EVALUATION OF ENGLISH AND ZEBU CATTLE TYPES RELATED TO CLIMATIC ORIGIN[1]

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ABSTRACT: Cattle of the British Isles (English) are generally better adapted to a temperate-climate whereas the cattle of India (Zebu) are better adapted to a tropical environment. An understanding of the relationships between climate of origin and physiological and performance differences between the English and Zebu cattle types can give useful information when cattle are moved to other environments. Differences have been reported in heat tolerance, responses to heat stress, ration utilization, reproductive performance and insect tolerance or resistance. These particular differences are directly related to the differences in the climates of the British Isles and the Indian subcontinent.

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Introduction

Many studies have evaluated the differences between Bos taurus and Bos indicus cattle. These studies have evaluated both the physiological and performance differences between the two species (Howes 1963; Bianca 1965; Moore, Essig and Smithson 1975; Turner, 1980). However little has been stated about these differences as related to their respective climates of origin. Because animals are adapted to their environment of origin, the relationships between climate of origin and physiological and performance traits may reveal important information for the evaluation of these species in other environments. The objective of this paper is to discuss the physiological and performance differences between B. taurus cattle originating in the British Isles (English) and B. indicus cattle originating in the Indian subcontinent (Zebu) as related to the climatic origin of the two groups.

An animal can be said to be adapted to a particular environment when it possess functional, structural or behavioral traits that favor its survival, performance (growth and/or milk production), or reproduction, especially in an extreme or adverse environment (Curtis 1983). It is expected that the incidence of these adapted traits would increase over time in a constant environment. However the selection pressures exerted on the English and Zebu types have not been the same, likely resulting in different rates of occurrence of these traits. In recent history selection pressure on English cattle has been man induced in that humans have attempted to increase the frequency of genes useful to himself through artificial selection. Zebu cattle, being 'the sacred cattle of India' (Briggs 1958), likely have had more natural selection pressure exerted on the population. However, in both populations the genes favoring adaptation would tend to increase in a constant environment whereas the frequency of unfavorable genes would tend to decrease. Because the selection

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intensities on the two types have differed in recent history, the rate of change has not been equal. This difference in the rate of change in the gene frequencies of the two populations may be of some importance in evaluating the climatological influences involved; however, it is beyond the scope of this paper to investigate these factors.

Prehistorical and Historical Origin

The genetic relationship between English and Zebu cattle types is crucial for understanding the influence various environmental factors have on the adaptive processes. However, both the ancestry of cattle and the time of their original domestication are obscure, and various writers on the subject differ in their interpretation of the existing information.

Fossil remains of prehistoric wild cattle have been found only in Europe, Asia and Africa. Numerous fossil remains of one important wild cattle species, *B. primigenius*, have been found over a wide region in western Asia, northern Africa and continental Europe. Such a wide ranging species is likely to have had a large number of geographical races that would have merged into each other as a cline, but these are difficult if not impossible to recognize from fragmentary osteological remains (Clutton-Brock, 1981). There is, however, some evidence for geographical variation in the coat color as can be seen in the Palaeolithic rock painting of different regions (Clutton-Brock, 1981). While there still exists some controversy, it has generally been concluded that both European and Zebu cattle descended from *B. primigenius* (Muntzing, 1959; Isaac, 1970). Many incorrect assertions were made earlier due to a failure to recognize the sexual dimorphism for size of *B. primigenius*. Archaeologist and zoologists interpreted the remains of bulls and cows as coming from different species (Clutton-Brock, 1981).

Remains have been found in Europe from the Neolithic and they are generally called *B. longifrons*, which were of small size (Zeuner, 1963). As, however, the remains of *B. longifrons* have never been found in deposits earlier than the Neolithic it may be safely assumed that they represent domestic animals (Clutton-Brock, 1981).

If it is concluded that all cattle of Europe, Asia and Africa are descendants of *B. primigenius*, the other commonly referred to species, *B. longifrons* and *B. namadicus*, would be related (Zeuner, 1963). The last living *B. primigenius* died in 1627 (Walker, 1964). Caesar mentioned this animal as being little smaller than an elephant, but with the form and character of a bull (Mumford, 1922).

