OSTRICH WELFARE AND TRANSPORT
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Original paper to Ratite Science Newsletter from the book Chapter “Ostrich welfare” In The Ostrich Biology Health and Production. Ed.CABI.

ABSTRACT Climate.

The ostrich is obviously extremely well adapted to the climatic environments prevailing in the African regions in which the species is indigenous and tolerates well hot arid conditions and cooler wet subtropical zones (Sauer and Sauer 1966b). Stewart (1994) asserts that the birds are very hardy and “can be successfully bred and reared in environmental extremes from desert heat to winter snows.” Indeed other authors assured of the hardiness and adaptability of the species suggest that this is an important reason for the global expansion of ostrich farming and that the birds will thrive under extreme conditions (Shanawany 1996) and that adults can be safely kept outdoors throughout the year in climates such as that encountered in the United Kingdom if basic shelter is provided (Moody 1992). Other studies express concern over the effects of extreme climatic conditions on ostriches of all ages (Hagen and Hagen 1996; Samson 1996; Deeming 1997) and this is perhaps prudent in view of the meteorological differences between some of the regions actively involved in ostrich production e.g. Texas (Duewer et al 1994) where a hot dry climate is found and Canada (Samson 1996) and Sweden (Jansson et al 1996) where very cold winters may be experienced. The suitability of the UK climate for ostrich farming has been questioned (Bertram 1993). Certainly production e.g. growth, may be affected by the climate (Samson 1996) with marked depressions (13-24%) observed in the winter season in one study undertaken in Indiana (Angel 1996) where the annual min-max temperature range was 20°C (-14.4 - +34.4°C). It is not known if the thermal challenges presented to farmed ostriches in the Northern hemisphere constitute a threat to the welfare of the birds and surprisingly little research has addressed the problem. In this context it has been suggested that in the absence of definitive scientific evidence caution should be exercised and the colder, wetter climates of Europe and perhaps North America should be regarded as potentially deleterious to the welfare of ostriches unless proper management of the birds is practiced (Bertram 1993).

The thermoregulatory physiology and behaviour and adaptability of the ostrich should be considered to facilitate the objective analysis of the risk to welfare of the range of climates and thermal microenvironments encountered in commercial production and transportation (see below). The ostrich, the largest living bird with a body mass of up to 120 kg., naturally inhabits areas with hot, arid climates an faces the same thermoregulatory problems as large animals of other classes under such conditions. Whilst birds are generally considered to have higher body temperatures (in the range 39-43°C) than mammals, seven orders contain species with core temperatures in the range 37-41°C (Phillips et al 1985). Four flightless orders, the Sphenisciformes, Apterigiformes, Casuariiformes and Struthioniformes, the latter being the ostriches, have body temperatures below 40°C and in the range of the eutherian mammals. Normal body temperature of the adult ostrich (body weight 100 kg.), measured in the rectum, is 38.3°C (Whittow 1976). The natural, daily fluctuation or rhythm in body temperature in birds is dependent upon size and in this largest of the class is less than 1.0°C. The highest environmental temperature for thermoneutrality is 20°C (Skadhauge 1981). The ostrich exhibits a comprehensive repertoire of behavioural and physiological thermoregulatory strategies. In the birds will tend to sit and/or cover the legs with the wings to reduce heat loss and will alter
ptiloerection (feather fluffing) to improve insulation (Stewart 1994) and will shiver if body temperature starts to fall. During episodes of high environmental temperatures the wings are elevated to expose thermal windows of unfeathered skin to enhance convective and radiative loss and in extreme heat stress (e.g. when air temperature exceeds body temperature) ptiloerection is employed to increase insulation against heat gain (Calder and King 1974). Indeed an increase in insulative thickness of 7cm has been measured in adult ostriches during heat stress which may also reduce gain from incident radiation in direct sunlight (Calder and King 1974).

Infrared thermography indicates that the ostrich employs the beak, neck, lower leg, feet and toes to specifically regulate heat exchange (Phillips and Sanborn 1994). Over a range of environmental temperatures from 0-27°C the ostrich was able to regulate surface temperature better than other ratites and could dissipate up to 40% of their metabolic heat production through these which represent only 12-17.5% of body surface area. The large wings of the ostrich, despite being flightless, also provide a valuable thermal exchange surface during exposure to high temperatures. The most obvious response to exposure to elevated environmental temperatures is panting and gular flutter which increase respiratory evaporative water loss and therefore heat loss (Calder and King 1974; Sturkie 1976). Osmoregulation and thermoregulation are closely linked and the ostrich is well adapted in the co-ordination of these sometimes conflicting demands (Skadhauge 1981; Skadhauge et al 1996). Potent water reabsorption in the intestinal tract and kidney conserve water which may be used in evaporative cooling. The relative amount of evaporative loss from birds decreases with body size and metabolic rate $E_\text{water per day} = 0.432 \text{ body weight}^{0.585}$ (Skadhauge 1981) and is least in the ostrich where it represents as little as 360g per day or 0.4% of body weight, compared to 20% in a 100g. bird or 60% in a 10g. bird (Skadhauge 1981).

