ABSTRACT Discoveries in behavior and welfare science have improved the health and well-being of egg laying flocks of chickens. The objectives of this review are to highlight research findings in genetics, health, environment, molting, morphological alterations, euthanasia, handling during depopulation, transportation, and harvesting to improve poultry welfare and to provide examples of additional opportunities to continue this progress. Although selection for disease resistance has improved the welfare of birds, use of genetic marker technologies may eventually advance the selection of healthier birds with fewer metabolic disease and cannibalistic tendencies. Animal health and welfare have been improved through development of vaccines, establishment of stringent biosecurity measures, and training of animal caretakers. Industry is currently making adjustments in bird space allocations to allow for less crowded conditions. Continued research in molting shows promise to avoid feed withdrawal regimens for laying hens. Beak trimming by trained personnel improves livability, reduces cannibalism, and should be used when nonaggressive strains are unavailable and when light intensity cannot be controlled. Extension specialists and veterinarians provide information on proper procedures for euthanasia. New systems for euthanasia of spent hens are being implemented by egg producers. New opportunities exist for use of enrichments in production facilities to offer environmental complexity. Further research on how sound and odors affect birds could provide new avenues for improving production systems.

INTRODUCTION

You can think up some birds. That’s what you can do. You can think about yellow or think about blue.... You can think about red. You can think about pink. You can think up a horse. Oh, the thinks you can think! (Seuss, 1975).

Seuss says it best when describing the innovative thinking of poultry industry and university scientists, veterinarians, extension specialists, and animal managers as discoveries in behavior and welfare science are implemented by the industry for improving the health and well-being of poultry flocks. Many of the recommendations come directly from industry where years of first-hand experience have provided valuable information on bird welfare. The objective of this review is to highlight research findings made in genetics, health, environment, molting, morphological alterations, euthanasia, handling during depopulation, transportation, and harvesting to improve welfare of egg laying strains of birds. It is also the purpose of this review to identify areas of additional opportunity to continue the improvement of welfare of egg laying strains of birds in production enterprises.

Genetic Selection

Traditional genetic selection programs have focused on production traits such as more uniform body weight, increased egg production, improved feed efficiency and egg quality, optimum egg weight, and disease resistance (e.g., lymphoid leucosis). Lesser attention has been given to the selection of chickens for the expression of desirable behavioral and physiological traits. For example, it has been recommended that breeding companies consider selecting hens that show less cannibalism and pecking (Craig and Swanson, 1994). Indeed, this concept is feasible because research has shown that the behavior of White Leghorns can be genetically altered to reduce cannibalism (Craig and Muir, 1991; Kuo et al., 1991). Likewise, selection for less feather pecking is also possible, given an...
estimated heritability of 0.38 at 69 wk of age (Kjaer and Sørensen, 1997). The fragile skeleton of laying hens is another area where emphasis should be placed for improvement of hen welfare. Genetic selection studies, using data from siblings (i.e., bone strength and radiographic density of the keel bone fixed in formalin), successfully selected against osteoporosis (heritability of 0.41; Bishop et al., 2000). Selection for behavioral and physiological traits such as fearfulness (Reed et al., 1993) and bone mineral density (Hester et al., 2004), respectively, is more complicated than selection for production traits because of difficulty in and time required for measurements. Use of genetic marker technologies should advance the selection of birds with stronger skeletons and lesser cannibalistic and aggressive tendencies.

**Biosecurity and Health**

Poultry companies have implemented stringent biosecurity and hygiene measures to ensure high health status for their flocks (Appleby et al., 2004). Layer breeder flocks are given preventive treatment for worms and vaccinated for many diseases to afford immunity to themselves and their progeny, which is passively transferred through the egg. Birds with external parasites such as mites are treated with appropriate parasiticides.

Opportunities to improve welfare include the elimination of practices such as backfilling cages with different aged birds to maintain a full house. Bird welfare is compromised when backfilling is done every month to replace mortality. Research has shown that mixing birds of different ages or from other flocks increases susceptibility to disease. Older hens may harbor disease-causing pathogens that are easily transmitted to younger pullets that may have not been fully vaccinated or have had the opportunity to develop full immunocompetency. In addition, the introduction of unfamiliar birds to resident birds increases aggression and stress (Siegel and Siegel, 1961; Candland et al., 1969; Craig et al., 1969).

