Welfare of poultry during transport – a review

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Summary
Poultry are exposed to a number of concurrent stressors during transportation. It is proposed that thermal challenges (both elevated thermal loads and cold stress) constitute the main threat to the birds' welfare and survival. The effects of thermal stress may be exacerbated by extended withdrawal of food or water and by exposure to vibrations and accelerations. Existing pathologies and injuries may further compound the situation. Whilst genetic selection in broiler chickens has resulted in major improvements in growth rates and production efficiency these advances may also be associated with a reduced resistance to thermal stress, altered heat exchange capacity and muscle and cardiovascular pathologies. These path-physiological states may render the birds more susceptible to thermal stress and may form a part of the "transport stress" experienced by poultry and lead to increased mortalities during exposure to hostile thermal micro-environments in transit and contribute to the observed increase in transport mortalities seen during challenging meteorological conditions. Solutions to these problems may be provided by changes in transport practices and procedures, improvements in the design of transport containers, vehicles and their ventilation systems and the introduction of genetic selection programmes for more robust lines that are less susceptible to thermal stress, exhibit fewer, idiopathic pathologies, and/or simply grow more slowly. Welfare during transport may be improved by a more holistic consideration of the birds' physiology, rearing conditions, pre-transport handling and the prevailing conditions and stressors that may be imposed during the journey.

Keywords: poultry, transport, welfare, stress, modelling

Introduction

Poultry production and consumption exhibit a global trend towards overall increase despite the temporary effects of the current recession. It is reasonable to predict that in the next decade the demand for meat poultry and egg production will expand further. All poultry species and major breeds employed in the main intensive production systems are transported at least twice during their lifetimes over distances that may range from a few kilometers to journeys with durations of many hours. Most journeys are by road e.g. form hatchery to production site or from farm to processing plant but some birds may also be transported by air or sea. All modes of transport involve the placement of birds or chicks in to transport containers which are subsequently loaded on to vehicles, aircraft or vessels for translocation to their intermediate of final destinations. All the procedures and practices involved in transportation and the micro-environments prevailing in containers and vehicles may impose varying degrees of stress upon the birds which will result in compromise in of their welfare status, health and productive efficiency depending upon the magnitude of the challenges imposed. Various components of the topic have previously been discussed and reviewed (e.g. Mitchell and Kettlewell 1998, 2004a and b, 2007, 2008; Mitchell *et al*. 2000; Mitchell 2006a and b, 2008) but it is timely to incorporate existing knowledge of the physical aspects of transport practices and environments with complementary knowledge of the physiology and behaviour of the major types of poultry that are transported and to assess also how these breeds and species of birds are equipped to respond to "transportation stress" and how these characteristics have been influenced by genetic selection for production traits. The current review, therefore, will attempt to address a number (5) of pertinent questions.

(1) What are the major welfare and production problems associated with poultry transportation in the 21st century?
(2) What factors or practices are responsible for these problems?
(3) What are the major features and consequences of transportation stress?
(4) What characteristics of modern breeds or strains of poultry may underlie a predisposition towards a susceptibility to transportation stress?
(5) What possible solutions or remedies are available to reduce the detrimental effects upon the well-being, health and productivity of poultry in an economically viable modern poultry industry?

In particular the review will examine the causes of losses, including mortalities in transit, product quality decrements in meat birds at slaughter and evidence that the transport process and associated environmental conditions may cause unacceptable stress in transported birds thus impinging upon their welfare. The consequences of selection for rapid growth rate and improved feed conversion efficiency will be considered in relation to the capacity of modern meat birds for adaptation in the face of environmental challenge and stress during transportation. This discussion will focus upon the problems of thermal stress in transit and resistance to elevated heat loads and cold stress, thermoregulatory ability of the birds, efficiency of heat exchange mechanisms, tissue dysfunction and pathology that may result from transportation and thermal stress and the mediation of the effects of transport and thermal loads upon water balance and weight loss and the results of these stimuli and associated responses fro bird welfare and product quality.

