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Review

Physiological and behavioural responses of livestock to road transportation stress: A review

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Physiological and behavioural responses of livestock to road transportation stress are reviewed. Livestock transported by road in most part of the world are predisposed to many stressors which affect the haematological, hormonal function as well as the behavioural activities of the livestock thereby disrupting body homeostasis.

Key words: Road transportation, livestock, physiological parameters, behavioural activities.

INTRODUCTION

Transportation is an inevitable husbandry practice, which livestock are subjected to (Gupta et al., 2007; Buckham Sporer et al., 2008a and b; Adenkola and Ayo, 2009a; Adenkola et al., 2009a and b) as a result of marketing and the need to slaughter them for meat in abattoirs, often located outside places where the animals are reared (Chandra and Das, 2001; Rajion et al., 2001; Minka and Ayo, 2007a; Voslarova et al., 2007). Livestock are also transported as a result of replacement of old stock (Moss, 1982), exhibitions, fair, sport competitions, seasonal tourism, taming, reproduction and health status (Giovagnoli et al., 2002). They are often transported to achieve translocation immediately prior to harvest and also to sources of less expensive or more abundant feed supplies for growth and fattening (Tarrant and Grandin, 2000).

In Nigeria generally, livestock transportation by train is not common because animals must first be transported to railway station and reloaded. The railway system in Nigeria today is predominantly non-functional and is restricted to certain parts of the country. The price of aircraft transportation limits its use to day-old chicks. Transportation by ships is mostly used in roll-off situations. Thus, the most common means of transport for all livestock species in many countries of the world is by road (Brown et al., 1999; Odore et al., 2004; Vecerek et al., 2006a; Buckham Sporer et al., 2008a), including Nigeria (Minka and Ayo, 2007b,c; Adenkola and Ayo, 2009a; Adenkola et al., 2009a,b). In Nigeria, food animals are transported often without observation of any welfare order and in vehicles meant for transportation of goods and not specifically for transportation of animals such as open trailers, trucks, pick-ups and even buses together with passengers (Minka and Ayo, 2007a). Transported animals are often exposed to a variety of environmental extraneous stimuli, which are called stress factors (Frazer and Brown, 1990) and thus road transportation of livestock is very stressful to animals (Sporer et al., 2008a; Ritter et al., 2009; Adenkola and Ayo, 2009a; Adenkola et al., 2009b,c). Road transportation represents a critical phase in animal production and utilization and it is often considered as one of the main causes of stress, adversely affecting production both in economic and animal welfare terms (Mormede et al., 1982; Eldridge and Winfield, 1988; Broom, 2003). It has been shown that road transportation of livestock result in live-weight loss (Ritter et al., 2009; Adenkola et al., 2009a). Vecereck et al. (2006a,b) reported death of 0.24% in broilers and 0.107% in pigs, while Voslarova et al. (2006) showed that 0.279% of turkeys transported to slaughter plant in Czech Republic died.

Environmental conditions due to transport logistics and management of animal interactions in the transporting vehicles and handling of individuals before and after transportation have different effects on animal welfare

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and health status (Ferlazzo, 2003). Indicators of welfare and stress during transportation are commonly evaluated in terms of behaviour, biochemical function, endocrine and pathological variables. They are used to assess the degree of stress during and after transportation and to achieve correct procedures for handling and transport-tation of different animal species (Ferlazzo, 2003).

The aim of the present paper was to review the effects of physiological and behavioural parameters affecting road transportation of livestock.

STRESS AND ITS GENERAL CONCEPT

In livestock production, stresses are usually conceived as a reflex response that occurs inevitably when animals are exposed to adverse environmental conditions. It has been described as the cause of many unfavourable consequences, ranging from discomfort traumatic injuries (Minka and Ayo, 2007a; Njidam et al., 2005) to death (Dantzer and Mormede, 1983; Vecerek et al., 2006a; Voslarova et al., 2007). Stress is the response of the body to extraneous stimuli that disturb the normal physiological equilibrium or homeostasis (Khansari et al., 1990; Mstl and Palme, 2002). The concept of stress embraces numerous deleterious factors, including pathogenic factor, toxic and biologically active substances and physical factors. Among the physical factors that are of great importance to livestock production world-wide are the climatic factors. Among the latter, is the ambient temperature which is particularly crucial to our local temperature environment (Ayo et al., 1996). As stress factors persist, immediate defensive responses are replaced by long-term and adaptive mechanisms (Armario et al., 2008) that either reduce the adverse effects of stress on the animal or terminate its life (Nikitchenko et al., 1988). Regardless of the severity of stress, the active response is considered to be mainly associated with activation of the adrenal-medulla and the sympathetic nervous system, whereas the passive response apparently reflects stimulation of the pituitary-adreno-cortical system (Griffin, 1989; Armario, 2006).

