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Influence of various environmental factors on dairy productionand adaptability of Holstein cattle maintained under tropical and subtropical conditions

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ABSTRACT

Milk yield and adaptability of Holstein are factors of major concern under tropical and subtropical conditions. Under these conditions the focus had always been on milk production and the adaptability and survival are often overlooked. Genotype by environment interactions pose a potential challenge for Holstein-Friesian cattle raised in tropical and subtropical environments by hampering the production and adaptability and predispose the cattle forinvoluntary culling.The present review was aimed at comparing milk yield, influence of various non-genetic factors and adaptability of Holstein dairy cattle under different environmental conditions with special focus on tropical and sub-tropical conditions. The milk production in tropical and subtropical conditions was 40% to 60% lower than the temperate conditions. This wide discrepancy in the milk production in different environmental conditionswasmainly the outcome of influence of non-genetic factors and most importantly the management of the farm under which the animals were kept. The management role was obvious in tropical and subtropical conditions, the more the country was technologically advance the better was the management and the higher was the production.Noticeably, in tropics and sub-tropics milk yield was significantly higher in cooler part of the year than the hotone. Environmental and physiological adaptability of Holstein needs considerable attentionin tropics and sub-tropics. In near future global warming is assumedto be even more disastrous to the dairy animals in tropics; therefore, selection for genetic merit of both production and adaptability should be of concern. Breeding systems, which include proxy indicators for adaptability and genetic markers in the evaluation program to assist the selection for higher accuracy and efficiency, are proposed to improve both milk yield and adaptability of dairy cattle under tropical and sub-tropical conditions.The future challenge is to maintain high producing dairy cattle performance in hot and humid climatic conditions. To avoid this alarm,considering integrated approach by improving cooling capability, efficient ration formulation and improved genetic potential for heat resistance through genetic manipulation are supposed to be promising approachestoimprove the production and survivability of lactating Holstein under these conditions.

Key words:Dairy cattle, adaptability, survival, environmental factors, heat stress.

Introduction

Dairying is an important enterprise for many countries of the world and is especially important source of income generation for rural families in the 3rd world agricultural countries. With increase in population the demand for milk increases [23,63]. Every country is trying to boost up milk production and for that different breeding strategies are considered [17,31]. Mostly, dairy breeds of the tropics and sub-tropics are slow maturing and low milk producers, this inferiority is partly inherited and partly due to the malnutrition, management and environment to which they are exposed [17]. In general, the tropical and subtropical countries employ policies such as, breed replacement, selection within the local breeds and crossbreeding with exotic breeds for improving the milk production. Holstein Friesian is highest milk producing dairy breed,which is imported by many developing countries mostly of tropics and subtropics, either for keeping it as pure breed or for crossing with the local low producing cattle from technologically developed countries of temperate zones [61].

Although, Holstein is imported with the idea to improve the national milk production but their performance in the tropical and subtropical environment is considerably low compared to the temperate environment [26,27,64]. Local breeds of tropics and subtropics are well adapted to the

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prevailing environmental stresses but have very low milk production, whereas, on the other hand, the specialized temperate dairy breeds, despite of having their high genetic potential for high milk yield in the intensive systems in which they were selected, cannot survive the harsh tropical conditions, to the point ofrisk of their survival [65]. The expression of the inherit genetics merit varies from one environmental condition to another conditions and is greatly influenced by non-genetic factors [26,17]. The performances of temperate genotype in tropical conditions like Bangladesh was30-40% lower than that of the countries of their origin. Environment and genetic (G x E) interaction plays an important role in the expression of the full genetic worth [34,26,47,23,53]. Seasonal heat stress effect on milk production, fertility and reproduction of dairy cattle is worldwide and exert heavy economic loses to the dairy industry [68]. In lactating Holstein cattle the comfortable temperature is between the range of 4-24^{o}C [21]. Heat stress effects on the cattle can be observed above 24^{o}C, and milk yield markedly decreases above 27^{o}C [29]. Whereas, in most of the tropical and subtropical areas the ambient temperature rises even above 40°C that is obviously suboptimal for Holstein cattle breed to maintain their health and production performance. Therefore, the present review was aimed at comparing milk yield and adaptability of Holstein across different environments, and effects of various non-genetic factors on milk production under different environmental conditions with special focus on tropical and subtropical conditions.

