Poultry Handling and Transport

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ABSTRACT
The FAO (2011) estimates that 87% of transported poultry is broiler chickens. Broiler death losses during transport average 0.2% but can vary greatly. In layers, low feather cover is associated with more mortalities and in broilers, poor health increases transport losses. It is difficult to remove hens from furnished colony cages and this can result in more injuries. Design innovations are needed. Mechanical catching of broilers reduces stress during container loading. It is slower than manual catching and may result in more heat stress mortalities during hot weather unless two machines are used. In hot temperatures, stocking rates should be reduced and trucks need to be kept moving to prevent heat stress. In cold winter temperatures, chickens can be exposed to both heat stress or cold stress in different parts of a vehicle with closed curtains. Death losses tend to increase with longer transit times.

Keywords: Broiler chickens, hens, transport mortality, mechanical catching.

Introduction
The numbers of poultry handled, transported and slaughtered is greater than any other livestock. The FAO estimate of poultrymeat production for 2012 is 106 million tonnes, 87% of which is from some 50 billion broilers. Laying hen numbers are about 6,400 million (Watt, 2011). It is common for production sites to place hundreds of thousands of chicks or pullets within 2-3 days and to depopulate to slaughter equally swiftly. All birds are handled and transported at least twice. There is a need for this to be carried out both efficiently and with due regard for the welfare of the individual bird. Both legislation and retailer codes cover many issues including the welfare of animals in transit. Improving welfare may benefit meat quality and performance. There have been developments in automated handling systems and gas stunning is more widely used thus eliminating live bird shackling. New colony (furnished) cage and multitier housing systems pose challenges for catching birds at depopulation. The importance of training humans to handle birds more efficiently and humanely is also widely recognised.

Placement and on farm handling
Recent studies have indicated that the husbandry system and management can affect the resilience and fitness of birds for catching, handling and transport at the end of production. For example Weeks et al (2012a) found that an increased risk of DOA for end of lay hens was positively associated ($P<0.001$) with poor feather cover, poor health, lower body weight and cumulative mortality of the flock; with flocks in group housing systems having significantly greater average on farm mortality rates than those kept in cages. Similarly Chauvin et al (2011) found flock cumulative mortality on farm to be a significant risk factor for broiler DOA, and Lupo et al (2010) found for turkeys the risk factors for condemnation at the plant were locomotor disorders and high cumulative mortality on farm in the final 2 weeks plus clinical signs of ill health observed by ante-

mortem veterinary inspection at the plant. The quality of delivered chicks and pullets can affect their lifetime health and performance. The transfer process to the production site is an important component of this.

Chicks

Careful handling and transport of both hatching eggs and newly hatched chicks are important for subsequent performance (Meijerhof, 1997, Mitchell, 2009; EFSA, 2011; de Lange, 2012). Major causes of losses in transit and post transport mortality and morbidity are dehydration and under-nutrition (Xin and Lee, 1997). Transporting chicks in the dark may reduce the rate of utilisation of yolk reserves (Tanaka and Xin, 1997). Control of humidity as well as temperature is particularly important for eggs. Newly hatched chicks are usually tipped from incubator trays onto a series of conveyors, creating accelerations of up to 882 ms^{-2} with several drops of 7 to 55 cm in height (Knowles et al., 2004) before passing through automatic counters into lightweight, disposable containers perforated with ventilation holes for transport (Figures 1 and 2). They also found that in passing from one conveyor to another, if the belt speeds differed by more than 0.4 ms^{-1}, few chicks were able to remain standing. Manual sexing and sorting of layer strains is routine and often used for meat birds. Automatic sexing before hatching is being developed with the potential to reduce handling stress (Phelps et al., 2003).

The yolk sac reserves can enable chicks to be transported for up to 48 hours from hatch with low mortality, however water (via hydration gels) and feed should be available in transit for longer journeys (Mitchell, 2009) and modern strains of fast-growing poultry may use up the reserves more rapidly. Chick containers are transported by either truck or aircraft, generally in controlled environments to maintain uniformly warm yet well-ventilated conditions. Optimum temperature for chicks at normal stocking density in transport containers was reported to be 24-26^{o}C and 60-63% relative humidity (Meijerhof, 1997; Mitchell, 2009). However Xin and Harmon (1996) found 30-32^{o}C was optimal at humidities below 40% and de Lange (2012) suggests 32-35^{o}C maintains chicks in their thermoneutral zone, and importantly ensures that yolk sac protein reserves are conserved for the development of the immune and digestive systems. Clearly air temperature is just one factor determining the heat balance of chicks; with the humidity, air movement impinging on them, design and stocking rate of containers plus radiative exchanges all being important. More research is needed to determine optimal specifications for different circumstances. Stocking rates are generally 21-25cm^2 per chick although 19cm^2 has been proposed to prevent chilling in extreme situations. There has been no research regarding handling of chicks on arrival, when they may be gently tipped out or removed manually.

Pullets

Laying hens may be reared in cages or on litter and will usually undergo transportation at 15-18 weeks of age when they approach point of lay and are taken to the egg production farm. Perforated plastic crates usually with solid floors are widely used, particularly when the rearer is responsible for delivery and may be using general purpose vehicles. Narrow, modular systems that can be loaded and unloaded directly into cages and wheeled onto the transporter are favoured by professionals using dedicated vehicles. These predominate in the USA and are increasing in popularity in Europe with reducing labour availability. Another system is crates built as permanent fixtures on the bed of the lorry with a central ventilation channel. Hinged openings to the outside are used to load and unload the birds, which have therefore to be carried out of and into their housing. They may also be passed in handfuls from person to person.

Pullets are relatively valuable birds with good plumage (insulation) and are resilient to transport and handling stressors. Egg producers require them to arrive in good condition so they tend to be handled and loaded carefully. The vehicles are usually generously ventilated with air gaps above the floor and below the roof, air inlets in the headboard and either roof fans or a central ventilation channel the length of the trailer, including a slot in the roof.