According to Mitchell et al. (1988), stress could be a hypothalamic-adreno-cortical phase, which is associated with neurogenic stress such as noise and transport. Combination of several stress events produce a response of the body to various extraneous factors called stress factors or stressors. The basis of the concept of general adaptation syndrome (GAS) put forward by Seyle (1936, 1977) comprises three stages, namely:

a) Mobilization (alarm reaction)
b) Resistance or adaptation and
c) Exhaustion

The first stage involves the mobilization of the defensive mechanisms, initiating the restructuring of the body control systems. The major symptoms of the first stage include secretion of the adrenal gland, high blood viscosity, hypochloraemia and increase in tissue catabolism. If the action of the extraneous stimulus overwhelms the compensatory ability of the body's defensive mechanisms, the reaction results in death of the animal. If not, this reaction terminates at the second stage of GAS called the stage of resistance or adaptation, characterized by the discharge of secretory granules of the adrenal gland. Haemodilution and hyperchloraemia occur, while anabolism prevails in the tissue with a tendency towards regaining body weight. If the action of the extraneous stimulus is prolonged, the compensatory ability of the body may be overwhelmed and GAS enters into its final stage-exhaustion. At this stage the symptoms of alarm reaction reappear, which are now deleterious to the body. GAS concept explains the mechanism of the increase in the resistance of the body to the action of an extraneous (suprathreshold) stimulus (Panin, 1983; Danilevsky, 1991).

In the daily life of the animal, stress could be either eustress or distress. Eustress and distress are closely interwoven and they are essential for existence and productivity of livestock. Thus, if the strength of the stress factor is not excessive that is, suprathreshold, the stresssor could favour animal adaptation and enhances increased productivity (Seyle, 1977; Panin, 1983). The rate at which various stress factors affect animals varies with respect to species, breed of animals and period of the day (Adenkola and Ayo, 2006; Adenkola and Sinkalu, 2007; Adenkola and Ayo, 2009b).

In several species of animals, the major cause of stress is the ambient temperature (Ayo et al., 1996; Adenkola et al., 2009d), which may occur concurrently with high humidity (Rajesh et al., 2003; Minka and Ayo, 2007b) and other meteorological stress factors (Mittal and Ghosh, 1979; Ayo et al., 1998b).

FREE RADICALS GENERATION IN ANIMALS DURING STRESS

A free radical is any atom (for example oxygen, nitrogen) with at least one unpaired electron in the outermost shell (Karlson, 1997). It is an extremely unstable and biochemically dangerous agent. Any free radical involving oxygen can be referred to as reactive oxygen specie (ROS). Oxygen-centred free radicals contain two unpaired electrons in the outmost shell. They (ROS) are capable of either accepting or donating a free electron, and thus are, to some extent unstable and react with other molecules (Tkaczyk and Vizek, 2007). When a free radical "steals" an electron from a surrounding compound or molecule, a new free radical is formed in place (Goldfarb, 1999). The electron which is found in the inner mitochondrial membranes utilizes oxygen to generate energy in the form of adenosine triphosphate (ATP). Free radical generation is a natural consequence of living in an oxidizing environment. Cells generate small amount of free radicals or ROS while performing their normal metabolic functions (Mates et al., 1999). A free radical prefers to abstract electrons from the lipid membrane of a cell, initiating free radical attack on the cell known as lipid peroxidation. ROS target the carbon-carbon double bond of polyunsaturated fatty acids. The double bond on the carbon weakens the carbon-hydrogen allowing for easy dissociation of the hydrogen by a free radical (Halliwell and Gutteridge, 1985). A free radical will abstract the single electron from the hydrogen associated with the carbon at the double bond. In turn, this leaves the carbon with an unpaired electron and hence becomes a free radical. In an effort to stabilize the carbon-centred free radicals, molecule arrangement occurs. The newly arranged molecule is called a conjugated diene which easily reacts with oxygen to form a peroxyl radical. The peroxyl radical “steals” an electron from another lipid molecule in a process called propagation. This process then continues in a chain reaction (Halliwell and Gutteridge, 1985). Thus, a free radical causes oxidation damage to cell components (Wulf, 2002) such as lipids (Buege and Aust, 1978; Frankel, 1985; Buettner, 1993), carbohydrates (Greenwald and Moy, 1980), proteins (Staldman, 1986) and deoxyribonucleic acid (Imlay and Linn, 1986). These deleterious effects of ROS are involved in many molecular, haematological (Sumikawa et al., 1993; Avellini et al., 1995) and biochemical changes occurring during stress-induced disease conditions (Akinwande and Adebule, 2003) and adaptation (Meerson, 1986). The mechanism of damage involves lipid peroxidation which destroys cell membranes with the release of intracellular components, such as lysosomal enzymes leading to further tissue damage (Demir et al., 2003).