A more recent study has suggested that the relationship between total evaporative water loss (TEWL) and body mass may be higher than previously suggested but that birds from arid environments, including the ostrich, have a statistically lower TEWL than those from more mesic environments (Williams 1996). The emphasis on water conservation in the ostrich is hard to reconcile with the observation that the naked neck epidermis of the ostrich has poor “waterproofing” and does not constitute an effective barrier to water loss (Menon et al 1996). It was argued that in birds relying on cutaneous water loss (CEWL) for thermoregulation the presence of such a barrier would compromise heat loss, however, the ostrich has such effective respiratory evaporation by panting (REWL) that CWL may not be important during moderate heat stress. Indeed in a fully hydrated, adult ostrich at environmental temperatures up to 35°C all significant evaporation is respiratory and REWL represents 98% of TEWL (Farner and King 1974). In severe heat stress, particularly if air temperature exceeds body temperature (Ta > 40°C), CWL may become more important but a 100 kg. ostrich is capable of evaporation (TEWL) 11.0g of water per minute under these conditions which is 100% of the heat dissipation and will adequately regulate deep body temperature (Calder and King 1974; Whittow 1976; Skadhauge 1981). So effective are the thermoregulatory mechanisms in the ostrich that “true hyperthermia”, where body temperature is regulated 2-4°C above the normal value, is rarely seen in these birds (Calder and King 1974). It has been demonstrated that in chronically dehydrated ostriches exposed to heat stress panting rate (-48%) and REWL are reduced and body temperature rises by 3.1°C (Skadhauge 1981).

In this context it is interesting that the ostrich can withstand dehydration producing a fall of up to 25% in body weight although their thermoregulatory capacity was markedly compromised
Healthy ostriches drink relatively large amounts of water but during periods of water deprivation the kidney conserves water by producing an extremely concentrated urine excreting urates (Levy et al 1990). A thick viscous urine is produced within two days of water withdrawal and no fluid is excreted after three days.

In many birds the thermal polypnea (panting) during heat stress may lead to excessive pulmonary ventilation and acid-base disturbances, specifically hypocapnic alkalosis due to loss of carbon dioxide (Phillips et al 1985). Even in severe heat stress there is minimal alteration in arterial pCO₂ in the ostrich indicating that most of the ventilation is acting in thermoregulation and little is passing over the gas exchange surfaces of the lung (Phillips et al 1985). This may also lead to small reductions in oxygenation. Ostriches thus rely upon active heat dissipation during thermal stress rather than heat storage which is employed by many other animals for purposes of water conservation (Calder and King 1974). This may be illustrated by a simple calculation. If we assume that the specific heat of ostrich tissue is 3.347 Jg°C⁻¹ then for a 100 kg. ostrich, if body temperature rose 3°C in 3 hours, then the heat storage would be 93 watts or 82% of total metabolic heat production. If the latent heat of vaporisation of water is 2.41 kJg⁻¹, then the bird would save 417 ml of water. The option selected in the evolution of the ostrich is to employ this water to lose the heat and to maintain a very stable deep body temperature. In the above conditions and if heat stress persisted over many hours then addition of the basal water loss and the demands imposed by thermoregulation indicate that the bird would require 4-5 litres of water per day.

It may thus be concluded that ostriches will thermoregulate extremely well in the face of a wide range of environmental temperatures but that in the event of heat stress adequate hydration must be ensured to minimise the risk of hyperthermia. If hot weather is expected then farmed ostriches must be allowed ad libitum access to clean, fresh water. In addition, in an animal relying heavily upon evaporative cooling the ambient humidity is an important factor as the efficiency of evaporation depends upon the gradient of water vapour density between the evaporating surface (e.g. the respiratory tract) and the air (Mitchell and Kettlewell 1998).

