Gir for the *Giriama*: The case for Zebu dairying in the tropics - a Review

T O Rewe[1,4], M G C D Peixoto[2], V L Cardoso[3], A E Vercesi Filho[3], L El Faro[3] and E Strandberg[4]

[1] *Pwani University, Department of Animal Sciences, Box 195, 80108 Kilifi, Kenya,*
thomas.rewe@slu.se
[2] *Embrapa Gado de Leite, Rua Eugênio do Nascimento, 610, 36.038-330 Juiz de Fora, MG, Brazil,*
[3] *APTA, Agriculture Secretariat, São Paulo State. Ribeirão Preto SP, Brazil*
[4] *Swedish University of Agricultural Sciences, Department of Animal Breeding and Genetics,Box 7023, SE-75007 Uppsala, Sweden*

Abstract

The aim of this review paper is to evaluate opportunities for selecting the most profitable cow for smallholder dairy production in hot and humid tropics. The inherent climatic characteristics of the tropics are discussed here as possible bottlenecks to productivity of dairy cattle. The traits relevant for dairy production cut across functionality of the animal, adaptation to the environment to the most important milk production traits. A contrast of performance in various traits between most common breeds utilized for dairy in the tropics has been highlighted. Body conformation, thermo-tolerance, parasitic resistance, feed efficiency, locomotion, fertility and milk production are discussed here as part of the unavoidable considerations when breeding for tropical dairy production. Notably, to sustain the production of milk, functional and survival traits account for the sustainability and profitability of the milk business. Longevity, a composite trait that enables achievement of higher milk average per cow per year should be targeted in an optimal milk breeding objective. Tropical highlands have benefitted from high milk producing *Bos taurus* breeds, however, dairy farmers from the coastal lowlands have been unable to replicate this success. It is proposed here that matching a dairy breed to the environment could be more sustainable than adjusting the environment to fit a particular breed. The development of Zebu cattle for dairy production has been attempted with varying levels of success. Very rarely are Zebu cattle developed for purebred dairy production. This review paper highlights the case of Brazilian-Gir cattle and recommends strategic use of proven Zebu genetics as an entry point for improving productivity of smallholder dairy farming in Coastal lowland tropics.

Keywords: *breeding programmes, coastal lowlands, smallholder*

Introduction

Can *Bos indicus* cattle sustain profitable dairy production in the tropics? Identifying the most profitable cow requires a wider discussion that should override the traditional notion that Zebus are adapted and therefore suitable to warmer climates. Berman (2011), reviewed dairy cattle adaptation to warm climates and observed that the comparative advantage of Zebu and Sanga cattle with respect to performance in warm climates was pegged on lower maintenance requirements, lower milk yields coupled with limited responses to improved feeding and management. These characteristics could be considered constitutive and useful for survival in conditions of feed scarcity and high temperatures. Strandberg and Sölkner (1996), Mirkena et al (2010) and Reda (2012) hinge their descriptions of the most profitable genotypes on longevity. Longevity, a functional trait in dairy production, broadly refers to the length of productive lifetime reflected on a cow's reproductive and lactation cycles including fitness characteristics which have indirect but notable impacts on profitability (Essl 1998). Although longevity enables reduction of replacement costs, it is also associated with late maturity. The lowly heritable functional longevity depicting the time from first calving to the last milk record, culling or death (Ducrocq et al 1988), could form a practical criteria in the process of identifying the most profitable cow, especially in the tropics (Bengtsson 2011, Mészáros et al 2014). This review paper aims to evaluate opportunities for selecting the most profitable cow for smallholder dairy production in hot and humid tropics, while highlighting the utility of Zebu cattle for dairying. The study draws from past and present research experiences while projecting future prospects of utilization for Zebu genetics with special attention to the Brazilian-Gir cattle developed.

Tropical dairy production

Most productive dairy production systems in the world are found in temperate climates, except for highly specialized systems in developed economies experiencing warmer climates. Tropical highlands in Brazil, India, Uganda, Ethiopia and Kenya are home to numerous dairy farms keeping either pure *Bos taurus* or their crosses with other exotic or Zebu cattle (FAO 2010;Wambugu et al 2011; Singh et al 2012; Santana et al 2014). Notably, dairy farmers in tropical lowlands face comparatively challenging conditions related to genotype and environment interactions. One of the major factors that affect dairy cows is heat stress attributable to a combination of air temperature and humidity. A temperature-humidity index (THI), developed in the late 50s (Thorn 1958) and adapted to dairy cattle in the mid 60s (Berry et al 1964), is widely used in major dairy industries to make decisions on temperature control. There are concerns about the accuracy of the procedures of THI estimation with indications that predicted values could underestimate the size of the thermal load and its impacts on animal productivity. This may lead to mistiming of decisions for provision of cooling (Colier and Zimbelman 2007). It has been suggested that including more microclimate elements such as air movement could increase the reliability of the THI estimates (Herbut and Angrecka 2012). Nonetheless, for purposes of comparing agro-ecological zones, the THI suffices as a useful indicator of similarity of production environments, for instance, the rainfall, temperature and humidity in Kenya (1000±200mm, 25±0.7°C, 87±3.0% (Nicholson et al 1999, King et al 2006)), Mexico (668±200mm, 24±6°C, 50±20% (Garatuza-Payan and Watts 2003, Mellado et al 2011)) and Benin (1351±121mm, 28.2±0.6°C, 73.4±1.9% (Alkoiret et al 2011)). Successful dairying in such environments has been observed in Asia and Latin America (De Leeuw et al 1999). A case in perspective is Brazil (T=28.2°C, H=68.9% - Lima et al (2013)), where Zebu dairy cattle production has contributed to the setting up of the Brazilian Dairy Gir Breeding Programme (PNMGL) in 1985.

An underlying process that contributes to the success of dairying in developing economies is the implementation of holistic approaches covering the whole value chain. The value chain approach allows dairy farmers to know the opportunities that exist across the whole spectrum of the milk chain depicting the interactions between farmers, traders, processors and consumers intertwined with support systems such as financial services, research and technology (Giuliani et al 2005; AFE 2014). A fundamental function that sustains the viability of the milk chain is chilling. Chilling has been the preserve of dairy processors until recently, where dairy farming groups through innovative value chain programmes have established chilling plants and in some cases, cottage milk processing industries. The East African Dairy Development (EADD) project, funded by the Bill and Melinda Gates Foundation, has reported success indicators for dairy farmers in Uganda, Tanzania, Rwanda, Ethiopia and Kenya (EADD 2012). To benefit from this approach, dairy farming groups ought to be able to produce consistently, enough volumes of milk that can support the profitability of a chilling plant. Milk volumes, is as much a function of cow genetics as it is a function of the environment. In this review, a deliberate focus is put on the coastal lowlands of Kenya, the home of the *Giriama* people, while exploring the possibilities of utilizing Zebu genetics in advancing farmers' interests within the vibrant dairy value chains in this region. The *Giriama* region is implied therefore in this paper to represent the coastal lowland tropics.

Commercial dairy production in the *Giriama* region began even before 1963, when Kenya became an independent nation. The sector has continued to receive support through government sponsored dairy development projects (DDP) (Leegwater and Hoorweg 2000). The DDP introduced improved management of dairy animals in trying to accommodate the promoted dairy breeds that were exotic to the region. This led to the application of zero-grazing in the early 1980s. In their critical evaluation of dairying in *Giriama*, Leegwater and Hoorweg (2000) admit that zero-grazing became a challenge in this rather dry agro-ecological zone because it depended on a cut-and-carry feeding strategy that essentially requires fertile soils and reliable rainfall for fodder production. The main cost elements for such smallholder farmers are related to supplementary feeding as well as labour for forage and water provision (Van der Valk 1992) indicating that the technical recommendations for the production system favours smaller breeds (Bebe et al 2003a). King et al (2006) postulated that the preferential choosing of high-yielding dairy cows for smallholder dairy farmers in the tropics cannot be explained by their performance, and further suggested that the continued promotion of the exotic breeds could be unsustainable if dependent on the assumption that the environment and production system can and will adapt in the future to support their high genetic merit for milk production.

