1,200	$1,572
December	3,572	$4,715	3,083	$4,070	3,196	$4,219	2,771	$3,658
February	1,263	$1,692	1,134	$1,520	1,114	$1,493	1,100	$1,474
Yearly Totals	**7,026**	**$9,425**	**6,167**	**$8,286**	**6,320**	**$8,487**	**5,963**	**$8,030**

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Light Electricity

Kilowatt hours of electricity used for lighting the 4 individual houses, along with the cost for those kilowatt hours, are presented in Table 4. At the end of 1 year, Houses 1 and 2 had used practically the same amount of light electricity (12,817 kilowatt hours in House 1 vs. 12,797 kilowatt hours in House 2) and there was only $1 difference in total cost between these houses. House 3 used 12,918 kilowatt hours at a cost of $775 while House 4 used 15,660 kilowatt hours at a cost of $940. There are differences in the number of light bulbs between the 2 sets of houses. Houses 3 and 4 have a total of 90 light bulbs (40 brood lights and 50 dimmable lights) per house while 75 light bulbs (33 brood lights and 42 dimmable lights) per house were in Houses 1 and 2. Differences in the number of bulbs per house may account for most of the differences in light electricity usage between the houses.

Before the start of the December 2006 flock, the incandescent lights in House 3 were replaced with a set of dimmable cold cathode bulbs, which accounts for the dramatic decrease in electricity usage for the flock (710 kilowatt hours). The February 2007 flock electricity usage in House 3 increased to 1,794 kilowatt hours due, largely to the fact that we managed the light program differently because we were growing a different genetic strain of bird that did not seem to perform as well when the cold cathode lights were dimmed and brood lights were used to provide supplemental light.

Table 4. Electricity used for lights at ABRF during first year after renovations (2006-07).

Month Placed	Light electricity use (kwh) and cost ($)							
	House 1	Cost	House 2	Cost	House 3	Cost	House 4	Cost
April	2,062	$124	2,032	$122	2,447	$147	2,668	$160
June	2,137	$128	2,171	$130	2,633	$158	2,539	$152
August	2,258	$135	2,260	$136	2,760	$166	2,722	$163
October	1,999	$120	2,059	$124	2,574	$154	2,405	$144
December	1,824	$109	1,783	$107	710	$43	2,097	$126
February	2,537	$152	2,492	$150	1,794	$108	3,229	$194
Yearly Totals	**12,817**	**$769**	**12,797**	**$768**	**12,918**	**$775**	**15,660**	**$940**

Fan Electricity

Kilowatt hours of electricity and associated costs for running the fans in the 4 houses are presented in Table 5. Houses 1 and 2 are fairly similar with house 1 using 17,055 hours at a cost of $1,023 and house 2 using 16,653 at a cost of $999. Houses 3 and 4 are also quite similar but usage and costs are less than for houses 1 and 2. House 3 used 14,835 hours at a cost of $890 while house 4 used 14,826 hours also at a cost of $890. All 4 houses have 4 direct-drive 36-inch sidewall fans in the north wall for minimum ventilation and 8 belt-drive tunnel fans with butterfly shutters and cones for summer cooling. However, the tunnel fans in houses 1 and 2 are 50-inch fans from one manufacturer while the tunnel fans in houses 3 and 4 are 48-inch fans from a different manufacturer. There are differences in the efficiency ratings between the 2 manufacturer's fans and this is evident in the kilowatt hour usage figures.

In house 4, it is interesting that the fan electricity cost ($890; Table 5) is actually less than the light electricity cost ($940; Table 4). In other words, it cost more to operate the lights for 1 year than it did to operate the fans in house 4. This fact points out the importance of lighting as a major cost center when solid sidewall housing is used. With natural light no longer an option at the ABRF, the only light the birds receive has an energy cost associated with it that can quickly add up over time.

Table 5. Electricity used for fans at ABRF during first year after renovations (2006-07).