Elsner (1991) and Halliwell (1996) reported that external stress factors such as heat can lead to increased generation of free radicals and other ROS in the body. In heat stress, free radicals are generated in the body in such a large quantity that the natural antioxidant defense systems of the body are overwhelmed. This results into lipid peroxidation of cytomembrane and consequently, cell damage and destruction (Freeman and Crapo, 1982; Meerson, 1986). A free radical can initiate many reactions which are damaging, if the free radical “quencher” is not available to stop it (Wulf, 2002; Akinwande and Adebule, 2003; Powers and Jackson, 2008). In living organisms, the ravaging effect of oxidative free radicals are “quenched” by antioxidants, which may be enzymatic and non-enzymatic (Buettner, 1993; Halliwell, 1996).

TRANSPORTATION STRESS IN FOOD ANIMALS

All animals reared directly or indirectly for meat are transported at some point in their lives. Often they are transported several times (Warris, 2004). The procedures for animal transportation involve many different domestic animal species and every year more than 300 million heads of livestock are transported within the European community (Ferlazzo, 2003). The transportation of poultry occurs at a rate of about 1, 000, 000 individual journeys per year in the United Kingdom alone (Freeman, 1984). In Nigeria, many food animals are transported daily by road from the neighbouring countries of Chad, Niger and Cameroon and from the Northern to Southern states of Nigeria for slaughter (Ayo and Oladele, 1996). The procedure of loading and unloading animals into and out of transport vehicles can have severe effects on the animals (Tarrant and Grandin, 2000). These effects vary considerably by species and they are revealed in part by the responses of the animals to loading procedures (Broom, 2000). In most efficient loading procedures, sheep are not generally affected adversely, cattle are sometimes affected, pigs are always affected and poultry which are handled by humans are always severely affected (Broom, 2000).

Road transportation is generally considered to be stressful to animals (Rajion et al., 2001; Giovagnoli et al., 2002; Buckam Sporer et al., 2008a; Adenkola and Ayo, 2009a; Adenkola et al., 2009c; Adenkola et al., 2009e). The stress may be more or less severe depending on a number of factors such as crowding, temperature, feed and water deprivation and length of travel (Dalin et al., 1993; Ritter et al., 2007; Adenkola et al., 2008; Adenkola et al., 2009a). Transportation disrupts normal patterns of feeding and drinking in animals. It is associated with exposure to novel environments, sometimes involving mixing with unfamiliar and closely confined animals, noise, vibration and extremes of AT and humidity (Warris, 2004).

Transportation affects the susceptibility of animals to infection. This is because exposure to stressors during transportation is associated with a reduction in the function of the immune system of animals. This effect is largely mediated through the hypothalamo-adreno-cortical system, the secretion of corticosteroid hormones, suppressing the immune response (Warris, 2004). Derkersen (2004) observed that long distance transport of horse commonly results in respiratory diseases and therefore, causes failure of the respiratory defense. Horses undergoing 24 h of transportation in hot, summer conditions showed physiological responses that induced changes in stress indices, serum metabolites, dehydration and immune indices, body weight and rectal temperature (RT). However, the metabolite responses appeared to be minimal compared to those in moderately exercised horses and was limited to the period of transport (Stull and Rodiek, 2000). An important stressor in horse transported by road is disruption in balance preservation (Giovagnoli et al., 2002). Isolation has also been identified as a possible source of stress during transportation as observed by Warran and Cudderford (1995). McAfee et al. (2002) and Mills and Davenport

(2002) demonstrated that the use of stable mirror can reduce the incidence of stereotypical behaviour in the horse transported by road by creating a surrogative companionship. Kay and Carol (2009) compared behavioural and physiological responses of horses travelling alone, with a live companion or with a mirror and concluded that isolation during transportation in a trailer can be associated with behavioural and physiological signs of stress and recommended that horses should be tran-sported with a live companion in the form of a travel mirror is preferable to transporting horse alone.

Friend (2000) characterized progressive dehydration, stress responses and water consumption patterns of horses transported long distances in hot weather and reported that mean weight loss after 30 h was greater in the penned [(57.1 kg, 12.8%) and transported (52.2 kg, 10.2%) groups than in the transported/watered (20.7 kg, 4.0%) and penned/watered (17.0 kg, 3.5%)] groups. He showed that transporting healthy horses for more than 24 h during hot weather and without water causes severe dehydration and that transporting for more than 28 h even with periodic access to water is, apparently, more harmful due to increasing fatigue. It was also observed that respiration rate (about 50 per minute) was the most efficacious measure of risk from dehydration and heat. Friend (2001) reviewed the literature on transportation of horses and concluded that horses show extreme dehydration after 28 h of transportation in hot and humid conditions. Watering horses on board trailers alleviates dehydration, but fatigue become extremes after 28 h of transport. The report of Kannan et al. (2000) showed that goats did not endure transportation stress well, especially if the journey is long and exhausting. It was also observed that goats become susceptible to respiratory infections after prolonged journeys under adverse weather conditions and the physiological responses began to increase within 3 h after transportation. Frank and Smith (1983) and Knowles (1995) observed an increase in incidence of infectious diseases in transported calves. This was attributed to pathogens. Long transportation of food animals without water and feeds, which occurs very often in the hot-dry period of the year in Nigeria, is accompanied by drastic loss in body weight (Ayo et al., 1996). Adenkola et al. (2009a) showed that pigs transported for 4 h loss 19.50% while those administered with ascorbic acid loss 7.29% indicating that ascorbic acid was able minimize loss often encountered with road transportation of livestock. Atkinson (1992) reported that dehydration occurs in transported calves and that keeping them in lairage may help in their recovery. Baldock and Sibly (1990) observed that placing ewes in a stationary trailer had no effect on heart rates, but transportation of ewes for 20 min in the trailer produced an increase of 12 beats per minute.