**Environmental Factors**

**Stockmanship.** Industry has been acutely aware of the effect of stockmanship on bird welfare (Dawkins et al., 2004). Frequent inspections of birds with adequate light levels and animal caretakers well-trained in proper managerial care and bird handling techniques greatly influence the welfare status of pullet and egg laying flocks.

**Housing.** Housing of egg laying strains of chickens is one of the more controversial welfare issues facing the egg industry (see review by Appleby and Hughes, 1991). The traditional cage is the most common housing system in the United States (see review by Tauson, 1998) because of the advantages of a more disease-free bird (e.g., prevention of coccidiosis; Koelkebeck and Cain, 1984; Appleby and Hughes, 1991), less bird aggression and cannibalism (Appleby and Hughes, 1991; Abrahamsson and Tauson, 1995), and stress (reduced corticosterone; Koelkebeck and Cain, 1984) with smaller group sizes of 6 hens or less, less ammonia and dust providing an improved environment for birds and workers (Appleby et al., 1989; Kangro, 1993), ease of bird inspection (Bell, 2002), cleaner eggs (Bell, 2002), and economics (van Horne, 2003; Appleby et al., 2004) compared with alternative housing systems such as deep littered housing. The major disadvantage of traditional cages is that hens are not able to express normal behaviors such as nesting, dust bathing, foraging, perching, scratching needed to prevent broken claws (Tauson, 1986), wing flapping, stretching, body shaking, walking (Koelkebeck and Cain, 1984), running, and freedom of movement and escape leading to inappropriate behaviors such as repetitive stereotypic (e.g., pacing before oviposition) and vacuum activities (e.g., hens going through the motions of dust bathing; Craig and Swanson, 1994). Poorer feathering condition due to feather pecking and the wear of the wired cage are also compromised in traditional cages compared with a deep litter flooring system (McLean et al., 1986; Appleby et al., 1988), but installation of a solid side partition consisting of sheet metal or plastic rather than a wire partition reduces feather damage due to wear and pecking between cages by 15 to 20% (Tauson, 1984). Caged hens have been shown to be more fearful than penned hens (Hughes and Black, 1974; Jones and Faure, 1981). Skeletal health is compromised due to lack of exercise in cages compared with other loose housing systems (Rowland and Harms, 1972; Meyer and Sunde, 1974; Fleming et al., 1994; Tauson and Abrahamsson, 1994a; Tauson, 1998). Installation of perches in cages improves skeletal integrity (Hughes and Appleby, 1989; Duncan et al., 1992; Tauson and Abrahamsson, 1994b), but perches can cause abnormalities of the sternum and hygiene problems underneath the perches because of the tendency for manure accumulation (Tauson, 1998). Cages modified with enrichments of a perch, nest, claw abrasives, and dust bath offer opportunity for expression of bird behavior not available in the traditional cage (Appleby et al., 1993) and hens show improved bone mineral density (Kopka et al., 2003), but problems exist with dirty (Pohle and Cheng, 2003) and cracked eggs (Tauson, 1998) and bird inspection is more difficult when hens are nesting. Redesign of furnished cages with egg collection closer to the darkest area of the nest box allows eggs to roll shorter distances thus reducing the incidence of broken shells (Tauson, 2000). Free-range birds with shelters are able to express additional behaviors such as freedom of movement, running, flying, and the scratching of soil, and have the opportunity to be exposed to a wide variety of environmental stimuli (Appleby and Hughes, 1991). They are also leaner with more muscle mass and plumage than caged hens (Hughes and Dun, 1986). However, ranged chickens are more susceptible to inclement weather resulting in fewer eggs laid (Koelkebeck and Cain, 1984), increase risks of disease outbreaks (e.g., avian influenza from wild birds), parasites, cannibalism ( Gibson et al., 1988) due to larger group sizes (Appleby et al., 1992), predators (Darre, 2003), increased frequency of old bone fractures (Gregory et al., 1990), and dirty eggs. The multiteried aviary designed to utilize three-dimensional
space or volume rather than deep litter or slatted floor systems allows for expression of bird behavior. Hens in aviaries have stronger bones than caged birds (McLean et al., 1986). Welfare issues of aviaries include increased incidence of bumble foot, keel bone lesions, cannibalism (Gibson et al., 1988), and parasites. Bird inspection and the working environment are more difficult in aviaries (Tauson, 1998). Hens housed in aviaries have inferior egg quality (Tauson, 1998), lower egg production (Tanaka and Hurnik, 1992; Abrahamsson and Tauson, 1995), and increased incidence of old bone fractures during the laying cycle due to crash landings (Gregory et al., 1990) than hens in traditional cages. It is obvious that no single housing system excels over the others, with each system offering its own advantages relative to bird welfare.