Poultry Transport (road)

In transit birds may be exposed to a variety of potential stressors including the thermal demands of the transport micro-environment, acceleration, vibration, motion, impacts, fasting, withdrawal of water, social disruption and noise (Nicol and Scott 1990; Mitchell and Kettlewell 1993; Mitchell and Kettlewell 1998; Carlisle *et al*. 1998; Abeyesinghe *et al.* 2001). Each of these factors and their various combinations may impose stress upon the birds, but it is well recognized that thermal challenges and in particular heat stress constitute the major threat to animal well-being and productivity (Mitchell and Kettlewell 1998; Mitchell *et al*. 2000; Weeks and Nicol 2000; Elrom 2000; Mitchell *et al*. 2001; Nilipour 2002; Mitchell 2006). The imposition of thermal loads upon the birds in transit will result in moderate to severe thermal stress and consequent reduced welfare (Mitchell *et al.* 1992; Mitchell and Kettlewell 1998; Mitchell *et al*. 2001), increased mortality due to either heat or cold stress (Hunter *et al.* 1999, 2001) and induced pathology including muscle damage and associated changes in product quality (Gregory 1994, 1998; Mitchell 1999). It is apparent that climatic conditions, which will influence the internal vehicle thermal micro-environment, will determine the effects of transport upon the birds. In turn the duration of the journey will be another important factor affecting the effects of any hostile "on-board" thermal conditions. Mortality has long been a concern in relation to poultry transportation (Bayliss and Hinton 1990) and continues to be an episodic issue in all countries where meat birds are produced. Thus Warriss *et al.* (2005) have described a highly significant relationship between mortality of broilers in transit (Dead on Arrivals or DOAs) or in lairage and the maximum daily ambient temperature. It was proposed that at external temperatures greater than 17ºC measures might be required to ameliorate the damaging effects of transport on bird welfare. In contrast Ritz *et al.* (2005) have reported that elevated temperature during hot weather pose a greater pre-slaughter risk of mortality to broilers during loading and lairage at the slaughterhouse than on the vehicle if it is constantly moving. The authors acknowledge, however, that it is difficult to precisely attribute DOAs to a specific part of the process of handing and transport. Under commercial conditions it is difficult to establish the causes of mortality in transit and there are few studies available that have provided such information. Hunter *et al.* (1997) examined the distribution of mortalities on commercial broiler transport vehicles and reported a significant link between the on-board thermal micro-environment and DOA values. Mortality was highest in those parts of the vehicle where temperatures and humidities were greatest or where the ingress of cold air and water resulted in cold stress (also Hunter *et al.* 1999). Post-mortem examination indicated that an underlying level of randomly distributed DOAs on the vehicles encountered on journeys at all times of the year could be attributed to existing pathologies and/or catching injuries. Elevations in DOA values above this baseline were almost entirely the result of thermal stress (95%) and were concentrated in specific vehicle locations. Nijdam et al (2006) placed little emphasis upon mortality due to thermal stress in transit when describing post-mortem examination findings on a number of birds that had died in transit although the conditions of transport or risk of thermal stress were not discussed in detail. They reported that 89.4% of dead birds (DOA) exhibited macroscopic pathological lesions. Infectious disease states were the main cause of lesions (64.9%) followed by heart and circulation disorders (42.4%) and trauma (25%). It should be noted, however, that birds affected by any of these pathologies will be rendered susceptible to thermal stress and thus may succumb at when exposed to thermal conditions that would so adversely affect healthy birds. Thus it may be assumed that the actual levels of mortality or DOA vary widely depending upon many factors including season, geographical location, journey length, size of bird stocking density, health status, vehicle design and slaughterhouse design and practice. Absolute mortalities are generally higher for turkeys and spent layers than for broilers (Petracci et al 2006; Voslarova et al 2007). Broiler DOA figures (annual averages) may vary from around 0.15% (Mitchell 2006) to values as high as 0.25% (Verecek 2006), 0.35% (Bianchi et al 2005; Petracci et al 2006) and 0.46% (Nijdam 2004). Average values of DOA tend to be elevated in the summer months in many and a model developed by Nijdam *et al.* (2004) indicates that temperature multiplied by journey duration is an important determinant of DOA as are transport time per se and lairage time. It was proposed that minimisation of the last two factors may be important strategies for the reduction of DOA in commercial practice. Journey length has long been recognised as an important factor in broiler DOA (Warriss et al 1990). More recent studies (Vecerek *et al.* 2006) indicate that short journeys (up to 50 km in length) are associated with relatively low mortalities (0.15%) but for journeys of 300km or greater the value increase to 0.86%. The mean value for all journeys in that study was 0.25% thus emphasising the requirement to optimise transport conditions on longer journeys to reduce mortality, losses and to improve welfare. In periods of high ambient temperatures in summer high episodic mortalities may occur where DOA figures may exceed 1-2% and occasionally even larger numbers of birds may be lost reaching many hundreds of birds on a few journeys (personal communications – industry). Another important consequence of transportation of broilers which is exacerbated by elevated thermal loads is weight loss through increased demand for evaporative heat loss (Mitchell *et al*. 2003). This reduces product delivery weight and significant dehydration will compromise bird welfare and affect product quality.