Barrior et al. (1993) found out that young pigs that are usually transported from breeding to finishing farms are exposed to changes in housing system, diet and social regrouping. It takes the animal about 6 to 9 days before the metabolic rate is normalized. An increase in high energy intake was observed during transport, and this favours a higher feed intake. Mortality due to transportation in pigs increases as the day-time temperature rises. Strong sunshine appears to increase the number of death in the transported pigs (Vecerek et al., 2006a). Adenkola et al. (2008) reported that rectal temperature recorded during 8-h and 4-h journey (Adenkola et al., 2009a) increased significantly in transported pigs, but the effect was less in experimental pigs administered with ascorbic acid during the harmattan season and thus concluded that road transportation imposes stress on the pigs but administration of ascorbic acid prior to transportation ameliorates the risk of adverse effects of road transportation stress. Lambooij (2000) identified that the following conditions may be caused or exacerbated by transportation of pigs:

a) Porcine stress syndrome – An acute reaction to stress which can cause severe distress and even death.
b) Liveweight loss of 40 – 60 g/kg
c) Mortality of 0.1 to 0.4%
d) Low meat quality due to injuries, skin blemishes, loss of live/carcass weights, and change in colour/firmness/ structure of muscle, resulting in increased incidence of pale, soft, exudative (PSE) and dark and firm dry (DFD) pork.
e) Contamination which increases the incidence of Salmonellosis during loading, transport and lairage.

Manual catching, handling and loading of poultry prior to transportation to slaughter have been identified as major sources of stress and trauma to birds (Kettlewell and Mitchell, 1994; Njidam et al., 2005). Minka and Ayo (2007b) showed that road transportation of ostrich chicks for 6 h has a transient stressful effect on the birds and that the physiological parameters of rectal temperature (RT) and respiratory rate (RR) are indicators of welfare of transported ostriches. The parameters were used for on-the-spot evaluation and monitoring of the health and stress status of transported ostriches.

Crowther et al. (2003) demonstrated that the heart rate (HR) and skin temperature recorded in ostriches transported at night were significantly lower than those recorded during the day. This indicates that road transportation stress is minimal in the night, apparently due to the reduced effect of meteorological stress on the transported birds.

Warriss et al. (1997) showed that vibration in a vertical plane at frequencies likely to be encountered during normal poultry transport are known to be aversive to birds and seems unlikely to be the complete cause of the glycogen depletion seen in the “red” femoris muscle and the liver during transport of broilers. Dantzer and Mormede (1983) observed that the vibration and movement of the vehicle are unfamiliar to the animals and are therefore, likely to elicit a stress response.

Todd et al. (2000) studied effects of food withdrawal and transport on 5 to 10 days' old calves and concluded that:

Transport and food withdrawal had no obvious effects on calf hydration.

a) Food withdrawal for up to 30 h and transport for up to 12 h had no detrimental effects on the metabolism of healthy and clinically normal calves.

EFFECTS OF ROAD TRANSPORTATION STRESS ON HAEMATOLOGICAL AND BIOCHEMICAL PARAMETERS IN LIVESTOCK

Road transportation is stressful to animals and adversely effects their productivity and well-being (Nwe et al., 1996). The transported animals are often exposed to a variety of physical and psychological stimuli, many of which are novel and some are aversive (Rajion et al., 2001). Physical and psychic exertions occurring during road transportation of food animals disrupt their homeostasis and metabolism and consequently, increase activity of enzymes and hormones (Ayo and Oladele, 1996; Mstl and Palme, 2002; Adenkola et al., 2009b). Also Bauer et al. (2001) and Saunders and Straub (2002) demonstrated that many stressors induced the activation of the autonomic nervous system as earlier reported by (Spencer et al., 1984) with the pituitary-adreno-cortical system also playing an important role in the modulation of stress response (Armario, 2006).