Milk production under different environmental conditions:

Lactation milk yield of Holstein under temperate environmental conditions ranged from 8153±1949.24 kg to 10069 kg [54,12,20,47,9,67,57,46,41]. Under tropical and sub-tropical conditions the lactation milk yield ranged from 2772.76±65.00 kg to 7454±2134 kg [42,55,1,47,39,60,13,52,62,2,7,16,63,50,64] reported that Milk yield decreased about 10 to 40% in Holstein cows during the summer as compared to the winter. From the reviewed literature it is evident that milk production was obviously high in Holstein maintained under temperate environmental conditions than those of tropical and sub-tropical environments. In temperate environments the milk production is touching the values of 10 tons but on the other hand milk production in the other two conditions is about 3 to 4 tons. This showed that the production performance of Holstein was 40% to 60% lower than the temperate conditions. This wide gap in milk yield was partly due to the management under which the animals were kept and partly due to the harsh environmental conditions common in tropics and subtropics rendering the milk yield lower. This is evident from the fact that milk production is widely different even under the same environmental conditions but different management system. Beside inadequate environment, substandard nutrition including poor roughage quality, low concentrate feed inputs and the high incidence of disease and parasites which are common under these conditions predisposes the animals to low profit generation. The other important factor is Poor husbandry practices, which are generally a reflection of underlying socio-economic factors such as the low level of farmers' education and the lack of supporting research, extension and animal health services.Studies from the tropical and subtropical environments showed that the performance of the Holstein drastically lowers down when the Holstein are imported from the technologically advanced countries of temperate environments to tropics and sub-tropics. In short, it is the management that bound the production of cattle; animals can perform better provided suitable environment (adequate feeding, open housing, use of sprinklers, cool air flow, control of pests, better veterinary care and husbandry practices etc.) is supplied.

Influence of non-genetic factors:

Significant effect of season of calving on age at first calving was found by Sahin*et al.,* [49]; Afridi [1]; Rivas *et al.,* [47]; Javed *et al.,* [27]; Muir *et al.*,[36]; Amani *et al.,* [2] and Sandhu *et al.,* [50]; whereas, Bilal *et al.,* [7] and Usman *et al.,* [64] found non-significant effect of season of calving on lactation milk yield. Afridi [1] and Javed *et al.,* [27] reported that milk production was highest in the autumn and spring seasons and was lowest in hot summer, whereas, Sandhu *et al.,* [50] and Usman *et al.,* [64] found higher lactation milk yield in spring and lower in the summer. Stadnik and louda, [56]; and Amani *et al.,* [2] reported that milk production was highest in winter than the other seasons. The finding of all the above studies indicated that milk production was higher in cooler part of the year and was adversely affected by hot weather. Holstein being a temperate breed in origin does not perform well under tropical and subtropical conditions [64, 65,26,27]. The authors reported the reasons for this discrepancy in milk yield, especially lower milk production in the summer were, heat stress, lower metabolism, poor quality and inadequate quantity of feed and high parasitic load in this weather that suffered the cattle to the extent that the animals could not maintain their production. This is evident from the fact that animals performed well in the cooler seasons than the hot and humid season. Overcoming the environmental barriers the production can be intensified in these conditions, which can be achieved by management interventions by providing suitable environment and balance ration in the hot summer. According to Armstrong [4], a number of methods are been in use by dairy farmers to cool

lactating cows during summer heat, but the most common is use of water spray and fans to facilitate evaporative cooling. Appropriate housing that assists in dissipating heat might bring about reduction in the severity of the problems.