If it assumed that thermal challenges represent a major risk to the welfare of birds in transit and to production efficiency then understanding the thermal micro-environment on commercial transport vehicles is essential to the development of appropriate strategies to control that environment and to reduce the risk of thermal stress in transit. The internal thermal micro-environment in the poultry transport containers is the product of the inlet air temperature and humidity, airflow rate and the heat and moisture production of the birds (Kettlewell and Mitchell 2001a and b; Mitchell *et al*. 2000; Mitchell 2006). The passive ventilation regimes of most commercial broiler transport vehicles result in low rates and heterogeneous distribution of airflow within the bio-load. Studies have characterized the pressure profiles over the surface of, and within, commercial broiler vehicles (Baker *et al.* 1996, Dalley *et al.* 1996, Hoxey *et al.*, 1996). It is these pressures that drive passive ventilation within the vehicle. A central feature is the tendency for air to move in the same direction as the motion of the vehicle: thus air tends to enter at the rear and move forward over the birds exiting towards the front. This pattern accounts for the distribution of temperatures and humidities observed on commercial vehicles, the existence of the "thermal core", the ingress of water spray and bird wetting and the pattern of DOAs and thermal stress found within the load (Hunter *et al.* 1997, 2001; Mitchell *et al.* 1997, 1998a). When vehicles are stationary there is no external force driving the ventilation, thus heat and moisture removal is then dependent upon free convection. Problems of heat stress may be markedly exacerbated even on open or semi-open vehicles, particularly when stationary in hot and humid weather conditions. Any practical solution to these problems must involve modification and improvement of the ventilation regime. The degree of physiological stress imposed upon slaughter weight broilers by a range of temperature and humidity combinations has been determined in transport simulation studies and the development of physiological stress models based upon Apparent Equivalent Temperature or AET (Mitchell and Kettlewell 1998; Mitchell *et al.* 2000, 2001; Mitchell 2006). This approach allowed definition of thermal comfort zones, optimum transport conditions, and acceptable limits for temperature and humidity for broilers in transport crates under commercial transport conditions. It was suggested that the "in-crate" dry bulb temperature should be maintained below 23-24°C and preferably around the controlled house temperature 0f 20-21ºC. It may therefore be proposed that the introduction of mechanical ventilation systems would facilitate control of the on-board thermal environments of poultry transport vehicles within the prescribed range. This can be achieved with knowledge of the thermal loads encountered in transport vehicles and the heat production of the birds in transit. The only published data on heat production based on field measurements rather than predictive models for poultry under transport conditions is that for broiler chickens (Kettlewell *et al.*, 2000). These data have been employed in the development of a fully controlled mechanically ventilated broiler transport vehicle (Kettlewell and

Mitchell 2001a and b). The transporter is equipped with mechanical ventilation that ensures an adequate airflow over all the animals throughout the whole transit period, irrespective of vehicle movement. Ventilation rates can be determined from purely physical considerations but the applicability of the findings must be ensured through due consideration of the physiological requirements of the animals. The scientific basis and modeling approaches employed in the development of such fan ventilated vehicles has been described in detail (Kettlewell and Mitchell 2001a and b; Kettlewell *et al*. 2001a and b; Mitchell 2006; Mitchell and Kettlewell 2007). Controlling the thermal environment within prescribed limits in transit (and indeed during catching and lairage) is a major step towards reducing losses and improving the welfare of meat type birds. Failure to adopt these measures is partly attributable to the costs of implementation and operation of the systems. In future, however, proposed and developing legislation (e.g. EC 1/2005 or WATO 2006), pressure from the public, welfare organizations and retailers of poultry products may result in a requirement for fan ventilation on poultry transport vehicles in Europe and perhaps other regions of the world where such issues are of significant concern.