Plyaschenko and Sidorov (1987) reported an increase in adrenal cortical activity in pigs transported by road by demonstrating an increase in blood level of 11-hydroxycorticosteroids (11-oxy) 30 min after the onset of transport. In a recent study, Odore et al. (2004) observed the activation of the hypothalamic-pituitary-adrenal axis and the catecholaminergic system in long-term transporttation of calves by road. They observed a rise in blood hormone levels, lymphocyte, glucocorticoid and β-adrenergic receptor, cortisol and catecholamine concentrations. The increased values, however, returned to normal at 24 h and one week after arrival. Adenkola et al. (2009b) demonstrated that road transportation induced leucocytosis, neutrophilia, lymphocytosis, eosinophilia in control pigs that were not supplemented with ascorbic acid while total protein, alkaline phosphatase, aspatate amino transferase and neutrophil lymphocyte ratio was found to decrease significantly in pigs administered with ascorbic acid as compared to control group after 4-h of road transportation during harmattan season in Northern Guinea Savanna zone of Nigeria in pigs. This finding indicates for the first time the beneficial effect of ascorbic acid administration on haematology and serum biochemistry of pigs transported during the harmattan season. In another study, Adenkola and Ayo (2009a) reported that administration of ascorbic acid prior to transportation of pigs is beneficial as it protects the integrity of the erythrocyte membranes in experimental pigs following road transportation and thus may alleviate the risk of increased haemolysis due to road transportation stress in pigs during the harmattan season. It is, therefore, recommended that ascorbic acid be administered to pigs before transportation in order to reduce the adverse effects of road transportation stress on erythrocytes. An increase in erythrocyte count, total leucocyte count, haemoglobin concentration and an elevated blood level of total cholesterol, lactic acid, total protein, beta- and gamma-globulins were obtained in pigs transported for a distance of 150 km in 3 - 4 h (Plyaschenko and Sidorov, 1987).

In the study carried out by Scope et al. (2002) in racing pigeons, it was noted that stress has an influence on some blood parameters. Although within 3 h, most values did not exceed the reference range, there was a highly significant increase in the number and percentage of heterophils and decrease in lymphocyte count. An insignificant decrease in the total leucocyte, basophil and monocyte counts was observed. The eosinophil count was not influenced by road transport stress. Kannan et al. (2003) found out that short-term preslaughter transport caused significant changes in stress responses of goats as evidenced by increase in plasma concentration of cortisol, glucose and non-esterified fatty acid, but the magnitude of cortisol and glucose responses to stressor treatment was greater in older goats than younger ones. Kannan et al. (2000) reported that physiological stress reponses begin to decrease within three hours after road transportation. It was also observed that the obtained profiles suggested that road transportation stress may have prolonged effects in goats, which could reduce their immunocompetence. Kumar et al. (2003) studied the effect of road transport stress on blood profile in Mecheri breed of sheep and found that plasma cortisol, protein albumin, globulin and glucose in sheep transported for 180 km and those transported for 410 km had a significant increase in these parameters immediately after transportation. However, the sheep had plasma cortisol and glucose decreasing significantly just to slaughter and the values still remained higher than those recorded pre-transportation. Nwe et al. (1996) reported that plasma glucose concentrations returned to base-line level at 3 h after a 6-h journey in male adult Japanese native goats. Sanhouri et al. (1992) observed that a 20-min van journey increased only plasma cortisol concentrations in goats. They also noted that in response to stress, elevation of glucose concentration was preceded by an elevation of cortisol concentration. Transportation stress has been reported to cause an elevation in plasma glucose concentration (Kent and Ewbank, 1983, 1986), primarily due to breakdown of glycogen in the liver (Murray et al., 1990).

Kannan et al. (2002) observed that the rate of decline in glucose concentration over time was greater in feed-deprived goats than those fed in holding pens and that the overall plasma creatine kinase activity peaked at 7 h before reaching a lower level at 14 and 21 h holding. Vigorous physical activity, such as herding, loading and unloading procedures are more important in determining plasma creatine kinase activity than transportation or feed deprivation (Kannan et al., 2000). Broom et al. (1996) and Kannan et al. (2000) observed that loading animals into a transport trailer markedly elevated plasma cortisol concentration in sheep. Apple et al. (2005) observed a dramatic increase in cortisol and glucose concentration in transported pigs over non-transported pigs, while cortisol increased during the first 30 min of transportation and remained elevated above the non-transported group throughout the duration of transporttation stress.

Perez et al. (2002) and Apple et al. (2005) noted an increase in lactate concentration in transported pigs. Plasma cortisol and corticotrophin concentration increased after loading pigs into vehicles by two-fold and more than three-fold, respectively after one hour of transportation in stress-susceptible, but not in stress resistant pigs (Spencer, 1995). After prolonged transportation of pigs, considerable increase occurred in the activity of aspartate aminotransferase, alanine aminotransferase and aldolase. The aldolase activity returned to normal after 8 h and the other two enzymes after 24 h. Also, activities of creatine kinase, aspartate aminotransferase and lactate dehydrogenase increased following transporttation of pigs (Ayo and Oladele*,* 1996; Adenkola et al., 2009b).