Month Placed	Fan electricity use (kwh) and cost ($)							
	House 1	**Cost**	**House 2**	**Cost**	**House 3**	**Cost**	**House 4**	**Cost**
April	1,430	$86	1,433	$86	1,536	$92	1,572	$94
June	3,010	$181	3,151	$189	3,568	$214	3,573	$214
August	4,566	$274	4,299	$258	4,412	$265	4,487	$269
October	4,095	$246	3,666	$220	1,934	$116	1,776	$107
December	1,497	$90	1,435	$86	1,251	$75	1,203	$72
February	2,457	$147	2,669	$160	2,134	$128	2,215	$133
Yearly Totals	**17,055**	**$1023**	**16,653**	**$999**	**14,835**	**$890**	**14,826**	**$890**

Summary

Propane and electricity usage and cost figures at the ABRF are presented for the one-year period since the farm was renovated. It is apparent that lighting is a major expense associated with solid sidewall housing, in some cases, more expensive than even the cost of ventilation. We will continue to monitor costs associated with both ventilation and lighting in an effort to help producers determine the best methods to reduce production costs without adversely affecting bird performance.

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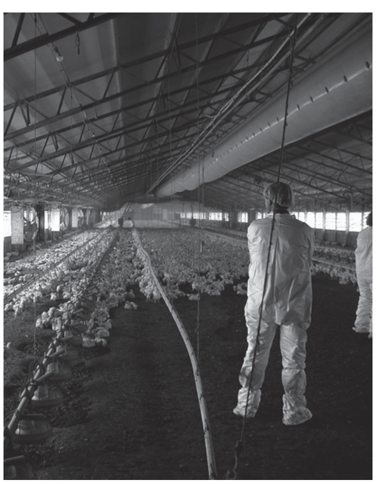
E. Coli an Opportunist that Causes Enteritis



Introduction

Enteritis caused by *Escherichia coli* (colibacilliosis) is an important disease in the poultry industry because of increased mortality and decreased performance. *E. coli* is a bacterium that can not be seen without a microscope and is often considered an opportunistic pathogen because it infects whenever it has the opportunity. *E. coli* is a normal inhabitant of the intestinal tracts of animals and is harmless as long as it is kept in check by other intestinal bacteria (Barnes et al., 2003). When an imbalance occurs in bacterial flora of the intestinal tract, *E. coli* may grow and cause an outbreak of colibacilliosis. Chickens of all ages are susceptible to colibacilliosis, but usually young birds are considered more susceptible.

Signs of *E. coli* enteritis

Since *E. coli* is an opportunistic pathogen and will (given the chance) attack a number of organs, infections can cause a wide variety of signs or symptoms. Symptoms may range from sudden death of the bird to a vague sense that the bird is not doing well. Symptoms will also

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depend on the age and general health of the bird. Generally, birds will appear unthrifty and have ruffled feathers. They may also be depressed and have a decreased appetite. During the acute phase of disease you may also notice yellowish colored droppings and birds may be soiled in the vent region.

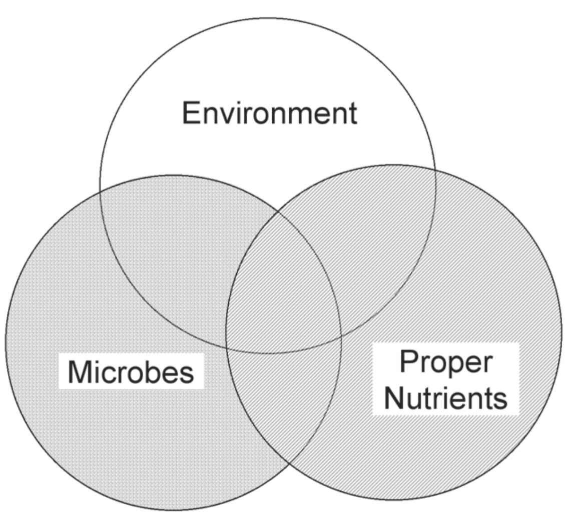
The cause of *E. coli* infections

E. coli enteritis does not fit the classic definition description of an infectious disease. This classic disease definition states that one microbe causes a given disease and that the illness can be reproduced in the laboratory by infecting susceptible animals with that one microbe (McMullin, 1998).

E. coli is normally present in the birds and the disease can be triggered by numerous events (see Figure 1). Immunosuppressive diseases such as Infectious Bursal Disease, Marek's disease, and Chicken Anemia may increase susceptibility to *E. coli* infection. However, other countless events or diseases can also increase susceptibility. For instance, an *E. coli* infection may appear if birds do not have regular access to feed or if their litter is too wet or if they are exposed to another disease. Generally, anything that causes stress in the bird may provide *E. coli* with the opening it needs.