Survival and adaptability:

Tropical and subtropical environments have both direct and indirect effects on livestock [53]. Factors such as temperature, solar radiation, humidity and wind all have direct effects on animals, whereas, factors i.e. digestibility of feed, intake, quality and quantity of grazing, pests and diseases all have indirect effects on animals under these conditions. A series of adaptation parameters have been involved in determining the tolerance of each breed to their particular environment, these include respiratory, circulatory, excretory, nervous, endocrine and enzymes [42,33]. Hernandez *et al.,* [24] while studying three breeds of cattle viz. Senepol, Brahman and Holstein reported that under tropical climate of Puerto Rico, Holstein rectal temperature and respiratory rate was significantly higher than the other two breeds, and also mentioned that Holstein performance in tropics in terms of production and tolerance was lowest amongst the three breeds. Furthermore, Menjo *et al.,* [31] while studying early survival of Holstein-Friesian heifers of diverse sire origins on commercial dairy farms in Kenya reported that daughters of sires from South Africa and Israel tended to have better survival rates than those sired by other regions like USA, Canada, New Zealand and Australia. According to Oseni *et al.,* even in tropical southern United States, Holstein suffered great loses in terms of milk production, fertility and reproduction, although, immediate and special efforts were made to control environmental influences. Dairy cattle in southern USA, exposed to hot conditions during late gestation produced calves with lower birth weights, and produced less milk than cows not exposed to hot conditions Collier *et al.,* [14], and according to Reyes *et al.,* [45] these situationswere the outcome of reduction in thyroxine, prolactin, growth hormone, and glucocorticoid levels in blood. Bonsma [8] while studying the level of weight loss in the Afrikaner exotic breed (Hereford) in Africa found that after 24 hours without water, weight loss was only 2% in Afrikaner, whereas, it was 15% in Herford.Moreover, a 24 hour water deprivation also did not reduce the feed intake of the Afrikaner, whereas, that of the exotic breed was reduced by 24%. According to McManus *et al.,* [33] the temperate dairy breeds imported to tropical environments are poorly adopted to the local environment and upon exposure of these animals to higher temperatures, humidity alterations and feed changes caused these genetically more productive animals to undergo behavioral, endocrine, and physiological changes, which could negatively affect their production and survival under prevailing conditions. Indigenous breeds might contain alleles which confer resistance to diseases or better survival in harsh environmental conditions thus could be of considerable importance for a national production scheme [69]. Weight and feed are the most important parameters in determining the milk production of the dairy cattle, and the reported significant loss in weight and feed intake by Holstein compared to the tropical local breeds are alarming factors for the economic dairy farming of this particular breed under these conditions. Integrated approached including management interventions by providing appropriate housing, better nutrition and marker assisted selection might provide a push to theproduction and adaptability of Holsteinunder tropical conditions.

Heat Stress Effects:

The climate in a certain geographical area, particularly temperature and relative humidity, greatly influence the production potential of the animals [33]. In lactating cows body heat production is associated with increases milk yield because metabolic processes, feed intake and digestive requirements increase with yield [66]. The heat stress to which a lactating cow is exposed is a combination of heat accumulated from an environment and a failure to dissipate heat associated with metabolic process. Purwanto *et al.,* [43] reported that when non-lactating cows, lower milk yielding (18.5 kg/d) or high yielding (31.6 kg/d) were compared, low and high yielding cows produced 27 and 48% more heat than non-lactating cows despite of having lower BW (752, 624, and 597 kg for non-lactating, low, and high producers, respectively). Beside production, fertility of dairy cattle exposed to heat stress was markedly reduced, such as reduced expression of estrus [22], decreased fertilization rate [71], and increased embryonic mortality [44,19]. Sartori *et al.,* [51] and Ambrose *et al.,* [3] found that hyperthermia can occur in lactating Holstein cows at air temperatures of 25-28^{0}C maintained under intensively managed system. Higher the blood level of Holstein lowers the resistance to the heat stress under tropical and subtropical conditions [5,40,60]. Pastsart*et al.,* [40], Collier *et al.,* [15] and Scholtz *et al.,* [53] reported that there is a network of genes that are directly or indirectly related to heat stress regulation, and therefore, marker assisted selection can be effective approach. According to the studies by Bonsma [8], Kadzere *et al.,* [30], St-Pierre *et al.,* [56], Berman [6] and Nardone *et al.,* [37] when high milk producing cattle were kept in hot climatic zones, metabolic heat production was intensified in high milk producers that resulted in an increase respiratory rate, consequently, decrease in the milk production. Pastsart *et al.,* [40] and Molee *et al.,* [35] found that Holstein crossed with local breeds in the tropics and subtropics perform better than the