The dairy sector in Kenya is estimated to have over 5 million improved cattle, projected as the largest dairy herd in sub-Sahara Africa (Muriuki et al 2003). As the rest of the country benefits from the vibrant dairy sector, dairying in *Giriama* has consistently lagged behind in critical indicators of dairy production showing low adoption rates for dairy technologies, low numbers of improved genotypes, low milk yields, low incomes from milk and smaller number of households in milk business (Wambugu et al 2011). Replicating the success observed elsewhere requires a fundamental review of the breeding and feeding strategies. The recent strategic developments in this region, where old milk processing plants are being revived and new ones are being built provides an opportunity for dairy farmers (DAILY-NATION 2014, The-STANDARD 2014). The argument for feeds and feeding, albeit fundamentally important for the success of dairying in this region, is however beyond the scope of this review. The highlighted problem facing the *Giriama* dairy farmers is the ability to produce consistently, adequate volumes of milk under conditions of high temperatures, dry season feeding, pests and diseases as well as unfavourable milk prices. Not losing the fact that sector-wide approaches are necessary, the kind of cow needed for these conditions should alleviate rather than amplify the bottlenecks in milk production in this already challenging production environment. The hypothesis presented in this review presupposes that matching a breed to the production environment could be more sustainable than converting the production environment to suit a desirable genotype.

Gir for the *Giriama*

As indicated earlier, the profitable cow for the *Giriama* should function in an environment characterised by heat stress, water stress, pests and diseases as well as seasonal feed scarcity. Expectedly, the common cows utilised for dairy have been the Holstein Friesian and their crosses, a choice based mainly on milk yield since payment for milk in Kenya is by volume (Kahi et al 2000, Wambugu et al 2011). Under performance of these high milkers in the coastal lowlands has become a subject of discussion in the recent past. Mwamuye et al (2013) reported negative growth rate for dairy cattle numbers (-0.49%) and for milk production (-0.6%) as a result of farmers pulling out of dairy farming in Kilifi region of the Kenyan Coast. In a country considered as one of the highest milk consumers in the developing world with an average of 145 litres per person per year (SDP 2005), dairy production is therefore still a promising enterprise. Coastal Kenya has a population of over 3.3 million people, of which over 1.2 million are in Kilifi region (KNBS 2009). Kilifi, one of the major counties in Coastal Kenya is home to small, medium and large scale dairy farms, including a dairy teaching unit housed in a public university (Pwani University). The evaluation of the potential utility of matching the unique attributes of a developed Zebu dairy breed, the Brazilian-Gir, to the lowland conditions warrants attention. The discussions herein are broad and applicable to other similar agro-ecological zones in the world where dairy production is practiced.

Body conformation traits

The adaptation of Zebu cattle to tropical climates has been well documented (Cunningham and Sysstad 1987, King et al 2006, Mirkena et al 2010, Berman 2011). The rusticity, docility, thermo-tolerance, parasite resistance and gross roughage utilisation support the case for their use in tropical dairying (Vercesi Filho et al 2010). However, adaptation to warm climates could be antagonistic to dairy characteristics (Berman 2011). Among the dairy traits, body conformation has been an indicator of true to type dairy animals. There is little evidence linking body conformation traits to milk production, however, these traits are important in sustaining the body form that supports a certain level of milk production. They are also important in identifying true-to-type individuals within a herd. Yakubu (2011) reported positive influence of udder circumference, udder height and heart girth on milk yield suggesting that body conformation could be useful in predicting milk yield, especially where animal recording schemes are undeveloped. The international committee for animal recording (ICAR) (2013) suggest that linear type traits form a basis for modern animal classification systems, for instance, stature (height from the tip of the rear spine point to the ground), chest width, rump angle, rump width (distance between most posterior points of the pin bones), udder depth, teat length and body conditions score among other linear traits. Body characteristics could have variable effects on locomotion, conception, pregnancy and to some extent milk quality and volume (Berry et al 2004, Pantelic et al 2010). Table 1 depicts a sample of body conformation traits for some *B. indicus* and *B. taurus* cattle. The presentation, though not a statistical comparison, provides an average compass to position the performance of Brazilian-Gir cattle on conformation traits relevant in dairy production.

Body conformation characteristics are objective traits and the preference levels vary from one breed to another. Whereas a stature of 136 cm would be considered relatively short for Holstein Friesian cattle, the size could be objectively tall for Zebu cattle. Important to note, would be the udder and teat qualities that determine capacity and pendulous characteristics.

Table 1. Body conformation traits for selected *Bos indicus* and *Bos taurus* breeds in thetropics

Body Conformation*	Gir	Holstein Friesian	E/African Zebu	Sahiwal	Boran
Stature (Rump height) (cm)	134	143	120	129	123

Heart girth (cm)	174	190	148		159
Rump angle (cm)	27			10	
Hip width (cm)	46	54	42		34
Udder width (cm)	6	9			
Udder depth (cm)	10.6	15.2		12.39	
Body length (cm)	102	167			
Teat length (cm)	7.4	4.5		6.92	

Adapted from: (Mwacharo et al 2006, Heins et al 2008, Verneque et al 2009, Bjelland et al 2011, Banerjee et al 2014, Dubey et al 2014, Singh et al 2014)

A cow with udder high above the ground is at a lesser risk of teat or udder injury. Teat length of 7.4cm for Brazilian-Gir cattle may be considered long and could potentially predispose a dairy cow to mastitis (Singh et al 2014). While considering Zebu cattle for dairy, udder characteristics could therefore be considered as a trait to be targeted for improvement.

Thermo-tolerance

The physiology of acclimation (single stressor response) or acclimatisation (response to a concert of stressors) is well known, what is not clearly known is the heritability of a particular response pattern, in this case, response to heat stress. Alteration of gene expression and enzyme activity that manifest changes in organs, fat deposition and energy consumption are individual-specific. Genetic adaptation allows for the fixing of such patterns of response within a breed such that the traits become heritable. The physiological responses to heat stress are similar in *B. taurus* and *B indicus* and negatively affects both production and fertility (Hansen 2004). Ferreira et al (2009a) demonstrated the effect of heat stress on fur length and coat thickness that were significantly higher in warmer than in colder climatic conditions. A more pronounced duration and intensity of responses is expressed by *B. taurus*, and is observed in their susceptibility to heat stress (Beatty et al 2006, Farooq et al 2010, Hansen 2013). It has also been shown that blood parameters change with temperature conditions exposed to cattle under heat stress whereby erythrocytes count, hemoglobin total concentration, hematocrit, concentration of total proteins, urea, creatinin, sodium, potassium, chlorides and cortisol generally increase as well as urinary pH and density, and the dry matter of feces (Ferreira et al 2009b). In dairy production, both poor fertility and low milk production are undesirable even under conditions of high temperatures and humidity. Figure 1 shows the rate of sweating for different breed mixes of Girolando cattle. Breed mixes with higher ratio of Zebu Gir genes responded with a higher sweating rate at exposure to higher temperatures. The combination at 0.5 Gir and 0.75 Gir have been found to have similar 305-day milk yields under similar production conditions (Mellado et al 2011). Having more of Gir genetics in the crossbreed did not significantly reduce milk production yet it has been shown to improve response to heat stress (Lima et al 2013).