Once on *E. coli* outbreak happens, conditions may be right for the disease to "feed on itself," and affect the entire flock. For example, if a significant number of birds develop diarrhea, litter moisture can increase, infecting more birds and, in turn, causing more wet litter. Consequently, the best approach to *E. coli* infections is prevention rather than control.

Figure 1. Multi-Factorial Disease*



*Adapted from McMullin, 1998

Prevention of *E. coli* Infections

Controlling all of the factors shown in Figure 1 is imperative if growers are to control E. coli infections. As the figure implies, these factors are interrelated.

A stressful house environment can easily encourage *E. coli* infections. As mentioned, wet litter can encourage infection, but most growers realize that wet litter is often related to inadequate ventilation rates. Regular and frequent checking of houses is also important, particularly as it involves collecting the dead. Since commercial strains are bred to eat, preventing stress means providing easy access to water and feed is also important.

Growers tend to think that the company nutritionist and the feed mill are the only ones responsible for the nutrition of the birds. Although the nutritionist and feed mill personnel bear much of the responsibility for bird nutrition, growers are the last link in the chain. If growers do not store feed in clean, dry tanks and ensure that feed is properly delivered to the feeder pans, then birds do not receive the nutrition they need.

Since infection with another microbe can increase the probability that birds will break with an *E. coli* infection, it is also important to reduce or prevent the exposure of your birds to pathogens. How do these pathogens arrive on the farm? Human visitors are likely the largest source of pathogen exposure. Thus, it is important to limit the number of visitors and insist that visitors wear protective equipment (e. g. disposable boots, coveralls and hair nets) during their visit. Rats, mice and wild birds are another important source of pathogen exposure so a vermin control program is essential.

Summary

In summary, *E. coli* is an opportunistic pathogen that can produce a variety of symptoms in commercial poultry. *E. coli* is present in the birds and the poultry house environment and infects birds. However, if growers provide birds with proper house environment, ensure that they have easy access to feed and water as well as limit exposure to pathogens, *E. coli* infections can be limited or eliminated.

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Understanding and Control of European Starlings

(Sturnus vulgaris)

Starling History

Starlings have apparently been associated with people since the beginning of agriculture. Starlings have been kept as pets for centuries. The Greek philosopher Aristotle (384–322 BC) described starlings. The Romans taught starlings to mimic human speech (Ehrlich et al. 1988). The Roman author and philosopher Pliny the elder (23-79 AD) reported that starlings could mimic Greek or Latin and that these birds "practiced diligently and spoke new phrases every day, in still longer sentences." The great composer Wolfgang Amadeus Mozart owned a pet starling and is reported to have patterned a part of one of his piano concertos after a tune whistled by the bird (West and King, 2007).

The first two attempts to introduce starlings into North America failed, but in 1890, Eugene Schieffelin, a wealthy New York pharmacologist and Shakespeare enthusiast, successfully introduced 60 birds into Central Park, New York. Another 40 birds were introduced at the same location the following year. Though disputed, it is reported that Mr. Schieffelin's purpose was to introduce all the birds mentioned in William Shakespeare's plays into North America (Collins, 2007). A little over a century later, this introduction of 100 birds in New York has produced over 200,000,000 starlings that are distributed virtually coast to coast (Ehrlich et al., 1988). Starlings have been intentionally introduced all over the world, most often for aesthetic purposes. Yet, ironically, due to the large flocks, noisy habits and large amounts of waste, starlings are now widely regarded as pests (Adeney, 2001).

Starling Biology and Behavior

Starlings are unusual anatomically in that their jaw muscles work "backwards" in comparison to most other birds.

Starlings are about the same size as robins (about 8.5 inches tall and weigh slightly over 3 oz.). They have dark feathers with a greenish sheen and with light speckles. The bill of adult starlings will be yellow between January and June (mating season) and dark brown the rest of the year (Lynch and Messmer, 2000).

Soon after learning to fly starlings form feeding and roosting flocks, which range in size from less than 100 to many thousands. These flocks help protect birds by increasing the number of eyes watching for approaching predators (Chow, 2000). Flock size tends to be larger in cold winter months and larger flocks can exceed a million birds (Lynch and Messmer, 2000).