Evidence indicates the *B. longifrons*, or Celtic ox, was bred by the ancient Swiss lake dwellers (Mumford, 1922; Zeuner, 1963). From this species came the Shorthorn (Mumford, 1922) and Jersey breeds (Zeuner, 1963). *B. longifrons* were the oxen in the British Isles until 500 A.D., when the Anglo Saxons came bringing with them animals derived from the *B. primigenius* of Europe (Ensminger, 1983). The Hungarian and Podolian steppe cattle, the Scottish Highland race and the fighting cattle of Spain all represent *B. primigenius* stock. But crossing has been practiced to such an extent that the vast majority of modern breeds must be intermediates (Zeuner, 1963). In Fresian cattle, for instance, it is possible to find skulls ranging from *B. primigenius* type to characteristic *B. longifrons* specimens. It probably is no longer possible to distinguish modern European cattle according to their ancestral stock except in rare cases.

One extinct Indian form of the B. primigenius is some times treated as a separate species, B. namadicus. This is probably the ancestor of the Indian humped cattle, B. indicus, or Zebu (Clutton-Brock, 1981). This species is represented by fossil skulls found on the Indian sub-continent. The vast majority of Zebus are distinguished by bifid spinous processes of the dorsal vertebra from the seventh vertebra on (Epstein, 1971). However, this bifurcated spine can occasionally be found in European breeds (Clutton-Brock, 1981).

It can be concluded, even though there are many interpretations of the zooarchaeological record, that it is probable that English and Zebu cattle types are related through B. primigenius. Hence, many of the differences between these two groups of cattle may be related to adaptive changes in genotype.

Indian Subcontinent

The area in which the Zebu cattle adapted was the Indian subcontinent. This area is separated from the rest of the continent by the Himalayas to the north and is isolated by an ocean to the south. The Himalayas run unbroken from about 35 °N and 74 °E, southeastward to 28 °N and 87 °E and then to 29.5 °N and 95 °E. Their height is generally above 4 km and frequently above 6 km. This northern mountain wall prevents atmospheric exchange in the lower troposphere between the Indian peninsula and the higher latitudes (Rao 1981). The Western Ghats range within 100 km of the west coast of the peninsula from 21 °N 74 °E to almost the southern tip of India, and rise to heights of 1 km, causing rain during the southwest monsoon. The less continuous Eastern Ghats, on the east side of the peninsula, have only local effect on the climate (Rao 1981).

By far the most dominant weather feature over this area is the southwest and northeast monsoon. Over most of the Indian subcontinent, the southwest monsoon rainfall is of greater magnitude than rainfall during the rest of the year, so much so that the annual and monsoon isohyets are very similar (Rao 1981). The seasonal reversal of pressure gradients, and thus winds, makes the patterns of annual averages misleading (Rao 1981). The monsoon is associated with the location of the inter tropical convergence zone (ITCZ). When the ITCZ is north of India a southwest wind results over the country and a northeast wind results when the ITCZ is south of India. Throughout much of the Indian peninsula local people recognize three seasons: the hot season (March to May), the wet season (June to September) and the cool season (October to February) (Lydolph 1985).

The mean daily temperature (average of the mean daily maximum and mean daily minimum) of the central portion of India is about 25 °C during January, 33 °C during April, 30 °C during July and 27.5 °C during October with the hottest temperatures occurring in May (Lydolph 1985). The lower temperatures during June to September, when one would expect temperatures to be hottest, are a result of the influence of the moist maritime air being brought over the country during the rainy season and the resulting cloud cover. The mean daily maximum temperature is about 32.5, 37.5, 32.5 and 32.5 °C for January, April, July and October, respectively, over central India; however, temperatures have gone above 45 °C in many areas of the country (Rao 1981).

Rainfall over India is greatest along the Western Ghats and the foothills of the Himalayas. When the moist southwest winds are forced to rise over the mountains, orographic lifting takes place, resulting in large amounts of precipitation. Most areas in these mountains receive between 200 and 400 cm of rain. In the center of the country, precipitation averages about 80 cm (Rao 1981). However, the rainfall distribution during the year is very skewed. During January and February very little rain (1 to 3 cm) falls over much of India. A slightly larger amount (5 cm) tends to fall over the southern part of the country. During March to May the interior receives about 5 cm while the northwest and southern portions receive about 15 cm. During October to December about 10 cm is received in the northwest and 55 cm in the far south with most of the increase running laterally along the east coast. All other rainfall occurs during June to September (Rao 1981). Relative humidity is between 30 and 50% during all seasons except the southwest monsoon when it is usually above 80%. The wetter areas of the country usually have less than a 10% difference in humidity between morning and evening during the monsoon, but the drier areas have about a 20 to 30% difference during this period (Rao 1981).