**Stocking Density and Group Size.** Caged laying hens given more space lay more eggs, demonstrate improved livability (Adams and Craig, 1985; Bell, 2002), and are less stressed (Lei et al., 1972; Mashaly et al., 1984; Craig et al., 1986), and less fearful (Okpokho et al., 1987; Craig and Millikan, 1989). To perform specific behaviors such as preening, wing and body stretching, resting, and feather ruffling, Leghorns need 458 to 581 cm² (71 to 90 in²) of caged floor space (Bogner et al., 1979). Preference testing, in which hens pecked at a key to provide more caged floor space, showed that hens selected a range of 400 to 79 in² of caged floor space to avoid crowded conditions. The United Egg Producers (2000) in the United States recommended that egg producers provide more space for caged layers (432 to 555 cm² or 67 to 86 in² of usable space per laying hen). A cage height of 41 to 43 cm (16 to 17 in) is needed to allow White Leghorns to stand upright. The slope of the cage floor should not exceed 8°.

Under conditions of identical floor space per laying hen, a smaller cage group size of hens (n = 4 vs. 14 birds) laid more eggs, showed improved livability and reduced agonistic behavior (Al-Rawi and Craig, 1975; Al-Rawi et al., 1976). Decreased fearfulness and disturbances have been associated with smaller group sizes (Kuijiyat et al., 1983; Okpokho et al., 1987; Craig and Millikan, 1989).

**Feeding Space and Drinking Behavior.** It has been argued that feeder space per bird is more critical to animal welfare than stocking density. Increased feeder space for caged laying hens improves egg production and livability leading to recommendations that a minimum of 10 cm (4 in) of feeder space is needed per caged hen (Bell, 2002). All hens should be able to consume feed at the same time; otherwise, without adequate feeder space, hens of lower social status suffer adverse effects under conditions of competitive feeding (Cunningham and van Tienhoven, 1983-84, 1984). Through social facilitation, birds are encouraged to eat when others do, producing a synchrony in feeding (Hughes, 1971).

Caged hens spend about 8 min of each hour or approximately 14% of their time drinking, considerably more than hens in loose housing systems that engage about 6% of their time in drinking (Gibson et al., 1988). It has been implied that the barren environment of caged systems causes some hens to become stressed leading to over-drinking. Lintern-Moore (1972) reported that some caged hens exhibit “psychogenic overdrinking” with droppings that were excessively wet compared with normal hens.

**Ammonia, Dust, and Ventilation.** Caged hens are exposed to less ammonia and dust than birds on littered floor systems. Hens on deep litter, housed at low densities of 3.4 or 6.3 hens/m², were exposed to an average ammonia level of 23 ppm with a peak at 50 ppm; dust particles averaged 30 mg/m³ with a maximum exposure of 47 mg/m³. Because of the low bird densities, the ventilation rate was reduced to conserve heat. When higher stocking densities were employed in the littered floor system, atmospheric ammonia and dust were reduced due to increased ventilation (Appleby and Hughes, 1991). Behavioral studies indicate that 25 ppm of ammonia is aversive to laying hens (Kristensen et al., 2000). To improve bird welfare and avoid keratoconjunctivitis and respiratory disease (Carlile, 1984), atmospheric ammonia should be kept below 20 ppm in poultry houses (Wathes, 1998).

**Lighting.** Low light intensity is an effective tool for controlling cannibalism in pullet and egg laying flocks where light control is possible. Because birds cannot see each other as well at lower light intensities, antagonistic encounters and aggressive behavior are minimized (Glatz, 2000). In addition, it appears that laying hens prefer low frequency fluorescent to incandescent light when given a choice (Duncan and Widowski, 1998).