Starlings are not particular about their diet; they are omnivores (that is they will consume whatever is available). Half or more of their diet often consists of insects (adult and larvae stages of crickets, grasshoppers, moths, butterflies and beetles), spiders and earth worms, but they also consume both natural and cultivated berries, seeds, and fruits (Chow, 2000). Starlings also consume large quantities of livestock feed and can have a significant negative impact on production costs (Kern, 2001).

Starlings are unusual anatomically in that their jaw muscles work "backwards" in comparison to most other birds. Most birds are structured so that the most powerful muscles are used to clamp the bill shut, but starlings are structured with the strongest muscles to spring the bill open. Starlings use this feature to pry fruit or seeds apart as well as to hunt small prey (e.g. insects). A starling will insert its bill between blades of grass in thick turf or other cover and then spring its bill open to expose prey. As the bill opens the starlings eyes move forward toward each other, permit-

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ting binocular vision and (presumably) easier capture of prey. This technique allows starlings to detect and consume both active and stationary prey. This foraging system is particularly effective during colder weather (Ehrlich et al., 1988; Keys and Dugatkin, 1990). Most starlings remain in the same general area year round, but some choose to migrate several hundred miles (Johnson and Glahn, 1998).

Resident male starlings begin checking out nesting sites in late winter, while migratory males begin the process in early spring. Starlings are secondary cavity nesters, meaning they do not excavate their own cavities. While typical nesting sites vary in size, floor areas for ideal sites are about 23 square inches (Zimmerman, 2005). In contrast to other cavity nesters, who lay their eggs on nothing more than a bed of wood chips or feathers, starlings build nests of sticks, dried grass, paper, feathers and debris in their cavities. Starlings also select fresh green vegetation (herbs) that contain volatile chemicals for incorporation into their nests (Ehrlich et al., 1988). Recent research has shown that the incorporation of fresh herbs in nests has a positive effect on fledgling body size. While the use of fresh herbs in nests does not affect the number of mites in the nest, they do reduce bacterial counts in nesting materials. Researchers believe that the herbs may have their beneficial effects by causing mites to feed less on young birds or by improving the sanitary condition of the nest (Gwinner and Berger, 2005).

Starlings are usually monogamous and begin to pair off in late February or early March. Nesting sites are so fiercely defended that death can result from the struggle. Male starlings choose the nesting site and begin gathering nesting materials, but the couple work together on the nest, usually completing the task in 1 to 3 days. One egg is laid per day with a total of 4 to 7 eggs per nest and most are laid between 8 and 11 am. Eggs are incubated for about 12 days mostly by the female, but males do participate. Nestlings are completely helpless and their eyes are closed for the first 6 to 7 days. Young birds leave the nest (fledge) in 21 to 23 days, but parents continue to feed their young for a few days following their departure (Zimmerman, 2005). Nesting starlings usually forage 200 to 500 yards from the nest, since parents visit the nest an average of 260 times per day when feeding nestlings (Ehrlich et al., 1988). While the length of the breeding season varies from season to season, it generally runs from late March through early July in the Northern Hemisphere and September through December in the Southern Hemisphere. Depending on the length of the season, as many as three clutches are eggs are laid during a single breeding season. The first clutch is usually synchronized with other starlings in the area, so that all eggs are laid within a few days of each other. However, the second and third clutches of eggs are less synchronized. The second clutch of eggs is laid almost immediately after nestlings fledge, while the third clutch is generally laid forty to fifty days after the first (Chow, 2000).

It has been reported that starlings have reduced the population of native species (Ingold, 1998). However, a recent scientific survey found no relationship between the reduction in native species numbers and the increase in starling numbers. Researchers speculated that reduced native species numbers are because of the loss of native habitats (Koenig, 2003).

Most observers agree that the characteristics of starlings (prolific breeding, aggressive nesting, an omnivorous diet [they eat anything], and a close association with humans) mean that they are here to stay. Indeed starlings have, in some cases, been beneficial. Starlings themselves are a food source for raptors (hawks, falcons or eagles) and other native predators. In fact, the starling population may have helped increase certain raptor populations (Collins, 2007). Also, in the Netherlands, Spain and France, starlings have been, and continue to be, harvested for human food (Adeney, 2001). Starlings voraciously consume harmful insects that affect crops, but on the other hand they consume fruit and vegetable crops. Thus, when starlings are not consuming pests, they become pests (Chow, 2000).