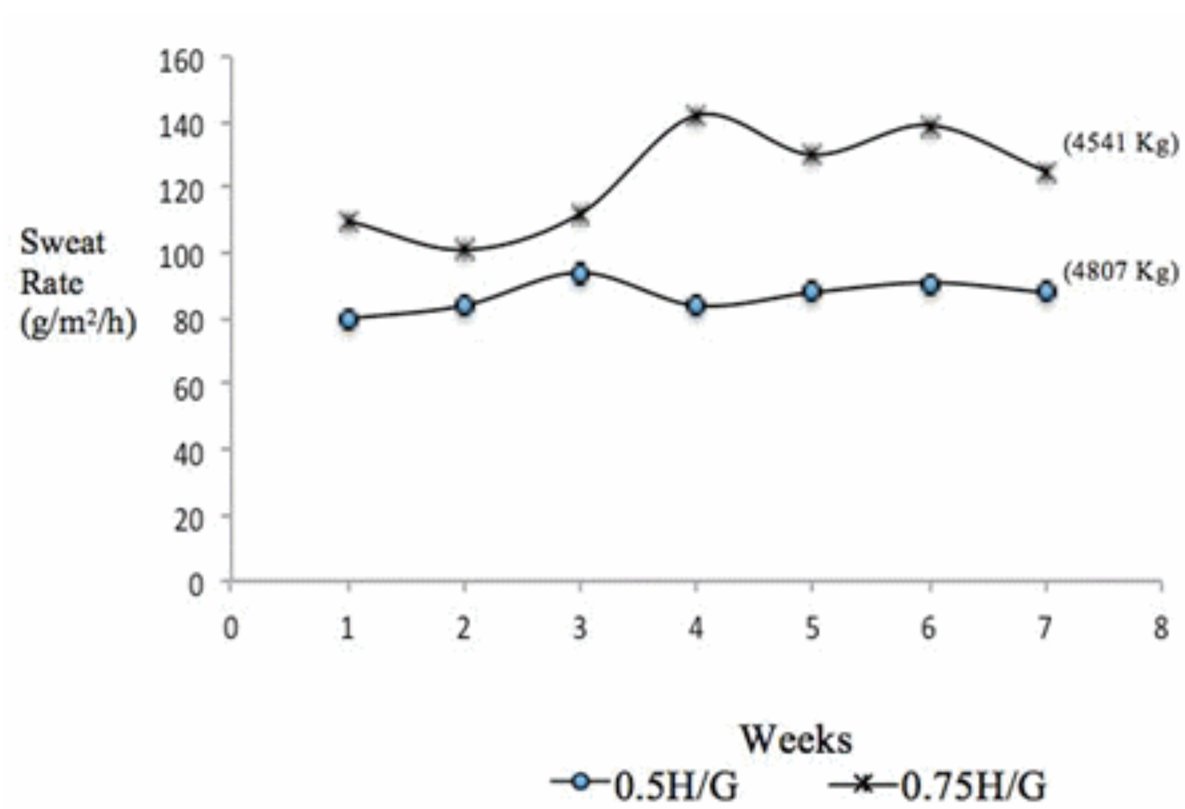

Figure 1. Sweating rate of different breed mixes of Girolando cattle (305-day milk yield in parentheses)
Adapted and modified from Lima (2013) and Mellado et al (2011).

One of the direct manifestations of heat stress is thirst. Beatty et al (2006) reported a doubling of water intake for cattle exposed to hotter temperatures suggesting a possible effect of polydipsia. In that study, the exposure of cattle to hot temperatures was also observed to lower feed intake in *B. taurus*, and relative preference of warm water to colder water. These observations relate closely to the coastal lowland of the *Giriama* region where dairy cattle are expected to not only survive but thrive in hot and humid conditions with related water stress.

Parasite resistance

In the coastal lowlands tropics, cattle diseases of economic importance in order of gravity include; tick borne diseases, worm infestation and trypanosomiasis (Ramadhan et al 2008). In general, due to long-term dairy intervention programmes, most dairy farmers now have the technical know-how and access to veterinary services for the management of these diseases. The immediate challenge to profitability therefore is the cost of veterinary care. The more frequent an animal gets sick the more expensive the cost of production. Can imported cattle survive with minimal changes in management in an area where most dairying is practiced under extensive grazing? The question could be approached by observing mast cells production associated with parasite resistance. An interesting outcome in comparing mast cells produced under infestation of Rhipicephalus (Boophilus) microplus (*R. microplus*) between Brazilian-Gir and Holstein revealed a no-difference result (Veríssimo et al 2008). However, lower tick load for Gir cattle is an indicator of a more robust resistance to parasitic infestation as presented in Table 2. The early works of Villares (1941) showed variation among cattle breeds in resistance to *R.microplus* and Lemos et al (1985) described a relationship where the ticks per animalexponentially increased against increasing fraction of *B. taurus* blood (Figure 2). In other observations, *B. indicus* and *B. taurus* F1 crosses have been reported to closely match the performance of purebred Zebu in tick resistance (Madalena et al 2012).

Table 2. Matching mast cells to tick load in different cattle breeds

	R. microplus	**Mast cells**

Nellore	21	139[a]
Gir	15	62[b]
Holstein	176	49[b]

Means with same letter are similar.
Modified from Veríssimo et al (2008)

Crossbreeding therefore, has been used as the breeding strategy that capitalises on the strengths of breeds with respect to milk production while minimising their weaknesses with respect to pathogen resistance.

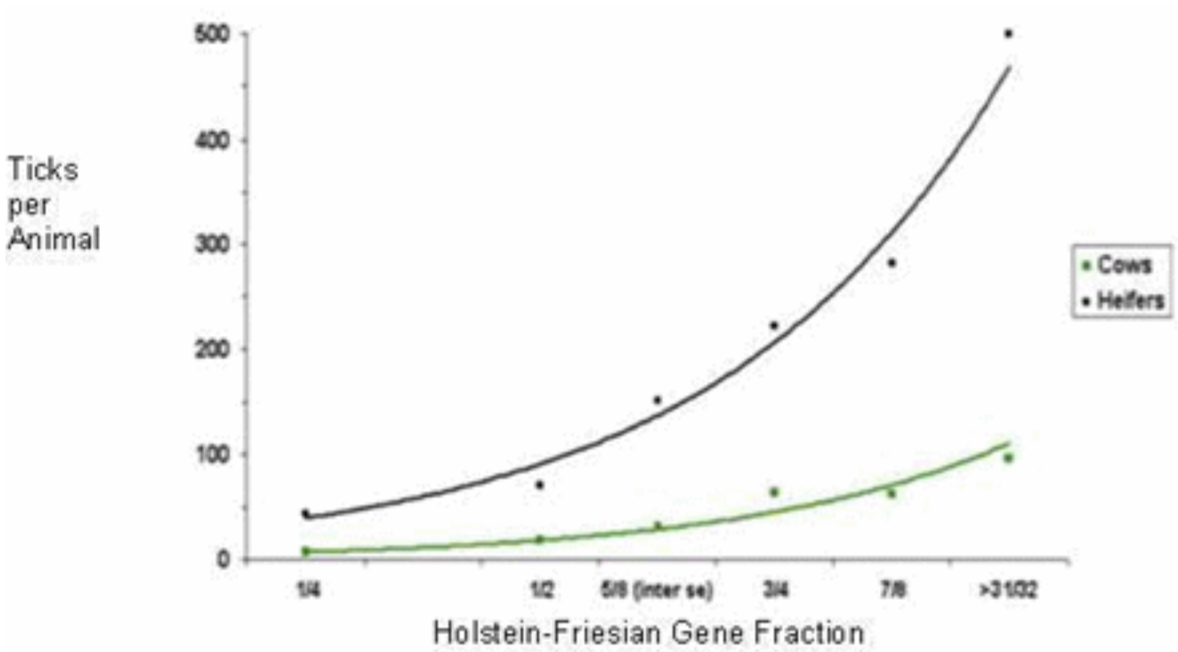

Figure 2. Relationship between *B. taurus* gene fraction and tick load.
Adapted from Lemos et al (1985)

Feeding efficiency and locomotion

Feed conversion efficiency, important as it is in cattle production could to some extent be outweighed by the ability to graze in pasture based production systems. The grazing ability or rather ability of a cow to fend for feed by walking on pasture while maintaining desirable levels of production was amplified by Nardone (2010). In that study, global warming was predicted to have effects on expected drought patterns that will present adverse negative impact on the quality and quantity of forages and crops. The profitable cow in coastal lowlands, where predominantly extensive grazing is practiced, is expected to perform in an environment with expected imminent challenges on feed supply. The ideal cow for these circumstances would therefore be required to walk and cover large grazing areas even in a semi-zero grazing system. In the recent past, the Holstein Friesian cattle were dominant as the exotic breed of choice for smallholder production, generally kept in zero-grazing systems (Bebe et al 2003b). The success of zero-grazing in *Giriama* region, as alluded to earlier, is limited and therefore grazing behaviour becomes important as a functional trait in these circumstances. Brazilian-Gir cattle are predominantly raised in pasture-oriented paddock-based grazing systems (Madalena et al 2012). This could be an entry point for investigating their perceived appropriateness as an alternative dairy animal in the coastal lowlands. There are suggestions that aiming for high milk production per cow through intensive management towards maximisation of profits has done more harm than good in smallholder systems in hot and humid zones (Bebe et al 2003a, King et al 2006, Madalena et al 2012)

Fertility

Profits from milk business is inevitably a function of reproduction, a composite trait that includes elements of conception, pregnancy, calving and age of cow (Sakaguchi 2011). Research as well as practice has provided evidence of antagonism between high milk production and fertility. The review of fertility in high milkers by Walsh et al (2011) suggests that the general decline in fertility could be multi-factorial with respect to genetics, physiology, nutrition and management. LeBlanc (2008) goes further to suggest that the perceived antagonism of milk and fertility could have been misreported due to analytical biases that ignored management factors. Nonetheless, the theory of energy partitioning would apply when arguing for milk increase as a reason for decline in fertility (Roche et al 2009). Reproductive trends for Brazilian-Gir cattle utilised for dairy production are rare, Vercesi Filho et al (2010) reported a reduction of calving interval by 51 days from 517 days and an annual decrease of 8.9 days age at first calving between 1970 and 2002. In a more recent analysis of Brazilian-Gir cattle data (1970 to 2011), calving interval is estimated at 446 days suggesting a reduction of up to 71 days (Prata et al 2014). The genetic progress is attributable to deliberate selection efforts by the PMMGL established in 1985. Innovations targeted to improve response in reproductive traits (both artificial insemination and multiple ovulation and embryo transfer) have been applied successfully to Brazilian-Gir cattle (Madalena 1999, Vercesi Filho et al 2010).