Broilers, turkeys and ducks

Most poultry intensively reared for meat are placed in mixed or single sex groups of up to 60,000 birds in environmentally controlled houses. There is a trend to fit windows providing natural light to enhance typically low levels of under 20 lux. Birds live at stocking densities of up to 45 kg per m^2 at slaughter age on a deep litter of wood shavings, straw or similar material, with automated provision of food and water. The EU Broiler Welfare Directive (EU, 2007) limits stocking densities to a maximum of 39 kg per m^2, with lower rates (33 kg per m^2) for broilers housed in less well managed and equipped accommodation. In hot climates and free range or organic systems birds may be grown more slowly in naturally ventilated and lit pole barns or with access outside. Catching birds in such systems is invariably harder, because the birds are more active and have more space, in which case portable pens are often used to confine birds for catching.
A new Patio system (www.vencomatic.com) of growing broilers is being developed in the Netherlands which comprises multi-tier units the length of the house, each level housing birds on belts covered with litter. Eggs close to hatch are automatically placed from one end and the hatched chicks then jump down into their production layer (Figure 3) and the eggshells are removed with the hatching shelf. At the end of production, birds can be loaded into module drawers via several moving belts without the need for any human catching and handling. The potential welfare advantages provided by reduced live bird transport and handling are somewhat offset by the difficulties of inspection of higher tiers during production.

Most poultry meat is grown on contract or as part of an integrated system; so processors usually own and are responsible for the transport system. They provide specialist catching teams to depopulate the houses. Birds are calmer and less affected by the catching process if they are handled in darkness (Duncan, 1989), thus catching in the early hours in very dim light is common. Blue lights are useful with turkeys (Siegel, personal communication to the editor). Broilers are caught by one leg, inverted and carried in bunches of 3 or 4 per hand to the waiting crates or modules (Gerrits et al., 1985). Inversion may cause fear as indicated by prolonged tonic immobility (TI) responses (Zulkifli et al., 2000). To avoid dislocated hips and other injuries, handling by two legs is preferable, as is maintaining the bird upright (Gerrits et al., 1985; Parry, 1989). Appropriate handling techniques for all species are given in Anderson and Edney (1991).

Methods of catching were reviewed by Mitchell and Kettlewell (2004). Particularly with heavier birds, loose crate systems are laborious and thus are decreasing in popularity. Changing to modular systems, comprising a unit of compartments or sliding drawers, which can be moved by fork lift on and off the transport vehicle and right into the poultry house or lairage, may reduce dead on arrivals to about a third of previous levels (Aitken, 1985; Stuart, 1985). However care needs to be exercised when lifting birds up into the topmost drawers particularly with heavy poultry. Nijdam et al (2004) found an effect of catching team and breed on broiler DOA. To avoid injury to birds that are already loaded it is very important to load drawers from the top down.

Manual catching is exhausting, repetitive and dirty for the humans employed (Bayliss and Hinton, 1990). Up to 1,500 broilers may be caught per man hour in shifts of 5 hours (Metheringham, 1996). Significant welfare benefits such as reduced heart rates and catching damage were recorded for turkeys that could be driven into a modular system in comparison to 3 other systems in which they were manually caught and loaded (Prescott et al., 2000). In many countries dump module systems are used. To unload the broilers at the processing plant, the module is tipped and the chickens slide down the chute onto a wide conveyor belt. These systems work well for light weight broilers, but they have increased levels of broken wings when used with heavy broilers. Unpublished industry data from Australia showed that on heavy birds, 1% of them had broken wings from the dumping process. This did not occur in the small roaster chickens. Another interesting finding was that 74% of the birds with broken wings were females. Birds with the longest slides from the top decks of the module had the most broken wings.

Skeletal defects are a serious welfare issue and cause substantial economic losses in broilers, broiler breeders, ducks and turkeys (reviewed by Mench, 2004). The most common defect is lameness, which results in significant changes to behaviour and in particular the number of visits to the feeders is reduced in proportion to the degree of walking disability (Weeks and Kestin, 1997a). This implies a cost to the bird of lameness, which may be painful (Danbury et al., 2000; McGeown et al., 1999). Thus most catching and handling procedures could cause pain, especially inverting and carrying birds by the leg(s) and shackling. European legislation (EU 2005) does not clearly define fitness to travel. Whilst severely lame birds might be considered to be unfit to travel, animals are considered fit to travel if they are 'slightly injured or ill and transport would not cause additional suffering'. Severe clinical lameness following transport of male breeding turkeys with dyschondroplasia has been reported (Wyers et al., 1991).

The husbandry and welfare of ducks in European systems was considered by Rodenburg et al., (2005), but there appears to be no literature considering catching and transportation of ducks or geese, despite over 2,000 million ducks and 500 million geese being slaughtered annually worldwide. Ducks are often caught and handled by their necks: care needs to be taken to avoid damage to their neck vertebrae and heavier birds should be carried with support under the breast.

Hens

The majority of laying hens are still kept in cages, which particularly in Europe are now the larger colony or furnished cage accommodating up to 80 birds. Numbers in alternative systems such as aviaries, barn and free-range have increased particularly in northern Europe. After a productive year, hens are caught and transported to the slaughterhouse. End of lay hens are generally purchased 'off farm'. Their economic value has increased slightly as markets, especially in Africa, develop for their meat. This has improved the care taken in handling and the investment in transport systems in some countries. Gradually the modular systems such as Anglia Autoflow and gas stunning are replacing loose crates handling and waterbath stunning. Many types of vehicle are used, but dedicated trucks with side curtains are increasingly common.

Hens are removed from cages either individually or in groups of 2 or 3 by pulling them out by one leg despite recommendations to handle poultry by two legs (e.g. UK Codes of Recommendation). They may be struck against the cage entrance or food trough during removal and in furnished cages the perches and nestboxes may form an obstruction. Hens may also hit cages or roof supports as they are carried down the narrow aisles of a battery house (Knowles, 1991). Depopulation is very labour intensive with bunches of inverted hens commonly being passed along a human chain. Depopulating enriched colony cages is especially difficult as the depth of the cages from front to back is about double that of a conventional (battery) cage so most catching teams have people at the far side (back) of the cage to help drive the hens towards the grasp of the catchers. The operation becomes hazardous and time consuming as catchers not only have to climb up to nine tiers high but also walk the full length of very large houses carrying the birds. There is a need for research into methods of improving the depopulation process as well as for designers and builders to at least incorporate doors at both ends and halfway down the houses. Kristensen et al. (2001) evaluated a modular system for depopulating battery cages and found a significant reduction in the time each bird was handled from 64.5 s to 4.5 s. Compared with manual handling there was no difference in the proportion of damaged birds in the small trial, but the catchers preferred the modular system.

Hens in many alternative aviary systems are difficult to catch, tending to crowd and pile up at the end of aisles creating a potential for suffocation, or flap and fly with the risk of injury to the catchers. In some systems the back of a tier is beyond arms' reach resulting in birds having to be goaded or driven out which is time consuming and hazardous (L. J. Wilkins, 1992 pers comm). Furthermore, some slatted areas are not built and maintained to carry the weight of several human catchers and a stack of crates, so that accidents can occur, particularly as depopulation is invariably carried out at night in semi-darkness. Many catching teams drive birds into temporary pens for catching and move these around the house as necessary. It is particularly important that producers cull unfit birds before the catching process commences (Weeks et al., 2012b).