**Enrichments and Environmental Complexity.** Providing enrichments to otherwise barren environments of domesticated fowl may offer stimulating opportunities for birds to perform natural behaviors (Newberry, 1995). Additional benefits of environmental enrichment include reduced aggressive behavior and improved livability, feather condition, and egg production (Yasutomi and Adachi, 1987; Church, 1992; Gyaryahu et al., 1994). For example, providing early access (by 4 wk of age) to perches for pullets reared in loose housing reduced cloacal cannibalism during egg laying and the incidence of floor eggs because hens acclimated to perches are used to moving around and can easily find and reach raised nest boxes (Gunnarsson et al., 1999). White string has been shown to be an attractive pecking substrate for chicks and adults (Jones, 2001; Jones et al., 2002). Although habituation has been cited as a problem (Appleby et al., 2004), colored environmental enrichment devices hung from the ceiling of cages resulted in hens pecking each other less compared with controls. Several strains of layers whose beaks were left intact had less mortality, increased production, and profit index due to the presence of the environmental enrichment devices in cages (Gyaryahu et al., 1998). Fearfulness is reduced by use of objects such as rattles, balls, colorful plastic bottles, strings or drawings on the wall (Reed et al., 1993). Leghorn chicks reared in pens that
were given straw early in life had less feather pecking suggesting that this enrichment encouraged a redirection away from aversive activities and towards foraging behavior (Huber-Eicher and Wechsler, 1997). Use of cover for purposes of concealment from conspecifics or predators was investigated in egg laying strains of pullets reared on littered floor. The pullets used the covered more than noncovered areas, suggesting a preference for concealment. Pullets in covered areas demonstrated increased resting and preening behaviors (Newberry and Shackleton, 1997).

**Smell, Noise, and Sound.** Domesticated poultry use olfaction to sense their environment (Jones and Roper, 1997). They use olfactory signals to not only evaluate palatability of feed and water, but also to sense familiarity (Jones and Gentle, 1985) and danger. Research is needed to determine if welfare can be improved through use of olfaction. An example includes the transfer of aromatic oils familiar to birds during rearing to new environments such as egg laying or breeder facilities. Rations could contain odoriferous ingredients that are pleasing to birds thus stimulating appetite (Jones and Roper, 1997).

Similar to smell, little information is available on the effects of environmental noise or sound on bird well-being. Disturbing noises can lead to increased incidence of blood spots in eggs (Stiles and Dawson, 1961). Environmental or nonspecific sound stimulates gonadal growth in nonphotostimulated quail (Guyomarc’h and Guyomarc’h, 1982; Millam et al., 1985; Li and Burke, 1987). Tapping sounds to mimic pecks to the feeder increases feeding behavior in chicks (Tolman, 1967a,b). Use of sound perceived as pleasant to birds and avoidance of noises perceived as alarming to birds in production enterprises needs to be further investigated.

**Molting**

Molting is induced to cause ovarian arrest leading to a second cycle of egg laying (see reviews by Webster, 2003 and Park et al., 2004). Because flocks are recycled, molting decreases the demand for chicks by 47% and thereby reduces the need to process, render, or bury the same percentage of spent hens. Rejuvenation of flocks prevents the annual euthanasia of one hundred million additional male chicks (Bell, 2003). Additional advantages of molting include feather rejuvenation thus improving thermoregulation. After a molt, livability and egg quality are improved during the second cycle of egg production compared with a nonmolt control group (Bell, 2003). Molting results in the repopulation of the thymus gland with lymphocytes (Brake et al., 1981).