Docility

Milk let down is a well known physiological process controlled by both hormones and nerves. Suckling or milking are common stimuli that induce milk let down. Indirect effects that contribute to the release of milk are attributable to the milking environment (human or machine) or the temperament of the cow. Docility therefore as a dairy cow trait, allows for ease in handling and, by extension, ease in milking (Gergovska et al 2014). Zebu dairy cattle are considered generally aggressive, however, adjustment in cow handling during milking could improve this trait (Becker and Lobato 1997, Rushen et al 1999), inferring that docility could be more of a conditional trait than genetic. The link of docility (temperament) and milk traits has been a subject of investigation. Praxedes et al (2009) observed that farmers that adopted milking in the presence of a calf did not experience problems with milking ease or temperament. Munksgaard et al (2001) indicated that differences in docility did not reflect on milk yield or milk composition alluding to an opinion that temperament may not necessarily impact adversely on milk traits. This opinion differed in some measure to an earlier study by Rushen et al (1999) that showed adverse effects of irritation on milk yield. However, it should be noted that milking ease is also a function of age as shown in Figure 3 (Praxedes et al 2009), a factor that may have contributed to differences observed in various experiments.

In the *Giriama* region where hand milking is predominant, milking ease could be highlighted as an important characteristic for the profitability of milk business after milk yield. Machine milking is a cost, which is only justifiable if milk volumes remit enough profits for their maintenance. Brazilian-Gir cows and their crossbred offspring have been shown to adapt well to machine-milking (Negrao 2008).

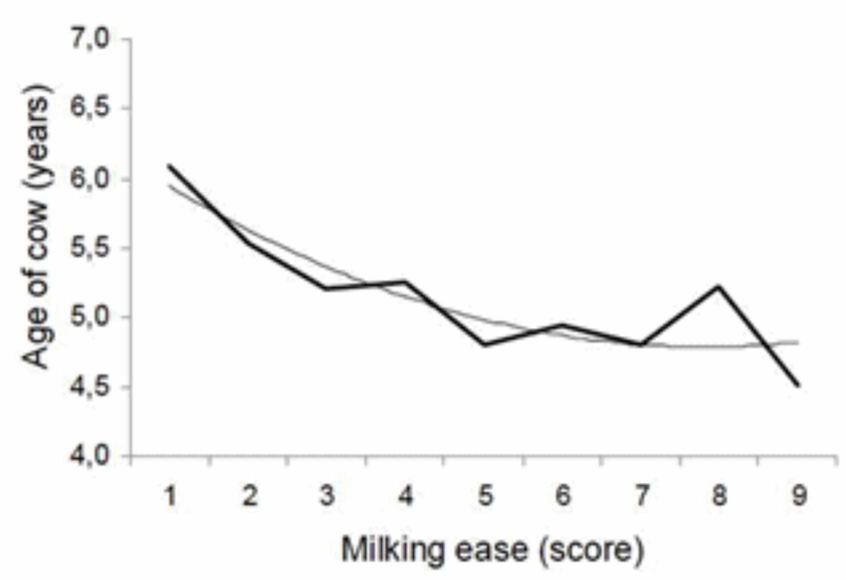

Figure 3. Relationship between milking ease score and cow age.
(Source: Praxedes et al 2009)

Restricted suckling

The effect of the presence of a calf on milk yield has been studied and techniques such as restricted suckling regimes modeled to suit different scenarios especially in smallholder dairy production systems (Sanh et al 1995). The presence of the calf has been associated with control of temperament during milking majorly for the *B. indicus* (Tesorero et al 2001). Although a strong connection between milk yield and temperament has not been widely established, the influence of the calf on milk yield has been reported. Assan (2015) looked at suckling effect and observed an improvement in milk yield attributable to additional stimulus of the mammary gland as well as improved mammary development indicating that restricted suckling had no adverse effects on total milk production available for consumption or commercial purposes. Similarly, Tesorero et al (2001) reported that restricted suckling before milking had considerable positive changes in milk components (fat and protein) without negatively affecting the total milk quantity. Restricted suckling is considered economical and is widely practiced in pasture-based, dual purpose systems in the tropical Brazil where Gir and Gir crosses with the Holstein Friesian are reared (Madalena et al 2012). In *Giriama* region, as is the case for most small holder dairy systems in Kenya, the use of a calf during milking is predominant. Milk is generally shared between the calf and home consumption with surplus for sale (Wambugu et al 2011). Research on performance of the Brazilian-Gir cattle in this target region should include observations on the effect of restricted suckling on both milking ease and milk yield.

Milk Production

The default utility for Zebu cattle has traditionally been dual purpose with a tendency towards beef rather than dairy production. This may be explained by their generally small body sizes and their utilisation in subsistence production systems. Agricultural extension services, prompted by evidence based research outputs, have increasingly targeted resource poor farmers in developing countries for training and support towards commercial dairy farming. One of the major bottlenecks for most dairy development projects has for more reasons than one been the cattle breed. The transfer of benefits based on working solutions from one agro-ecological zone to another has to some extent proven unsuccessful especially in the Kenyan case (King et al 2006, Mwamuye et al 2013). It is worth noting that the viability of Zebu cattle for dairy production cannot be ignored. Milk production data for Zebu cattle utilised in various regions of the world is now available albeit limited in breed numbers and records. Table 3 presents milk and reproductive traits for some selected breed clusters reared in the hot and humid tropics.

Table 3. Milk and reproductive performance of cattle breed clusters in hot and humid tropics

Breed of Cattle	Age at first Calving	Calving Interval	Lactation Milk yield	Mean Lactation Length	References
Sahiwal	44	468	1368	282	Ilatsia et al (2007)
½ Sahiwal x ½ Friesian	32	441	1611	290	Thorpe et al (1993)
Red sindhi	44	515	1531	277	Mustafa et al (2002), Mustafa et al (2003)
Boran (Ethiopia)	43	447	507	240	Haile et al (2011)
½ Boran x ½ Friesian		440	2019	337	Tadesse and Dessie (2003), Haile et al (2009)
Gir (Brazil)		446	3278*	305*	Prata et al (2014)
Gir (Brazil)	47	415	1188	256	McManus et al (2011)
½ Gir x ½ Friesian		401	2241	268	McManus et al (2011)
½ Gir x ½ Friesian			4542*	305*	Mellado et al (2011)
Holstein Friesian			5417*	305*	Mellado et al (2011)

**305 day milk production: Prata et al (2014) estimated daily milk yield for Gir cattle in Brazil*

The tabulated estimates, although not statistically related, portray an extrapolation of the performance of Zebu dairy breeds vis a vis their cross bred groups. Differences of performance cannot be attributable to the genotype alone, obviously the feeding and care are known to play significant role in dairy production. McManus et al (2011) found significant differences between the total milk yield of purebred Brazilian-Gir (1188) and their crosses with Holstein (2241), alluding to the fact that crossbreeding under the same management regime could be more profitable. Most of the estimates for the Zebu cattle performance in milk traits were from designed experiments in research institutions and farms. Smallholder production data would probably yield a modestly lower milk production result. In the coastal lowlands of Kenya, the average daily milk yield is reported to range between 1-6 kg per cow, in a region relying heavily on the use of Friesian crossbreds (Ramadhan et al 2008). Friesian crossbreds are more popular (60.0%) followed by Ayrshire (20.0%) then Guernsey and Jersey (Muraguri et al 2004). The average daily milk production for Brazilian-Gir cattle of 10.5 kg (Prata et al 2014), would potentially influence smallholder farmer breed preferences if achievable in the focus region of *Giriama*. Outside Brazil, the performance of Gir and Gir crosses is documented in India (Singh et al 2014), Mexico (Mellado et al 2011), Benin (Alkoiret et al 2011) among other regions in the tropics. By 1980, overall annual means for milk yield for Brazilian-Gir cattle reared in humid tropics of Mococa was 2690 kg, showing positive annual phenotypic and genetics trends of 25 and 7 kg respectively (Lobo et al 1980).

In figure 4, annual means for the first three lactations for Brazilian-Gir cattle (1979 to 1994) alongside breeding values for milk (1970 to 2002) are presented. Vercesi Filho et al (2010) reported a genetic trend of 14.3 kg for milk yield when data from 1970 to 2002 was considered and 19.69 kg when data from 1985 to 2002 was considered. The differences were attributable to the improved selection strategies following the introduction of the progeny-testing programme in 1985.