The climate of India has it maximum temperatures during April to May and its maximum rainfall during June to September. Maximum temperatures occur just before the southwest monsoon during May, and it is not uncommon for them to be 40 °C. More rain occurs along the west coast mountains and less over the interior of the subcontinent. The relative humidity is highest during the monsoon period and is generally higher along the coasts, especially along the west coast where much rainfall occurs.

British Isles

In contrast to India, the climate of the British Isles is controlled by the westerlies. Sixteenth-century descriptions of the climate commonly included adjectives such as 'mild' or 'piercing'. This reflects that the sensations experienced while outside depend more on the wind that is blowing than on temperature. Viewed in the most general terms, the climate is an expression of the proximity to the principle route of travel of active frontal depressions. The northwest areas tend to have more wind and clouds, increased rainfall and more frequent rain with rainfall diminishing rapidly to the leeward side (Manley 1970).

The temperature in England tends to be much cooler than that associated with India. The coldest month, January, has a mean temperature of 3.4 °C and the warmest month, July, has a mean temperature of 16.2 °C, with the average daily range being 5.8° and 8.8 °C, respectively. The average number of days with 0 °C is 15 during January and interestingly is one during May and two during October (Manley 1970). These moderate temperatures are the result of the North Atlantic Drift.

The monthly rainfall over England is lower during the months of February to June at about 47 mm while from July to January monthly rainfall is about 65 mm. It is of some interest to note that the average number of days receiving .2 mm ranges from a low of 12 in June to a high of 17 during October and December. In addition, the number of days with fog (visibility < 1 km) is less during April to August and more during the other months. The range of average relative humidity for a day tends to be higher from September to March (Manley 1970). However, the mean range for the whole year is narrower (74 to 89%) than that of India and tends to be higher.

English and Zebu Cattle

The physiological and performance differences between English and Zebu cattle have been widely documented. Differences in heat tolerance, responses to heat stress, ration utilization, reproductive performance and insect resistance have been found. Researchers have generally concluded that Zebu cattle are better adapted to tropical climates than are the cattle of English origin. An attempt will be made to directly relate these differences to the specific climates of origin of the two cattle types.

It is important to note that ambient temperature alone is not what affects the ability of an animal to maintain thermo neutrality. Radiation, humidity and wind movement, as well as the number of hours in which a combination of these components prevail in the 24 hours of a day, are as important as the upper and lower critical temperatures (Alba 1977).

Heat tolerance is usually determined by physiological responses of animals to changes in climatic conditions. Some of the physiological responses which have been measured are pulse rate, respiration rate, rectal temperature, feed and water intake, growth and milk production (Ragsdale et al. 1948; Kibler and Brody 1949, 1950; Ragsdale et al. 1950, 1951; Thompson et al., 1951; Alba 1977). Due to the varied methods of measurement of heat tolerance and differences found between individuals, specific critical temperatures are difficult to state. However, it has been concluded that English cattle's upper critical temperature is normally between 21 and 29 °C (Ragsdale et al. 1948; Kibler and Brody 1950) and Zebu cattle between 32 and 35 °C (Kibler and Brody 1950; Ragsdale et al. 1950; Curtis 1983). Alba (1977) stated, 'It is obvious that more tropically-adapted cattle have different productive critical temperatures and presumably the whole zone would move upward, in relation to that of temperate-climate cattle.'

Heat loss must be effected through radiation, evaporation, conduction or convection for animals to remain in homeothermy. If atmospheric temperature is above the normal temperature of the cow, convective heat loss cannot be used. If the surrounding surfaces are warmer than the cow, conductive heat loss will not occur. Radiation would be variable and would normally be working for heat gain during sunshine. This leaves evaporation as the only means of heat loss, unless the animal can reduce its metabolism.

One of the means available for evaporation is the loss of water vapor through increased respiration rate. It has been reported that when temperatures reach 26 °C, thermal panting is initiated in the *B. taurus* (Brody 1956). Alba (1977) stated that Zebu cattle may adjust their breathing to deep ventilation, rather than panting, to maintain a greater tidal volume and more effective gas exchange. Researchers have shown that from 38.5 to 40.5 °C, Zebu cattle maintain a lower respiration rate than do English cattle (Cartwright 1955; Alba and Sampaio 1957). It is important to note that increased respiration rate can result in decreased CO_2 in the blood, causing alkalosis. Research has found that Zebu cattle may be able to maintain lower respiration rates during high ambient temperatures because of higher red blood cell counts, total cell volume and hemoglobin values (Evans 1963; Howes 1963). It is of interest that the Zebu cattle have more difficulty in maintaining this advantage when a diurnal temperature rhythm is not maintained (Alba and Sampaio 1957; Alba 1977). This indicates that the Zebu cattle depend heavily on 'cool' nighttime temperatures to maintain homeothermy.