Knowles et al. (1999a) investigated the effects of road transportation on cattle for up to 31 h and found that plasma creatine kinase increased maximally after 26 h. High levels of cortisol were found in those animals that lie down during the journey. Plasma protein and albumin rose with increasing journey, plasma glucose increased but decreased after 21 h of transport and plasma urea increased with increasing journey time. Packed cell volume (PCV) increased during the first 12 h of recovery, but decreased after 72 h. Galipalli et al. *(*2004) observed that Tasco seaweed (*Ascophyllum nodosum)* supplementation increased antioxidant activity and immune responses following road transportation in goats. They showed that plasma cortisol and glucose increased due to transportation, but decreased significantly after holding and that plasma creatine kinase activities and neutrophil count increased. Although lymphocyle count decreased significantly during the transportation, eosinophil and monocyte counts were not influenced by transportation stress.

Stull and Rodiek (2000) investigated the physiological responses of horses to 24 h of transportation using a commercial van during summer conditions in a study carried out in four consecutive days. They reported that the total leucocyte count showed a progressive increase with duration of travel and peaked at the termination of transport. The measurement of dehydration as an index of haematocrit and total protein during transport showed that the values increased during the journey and they returned to base-line during the post-transport period. Serum concentrations of lactate, creatine kinase and aspartate aminotransferase increased during transport and in the early post-transit period, but returned to base-line concentration at the end of the 24 h post-transport period. Plasma cortisol and neutrophil: lymphocyte ratio increased with duration of transit and returned to base-line values during the post-transport period. The effect of road transportation was investigated on rough and smooth journeys. The results of the study indicated that there was no significant difference between the mean plasma levels of creatine kinase and lactate dehydrogenase, but the level of cortisol was significantly higher during transportation on the rough journey than during the smooth journey (Ruiz-De-la-Torre et al., 2001).

Sprinongkote et al. (2003) studied the impact of a diet fortified with L-lysine and L-arginine on the plasma levels of cortisol in road transported pigs. In the pigs with L-lysine and L-arginine fortified diet, they observed lower plasma levels of cortisol than in those pigs with a diet without the addition of L-lysine and L-arginine. The behavioural results indicated a reduction in stress-induced anxiety in pigs fed with L-lysine and L-arginine. Kim et al. (2004) studied the differing levels of glucose concentration in the blood, creatine kinase and lactate dehydrogenase as indicators of road transportation stress in pigs. The concentration of glucose, creatine kinase, and lacate dehydrogenase increased after loading and declined to the resting level after lairage. The concentrations of creatine kinase and lactate dehydrogenase were greater in the 3 h compared to the 1 h transportation group. Saco et al. (2003) ascertained the impact of the journey duration on pigs transported by road on the acute phase protein and cortisol levels. They reported that short-duration transport did not modify the levels of acute phase proteins, whereas cortisol increased just after transport. After long-duration transport, acute phase proteins in serum increased and cortisol levels did not increase. They, therefore, postulated that the combination of acute phase protein and cortisol levels could provide valuable information on the welfare problems related to transport.

EFFECT OF ROAD TRANSPORTATION STRESS ON BEHAVIOURAL ACTIVITIES IN LIVESTOCK

Behavioural changes are often the first sign of distress (Ayo et al., 2002). Animal behaviour is one the most important mechanisms of adaptation. As stress factor persists, immediate defensive responses are replaced by long-term and adaptive mechanisms that may either reduce stress on the animal or terminate its life (Ayo et al., 2002).

The behavioural responses of livestock during transporttation are diverse and most are dependent on the stimuli perceived. The greatest stress is induced by handling and the start of a journey, which activate the sympathetic nervous system, including the adrenal medulla and the adrenal cortex (Grandin, 1997; Fazio and Ferlazzo, 2003).

Crowther et al. (2003) reported that ostriches transported during the period of darkness chose to sit, which was attributed to diurnal or nocturnal responses or simply an instinctive reaction to darkness. Minka and Ayo (2008) studied the behavioural responses of ostrich chicks transported by road for six hours during the hot-dry season in Northern Nigeria. They reported that during road transportation and four-hour post-transportation period, the percentage numbers of ostrich chicks observed to exhibit the behaviour of standing, pecking and urinating or defaecating were higher than those of the pre-transportation values. It was also observed that the number of visits made by ostriches to drinkers' post-transportation period doubled that of the pre-transportation, suggesting that 6-h road transportation during the hot-dry season was stressful to the ostrich chicks.

In the study carried out by Chandra and Das (2001), on the handling and short-haul road, eliminative behaviour measured as an indication of the nervousness of the animals, was evident from the high frequency of urination and defaecation and this was more pronounced during loading than unloading. Ayo et al. (2006) demonstrated that goats transported for six hours during the hot-dry season in Nigeria had lower excitability score post-transportation, indicating that road transportation induces considerable stress manifested in the depression of higher cortical functions. Adenkola et al. (2009d) reported that road transportation durring harmattan season induced considerable stress followed by depression as evidenced by a lower excitability score recorded post-transportation in control pigs. The administration of AA pre-transportation resulted in the maintenance of excitability of the central nervous system in the experimental pigs following road transportation. The results demonstrated for the first time the beneficial effect of AA administration on excitability of pigs transported by road during the harmattan season for long journey of 8-h.