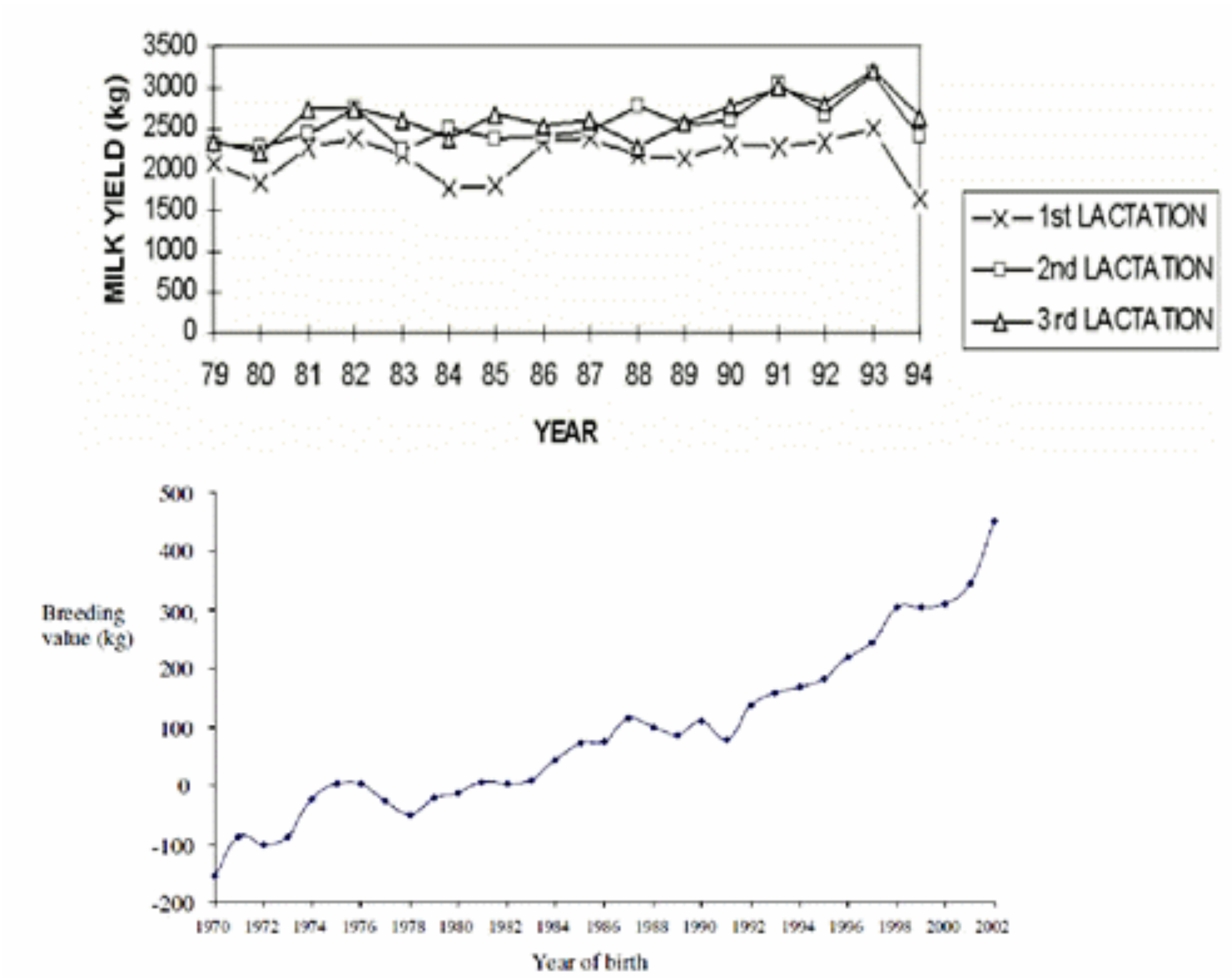

Figure 4. Annual means for the first three lactations (above) and mean breeding values (below) for milk yield Adapted from Albuquerque et al 1999 and Vercesi Filho et al 2010.

Implications

Sustainable dairy cattle breeding programmes in developing countries are in progress; however, milk value chains operate with tangible returns especially in Eastern Africa. One reason for the slow progress in organised breeding programmes in sub-Saharan Africa highlighted in Rewe et al (2009) is farmer type. Neidhardt et al (1996) distinguished livestock farmer classes as livestock users, livestock keepers, livestock producers and livestock breeders. Among these, livestock breeders and producers are primed to respond to systematic breeding practices as opposed to livestock users who keep cattle as a secondary investment. The step from livestock user to livestock breeder is considered gigantic and should first be preceded by the step from livestock user to livestock keeper. Livestock users, due to their relatively low inputs, obtain high work productivity but with low product output compared with livestock keepers (Neidhardt et al 1996). Therefore, the market-oriented groups of livestock owners (breeders and producers) are considered as primary target for the establishment of genetic improvement programmes. The interactions between the different classes of livestock farmers could allow for improved genetics to flow across different production systems (Kahi et al 2005). In the current scenario, the smallholder market oriented dairy farmers in the coastal lowlands of *Giriama* Kenya have been considered. These are farmers that keep grade cows, mostly crossbred local cattle with Friesian sires and are actively involved in the milk business either through formal or informal value chains. Following the fact that constraints to milk production relate to thermo-tolerance, pathogen resistance, docility, fertility and milk yield, it was important in this study to consider novel interventions through breeds and breeding.

Thermo-tolerant breeds tend to have suppressed production as a survival mechanism warranting the selection for improved milk production under costly improvised management options that supply the much needed physiological needs of high milkers. The paradox has always been the inability of smallholder farmers to exploit the genetic potential of the “breed of choice” for dairy production. Brazilian-Gir cattle have been observed to be relatively more thermo-tolerant than *B. taurus* (Lima et al 2013). The choice however for the Brazilian-Gir cannot be made on account of thermo-tolerance alone since the smallholder milk production system relies on volumes for profit. In these hot and humid conditions the average daily milk yield for Brazilian-Gir cattle of 10 kg (Prata et al 2014) stands against a backdrop of an average of 6.5 kg for the exotic crossbreds utilised in the focus region of *Giriama* (Muraguri et al 2004, Ramadhan et al 2008). Coupled with the pathogen resistance capabilities, the milk production ability of the thermo-tolerant Zebu breed presents an opportunity for research to match the Brazilian-Gir to the *Giriama* region. As alluded to earlier, the most profitable cow for coastal lowlands should thrive in these hot and humid conditions. The best performers in the hot and humid tropics therefore would be the cows that thrive for longer with above average milk production. Notably, the design of appropriate crossbreeding strategies to capitalise on the strength of the available dairy breeds is a viable option. Profitability should be assessed while accounting not only for targeted milk traits but also traits related to longevity and fertility. Congleton and King (1984) presented a profitability model utilising discounted income of cow over 25 year discounted at 5% as a criteria for evaluating dairy herd profitability. The model components included estimates of relationships between cow age, milk production, labor requirements, health costs, reproductive diseases, mastitis, and fertility. In that study it was observed that extending average herd life from 2.8 to 3.3 lactations increased average annual income by $30 per cow and increased discounted income by $315.The profitability of a dairy herd could therefore be attributable to both production and functional traits. In advanced breeding programmes, relevant livestock traits in the breeding objectives are arrayed in an index and weighed by their respective economic values (Kluyts et al 2003). The predominant profit maximisation objective of most breeding programmes has recently been critiqued especially in dairy cattle. Rauw et al (1998) concluded that populations that are genetically driven towards high production would have less resources left to respond adequately to other demands, e.g. response to stressors and reproduction. The increase in calving interval in the United States (US) (Lucy 2001), to the decline in conception rate in the US, United Kingdom and Sweden (Beam and Butler 1999; Royal et al 2000; Roxstrom 2001) indicate an undesirable trend in traits of economic importance in dairy cattle. Moreover, the loss of performance in other fundamental traits due to maximisation of targeted production traits has been considered an animal welfare issue (Oltenacu and Broom 2010). The pursuit of profit maximisation based on few major economic traits may not be sustainable or profitable in the long run. Optimal profitability in dairy production has been calculated to occur if the cows live for at least six lactations (Essl 1998). It is postulated here that the design of breeding programmes to obtain the most profitable cow for the *Giriama* would therefore require an optimal approach that includes adaptation traits together with fertility and milk traits in the breeding objective.