These differences in breathing rates, air volume and blood constituents are likely related to environmental adaptation. With the Zebu cattle being under a greater heat load, the control of respiration is essential to survival. If these differences did not exist, the Zebu cattle would likely have become extinct long ago from the resultant alkalosis.

The other means for evaporation is sweating. Curtis (1983), who summarized previous work, reported that thermal sweating begins when skin temperature reaches 32 °C in English cattle and around 34 °C in Zebu. Dowling (1955) reported that Zebu cattle have a higher follicle population density of 1,565 cm^{-2} and European around 829 cm^{-2} at four years of age, but sweat-gland population density and individual sweat-gland volume tend to be inversely related (Pan et al., 1969). It has been found that Zebu cattle do tend to sweat slightly more than do English cattle (Briggs 1958; Taneja 1959; Alba 1977).

Due to the relatively moderate temperatures and high humidities associated with the British Isles, the usefulness and/or effectiveness of sweating in cattle would be of little advantage in dissipating heat. However, in the Indian subcontinent, with its higher temperatures and lower humidities, except during the northeast monsoon, sweating would be advantageous in maintaining body temperature.

The utilization of feedstuffs has also been found to be different between the two cattle types. It has been reported that when nutritional levels are low, Zebu cattle tend to perform better than English cattle, but when nutritional levels are high, the English cattle out-perform the Zebu (Moran 1970; Moore et al., 1975; Turner 1980). This may be due in part to differences in rumen motility during hot weather, when feedstuffs would likely be of lower quality. Attebery and Johnson (1969) found that with cattle kept in temperatures above 38 °C for five days, rumen motility decreased. However, because English cattle were studied, it is likely that the body temperature of the individuals also increased. Perhaps if Zebu cattle, which should be better able to control their body temperature, were evaluated, rumen motility would not decrease as much.

Joshi and Phillips (1953) stated that, due to the rainfall pattern over the Indian subcontinent, the forage has a short growing season and then turns coarse quickly. However, the climate of the British Isles permits a longer growing season with lush vegetation present for a longer period of time. As a result, English cattle would not have as great a need to effectively utilize a low quality diet as would the Zebu cattle.

Reproductive performance is another area in which the two differ. Zebu cattle are older at sexual maturity than English cattle. B. indicus populations in India tend to calve at 42 to 56 months of age (Johari and Talapatra 1957; Amble et al., 1958; Luktuke and Subramanian 1961). Cattle in temperate areas are usually mated to calve at 24 to 36 months of age. Work has also shown that Zebu cattle in the United States tend to reach puberty later than Zebu crossbred cattle (Plasse et al., 1968).

This tendency to reach puberty at a later age may have some advantages in the Indian climate. Because of the lower level of nutrition, the animals would weigh less at a constant age. The result would be pregnancy at a lighter weight, likely causing calving difficulty. It may be that early puberty has been selected against naturally in the Zebu cattle of India. In addition, English cattle have traditionally been selected for reproduction at an early age by man. Because the heritability of age at puberty in heifers is around 40% (Taylor 1984), some gene shifts may have resulted, causing English cattle to reach puberty at a younger age than if artificial selection had not been practiced.

Insect resistance is another area in which differences have been found. Zebu and Zebu crossbreds have been found to be more resistant to ticks (Hewetson and Nolan 1968; Strother et al., 1974), able to gain more weight while exposed to mosquito attack (Steelman et al., 1973, 1976) and more resistant to horn flies (Tugwell et al., 1969) than English cattle. It has been suggested that this advantage may be the result of the Zebu's ability to shake its skin and because of an oil it secretes (Briggs 1958). These traits have not been found in English cattle. Because islands tend to be freer from insect pests than do large land masses (Janzen 1975), it would be expected that Zebu cattle would be more resistant or tolerant to insect attack.

Zebu cattle are better adapted to tropical climates than English cattle. This adaptiveness is related to differences in heat tolerance, responses to heat stress, ration utilization, reproductive performance and insect resistance. It has been suggested that these differences are specifically related to the climates of origin. When cattle are moved from tropical to temperate environments or vice-versa, great care should be given to the climate of origin. This is of particular importance when 'superior' genes from temperate-climates are to be introduced into a tropical environment. It is likely that both climatically and nutritionally, adjustments by individual animals will be difficult to make.

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