Maria et al. (2004) reported that loading was more stressful than unloading in cattle as this was evidenced by the animal behaviour-mounts and bouts of fighting were infrequent and balks and fall were significantly more frequent during loading than unloading. Brown et al. (1999) showed that pigs transported for 8-h and 16-h seemed to have longer sessions of feeding, while those transported for 8-h fed and drank at the beginning of the lairage period and for a short time at the end. The group transported for 16-h fed and drank at the beginning, in the middle and at the end of the lairage period. The control animals fed and drank, apparently, at random interval throughout the 6-h recovery period. The behavioural patterns of the pigs transported for 24-h were similar to those of control pigs, except that the control pigs spent a lot more time standing up. This indicated that the transported animals were subjected to nutritional stress, that is they were hungry and thirsty, particularly those transported for 24-h.

Aoyama et al. (2003) showed that differences exist in stress response to transportation in goats. They observed that feed intake following transportation in goats decreased in those given 5α-dihydrotestosterone compared with those on basal session, which were not transported. They then postulated that ingestive behaviour may have some relationship with androgen induced inhibition of hypothalamo-pituitary axis response. Atkinson (1992) investigated the effects of transport and resting behaviour of calves for export. He noted that the average number of calves that slept throughout the observation was low compared to those recumbent. The number of those asleep decreased during the lairage period. The values were higher for similar calves than for the larger group at each observation.

Eicher (2001) in his review on transported dairy cattle reported that during transport, adult cattle stand more, but lie more during the recovery period. He also reported that young calves exhibited less physiological stress with transport, but succumbed to post-secondary mortality, which is correlated with age at transport. The duration of the journey has a greater impact than the distance and after long transport most animals drink and then lie down. Therapies during and following transport showed that water and electrolytes are important. Cockram et al. (2000) transported sheep for 16 h and concluded that the lower post-transport feed and water intakes in a novel environment did not have a significant effect on the ability of sheep to recover from the feed and water deprivation associated with transport. Road transportation of food animals for the purpose of marketing and slaughtering for meat in abattoirs is found to be associated with different forms of injuries in transported animals (Njidam et al., 2004; Minka and Ayo, 2007a). The welfare conditions of animals during the transportation period are the most important factors, possibly influencing the level of stress burden of transported animals. Failure to maintain the recommended welfare conditions during transportation has a significant impact on the increase of stress burden in animals before slaughter in the slaughter house. This in turn has an impact on decision making about meat and organ edibility and also on the quality of slaughtered pig meat (Vecerek et al., 2006a). This improper handling and transportation are responsible for stress-induced meat quality problem such as shrinkage of the carcass, dark-cutting beef and damage to the carcass through bruising (Chandra and Das, 2001).

A lot of publications have appeared in the literature advancing the relationship between various stressors on carcass quality (Sykes and Fatahftah, 1986; Meilnik and Kolstad, 1991; Awonorin and Ayoade, 1995). The energy required for muscle activity in the live animal is obtained from glycogen in the muscle. In the healthy and well-rested animal, the glycogen content of the muscle is high. After the animal has been slaughtered, the glycogen in the muscle is converted into lactic acid, and the muscle and carcass becomes firm (*rigor mortis)*. This lactic acid is necessary to produce meat which is tasteful and tender, of good keeping quality and good colour. If the animal is stressed before and during slaughter, the glycogen is used up and the lactic acid level that develops in the meat after slaughter is reduced. In specific terms, stressors accelerate post-mortem glycolysis by causing an accumulation of lactic acid in the muscle tissue and subsequently the decline in muscle pH below 5.4, while the carcass temperature is about 38°C with consequent, high drip losses, decreases in water holding capacity and protein denaturation (Lawrie, 1966). Indeed, water holding capacity is of major importance economically for the following reasons:

a) Lost of water from meat affects its mass and meat consumption.
b) Nutrients such as the water soluble vitamins are lost in the drip (Awonorin and Rotimi, 1991).
c) Tenderness, juiciness, firmness and colour are greatly reduced and these affect the overall acceptability of the meat.
d) Storage stability decreases due to oxidation rancidity.

Awonorin et al. (1999) studied the effects of pre-slaughter exercise of broiler chickens on carcass quality and concluded that stressful conditions cause increased live-weight losses and a subsequent reduction in the moisture content and dressed carcass yield. It also decreased water holding capacity of the carcass. It was noted that thiobarbituric acid value increased significantly and this may decrease the duration of storage.