Body conformation, thermo-tolerance, parasitic resistance, feed efficiency, locomotion, fertility docility, restricted suckling and milk production are proposed here as criteria for evaluating cattle for dairy production in coastal lowlands. There are Zebu breeds that have already been developed for dairy and should be targeted as a natural choice to speed up genetic progress in populations operating in similar environments. Since most of the local Zebus in the tropics are not organized in breeding programs, their utilisation has remained limited to dual purpose or mostly as meat animals among other traditional utilities. As a consideration for success in any breeding intervention, the target famers should be categorized to differentiate between livestock breeders, livestock producers and livestock keepers (Neidhardt et al 1996). Livestock breeders and producers will be essential in enabling the success of the proposed intervention. In this review, it has been demonstrated that among the potent Zebu breeds, the Gir cattle of Brazil present an opportunity for dairy production in the hot and humid tropics of sub-Saharan Africa.

Concluding remarks

- The edge in the argument for Brazilian-Gir cattle as a relevant option for dairying in the tropics is not largely supported by their adaptation to warm climates, but mostly by their genetic potential for dairy production.
- The implication of this characteristic opens opportunities for breeding simultaneously for improved thermo-tolerance and dairy production. Smallholder farmers would appreciate a degree of risk in adopting new breeds when they are assured of profitability.
- A combination of interventions around the dairy value chain that target beneficial involvement of smallholder farmers with socio-economic benefits should be encouraged to support the contribution of Zebu cattle towards a sustainable and profitable dairy enterprise, all in the efforts of finding the most profitable cow for the *Giriama*.

Acknowledgements

The authors humbly acknowledge the Swedish Institute who provided the much needed financial support to the first author, and the Swedish University of Agricultural Sciences that provided working resources and reliable literature through their state of art Library. The authors appreciate and thank Pwani University in Kilifi, Kenya , for background information on this study and for offering the first author study leave.

References

AFE 2014 Value Chain Programme Design: Promoting Market-Based Solutions for MSME and Industry Competitiveness. AFE, USA, Arlington. Retrieved March 2015 from http://www.actionforenterprise.org/paper07.pdf

Albuquerque M D S M, de Freitas M A R and Teodoro R L 1999 Genetic and phenotypicparameters of productivity traits on the first three lactations in Gyr cattle herds. Genetic Molecular Biology 22, 177-181.

Alkoiret I T, Yari H M, Gbangboche A M and Lokossou R 2011 Reproductive performance and milk Production of Girolando cows in the Ranch of Kpinnou, South-West of Benin Republic. Journal of Animal and Veterinary Advances 10, 2588-2592.

Assan A 2015 Influence of suckling and/or milking method on yield and milk composition indairy animals. Scientific Journal of Zoology 4, 1-7.

Beam S W and Butler W R 1999 Effects of energy balance on follicular development and first ovulation in postpartum dairy cows. Journal of Reproduction and Fertility 54, 411-424. Retrieved April 2015 from http://www.biolreprod.org/content/56/1/133.full.pdf

Beatty D T, Barnes A, Taylor E, Pethick D, McCarthy M and Maloney S K 2006 Physiological responses of *Bos taurus* and *Bos indicus* cattle to prolonged, continuous heat and humidity. Journal of Animal Sciences 84, 972-985.

Bebe B O, Udo H M J, Rowlands G J and Thorpe W 2003a Smallholder dairy systems inthe Kenya highlands: breed preferences and breeding practices. Livestock Production Science 82, 117-127.

Bebe B O, Udo H M J, Rowlands G J and Thorpe W 2003b Smallholder dairy systems inthe Kenya highlands: cattle population dynamics under increasing intensification. Livestock Production Science 82, 211-221.

Becker B G and Lobato J F P 1997 Effect of gentle handling on the reactivity of zebu crossed calves to humans. Applied Animal Behaviour Science 53, 219-224.

Banerjee S, Ahmed M B and Tefere G 2014 Studies on morphometrical traits of Boran bulls reared on two feedlots in Southern Ethiopia. Animal Genetic Resources/Ressources génétiques animales/Recursos genéticos animales 54, 53-63.

Bengtsson C 2011 What traits make Swedish dairy cows survive. MSc. Thesis, Swedish University of Agricultural Sciences (SLU) Uppsala, Sweden. Retrieved April 2015 from http://stud.epsilon.slu.se/2353/1/bengtsson_c_110314.pdf

Berman A 2011 Invited review: Are adaptations present to support dairy cattle productivityin warm climates? Journal of Dairy Science 94, 2147-2158.

Berry I L, Shanklin M D and Johnson H D 1964 Dairy shelter design based on milk production decline as affected by temperature and humidity. Transactions of the American Society of Agricultural Engineering 7, 329-331.

Berry I L, Buckley F, Dillon P, Evans R D and Veerkamp R F 2004 Genetic relationships among linear type traits, milk yield, body weight, fertility and somatic cell count in primiparous dairy cows. Irish Journal of Agricultural Food Research 43, 161-176. Retrieved April 2015 http://www.teagasc.ie/research/journalarchives/vol43no2/0201.pdf

Bjelland D W, Weigel K A, Hoffman P C, Esser N M, Coblentz W K and Halbach T J 2011 Production, reproduction, health, and growth traits in backcross Holstein x Jersey cowsand their Holstein contemporaries. Journal of Dairy Science 94, 5194-5203.

Colier R J and Zimbelman R B 2007 Heat Stress Effects on Cattle: What We Know and What We Don't Know. In 22nd Annual Southwest Nutrition & Management Conference, Tempe, Arizona, USA, pp. 76-83. Retrieved April 2015 from http://cals.arizona.edu/extension/dairy/az_nm_newsletter/2007/june.pdf

Congleton W R and King L W 1984 Profitability of Dairy Cow Herd Life. Journal of DairyScience 67, 661-674. Retrieved April 2015 from http://www.journalofdairyscience.org/article/S0022-0302(84)81351-X/pdf

Cunningham E P and Sysstad O 1987 Crossbreeding *Bos indicus* and *Bos taurus* for milkproduction in the tropics. FAO, FAO, Rome. Retrieved April 2015 from ftp://ftp.fao.org/docrep/fao/009/t0095e/T0095E00.pdf

DAILY-NATION 2014 Farmers pin hopes on milk factory in Kilifi, Kenya. In The DAILYNATION Newspapers, 13th October 2014, Nairobi, Kenya. Retrieved April 2015 from http://www.nation.co.ke/business/Farmers-pin-hopes-on-milk-factory-in-Kilifi/-/996/2485452/-/mc6p41z/-/index.html

De Leeuw P N, Omore A, Staal S J and Thorpe W 1999 Dairy Production Systems in theTropics. ILRI, Nairobi, Kenya.

Dubey A, Mishra S and Khune V 2014 Appraisal of linear type traits in Sahiwal cattle.Indian Journal of Animal Research 48, 258-261.

Ducrocq V, Quaas R L, Pollak E J and Casella G 1988 Length of Productive Life of Dairy Cows. 2. Variance Component Estimation and Sire Evaluation. Journal of Dairy Science 71, 3071-3079.

EADD 2012 EADD 2 Development: A Regional Overview. EADD, Nairobi, Kenya. p. 28. Retrieved March 2015 from http://eadd.wikispaces.com/file/view/SC+EADD2+Regional.pdf

Essl A 1998 Longevity in Dairy Cattle Breeeding: a Review. Livestock Production Science57, 79-89.

FAO 2010 Status of and Prospects for Smallholder Milk Production–A Global Perspective.FAO, Rome. Retrieved March 2015 from http://www.fao.org/docrep/012/i1522e/i1522e.pdf

Ferreira F, Campos W E, Carvalho A U, Pires M F A, Martinez M L, Silva M V G B, Verneque R S and Silva P F 2009a a a de s da o e ar me ros his o icos de bo i oss bme idos ao es resse ca rico Arquivo Brasileiro de Medicina Veterinária e Zootecnia 61, 763-768.

Ferreira F, Campos W E, Carvalho A U, Pires M F A, Martinez M L, Silva M V G B, Verneque R S and Silva P F 2009b Clinical, hematological, biochemical, and hormonalparameters of cattle submitted to heat stress. Arquivo Brasileiro de Medicina Veterinária e Zootecnia 61, 769-776.

Farooq U, Samad H A, Shehzad F and Qayyum A 2010 Physiological Responses of Cattleto Heat Stress. World Applied Sciences Journal 8, 38-43.

Garatuza-Payan J and Watts C J 2003 The use of remote sensing for estimating ET in NWMexico. In ICID Workshop on Remote Sensing of ET for Large Regions, 17 Sept. 2003 (Ed. ICID), pp. 1-12. ICID, Montpellier, France.