Feed withdrawal in combination with light restriction is commonly used to synchronize molting in a flock of hens (Brake and Carey, 1983; Christmas et al., 1985; Ingram and Mather, 1988; Castanon et al., 1990; Koelkebeck et al., 1991, 1992, 1993a,b, 1999, 2001; Ruszler, 1996). However, feed withdrawal for inducement of ovarian arrest is stressful (Alodan and Mashaly, 1999; Kogut et al., 1999; Davis et al., 2000; Kuenzel, 2003) leading to increased mortality during the first 2 wk of the molt (Bell, 2003). Temporary frustration (Duncan and Wood-Gush, 1971) as indicated by a moderate increase in aggression on the first day of feed removal has been noted in molted hens compared with non molted full-fed controls (Webster, 2000). Aggression dissipates by the end of the first day, and on the second day of fasting, molting hens show elevated activity as indicated by increased non-nutritive pecking, standing, and head movement. Resting behavior increases by d 3 of fasting, and although non-nutritive pecking decreases from d 2, this pecking, interpreted as a redirection of foraging activity, remains higher than in control hens (Webster, 2000). Resting behavior persists for the remaining part of the fast (Webster, 2000; Anderson et al., 2004). Similar changes in behavior of hens subjected to a fasting molting regimen have been reported by Simonsen (1979) and Aggrey et al. (1990) with the notation of an additional behavioral repertoire of increased preening on d 8 to 10 after feed removal, most likely coinciding with the dropping of feathers.

Hens subjected to a fasting molt compared with non-molting controls demonstrate decreased skeletal integrity (Mazzuco et al., 2003), immunity (Boyle and Smyth, 1984; Holt, 1992a), helper T-cells (CD4+ T cells; Holt, 1992b), and heterophil phagocytic activity (Kogut et al., 1999). Hens subjected to a fasting molt show an increase in Salmonella enteridis (SE) fecal shedding (Holt and Porter, 1992a,b, 1993; Holt, 1993; Holt et al., 1994, 1995), prevalence of SE in organs (Holt et al., 1995), inflammation of the intestines (Holt and Porter, 1992b; Porter and Holt, 1993; Macri et al., 1997), recrudescence of a previous SE infection (Holt and Porter, 1993), and susceptibility to SE infection (Holt, 1993) compared with nonmolting controls. Because only a small number of organisms are needed in fasting hens to induce an infection, SE is readily transmitted via the air or horizontally among molting birds under simulated experimental conditions (Holt and Porter, 1992b; Holt, 1995; Holt et al., 1998). Commercial settings have demonstrated a dramatic increase in Salmonella organisms in the environment of molted compared with nonmolting flocks (NAHMS, 2000; Murase et al., 2001).

As an alternative to fasting, hens subjected to non-feed removal molting regimens show postmolt performance (egg production, egg weight, feed efficiency, or egg shell quality) not unlike the hens of the fasting molting regimen. Examples of successful non-feed removal molting methods include the ad libitum feeding of diets high in corn gluten, wheat middlings, corn, or a combination of 71% wheat middlings and 23% corn (Biggs et al., 2003, 2004). Low sodium diets (Whitehead and Shannon, 1974; Nesbeth et al., 1976; Ross and Herrick, 1981; Naber et al., 1984; Berry and Brake, 1987; LaBrash and Scheideler, 2003), 10 and 15% guar meal (Zimmerman et al., 1987), and grape pomace with added thyroxin (Keshavarz and Quimby, 2002) are additional non-feed withdrawal molting regimens. Diets high in zinc (20,000 ppm) to induce molting (McCormick and Cunningham, 1984, 1987; Berry...
Salmonella shedding, intestinal inflammation, and internal organ contamination of SE-challenged hens are reduced (Holt et al., 1994; Seo et al., 2001) and bone mineral density improved (Mazzuco and Hester, 2004) using non-feed withdrawal molting programs (wheat middlings or wheat middling/corn combinations) when compared with hens of a fasted molt. In a field trial using 26,000 hens, those fed wheat middlings to induce a molt had 40% lower mortality from 31 to 100 d postmolt than fasted hens (Murase et al., 2004). Environmental presence of Salmonella increased during the molt in rooms containing fasting hens, but not in rooms of hens molted through wheat middlings (T. Murase, personal communication). Webster (2003) cautioned that non-feed removal molting regimens might not improve bird welfare from a behavioral point of view if molten hens do not proceed to a resting phase and aggression and frustration persist throughout the molt. Although Anderson et al. (2002) reported that hens molted through a non-feed withdrawal program maintained higher levels of aggression (0.70% of total acts) than hens subjected to a fast (0.18% of total acts), Biggs et al. (2004) reported no differences in social behavior between fasted hens and hens subjected to a non-feed withdrawal molting program of 94% wheat middlings. These results on increased resistance to Salmonella, livability, and improved skeletal integrity suggest that non-feed withdrawal methods of molting may be more welfare friendly than the more conventional feed withdrawal molting regimens.