A direct comparison of different catching and carrying methods for end-of lay hens showed that plasma corticosterone concentrations were significantly higher when they were removed from their cages three at a time and carried in an inverted position from the house, than when they were removed singly and crated before removal from the house (Knowles and Broom, 1993). However, all hens in experimental handling treatments had high concentrations of corticosterone in comparison with the control birds, which were removed individually and gently from their cages in an upright position (Knowles and Broom, 1993). Scott and Moran (1993) found that the fear levels of laying hens carried for 20 m on a flat belt conveyor were lower than those of hens carried the same distance in an inverted position by hand or on a processing shackle. However, in the absence of a non-inverted control in this study, it is difficult to know whether the reduced fear was a consequence of upright conveyance or some other fear-reducing property of the flat-bed conveyor. As with broilers, well-designed automated handling devices would seem to have the potential to reduce trauma and fear.

Automated catching and handling systems

Automated catching and handling systems have great potential for reducing injury and distress for birds and humans alike (Lacy and Czarick, 1998; Knierim and Gocke, 2003). Several are now commercially available (Mitchell and Kettlewell, 2004). Uptake by the industry is increasing as the systems become more reliable, and the difficulty of recruiting human catchers in some countries increases. An early study revealed that the heart rate of broilers caught by an automatic combine returned to base levels more quickly than the heart rate of broilers caught manually (Duncan et al., 1986) and Delezie et al. (2006) have reported a quicker decline in levels of corticosterone and of TI following mechanical compared with manual catching. A possible explanation for less stress is that the birds remain upright during mechanical catching and they are not inverted. Scott and Moran (1992) found significant increases in loss of balance, wing flapping and alarm calls by hens conveyed up or down slopes rather than horizontally. In particular, drops from one conveyor belt to another must be avoided as they tend to cause injuries and wing-flapping. Although Ekstrand (1998) did not observe the birds during catching, this is the probable cause of differences found in carcases examined after slaughter, where twice as many wing fractures and significantly more bruising, mainly of the wings, was seen on mechanically caught birds, but insignificant differences in birds dead on arrival (DOA) compared with manual catching. Nijdam et al (2005) in paired comparisons of commercial depopulation by hand or mechanically on 8 farms, found few differences in DOA and none in the proportion of bruising, in meat quality or in biochemical indices of stress such as corticosterone levels. In the U.S., improvements in catching machine technology during 2005 and 2006 have reduced broken wings. Unpublished industry data indicates that machine caught and hand caught birds have similar levels of broken wings.

Gracey (1986) noted DOAs averaged 0.2% for mechanically caught flocks compared with 0.3-0.6% for manually caught broilers. Other surveys have recorded similar levels of DOAs for mechanically harvested broilers compared with manually caught birds, or higher levels in Spring (Knierim and Gocke, 2003; Nijdam et al., 2005a). In the U.S. where there are extremely hot temperatures of 38^{o}C, mechanical catching had higher DOAs because it took longer than manual catching. One innovative company solved this problem by using two catching machines. It is likely that in both these studies the increased mortality was due to heat stress: Knierim and Gocke (2003) noted uneven stocking rates for machine filled compartments and Nijdam et al., (2005a) suggested that particular climatic conditions were associated with the higher losses. It is possible this could explain the increased risk of DOA for mechanical versus manual handling modelled by Chauvin et al (2011), as climatic factors also increased the risk of loss. Compared with almost 88,000 manually caught broilers, Knierim and Gocke (2003) recorded significantly reduced injuries (3.1% v. 4.4% of birds) in over 108,000 mechanically caught broilers, particularly in respect of leg injuries, thus confirming the results of an earlier study by Lacy and Czarick (1998) and results of field trials of the Easyload system that found a halving of catching damage from 4-6% manually to 1-3% using the machine (Poultry International, 1998). However in a 2001 field study at a commercial slaughterhouse Nijdam et al., (2005a) found no differences in the percentages of bruises, meat quality or corticosterone levels between catching methods, indicating similar levels of stress. It therefore appears that with experience and careful management, mechanical and automated systems can perform at least as well and generally better than manual handling. Indeed during the year of their survey Knierim and Gocke (2003) noted a reduction in loading time by a third and significantly decreased rates of injury, which might in part be attributed to a reduction in speed of the conveyor from 1.4-1.6 ms^{-1} to 0.8-1.0 ms^{-1}. Turkeys are herded in groups of 25 to 30 through a bugle-shaped yard onto a 1.2 m wide loading conveyor (Figure 4).

Transport practices and consequences

Transportation is an extremely stressful process for commercial poultry. Having lived in relatively uniform environments they are suddenly exposed to multiple changes that include being handled, as discussed above, and withdrawal of food and water. They experience stimuli that may be new - such as motion with vibration and impacts - or of greater intensity and more varied than previously - such as daylight, noise, overcrowding and temperature extremes. New genetic techniques are now being used to study the combined acute stressors associated with food withdrawal, catching and transport. Sherlock et al (2012) compared global hepatic gene expression between control broilers and those exposed to commercial handling and transport using 20K chicken oligonucleotide microarrays. Hundreds of hepatic genes associated with energy metabolism, with exhaustion of stored hepatic and with pectoral muscle glycogen were expressed in response to commercial transport together with significant differential expression of genes associated with cellular control and immune function. Studies have the potential to inform breeding and husbandry practices to improve welfare and meat quality. The potentially adverse consequences of transportation include physical, physiological and behavioural changes. The greater the duration of exposure to stressors, the greater the integrated stress for the bird. The resistance of birds to handling (Zulkifli et al., 2000) and to transportation stressors (Kolb and Seehawer, 2001) may be enhanced by the addition of ascorbic acid (vitamin C) to the drinking water.

Irrespective of the catching method, catching and crating are stressful (Beuving, 1980). In a small study Bedanova et al., (2006) reported significantly elevated haemoglobin and reduced erythrocyte counts in heavy (3 kg) broilers crated at 105 cm^2 per kg compared with those at 115 cm^2 per kg and uncrated controls; plus increased heterophil:lymphocyte ratios against the controls, thus high stocking rates can increase levels of stress, possibly due to heat stress. Immediate elevations of plasma corticosterone following catching and crating may persist for over 2 hours (Voslarova et al., 2011) without the additional stress of transport. Compared with uncrated controls these authors found lactated dehydrogenase levels rose steadily from 30–120 minutes after crating plus changes in other biochemical indices. Further physiological changes are associated with moving poultry after they have been caught. Increased glucagon and plasma corticosterone (Freeman et al., 1984), and increased heterophil:lymphocyte ratios (Mitchell et al., 1992) have been found in broilers transported for two or three hours.