If humidity rises this may impair evaporative heat loss and induce hyperthermia. Artificial environments should be ventilated with a view to removing water vapour as well as heat. When considering the thermal environment of ostriches in commercial production, particularly in closed sheds or during transportation, then ventilation rates have to be calculated upon a sound scientific basis. A starting point may be a knowledge the standard or basal and total metabolic rates (SMR, BMR or TMR) of the birds from which the mass air flows required to dissipate the heat load may be calculated. Estimates of SMR in ostriches are often based upon empirical relationships between body mass and heat production or oxygen consumption (Calder and King 1974) yielding values such as 114W for a 100 kg. bird (Whittow 1976).

Other studies (Withers 1983) using measurements of oxygen consumption suggest that the BMR of the ostrich is best described by ml oxygen per hour = 389 kg.0.73 which indicates that the basal heat production of a 100 kg. ostrich is about 62W or 54% of that predicted from previously established relationships for nonpasserine carinate birds. The TMR in active fed birds may be at least 2-3 times the basal value as suggested by McKeegan and Deeming (1997). This is confirmed by calculation of the BMR of a 88.5 kg ostrich from the equation of Withers (1983) which gives a value of 57W and comparison with measures of field metabolic rate (FMR) in birds of this size made by Williams et al (1993) who reported a energy metabolism of 18040 kJ per day which equates to 209W (3.7 fold basal). Ventilation rates can therefore be
calculated from \( \text{Flow rate (m}^3\text{ s}^{-1}) = \) the effects of climatic conditions on the behaviour of captive adult ostriches in a European system (Deeming 1997, 1998). The major finding of time-budget analysis was a behavioural response to periods of rain during which birds of both sexes greatly increased the amount of time sitting at the expense of pacing and other behaviours but not feeding or foraging when compared to dull, bright or sunny conditions.

These results could have important welfare implications for commercial production in countries such as the UK as the birds exhibited a propensity to sit out in rainy weather rather than seeking shelter and could thus be adversely affected by wetting during cold conditions (Deeming 1997). As ostriches lack a preen gland and thus may have poor waterproofing of the feather cover, then this may lead to a major disruption of the insulative properties of the plumage during wetting. This is known to increase heat loss markedly and cause profound hypothermia especially in conjunction with air movement, in other birds (Mitchell et al 1997). In the winter, captive ostriches have to feed and forage at a higher rate than in spring or summer to maintain a higher energy intake to support thermoregulation (Deeming 1998).

The provision of a diet (\textit{ad libitum}) with a higher energy content or concentration may be benificial particularly in episodes of very cold (and wet) weather under Northern European or North American conditions. It is also recommended that ostriches be brought into shelter during prolonged periods of rain particularly in cold European winters (Deeming 1997, 1998). Shelters should be capable of accommodating all birds in an enclosure and a space allowance of 10m\(^2\) per bird has been proposed (Council of Europe T-AP (94) 1997). 

Total heat loss from animals (kJ s\(^{-1}\)) / dT \times c_p \text{ where } dT = \text{ the acceptable temperature rise (°C) and } c_p = \text{ the specific heat capacity of air (kJ kg}^{-1}\text{C}^{-1}\text{) and assuming a density of air of 1.183 kg m}^{-3}. \text{ Thus for 100kg captive ostriches with a metabolic heat production of 160W an airflow of 0.134m}^3\text{ would be required for a 1.0 °C acceptable rise in air temperature. Such information is extremely important in the development of controlled artificial environments for ostrich production and transportation in order to match conditions to the birds biological requirements and to minimise stress and improve welfare.}

In addition to the physiological and metabolic responses relating to the climatic environment the behavioural aspects should also be considered. Only two studies have attempted to examine.

In temperate and cool climates the failure to provide appropriate shelter in winter may constitute a serious compromise of the welfare of farm reared ostriches. The climate and the artificial thermal micro-environments to which ostriches are exposed in commercial systems may affect both welfare and productivity. Whilst the ostrich is physiologically well adapted to survival in a wide range of environments this is dependent upon the birds being able to exploit their full repertoire of behavioural and physiological responses. These factors should be taken into consideration when housing and transportation designs are implemented. The birds should be able to express behavioural responses to heat and cold, such a seeking shelter, which should therefore be available (Moody 1992), and have the freedom to use wing spreading and postural changes to increase heat loss when appropriate e.g. during transportation or holding in indoor pens. If heat stress is likely then a fresh water supply is essential. Future improvements in ostrich production systems and environments aimed at increasing welfare standards should be based upon a sound scientific knowledge of the basic physiology and behaviour of the birds.