**Morphological Alterations**

Research has shown that beak trimming improves livability; reduces cannibalism, feather pulling and pecking; improves feather condition; and causes less nervousness, fearfulness, and chronic stress (Gentle, 1986; Hughes and Gentle, 1995; Hester and Shea-Moore, 2003; Davis et al., 2004). However, beak trimming can cause short- and long-term pain with impairment of a bird’s ability to consume feed. A recent study with DeKalb XL pullets showed reduced feeding and BW following a beak trim which lasted to 6 wk of age for the chicks whose beaks were trimmed at 6 d, and to 16 wk of age for pullets whose beaks were trimmed at 11 wk of age (Davis et al., 2004). It is apparent that the welfare advantages are more relevant to the interactive flock, whereas disadvantages apply more to individual birds whose beaks are trimmed. Behavioral evidence suggests that breeding companies can select for birds that are more docile, minimizing the need for beak trimming (Craig and Muir, 1991; Kuo et al., 1991; Craig and Muir, 1996; Muir, 1996). Therefore, the most desirable approach is to use genetic stocks that do not require beak trimming (Hughes and Gentle, 1995). However, certain management systems such as exposure to high intensity natural lighting and some genetic stocks of laying hens may need beak trimming to prevent feather pecking and mortalities due to cannibalism. When beak trimming is used, it should be done before 10 d of age in chicks by trained personnel to prevent persistent neuromas of the beak stump.

Other morphological alterations, including dubbing and removal of claws or toe nails, are not routinely practiced in today’s egg industry. For example, dubbing (partial comb removal) is normally not needed to prevent comb tears or frostbite because of technological advances in equipment design and enclosed housing. In fact, the comb facilitates heat dissipation through vasodilation of blood vessels during hot weather. Trimming the claws of White Leghorns with microwave energy at hatch reduced pullet fearfulness, growth, and feed consumption, and doubled mortality during the growing period (1.87 vs. 0.97 for reduced- and intact-clawed birds, respectively; Honaker andruszler, 2004). Similar growth results were reported by Compton et al. (1981) using a hot blade for claw reduction of pullets. Compton et al. (1981) suggested that the shortened claw of pullets did not allow for adequate foot spread, thus reducing movement within the cage. Honaker and Ruzsler (2004) commented that Leghorns with intact claws were more excitable and may have had increased feeding, drinking, and motor activity compared with Leghorns with reduced claws. Partial removal of one toe of a breeder chick did not appear to cause chronic pain (Gentle and Hunter, 1988).

**Euthanasia**

Due to the low market value of spent hens and lack of processing facilities, on-farm euthanasia is commonly employed with end-of-lay hens using a modified atmosphere killing (MAK) system (Webster et al., 1996). Hens are removed from cages and placed directly in airtight carts containing carbon dioxide. As the cart rolls down the aisles of the layer facility, hens are added to the cart with intermittent exposure to carbon dioxide until the cart reaches its capacity of 200 to 250 hens. A final exposure of carbon dioxide occurs before unloading the dead birds onto a truck for transport to rendering facilities. When properly used, the modified atmosphere killing system is more humane than a live haul to a processing plant because hens are unconscious within minutes of being removed from their cages (Newberry et al., 1999).

Carbon dioxide gas at concentrations of 60 to 70% with 5 min of exposure time is commonly used for euthanizing hatchery culls (American Veterinary Medical Association, 2000). Pre-exposure to argon gas to induce unconsciousness followed by carbon dioxide may reduce respiratory distress of hatchery culls (Raj and Whittington, 1995). Instant maceration is also an acceptable method for euthanizing hatchery culls (Agriculture Canada, 1989).

Cervical dislocation is appropriate for small numbers of pullets or laying hens by trained personnel. Carbon dioxide or argon gas can be used for large numbers of birds (Center for Animal Welfare, undated).