Factors associated with mortality in transit (DOA)

Death is the most obvious and easily recorded indicator of intolerable stress. Global figures for dead on arrivals (DOAs) are unknown. A survey of 59 million broilers at one UK plant had average DOAs of 0.13% (Warriss et al., 2005) with a fairly similar mean of 0.18% found by Chauvin et al (2011) for 404 broiler flocks processed in France during 2005 (range 0 - 1.4%). In the Czech Republic one survey from 1997 to 2004 (Vecerek et al., 2006) found that DOA of broilers was 0.25%. In the hot tropical climate of Brazil, death losses for broilers ranged from 0.12% for trips averaging 25 to 50 km and 0.41% for very short trips and trips over 51 km (Viera et al., 2010). The short transit birds benefited from a longer time in a fan-cooled lairage. This allowed the body temperatures of the birds of normalize. A second survey of all poultry species transported in the Czech Republic from 1997-2006 revealed the highest DOA to be for end of lay hens and cockerels; averaging 1.01 % per annum followed by turkeys (0.27%), broilers (0.25%), ducks (0.10%), geese (0.06%) and 0.25% for broilers (Voslarova et al., 2007). A large survey over 5 years in Italy (Petracci et al., 2006) found the average mortality of 1,266 million broilers was 0.35%, of 118 million turkeys was 0.38% and 54 million end of lay hens was 1.22%. For 13.3 million end of lay hens transported to 5 UK plants during 2009, DOA averaged 0.27% (Weeks et al., 2012a).

To illustrate the global scale of the losses a conservative estimate of 0.2% DOA, based on the surveys above, represents some 100 million broilers alone dying annually between farm and factory, with impacts on profit, food security, environment and bird welfare.

Large surveys in several countries have found a significant (risk of) increased mortality rates for all species with transport distance and marketing time (Warriss et al., 1992a; Vecerek et al., 2006; Voslarova et al., 2007; Weeks et al., 2012a). Whilst longer journeys may increase the risk of DOA this is not inevitable. Varied levels of mortality were recorded for end of lay hens transported in 2009 in the UK at all lengths of journey up to 500km (Weeks et al., 2012a) and in 7% of loads no losses were sustained.

If some birds are sufficiently stressed to die, many more will be stressed close to their capacity to survive and have compromised welfare. Typical times in transit are unreported in most countries, but vary considerably. A survey of 4 UK broiler processing plants by Warriss et al (1990) found average time from loading to unloading was 3.6 h with a maximum of 12.8 h. Unpublished U.S. figures would be similar. Time in transit for 90% of turkeys was under 5 h, with a maximum of 10.2 h (Warriss and Brown, 1996). A small study of 24 commercial end of lay hen journeys in the UK found mean marketing time to range from 5.4 - 17.6 h (Richards et al., 2012). In the USA and Canada a review of DOAs by Newberry et al., (1999) found a substantial increase in hen mortality with marketing time for example from 0.7% (under 12 h) to 9.9% (over 24 h). In Hungary during 2005-06, mean time from first bird loaded to first bird unloaded averaged 7.2 h at one plant with mortalities of 0.74% for broilers with longer marketing time significantly greater than for those experiencing shorter periods where average losses were 0.40% (Miklos, 2008).

Thermal stress

Heat stress is thought to be the major contributor to both deaths (attributed to 40% of DOAs by Bayliss and Hinton, 1990) and overall transit stress. Petracci et al (2006) in a large survey in Italy found significantly increased DOAs for all poultry in summer, indicating heat stress to be a likely cause of mortality during hot weather. Gregory and Devine (1999) associated high mortality rates of 11% in two out of nine flocks of end of lay hens in New Zealand (overall mean DOA 2.5%) with either hyperthermia or hypothermia, but did not report journey times or conditions. The UK survey of broilers by Warriss et al. (2005) indicated that mortality increased when ambient temperature rose above 17^{o}C, with DOAs almost 7 times greater when air temperatures were over 23^{o}C. Broilers may also be subject to cold stress: Vosmerova et al (2010) having sequentially measured biochemical indices of broilers transported over different distances throughout the year, concluded that transport in winter, when ambient temperatures were around zero (+/- 5^{o}C) and internal load temperature averaged 18.5 ^{o}C, was the most stressful. Cyanosis damage in turkeys in Canada was found to be associated with prolonged journey times (>8 h) and sub-zero ambient temperatures (Mallia et al., 2000). Risk factors for DOA of hens in the UK included the slaughter plant, distance travelled and external air temperature, with longer journeys and low external air temperatures increasing the risk (Weeks et al., 2012). In broiler transport an increased risk of mortality was also associated with high (>15^{o}C) or low (≤5^{o}C) ambient temperature, daytime rather than night time transport, larger flock size, heavier mean body weight, and an interaction between ambient temperature and transport time (Nijdam et al., 2004) and Vecerek et al., (2006) noted significantly higher losses in hot summer weather or cold winter weather. Rain and wind were associated ($P< 0.05$) with an increased risk of broiler DOA in a model by Chauvin et al., (2011).

Thus the degree of thermal stress experienced by birds in transit depends on the duration and intensity of both heat and cold stressors.

Side curtains are used as protection against precipitation, wind, solar radiation and to hide the birds from public view. However, even in winter, these often restrict ventilation too much and excessive heat and moisture levels build up around the birds (Mitchell et al., 1992; Webster et al., 1992; Kettlewell et al., 1993; Burlinguette et al., 2012). The risk of increased mortality (DOAs) tends to be associated with high environmental temperatures and the stationary parts of the transportation process (i.e. loading, unloading and waiting at the factory (Ritz et al., 2005)).

Several studies in the temperate UK climate have measured the thermal environment in different parts of the loads of pullets, hens and broilers during winter and summer conditions and on stationary and moving vehicles of varying design (Webster et al., 1992; Kettlewell et al., 1993; Weeks et al., 1997; Richards et al., 2012). These have shown that most vehicles used for transporting poultry, which are naturally-ventilated, do not provide a uniform thermal environment. Studies of the aerodynamics of full-size and scale models of one design of vehicle, including a trailer, have shown that, when moving, air predominantly enters at the lower rear of the vehicle and moves forward to exit at the front of the vehicle (Baker et al., 1996, Hoxey et al., 1996).