Gergovska Z, Marinov I, Penev T and Angelova T 2014 Effect of milking temperament onproductive traits and SCC in Black-and-White cows. International Journal Current Microbiology and Applied Science 3, 1-11.

Giuliani E, Pietrobelli C and Rabellotti R 2005 Upgrading in Global Value Chains: Lessons from Latin American Clusters. World Development 33, 549-573.

Haile A, Joshi B K, Ayalew W, Tegegne A and Singh A 2009 Genetic evaluation ofEthiopian Boran cattle and their crosses with Holstein Friesian in central Ethiopia: milk production traits. Animal 3, 486-493

Haile A, Ayalew W, Kabede N, Dessie T and Tegegne A 2011 Breeding strategy toimprove Ethiopian Boran cattle for meat and milk production. Working Paper No. 26. IPMS, ILRI Addis Ababa, Ethiopia.

Hansen P J 2004 Physiological and cellular adaptations of zebu cattle to thermal stress.Animal Reproduction Science 82-83, 349-360.

Hansen P J 2013 Genetic Control of Heat Stress in Dairy Cattle. In 49th Florida DairyProduction Conference, Gainesville 7pp.

Heins B J, Hansen L B, Seykora A J, Johnson D G, Linn J G, Romano J E and Hazel A R 2008 Crossbreds of Jersey x Holstein compared with pure Holsteins for production,fertility, and body and udder measurements during first lactation. Journal of Dairy Sci 91, 1270-1278.

Herbut P and Angrecka S 2012 Forming of temperature-humidity index (THI) and milkproduction of cows in the free-stall barn during the period of summer heat. Animal Science Papers and Reports 30, 363-372.

ICAR 2013 Conformation recording of Dairy Cattle. In (Ed. ICAR), p. 13pp. ICAR, Rome,Italy. Retrieved April 2015 from http://academic.uprm.edu/fjperez/Backup Agosto 2014/CITAI/Talleres y Seminarios/Calidad/Dairy Boby Conformation Score.pdf

Ilatsia E D, Muasya T K, Muhuyi W B and Kahi A K 2007 Milk production andreproductive performance of Sahiwal cattle in semi-arid Kenya. Tropical Science 47, 120-127.

Kahi A K, Rewe T O and Kosgey I S 2005 Sustainable community-based organizations forthe genetic improvement of livestock in developing countries. Outlook on Agriculture 34 (4), 261-270.

Kahi A K, Nitter G, Thorpe W and Gall C F 2000 Crossbreeding for dairy production inthe lowland tropics of Kenya II. Prediction of performance of alternative crossbreeding strategies. Livestock Production Science 63.

King J M, Parsons D J, Turnpenny J R, Nyangaga J, Bakari P and Wathes C M 2006 Modelling energy metabolism of Friesians in Kenya smallholdings shows how heat stress and energy deficit constrain milk yield and cow replacement rate. Animal Science 82, 705.

Kluyts J F, Neser F W C and Bradfield M J 2003 Development of breeding objectives forbeef cattle breeding: Derivation of economic values. South African Journal Animal Science 33, 142-158. Retrieved April 2015 from http://www.sasas.co.za/sites/sasas.co.za/files/kluytsvol33no3_1.pdf

KNBS 2009 Kenya Population and Housing Census. In Population Census (Ed. KNBoStatistics), KNBS, Government Printers, Nairobi, Kenya. 93pp. Retrieved April 2015 from http://www.knbs.or.ke/index.php

LeBlanc S J 2008 Postpartum uterine disease and dairy herd reproductive performance: areview. Veterinary Journal 176, 102-114.

Leegwater P and Hoorweg J 2000 Dairy Development: The Case of Kilifi and Malindi,Kenya. In Dairy Development, 24, 359-372. Retrieved March 2015 from https://openaccess.leidenuniv.nl/bitstream/handle/1887/9674/ASC_1253933_089.pdf

Lemos A M, Teodoro R L, Oliveira G P and Madalena F E 1985 ComparativePerformance of Six Holstein-Friesian x Guzera Grades in Brazil. Animal Production 41, 73-83.

Lima I A, de Azevedo M, Borges C R A, Ferreira M A, Guim A and de Almeida G L P 2013 Thermoregulation of Girolando cows during summertime, in Pernambuco State,Brazilia c a cie iar m ari 35, 193-199.

Lobo R B, Duarte F A M, Ramos A A, King M J and Wilcox C J 1980 Genetic trends inmilk production in a closed herd of Gir cattle. Journal Dairy Science 63 (suppl. 1), 101.

Lucy M C 2001 Reproductive Loss in High-Producing Dairy Cattle: Where Will It End?Journal of Dairy Science 84, 1277-1293.

Madalena F E 1999 Dairy cattle breeding programme in Brazil; development of the Brazilian milking hybrid (MLB). In Breeding Strategy Workshop: ICAR Technical Series - No 3 (Ed. ICAR), pp. 365-378. ICAR. Retrieved March 2015 from http://agtr.ilri.cgiar.org/Documents/CS1_28.pdf

Madalena F E, Peixoto M G C D and Gibson J 2012 Dairy cattle genetics and its applications in Brazil. Livestock Research and Rural Development 24, 58pp. Retrieved March 2015 from http://www.lrrd.org/lrrd24/6/made24097.htm

McManus C, Louvandini H, Carneiro H C, Lima P R M and Neto J B 2011 Productionindices for dual purpose cattle in central Brazil. Revista Brasileira de Zootec40, 1576-1586.

Mellado M, Coronel F, Estrada A and os F G 2011 Lactation Performance of Holsteinand Holstein x Gyr Cattle under Intensive Condition in a Subtropical Environment. Tropical Subtropical Agroecosystems 14, 927-931.

Mészáros G, Eaglen S, Waldmann P and Sölkner J 2014 A Genome Wide AssociationStudy for Longevity in Cattle. Open Journal of Genetics 04, 46-55. Retrieved December 2014 from http://dx.doi.org/10.4236/ojgen.2014.41007

Mirkena T, Duguma G, Haile A, Tibbo M, Okeyo A M, Wurzinger M and Sölkner J 2010 Genetics of adaptation in domestic farm animals: A review. Livestock Science 132, 1-12.

Munksgaarda L, DePassille A M, Rushenb J, Herskina M S and Kristensena A M 2001 Dairy cows' fear of people: social learning, milk yield and behaviour at milking. Applied Animal Behaviour Science 73, 15-26.

Muraguri G R, McLeod A and Taylor N 2004 Estimation of Milk Production fromSmallholder Dairy Cattle in the Coastal Lowlands of Kenya. Tropical Animal Health and Production 36, 673-684.

Muriuki H, Omore A, Hooton N, Waithaka M, Ouma R, Staal S J and Odhiambo P 2003 The Policy environment in the Kenya dairy sub-sector: A review. In SDP Research andDevelopment Report 2 (Ed. TSDRaDP (SDP)), p. 81pp. Nairobi, Kenya. Retrieved April 2015 from https://cgspace.cgiar.org/bitstream/handle/10568/1784/Muriuki et al-2003-Policy environment report.pdf

Mustafa M I, Latif M, Bashir M K and Ahmad B 2002 Productive performance of RedSindhi cattle under hot and humid environment of Baluchistan province of Pakistan. Pakistan Veterinary Journal 22, 151-157.

Mustafa M I, Latif M, Bashir M K and Ahmad B 2003 Reproductive Performance of redSindhi cattle under hot and humid environments of Balochistan Province of Pakistan. Pakistan Veterinary Journal 23, 66-72.

Mwacharo J M, Okeyo A M, Kamande G K and Rege J E O 2006 The small East Africanshorthorn zebu cows in Kenya. I: Linear body measurements. Tropical Animal Health and Production 38, 65-74.

Mwamuye K M, Kisimbii J and Otieno M 2013 Factors Influencing Adoption of DairyTechnologies in Coast Province, Kenya. International Journal of Business and Commerce 2, 1-36.

Nardone A, Ronchi B, Lacetera N, Ranieri M S and Bernabucci U 2010 Effects ofclimate changes on animal production and sustainability of livestock systems. Livestock Science 130, 57-69.

Negrao J A 2008 Hormone release and behavior during suckling and milking in Gir, Gir xHolstein, and Holstein cows. Journal of Animal Science 86, 21-26.

Neidhardt R, Grell H, Schrecke W and Jakob H 1996 Sustainable livestock farming inEast Africa. Animal Research and Development 43/44, 44-52.

Nicholson C F, Thornton P K, Mohammed L, Muinga R W, Mwamachi D M, Elbasha E H, Staal S J and Thorpe W 1999 Coast Province, Kenya, and the environment for smallholder dairying:. In Smallholder Dairy Technology in Coastal Kenya. An adoption and impact study (ed. ILRI), p. 68pp, ILRI, Nairobi, Kenya.