Threats from Starlings

In spite of their musical abilities, their ingenuity, and their unique abilities, most folks in the United States view starlings as loud, obnoxious birds, who ruin crops, steal grain and generally make an unsightly mess. Indeed, when a flock of starlings descends on a fruit or grain crop, it is not difficult to envision a total crop failure (Adeney, 2001). Lee (2005) estimated that starlings consume about 1.8 pounds of livestock feed per bird per month. In addition to the feed consumed, starlings will contaminate many more pounds of feed with feces containing numerous bacterial, protozoan and viral pathogens. Since starlings travel from farm to farm, they represent a biosecurity threat (Byler, 2002). Starlings are important reservoirs and vectors for the introduction of external parasites such as mites, fleas, and bed bugs into poultry houses. Starlings are also associated with: food borne pathogens (like Salmonella), human fungal diseases (such as blastomycosis and histoplasmosis), human protozoan diseases (toxoplamosis), human rickettsial diseases (Q fever), horse diseases (eastern equine encephalitis (EEE), and St. Louis encephalitis), poultry diseases (coccidiosis, chlamydiosis, Newcastle Disease, and fowl pox) and swine diseases (transmissible gastroenteritis (TGE)) as well as tapeworms, round worms (Tetrameres), intestinal worms (Capillaria) and gapeworms, which affect multiple species (Kern, 2001). It has been estimated that starlings cost American agriculture (conservatively) $100 million per year (Byler, 2002)

Control of Starlings

Successfully managing starling and other pests means stopping the problem before it becomes a major issue. Start control efforts before the birds have a strong attraction to the site; keep at it until the problem is solved and use a variety of techniques including: bird-proofing (exclusion), trapping, frightening, shooting and toxicants (Lee, 2005).

Bird Proofing (Exclusion)

Structures can be bird-proofed by closing all openings larger than one inch, placing heavy PVC or rubber strips over entrances or doorways and covering boards, ledges or rafters with netting or porcupine wire to prevent roosting (Johnson and Glahn, 1998). While exclusion (bird-proofing) is the best long-term solution to starling problems, few producers are willing to take such steps (Lee, 2005).

Starlings are attracted to feed, water and shelter. Limit or eliminate these factors and starlings will not remain long. Clean up spilled grain or feed. Prevent standing water and keep water in large troughs low enough so birds can not perch on the edge to drink. Since starlings can not swallow large particles, where possible present animals with feed in blocks or cubes that are 0.5" or greater in diameter (Johnson and Glahn, 1998).

Trapping

When dealing with small static populations of starlings trapping and removal may be an effective method of dealing with the situation. Traps should be placed where starlings congregate and be maintained regularly. While a number of effective trap designs are available, it is important to purchase a trap that provides enough capacity to address the problem. It is also important to release non-target species (Lee, 2005).

Frightening

Frightening techniques work well in roosting situations, PROVIDED the problem is addressed as it begins to develop. The difficulty of dealing with roosting problems increases with flock size. To be effective, efforts to frighten birds must be persistent and the location, intensity and type of scare devices must be varied. Examples of frightening devices include distress calls, alarms, noise makers, exploders, propane cannons, bright objects, laser beams, eye spot balloons, pyrotechnics and hawk kites. Depending on the location, it may also be wise to notify law enforcement officials and neighbors of your efforts. Effective frightening apply techniques as birds are beginning to roost late in the day and maintain daily efforts until the flock moves (Lee, 2005).

Shooting

Since rifle slugs can penetrate tin, drywall, plywood or other such materials and travel over a mile, it may be wise to use air guns, a 410 gauge shotgun with a no. 10 to 12 size shot or a .22 rifle with rat shot. Such weapons may be an effective method of controlling a few birds in a relatively small area, but are ineffective at controlling large numbers of birds. However, it may be an effective means of reinforcing scaring and harassment efforts (Lee, 2005).

Toxicants

Toxicants used to control starling populations are usually restricted use pesticides, which means that they are regulated by both federal and state laws. Considerable skill is required to ensure that these poisons do not affect humans. The use of toxicants can have very serious and unintended consequences and will also require considerable study of starling roosting and feeding sites. Remember that most bird species are legally protected by state laws, federal laws and international treaties. The person using toxicants as a control method is legally responsible for the consequences (intended or not). In addition, toxicants that affect starlings may have similar effect on poultry species and/or could produce residues in poultry products.

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