Filho and others (2008) using data loggers within loads of broilers in Brazil found that the summer season produced the worst thermal conditions for the birds and that the combination of afternoon and summer ranked as critical and lethal in most areas of the load. Recent studies in Canada using similar methods (Burlinguette et al., 2012) have observed that during milder ambient conditions (9.8°C) trailer roof vents and side curtains were kept open, resulting in a more even distribution of air and on-board temperature ranged between 10.3 and 16.7°C. As external temperatures dropped, the side curtains and some of the roof vents were closed. This resulted in increasingly variable and more extreme thermal conditions, with heat and moisture accumulated along the mid-line of the load near the front of the lead trailer and near the back of the rear trailer. At an ambient temperature of -22.1°C, temperatures within the trailer varied widely between -20.7 to 21.7°C with an estimated 58.6% of the load volume being exposed to temperatures below 0°C. In addition, the trailer humidity ratio rose 14.0g per kg above ambient and conditions approached saturation (RH>80 per cent) in 55.2% of the load volume. Rectal temperatues showed that during winter weather in Canada, when the trailer is closed up and tarped, both hypothermia and hyperthermia occurred within the same trailer (Knezacek et al., 2010).

With a reliance on natural ventilation, different parts of a load of poultry are over or under-ventilated and birds at the main inlet point are also susceptible to becoming wet and chilled unless protected. In certain positions there is virtually no air movement to dissipate the body heat produced by the birds. Weeks et al (1997) calculated average air speeds immediately surrounding the birds in moving vehicles varied between 0.9 and 2.4 m per s with maxima of 6.0 ms^{-1}. There are also large differences between conditions on moving and on stationary vehicles, again primarily due to ventilation and to speed of air movement. Ritz et al (2005) reported an increased level of mortality in broilers during loading, unloading and lairage but not during the journey. Richards et al., (2012) modelled data from loggers in eight positions within loads of end of lay hens transported in modules and confirmed that both when travelling and in lairage some parts of the load tracked outside air temperatures whereas others were dominated by bird heat. Conditions also varied within modules, with upper and central drawers unsurprisingly being warmer. Thermal ‘hot’ or ‘cold’ spots within loads are frequently detrimental to welfare and may lead to deaths associated with climatic conditions and excessive or inadequate ventilation (Hunter et al., 1997).

This knowledge of thermal conditions experienced by live birds in road transit and the physiological consequences of these (Mitchell and Kettlewell, 1994; Vosmerova et al., 2010) leads to the inescapable conclusion that, to achieve thermal comfort for all birds in transit, controlled and uniform ventilation is essential (Weeks et al., 1997; Mitchell and Kettlewell, 1998; Kettlewell et al., 2000; Burlinguette et al., 2012). Heat losses from model chickens among live birds in vehicles fitted with both side curtains and roof-mounted inlet fans were generally in the comfortable range with little variation between areas of the load (Weeks et al., 1997). These authors suggested air speeds within bird crates or modules should be maintained between 0.3 and 1.0 ms^{-1} except in extremely hot weather. Ventilation requirement is between 100 and 600 cubic metres per hour for typical commercial loads. Kettlewell et al. (2000) proposed for uniformly ventilated loads in temperate conditions (up to 20 ^{o}C) that 2.2 $m^3.h^{-1}$ per kg of chickens was sufficient.

It is strongly recommended that all vehicles be fitted with several temperature probes placed in close proximity to the birds. Temperatures should be both recorded and linked to an in-cab monitoring and alarm system. As a guide, that should be modified according to individual loads and vehicle designs, Weeks et al (1997) indicated broilers and pullets transported at 10-15^{o}C and poorly-feathered end of lay birds at 22-28^{o}C were likely to be thermally comfortable at the usual high stocking densities. EFSA (2011) recommended that specific thermal limits should be defined for broilers and end of lay hens, giving an upper limit in transport containers for broilers of 24-25^{o}C, assuming a relative humidity of 70% or higher. In hot weather the direct and indirect heating effects of solar radiation should be avoided by transporting at night or early in the day and parking in the shade. Commercially operated, fan-ventilated, temperature-controlled vehicles with sensors within the load were developed similar to the 'Concept 2000' vehicle (Mitchell and Kettlewell, 2004), but are not widely used. It could be more relevant to adopt management strategies during the loading and unloading of vehicles to minimise thermal impact. For example, loading alternate stacks of modules from the rear of the vehicle in hot weather and either not using curtains or drawing them just before the journey commences. In winter it is especially important to minimise wind chill by the use of curtains and parking in the lea of buildings or trees and to avoid birds becoming wet. Canadian research showed that when cold -5 degree C air was blown through chickens in a standard transport drawer, they moved away from the front of the drawer to avoid the draft (Strawford et al., 2011).

Clearly the proximity of other birds has a large impact on their ability to dissipate heat. The ceiling height of the crate may have an effect on heat stress. Turkeys transported in 55 cm height crates panted less compared to birds transported in 40 cm high crates (Wichman et al., 2011). The disadvantages of providing more headroom was more scratched backs. At high stocking densities individual birds have a reduced surface area to lose heat and also gain it via conduction from those surrounding them. This could be advantageous in extremely cold weather but, as indicated above, often leads to heat stress during transit. There needs to be more research on optimum stocking rates during transit and it is important that a representative sample of birds is weighed prior to transport so that appropriate stocking rates can be planned. In practice broilers and hens are frequently loaded by the handful (i.e. in multiples of 3 per drawer) so that guidelines should take this into account. Based on our recent research (Richards et al., 2012) I feel there is a strong argument for using different stocking rates in different areas of the load (in particular for reduced numbers in drawers at the top, front of the load) if this could be achieved in practice.

Space allowances are dependent on bird age and condition, weather and vehicle design and to a lesser extent on journey duration and should be adjusted accordingly. Delezie et al (2007) considered that stocking density during transit may have a greater influence on levels of stress than feed withdrawal or transportation. Miklos (2008) reported that space allowances for broilers and hens of less than 207 cm^2/kg led to higher mortality from traumatic injuries (0.60%) in journeys of up to 8 hours duration in Hungary than a more generous space allowance, which reduced levels to 0.49%, which is still high. Nijdam et al., (2004) in modelling data from Dutch and German broiler flocks concluded that reducing the stocking density of broilers would significantly reduce mortality and enhance welfare. This finding was confirmed by Chauvin (2011) for French broilers. The stocking densities recommended by European legislation (EC, 2005) may be used as a guide that needs adjusting according to weather, bird condition and journey duration (Table 1).