Oltenacu P and Broom D 2010 The impact of genetic selection for increased milk yield on the welfare of dairy cows. Animal Welfare 19, 39-49. Retrieved April 2015 from http://www.fao.org/fileadmin/user_upload/animalwelfare/dairy.pdf

Pantelic V, Aleksic S, Ostojic-Andric D, Sretenovic L, Petrovic M M and Novakovic Z 2010 Linear evaluation of the type of Holstein-Friesian bull dams. Archiva Zootechnica 13,83-90.

Prata M A, El Faro L E, Verneque R S, Vercesi Filho A E, Peixoto M G C D, Moreira H L and Cardoso V L 2014 Genetic parameters for milk production traits and breeding goals forGir dairy cattle in Brazil. 10th World Congress on Genetics Applied to Livestock Production, 3pp.

Praxedes V A, Verneque R S, Pereira M C, Pires M F A, Machado M A and Peixoto M G C D 2009 Evaluation of Factors Influencing Milk Ejection in the Brazilian Gyr DairyCattle. In Proceedings of the 2009 Interbull meeting, p. 4pp. Retrieved April 2015 from https://journal.interbull.org/index.php/ib/article/view/1101/1092

Ramadhan A, Kiura J N and Njunie M N 2008 Dairy production in coastal Kenya: thecurrent status. 11th KARI Biennial Scientific Conference, 10-14 November 2008 KARI Headquarters, Nairobi, Kenya, 1-13.

Rauw W M, Kanis E, Noordhuizen-Stassen E N and Grommers F J 1998 Undesirableside effects of selection for high production efficiency in farm animals: a review. Livestock Production Science 56, 15-33.

Reda S 2012 The most profitable Dairy Cow. Livestock Kenya. Retrieved April 2015 fromhttp://www.livestockkenya.com/index.php/cattle/285-the-most-profitable-dairy-cow.

Rewe T O, Herold P, Kahi A K and A 2009 Breeding indigenous cattlegenetic resources for beef production in Sub-Saharan Africa. Outlook on Agriculture 38, 317-326.

Roche J R, Friggens N C, Kay J K, Fisher M W, Stafford K J and Berry D P 2009.Invited review: Body condition score and its association with dairy cow productivity, health, and welfare. Journal of Dairy Science 92, 5769-5801.

Roxstrom A 2001 Genetic Aspects of Fertility and Longevity in Dairy Cattle. PhD Thesis,Swedish University of Agricultural, SLU, Uppsala, Sweden. Retrieved April 2015 from http://pub.epsilon.slu.se/27/1/91-576-5812-9.pdf

Royal M D, Darwash A O, Flint A P F, Webb R, Woolliams J E and Lamming G E 2000 Declining fertility in dairy cattle: changes in traditional and endocrine parameters of fertility. Animal Science 70, 487-501.

Rushen J, De Passille A M B and Munksgaard L 1999 Fear of People by Cows andEffects on Milk Yield, Behavior, and Heart Rate at Milking. Journal of Dairy Science 82, 720-727.

Sakaguchi M 2011 Practical Aspects of the Fertility of Dairy Cattle. Journal ofReproduction and Development 57, 17-33.

Santana M L, Pereira R J, Bignardi A B, El Faro L, Tonhati H and Albuquerque L G 2014 History, structure, and genetic diversity of Brazilian Gir cattle. Livestock Science 163,26-33.

Sanh M V 1, Preston T R and Fajersson P 1995 Effects of restricted suckling versusartificial rearing on performance and fertility of *Bos taurus* and *Bos indicus* cows and calves in Tanzania. Livestock Research for Rural Development 6 (3). http://www.lrrd.org/lrrd6/3/10.htm

SDP 2005 Smallholder Dairy Project (SDP), Kenya Policy Briefs No. 10. Retrieved May2015 from https://cgspace.cgiar.org/bitstream/handle/10568/1785/SDP Brief 10.pdf

Singh G, Dutt G, Sharma R B, Singh S K, Fatima A and Chauhan S V S 2012 An Analytical Study of Reproductive Performance in Gir Cows. Indian Research Journal of Extension Education 1, 203-206.

Singh R S, Bansal B K and Gupta D K 2014 Udder health in relation to udder and teatmorphometry in Holstein Friesian x Sahiwal crossbred dairy cows. Tropical Animal Health and Production 46, 93-98.

Strandberg E and Sölkner J 1996 Breeding for Longevity and Survival in Dairy cattle. in:Proceedings of International Workshop on Genetic Improvement of Functional Traits in Cattle. Gembloux, Belgium. Interbull Bulletin 12, 111-119. Retrieved April 2015 from https://journal.interbull.org/index.php/ib/article/download/257/257

Tadesse M and Dessie T 2003 Milk production performance of Zebu, Holstein Friesian and their crosses in Ethiopia. Livestock Research for Rural Development 15 (3), http://www.lrrd.org/lrrd15/3/Tade153.htm

Tesorero M, Combellas J, Uzcátegui W and Gabaldón L 2001 Influence of suckling before milking on yield and composition of milk from dual purpose cows with restricted suckling. Livestock Research for Rural Development 13. http://www.lrrd.org/lrrd13/1/teso131.htm

The-STANDARD 2014 Boost for Coast Farmers as New Milk Plant is Launched. In TheSTANDARD, Newspapers 20th October 2014, p. 24. Nairobi, Kenya. Retrieved April 2015 from http://www.ipsos.co.ke/NEWBASE_EXPORTS/Brookside/141020_The Standard - Monday_24_8842a.pdf

Thorn E C 1958 Cooling degree days. Air Conditioning, Heating and Ventilation 55, 65-69.

Thorpe W, Kang'ethe P, Rege J E O, Mosi R O, Mwandoto B A J and Njuguna P 1993 Crossbreeding Ayshire, Friesian, and Sahiwal Cattle for Milk Yield and Preweaning Traits of Progeny in the semiarid Tropics of Kenya. Journal of Dairy Science 76, 2001-2012.

Van der Valk Y S 1992 Cost-price calculation of milk production under small scale zerograzing conditions. Working Paper NDDP/ M-45/242. Ministry of Livestock Development, Nairobi. In Working Paper NDDP/M-45/242. (Ed. GoK) Ministry of Livestock Development, GoK, Nairobi, Kenya.

Vercesi Filho A E, Verneque R S, Peixoto M G C D, Machado M A, Penna V M and Cardoso V L 2010 Selection Of Tropical Dairy Cattle–The Experience From The BrazilianGyr And Guzerat. In 9th World Congress on Genetics Applied to Livestock Production, Leipzig, Germany, p. 8pp. Retrieved April 2015 from http://www.kongressband.de/wcgalp2010/assets/pdf/0829.pdf

Veríssimo C J, Bechara G H, Mukai L, Otsuk I P and Pozzi Arcaro J R 2008 Mast cellcounts correlate with Rhipicephalus (Boophilus) microplus tick load in different cattle breeds. Brazilian Journal of Veterinary Patholology 81-87. Retrieved April 2015 from http://www.abpv.vet.br/upload/documentos/V.1,-N.2,-19-20881_2009_12_30_38_45.pdf

Verneque R S, Peixoto M G C D, Filho A E V, Machado M A, Filho J C R, da Silva M V G B, Fernandes A R and Machado C H C 2009 Brazilian Gir Breeding Program Sire Summary Test Results. 19pp

Villares J B 1941 Climatologia Zootécnica. III. Contribuição ao estudo da resistência e susceptibilidade genética dos bovinos ao Boophilus microplus. Bolet da Indústria Animal 4

Walsh S W, Williams E J and Evans A C 2011 A review of the causes of poor fertility inhigh milk producing dairy cows. Animal Reproduction Science 123, 127-138.

Wambugu S, Karimi L and Opiyo J 2011 Productivity trends and performance of dairyfarming in Kenya. Tegemeo Institute of Agricultural Policy and Development WPS 43, 1-37. Retrieved April 2015 from http://www.tegemeo.org/images/downloads/Working papers/WP43-Productivity-Trends-and-Performance-of-Dairy-Farming-in.pdf

Yakubu A 2011 Path Analysis of Conformation traits and Milk yield of Bunaji Cows inSmallholder's Herds in Nigeria. Agricultura Tropica Et Subtropica 44, 152-157. Retrieved April 2015 from http://www.agriculturaits.czu.cz/pdf_files/vol_44_3_pdf/yakubu.pdf

Received 22 April 2015; Accepted 7 July 2015; Published 1 August 2015

Go to top