**Handling, Depopulation, and Transportation**

Shorter shipping times and proper temperatures during transport from hatchery to placement of hatchlings.
in brooding facilities improve livability. Handling of birds is also required when transitioning from pullet cages to egg laying or breeder facilities. The poorer skeletal integrity of aging spent hens compared with younger broilers (Schreiwies et al., 2003) or turkeys makes them more susceptible to bone fracture during depopulation. To reduce the probability of fractures, spent hens should remain on feed until the day of processing (Savage, 1991; Newberry et al., 1999). Water should be available up to the time the hen is removed from its cage. In addition, care in handling (Gregory and Wilkins, 1989) such as catching spent hens by both legs rather than one reduces bone breakage (Gregory et al., 1992, 1993). Injuries are reduced by lowering house light intensity during catching because of reductions in escape behavior (Gregory et al., 1993). Cage door openings should be large enough to allow for easy addition and removal of birds from cages (Newberry et al., 1999). Placement of spent hens into coops or transport carts rather than manually carrying birds to the transport trucks resulted in fewer injuries (Broom, 1990; Alvey et al., 1992).

During hot weather, it is recommended that all poultry be loaded at night with mobile fans and misters strategically placed in front of the transportation truck to keep birds cool while the remaining part of the house is being depopulated. Lower transportation densities during hot weather and tarps to cover the sides of the transport trucks during cold weather are additional tools used to improve the welfare of poultry during transportation (Newberry et al., 1999). New approaches to improve air quality and vibrations during transport and to reduce the variability of microclimates within trucks are needed to improve welfare.

**Harvesting**

Once transportation trucks arrive at the processing plant, insulating sheds complete with fans and misters for hot weather improves livability while birds await harvesting. Prolonged waiting times at processing plants can lead to increased mortality (Newberry et al., 1999), so careful coordination of farm loading schedules is warranted. Gentle removal from transportation crates, proper shackling of poultry using darkened rooms to calm birds, proper stunning, and insuring that all birds are dead before entering the scalding tanks are crucial for animal welfare (Newberry et al., 1999). Gas stunning has shown promise for improved welfare in broilers (Hoen and Lan- khaar, 1999) and may have application for spent hens. Preventing back flow of odors from the killing floor to the area where the hens are being unloaded (Jones and Roper, 1997) and noise transfers from the killing floor may offer additional opportunities for advancement of welfare.

**Summary**

Although selection for disease resistance has improved the welfare of birds, use of genetic marker technologies

should advance the selection of healthier birds with less metabolic disease and fewer aggressive and cannibalistic tendencies. No other area has made as expedient progress as that of improving animal health through development of vaccines and establishment of stringent biosecurity measures. Housing for birds has evolved from range rearing to confinement, with research showing advantages and disadvantages for different systems. Research is showing that commercial birds in confinement need more space than often given in many industrial operations. Industry is currently making adjustments based on available scientific information. Continued research in molting shows promise for non-feed withdrawal regimens for laying hens. Research has shown that beak trimming by trained personnel improves livability and reduces cannibalism and should be used with aggressive strains of birds when light intensity cannot be controlled. Extension efforts coordinated with veterinarians provide web sites and informational bulletins on proper procedures for euthanasia. New systems for euthanasia of spent hens, developed by university scientists and funded by industry, were quickly implemented by egg producers. Opportunities to improve air quality and vibrations during transport and to reduce the variability of microclimates within trucks should continue to be pursued. Welfare officers are currently being employed by many companies to train and monitor personnel involved in handling, depopulation, and harvesting of birds. New opportunities exist for use of enrichments in production facilities to offer complexity to environments. Further research on how sounds and odors affect bird welfare could provide new avenues for improving production systems. Sustained progress in improving animal welfare is imminent as long as industry personnel, scientists, veterinarians, and extension specialists continue to work as a team and “Think left and think right and think low and think high. Oh, the thinks you can think up if only you try!” (Seuss, 1975).

**ACKNOWLEDGMENTS**

The invaluable critique of this manuscript by Inmaculada Estevez and her graduate students at the University of Maryland (College Park, MD) was greatly appreciated.

**REFERENCES**


Murase, T., S. Miyahara, T. Sato, K. Otsuki, and P. Holt. 2004. Feeding of wheat middlings to commercial layers as an alternative method to feed withdrawal that can be used to molt birds. Poult. Sci. 83:1782. (Abstr.)