[Table 1 here]

Trauma

Osteoporosis in laying hens is ubiquitous, and a survey by Sandilands et al., (2005) found 26-55% of laying hens had sustained fractures during production and 4-25% during depopulation depending on housing system. Another UK survey of prevalent housing systems confirms high levels of keel damage with mean prevalence least for flocks housed in furnished cages (36%) despite also having significantly weaker bones. Hens in systems equipped with multilevel perches showed the highest levels of damage (over 80%) and the highest severity scores (Wilkins et al., 2011). Previously the problem of weak bones was thought to be primarily confined to caged birds (Gregory et al., 1990; Knowles and Broom, 1990; Keutgen et al., 1999). Two leg handling substantially reduces bone breakage (Gregory and Wilkins, 1992). Thus hens in all systems need to be handled with great care to avoid creating new fractures. Unhealed old breaks are likely to be painful during handling. Although the overall incidence of leg fractures in DOA birds was low, Weeks et al (2012b) found in a small study of 24 loads levels were 10 times greater for hens depopulated from the new colony (furnished) cages, which are now the only legal caged system within the EU, than from free-range systems. The depth of colony cages (from front opening to the rear) means it is hard to catch the hens at depopulation.

Injuries to broilers from careless handling and catching include bruising to the breast, wings and legs as well as fractures and dislocations especially of the legs of heavier birds carried by a single leg (see reviews by Nicol and Scott, 1990; Knowles and Broom, 1990). It has been estimated that 25% of broilers processed in the U.S. may have such bruising damage (Farsaie et al., 1983). Post-slaughter rejection rates due to trauma damage range from 5 to 30% (Jepersen, 1982; Kettlewell and Turner, 1985; Gerrits et al., 1985). In a survey of downgrading at a turkey abattoir, McEwen and Barbut (1992) found substantial levels of bruised drums: fewer leg and breast scratches were seen where birds had clipped toenails, and spur clipping reduced back scratches. They found no effect on injuries of truck design or stocking density, but increased half wing trim and bruising of drums was associated with length of time spent on the truck. In their model, Nijdam et al. (2004) found low ambient temperatures (<5°C) increased the risk of bruising as did transport during the day and in summer.

Damage to muscle cells results in an increase in the concentration of creatine kinase in blood plasma, so it may be possible to use creatine kinase concentrations as a quantitative index of injury (Mitchell et al., 1992). Apart from muscle damage, broilers also sustain a worrying number of broken bones and dislocations during the catching and transportation process. Gregory and Wilkins (1990) found 3% of broilers had complete fractures before stunning at the processing plant, and 4.5% had dislocated femurs. The dislocated femurs were probably caused by swinging the birds by one leg before placing them in the crate, as the chance of a broiler suffering a dislocation of this type increases with its bodyweight. The incidence of dislocations recorded in live birds before stunning may not be a true reflection of the problem, since many dislocations result in fatal haemorrhaging. Indeed, when 1,324 DOA broilers from 6 UK plants were examined, it was found that 27% had dislocated femurs (Gregory and Wilkins, 1992). These data indicate that the physical injury that occurs during manual catching and loading is a severe welfare problem for all poultry, and should accelerate the search for more humane alternative methods.

Fatigue

Many birds arrive at the slaughterhouse in an apparently exhausted state. It has been argued that the dehydration and depletion of body glycogen stores (Warriss et al., 1988), which occurs when broilers are subjected to food deprivation and simulated commercial transport, may produce a sensation of fatigue in birds (Warriss et al., 1993). However, progressive immobility is also a correlate of increasing fearfulness (Jones, 1996), and a response to painful (nocioceptive) stimulation. This immobility may be related to learned helplessness, and could be an important "cut-off" response in transported poultry.

Sherwin et al (1993) investigated the effects of fasting and transportation on measures of fear and fatigue in broilers. Broilers subjected to either food deprivation for 10 hours or a journey of 6 hours, or both, were compared with control birds, which were neither fasted nor transported. When the behaviour of birds was monitored in their home pens after the treatments had ended it was found that both fasted and transported birds were more active than controls, showing less lying behaviour for at least 12 h, suggesting they were not particularly fatigued.

Hunger and Thirst

Newly hatched chicks are not provided with food and water until they reach the rearing unit. During transportation, which may last up to 2 days on international journeys, chicks are thus completely reliant on yolk sac metabolism. Warriss et al (1992b) found that chicks deprived in this way for 48 hours weighed 16.5 g less than control chicks, which had access to food and water within 6 hours of hatching, and showed both physiological and behavioural signs of dehydration and thirst.

The fasting regime imposed on broilers before transportation may have important implications for welfare. At the very least it affects the amount of weight lost, which occurs after 4 to 6h of fasting at a rate of 0.2 -0.5%.h^{-1} as birds begin to metabolise body tissue (Veerkamp, 1986). Fasting is also aversive (Nicol and Scott, 1990) and may also increase stress (see below).

Broilers transported for 2, 4 or 6 hours after feed withdrawal for 1-10 h had similar live and carcass weights to untransported controls (Warriss et al., 1993). However, transport significantly reduced liver weight and liver glycogen concentration. Glycogen depletion of the biceps muscle increased progressively with journey time, which could have reflected muscular effort involved with maintaining balance in a moving vehicle. There was also evidence from this study that transported broilers were becoming dehydrated.

Withdrawal of food or both food and water for 24 h resulted in a 10% drop in live weight (0.43% per h) of which 41% was loss in carcass weight (Knowles et al., 1995). There was no evidence of significant dehydration in this study nor in a survey of 800 broilers at 2 plants (Knowles et al., 1996).

A more recent study (Nijdam et al., 2005b) also noted significantly reduced bodyweight (0.42% per h) at slaughter in broilers that had feed withdrawn for 10 h before transport for 3 h plus 1 h lairage, compared with those that had access to feed until transported, which had minimal weight loss. Changes in blood metabolites indicated stress and negative energy balance.

Fear and Aversion

Cashman et al. (1989) assessed the TI duration of nearly 700 broilers on arrival at four commercial processing plants. The overall mean TI duration was 12.6 min, a level comparable to that reported after exposure to high intensity electric shock (Gallup, 1973). Journey duration had the most significant effect on duration of TI. A strong positive linear relationship indicated that the birds' fear levels were increased by transportation and not just determined by the catching and loading procedures. When a similar study was conducted with 300 laying hens there was no evidence of a positive linear relationship between journey duration and the duration of TI (Mills and Nicol, 1990). However, the TI durations of hens undergoing short journeys were higher than those found for broilers (Mills and Nicol, 1990). Differences in catching procedures for broilers and caged hens are a possible explanation. Fear or stress reactions can be modified by changes in handling procedures. Jones (1992) found the TI response of both broilers and hens was reduced by gentle handling. Kannan and Mench (1997) confirmed this result in broiler chickens that were subjected to a 2 minute handling treatment and then returned to their home pens where plasma corticosterone was sampled at hourly intervals for the next 4 hours. Birds that received upright handling had lower plasma corticosterone concentrations than birds that were inverted either individually or in groups of three. However, the effects of handling treatment were masked when the broilers were crated after the 2 minute handling period, suggesting that crating was stressful.