Modern, rapidly growing strains of meat poultry exhibit an elevated incidence of spontaneous or idiopathic myopathy and an increased susceptibility to stress induced myopathy (Mitchell 1999: Sandercock and Mitchell 2003; Sandercock *et al.* 2006). These pathologies are attributable to alterations in intracellular calcium homeostasis (Sandercock and Mitchell 2003; Sandercock *et al.* 2006) and consequent changes in sarcolemmal integrity and may result from excessive myofibre hypertrophy and inadequate development of support tissues and vascular supply (MacRae *et al*. 2006, 2007. These myopathies may have, in turn, a range of implications for both product quality and bird welfare (Mitchell 1999). Rapidly growing lines of birds may exhibit a reduced thermoregulatory capacity compared to their genetic predecessors and may thus be more susceptible to heat stress in transit and to consequent problems including muscle damage, acid-base disturbances and reduced meat quality (Sandercock *et al*. 2001, 2006 Genetic selection for improved growth rate and feed conversion efficiency may be associated with altered mitochondrial function (Bottje *et al*. 2006) and changes in the production of reactive oxygen species (ROS). In this context acute heat stress has been demonstrated to increase superoxide free radical production in chicken skeletal muscle (Mujahid *et al.* 2005). This process is mediated by altered mitochondrial function and down-regulation of "uncoupling protein content" (Mujahid *et al.* 2006, 2007). This mechanism may be responsible for the transport stress and heat stress induced muscle damage and for the changes in muscle and meat quality observed in broilers. Thus derangements of ante-mortem muscle cell metabolism and alterations in sarcolemmal integrity and tissue structure associated with oxidative damage and myopathy may have profound implications for meat quality and the incidence of specific conditions such as Pale, Soft, Exudative (PSE) like meat. Also it may be suggested that muscle dysfunction may lead to problems of altered locomotor capability and therefore behavioural changes and reduced welfare. This situation may be further compounded if the observed myopathies are accompanied by muscle discomfort or pain.

Inspection of the scientific literature thus reveals that a number of answers are available to the questions posed in the initial section of the current review. Thus :-

(1) What are the major welfare and production problems associated with poultry transportation in the 21st century?

(a) Mortality in transit
(b) Poor welfare associated with the transport thermal environment
(c) Stress induced pathologies and decreased muscle/meat quality in slaughter birds

(2) What factors or practices are responsible for these problems?
(a) Poor vehicle and transport container design
(b) Poor control of the "on-board thermal micro-environment; inadequate ventilation
(c) Physiological characteristics of the birds resulting from genetic selection for production traits

(3) What are the major features and consequences of transportation stress?
(a) Thermal stress (discomfort) – a welfare issue
(b) Dehydration, weight loss, energy depletion and fatigue
(c) Stress induced myopathy, vascular pathology (e.g. ecchymotic or punctate haemorrhage)
(d) Blood gas and acid base disturbances, changes in electrolyte balance and distribution
(e) Tissue dysfunction and pathology which may affect welfare status and product quality in slaughter birds
(f) Injuries to birds resulting from stress induced behaviours in transit and catching methods may render birds more susceptible to other aspects of transport stress

(4) What characteristics of modern breeds or strains of poultry may underlie a predisposition towards a susceptibility to transportation stress?
(a) Rapid growth rate appears to be associated with a higher basal metabolic rate and a reduced heat stress resistance
(b) In heat stress an increased metabolic rate and greater degree of hyperthermia may predispose modern lines to disruption of homeostatic systems, heat stroke, tissue damage and heat induced mortality in transit
(c) Rapid growth rate appears to be associated with an idiopathic myopathy that may predispose towards stress induced myopathy and a reduced heat stress resistance
(d) Rapid growth rate appears to be associated with a number of pathological conditions (e.g. pulmonary hypertension) which may render birds more susceptible to other aspects of transport stress

(5) What possible solutions or remedies are available to reduce the detrimental effects upon the well-being, health and productivity of poultry in an economically viable modern poultry industry?
(a) The thermal environment maybe better regulated by improvements to vehicle and container design.
(b) Improved passive ventilation systems focused upon enhanced passive airflow and better distribution within the "bio-load" may be adequate
(c) In some circumstances active or mechanical ventilation systems are required to prevent or avoid thermal stress
(d) Improved transport practices and procedures including changing stocking densities and transport scheduling and minimizing journey durations would prove beneficial

(e) Selection for slower growing lines in meat birds may reduce the problems of heat stress susceptibility and predisposition towards thermal stress and associated pathologies

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