Broom (2000) reported that measurement of injuries, bruises, mortality, morbidity and carcass quality can be used as indicators of welfare during handling and transport. He also showed that mortality records give information about welfare during the journey, while bruises, scratches, blemishes, broken bones and incidence of pale soft exudates (PSE) and dark, firm, dry (DFD) pork and dark-cutting beef or lamb provide information about the welfare of the animals during handling, transport and lairage.

Warris (1996), Vecerek et al. (2006a) and Voslarova et al. (2007) observed that economic losses incurred during transportation of animals are due to mortality (particularly in pigs and poultry), carcass bruising and shrinking (loss of weight), and reductions in meat quality. Tarrant (1981) noted that DFD meat occurs regularly in pigs and it is mostly related to their welfare during transportation. Troeger (1995) reported that the level of welfare in relation to the transport of pigs to the slaughterhouse has an impact on the carcass and meat quality. It was observed that meat quality can be reduced by mechanical injury to the animals during transport and as a result of the stress burden in the pigs. The damage to the animals is reflected in veterinary decision-making about meat edibility and increases the occurrence of DFD/PSE in meat from its sensorial characteristics (Kozak et al., 2003).

In a study carried out by Schuttee et al. (1994), it was observed that worst damage is often connected with the transport conditions, which are influenced by loading and unloading, density, design of the vehicle, the manner of travelling and the length of the journey. Warris (1998a) had earlier reported that longer transportation times lead to the increased occurrence of DFD meat in pigs. Kim et al. (2004) proposed that the incidence of PSE was greatest in the high-stocking density group. It was then concluded that the medium-density stocking may be preferable to the low-density in the long-distance (8 h) transport. Apple et al. (2005) reported that there was an increased risk of PSE in pigs subjected to short-duration, but pork industry may benefit by feeding finishing diets fortified with magnesium mica. Perez et al. (2002) observed that under Spanish commercial conditions, the effect of transport time on welfare and meat quality parameters was more than genotype and sex in pigs slaughtered immediately on arrival at the slaughterhouse after 3 h road transportation. This is because transport of 3 h might have allowed the animals to adapt to transport conditions and then could act as a resting period like a lairage time. Kannan et al. (2003) reported that road transportation stress has more pronounced adverse effects on meat quality in goats in younger animals than older ones, as evidenced by higher ultimate pH in the longissimus muscle and lower glycogen content in older goats. Transportation has been found to be responsible for stress-induced poor meat quality such as shrinkage of the carcass, dark-cutting beef and damage to the carcass through bruising (Chandra and Das, 2001).

Ruiz-De-La-Torre (2001) demonstrated that the pH of the meat of lamb, indicative of DFD was noticed after 24 h post-mortem examination on the carcass of lamb transported on rougher roads, but the meat of lamb transported on a smoother road had a lower pH. This suggested that rough journey to the slaughter house may have a deleterious effect on the meat quality of sheep than smooth journey. Tarrant and Grandin (2000) reported that the skill of the driver and the quality of the road appear to be more important in determining transport stress and losses in carcass value than the distance traveled. The welfare of birds during transit might be improved by using darkened vehicles (Crowther et al., 2003). Cockram et al. (2000) videotaped simultaneously activities on a vehicle during transport of sheep and determined that “driving style” had a major influence on the welfare of the animal, especially the risk of injury through the accelerations caused by breaking, cornering and various other driving events and the manner of the driving performance. Bradshaw et al. (1996) and Warriss et al. (1998) reported that duration of the journey is an aspect of transport that can have negative effects on the welfare and meat quality of pigs. Perez et al. (2002) studied the effect on transport time on welfare and meat quality in pigs. They found out that pigs subjected to short transport (15 min) showed a more intensive stress response and poorer meat quality than those subjected to moderately long transport (3-h), when they were immediately slaughtered on arrival at the slaughter house. Long transport (over 8-h) resulted in decreased tenderness score in muscles. However, reducing transport duration seems to be a viable way of optimizing veal qualities, including sensory traits and colour (Fernandez et al., 1996). Gispert et al. (2000) has demonstrated that genotype has influence on susceptibility to transport stress, deaths and meat quality, particularly in pigs and poultry, carcass bruising and shrinkage (loss of weight and reductions in meat quality). Cannon et al. (1995) reported that testing pigs prior to transport decreases the mortality rate from production facility to the packing plant and that short period of fasting prior to transport of pigs resulted in improved meat colour, firmness and water holding capacity. It was also shown that fasting pigs after transport (before slaughter) can increase pH, meat colour intensity and water holding capacity of pork. According to Cannon et al. (1995), the disadvantages of fasting prior to slaughter include decreased carcass yield and increased incidence of DFD muscle in pork.

CONCLUSION

Road transportation of livestock is very stressful; the impaired homeostatic mechanisms associated with road transportation may be ameliorated by antioxidant administration and thus reduced economic losses incurred due to road transportation of livestock.

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