Transportation involves simultaneous exposure to many factors, including noise, motion, heat, and crowding. The birds' experience of some of these separate factors has been examined by tests of preference and aversion. Mean sound levels on animal transportation lorries typically fall within the range 95 to 103 dB(A). The response of poultry to the specific noise encountered during transportation has not been assessed. It is generally thought that vibration is likely to be more aversive than noise.

Vibration

The fundamental frequency of most trucks used for poultry transport is 1-2 Hz, with a secondary peak at 10 Hz that coincides with the resonance frequency of poultry viscera (Scott, 1994). More detailed measurements by Randall et al. (1996) found resonant frequencies of broilers were around 15 Hz when sitting and 4 Hz when standing. Experimentally, passive avoidance procedures have been used to examine responses to vibration. For example, Randall et al. (1997) used a wide range of horizontal and vertical vibrations, imposed for a 2 hour period. They showed that both vertical and horizontal vibrations were aversive to broiler chickens, although a greater sensitivity to vertical vibration by a factor of between 1.3 and 2.5 was found at all acceleration levels. Aversion tended to increase with acceleration magnitude (0 to 5 ms^{-2}) and to decrease with increasing frequency (0 to 10 Hz) of the motion. As chickens find vibration below 5 Hz particularly aversive, Randall et al. (1997) concluded that the resonant frequencies of 1-5 Hz found on transporters are undesirable. Although animals can reduce the effects of vibration by moving, and by skeletal muscle tone, the scope for this in broilers with leg problems at high stocking density is very limited. Thus evidence suggests that vibration does adversely affect the birds and should be reduced, for example by using air suspension. Appropriate methodology to compare aversiveness of concurrent stressors during transport is being developed, initially using thermal and vibrational stressors (e.g. MacCalium et al., 2003).

Post transport handling and environment

Thermal conditions at the end of the journey must be considered as it can take 2-3 hours to manually unload pullets. Broilers and spent hens may also have to wait at the processing plant (Warriss et al., 1990) either on the vehicle or unloaded in modules or stacks of crates. In both instances a well-designed lairage is preferable to remaining outside exposed to the elements. It is important that the birds themselves receive adequate ventilation - measurements in two lairages found air movements around the stacks of modules greater than 1 m per s but less than 0.1 m per s adjacent to the broilers (Quinn et al., 1998). Temperatures and humidities among the birds consequently rose rapidly to give rise to conditions of heat stress within an hour in both winter and summer. Average body temperatures rose by 0.3^{o}C in the first hour of lairage and by 0.1^{o}C thereafter for the 4 hours of measurement (Warriss et al., 1999). The model birds used by Webster et al (1992) and Weeks et al (1997b) indicated conditions of substantial heat and cold stress were frequently experienced by hens and broilers in lairage during loading and unloading. Thus the duration of such times needs to be kept to a minimum of preferably less than 1 hour.

A controlled environment providing adequate ventilation while avoiding excessive wind and air movement (except in hot weather) onto the birds is highly desirable. There should also be sufficient space around each module or stack for effective air exchange and flow. Monitoring of the condition of birds and their environment in lairage is as necessary as during the journey. In practical terms, birds observed to be panting will become progressively dehydrated and increasingly heat stressed. In some cases the stress of transport may lead to PSE (pale, soft, exudative) meat in broilers similar to that in pigs. Showering heat-stressed broilers with water appears to be effective in reducing PSE and improving breast meat quality (Guarnieri et al., 2004). Vieira et al (2011) found that lairage in a controlled environment reduced mortality of broilers transported in summer in a subtropical climate.

Following arrival at the processing plant most broiler chickens and end-of-lay hens are manually removed from containers. Where electrical stunning is used, live birds are suspended by their legs from shackles for conveyance to the bath. Many birds react to this potentially painful procedure by struggling, flapping their wings and attempting to right themselves. Bedanova et al. (2007) reported that shackling chickens by their legs is stressful. To reduce the stress of hanging birds in shackles, Liner et al. (2011) found that struggling was reduced through the use of a breast support conveyor. This can lead to injury and reduces the chance that the bird will be effectively stunned prior to slaughter. Jones and Satterlee (1997) reported that covering broilers' heads with a hood immediately before shackling reduced struggling in comparison with non-hooded controls. A smaller reduction in struggling was also obtained when the birds were fitted with transparent hoods, leading Jones et al. (1998a) to suggest that the effect was due both to the tactile properties of the hoods and to their ability to impair patterned vision. Observations in U.S. plants show that providing a breast rub made from strips of smooth conveyor belting will also reduce struggling and flapping. Reducing ambient light intensity by itself reduced struggling in broilers shackled in groups of three (Jones et al., 1998b) but not in broilers shackled individually (Jones et al., 1998a). The authors argue that the welfare benefits of reduced injury would outweigh any possible increases in fear suggested by the increased immobility observed when hoods are fitted. Fitting birds with hoods would not be practical on most commercial processing lines but it may be possible to design a system for a slaughterhouse based on the principles of reduced light intensity, mild tactile contact and interference with clear vision.

Bird welfare is greatly improved when the labour intensive, stressful and often painful procedure of removing them from the containers and hanging them on shackles is eliminated. Controlled atmosphere (gas) stunning of chickens and turkeys is now the commercial norm in some countries, with welfare and meat quality benefits such as reduced breast muscle haemorrhaging and bone breaks (Raj et al 1997, Hoen and Lankhaar, 1999). It may also be used for ducks which can be difficult to stun electrically (Raj et al., 1998). Automation of shackling is has been investigated (e.g. Lee, 2001; Tinker et al., 2005) and is easier with gas-stunned birds than conscious ones that may flap, struggle and experience pain when shackled (Sparrey and Kettlewell, 1994).

Training

The benefits for animal welfare of training stockpeople and handlers is increasingly recognised (Hester, 2005) with specific benefits from altering attitudes (Hemsworth, 2003) and in handling and transport (Broom, 2005). Incentive programmes are also effective in reducing damage to birds. Providing incentive pay to employees will greatly reduce broken wings during catching of broilers. In U.S. plants, broken wings averaged 5 to 6%. The implementation of both incentive pay and auditing by restaurant company customers reduced broken wings to 1% or less in light weight birds and less than 3% in jumbo heavy birds.

Conclusions

Systems of housing, catching, handling, transport and lairage that are more humane both for poultry and for human workers need further development. In many cases mechanisation is less stressful and more efficient. Improved techniques for depopulating houses need to be developed, especially for large colony cage and multi-tier systems, and should be considered as part of the design and planning process. Machine harvesting of broilers is now more reliable and should be more widely adopted. Improved designs of vehicles are becoming commercially available. It is now possible to inspect birds in transit by accessing on-board information records of the conditions experienced on the journey so far. The ability to access such information is a pre-requisite for the sensible enforcement of welfare legislation or farm assurance standards and can even be monitored remotely alongside GPS vehicle tracking.

Scientific evidence shows increasing stress and mortality in all classes of poultry as transportation time, holding time and feed and water deprivation time increase. Thermal stress is a major component of overall stress. Control of ventilation during transit should be provided to reduce this, as well as minimizing the duration of all stages of transportation plus adjusting stocking rates, use of curtains and management practices according to weather and the condition of the birds. It is feasible by applying existing knowledge and best practice to reduce losses in transit by at least half of current mean levels. Doing so would have substantial positive impacts on profit, food security, pollution and bird welfare.

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Figures

Figure 1

Figure 2

Figure 3A

Figure 3B

Figure 4

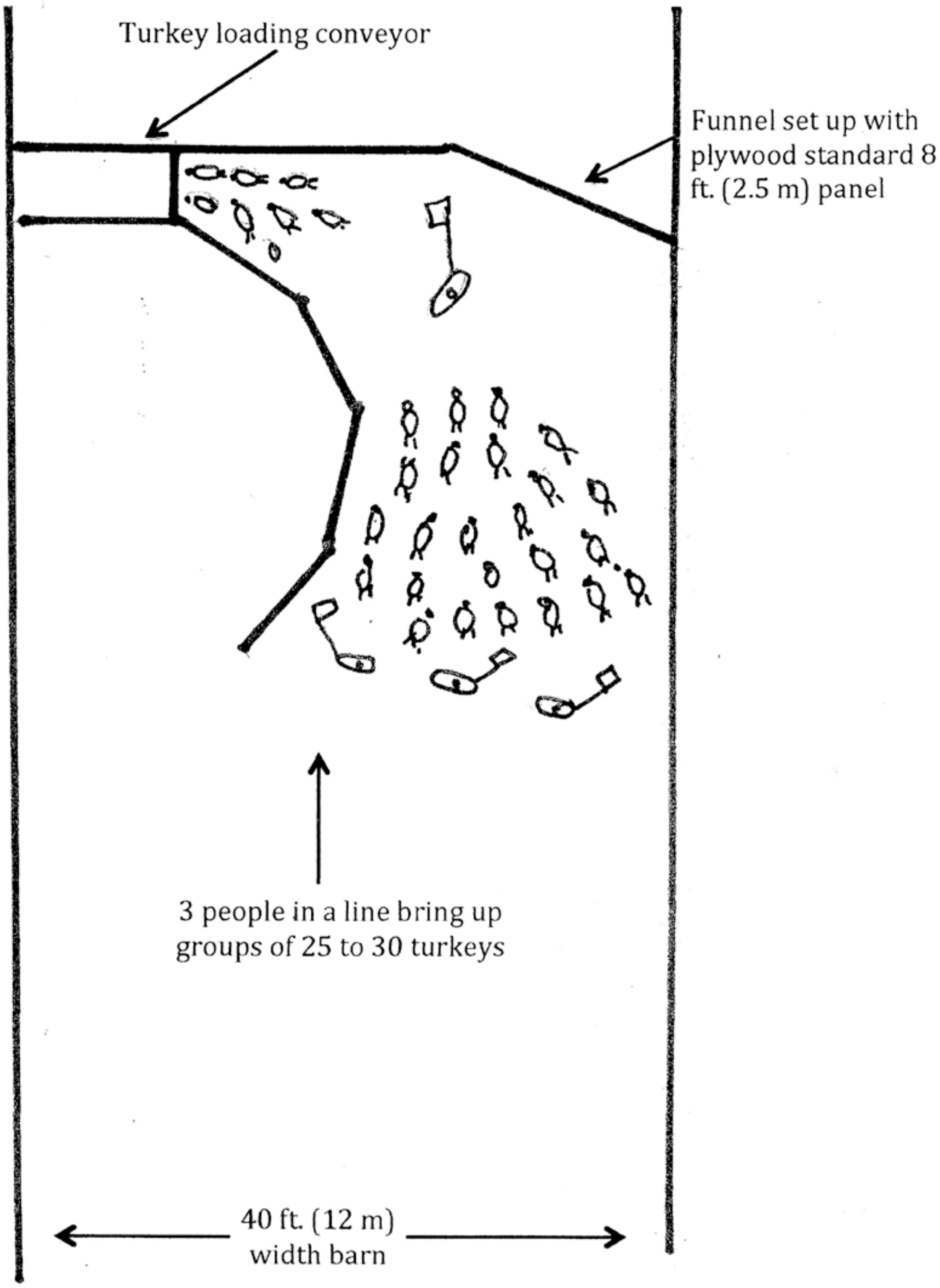
Turkey loading conveyor
Funnel set up with plywood standard 8 ft. (2.5 m) panel
3 people in a line bring up groups of 25 to 30 turkeys
40 ft. (12 m) width barn

Figure Captions

Figure 1. Automated chick handling. Photo courtesy of Dr Andrew Butterworth.

Figure 2. Automated chick counting into transport crate. Photo courtesy of Dr Andrew Butterworth.

Figure 3. Hatching eggs are placed above the rearing belt in the new ‘Patio’ multi-tier housing system for broilers (3a) from which the chicks place themselves (3b). Photos courtesy of Vencomatic.

Figure 4. Portable pen layout for herding turkeys onto a conveyor that loads the transport containers.

NB I will aim to get the original quality photos (Fig 3) for publication.

Table 1. Guideline space allowances for poultry in transit (EU, 2005)

Weight of poultry (kg)	**Space allowance (cm^2/kg)**
Chicks (day old)	21-25 cm^2/chick
<1.6	180 – 200
1.6 – 3.0	160
3.0 – 5.0	115
> 5.0	105

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