pure bred Holstein and were also resistant to heat stress. According to Shioya *et al.,* [59], the temperature (28^{o}C) at a high humidity (80% RH) showed more effect on the cows' feed intake, milk yield, milk composition, heat production, evaporative heat loss and time spent lying down than when humidity was low (40% RH). The authors further demonstrated that the effect of radiant heat were also considerable and the milk yield fell by 17% among the cows exposed to radiant heat, compared to those which were not. The effects of humid hot conditions are more severe than the dry hot. High temperature and relative humidity reduces evaporative cooling, so under hot and humid conditions the dairy cattle cannot dissipate sufficient body heat to avert a rise in body temperature. The dry hot condition can be relieved by providing sprinklers and fans, whereas, in the humid hot case the cows solelyrely upon evaporative cooling in the form of sweating and panting [66]. Vaccaro [65] and Molee *et al.,* [35] reported that under tropical and sub-tropical conditions temperate breed faces heavy losses and their health and adaptability are of concern because of continuous exposure to multiple stresses such as heat stress, poor quality and low quantity feed, high risk of diseases, parasitic load, inadequate husbandry and breeding practices.

Impact of Temperature Humidity Index (THI) and Global Warming:

Beside many indicators, temperature humidity index (THI) is also useful tool to measure heat tolerance. Berman [6] studying temperature humidity index reported that Holstein is the primary target of heat stress relief. Preez *et al.,* [42] and Johnson [29] documented that milk production is not affected by heat stress when mean THI values are between 35 and 72. However, milk production and feed intake begin to decline when THI reaches 72 and continue to decline sharply at a THI value of 76 or greater. Molee *et al.,* [35] reported that in Thailand average THI was above 80 during 2007 to 2009 that was uncomfortable to the dairy animals, as heat stress is common at this level that badly effected milk production. Bouraoui *et al.,* [11] studying the effects of temperature-humidity index (THI) on milk production and dry matter intake (DMI), reported that when the THI value increased from 68 to 78, milk production decreased by 21% and DMI by 9.6%, and milk yield decreased by 0.41 kg per cow per day for each point increase in the THI values above 69. Moreover, the authors reported that when the THI values increased from 68 to 78, rectal temperature increased by 0.5 C^{o}, heart rate by 6 beats and respiratory rate by 5 inspirations per minutes. Holter *et al.,* [25] reported a significant negative correlation between THI and DMI for dairy cattle in the southeastern United States. According to Boonkum *et al.,* [10], heat stress effects on Thai Holstein crossbreds increased greatly with parity and after a THI of 80, with the increase in percentage of Holstein genetics (≥93.7%), the effects were also intensified. All these studies indicated that in tropics and subtropics it is not only the production that is adversely affected but the survival and adaptability of Holstein is also at risk. West *et al.,* [66] mentioned that in the absence of protective measures, global warming could create conditions that not only impair productivity of cattle but can also increase mortality of cattle. Molee *et al.,* [35] documented the most worried signal that due to global warming in the coming ten years, it would be hard to raise pure bred Holstein in open houses under tropical and sub-tropical conditions.

Conclusions:

From the reviewed literature, it is evident that Holstein performance varies greatly under different environmental conditions. In temperate zones milk yield of Holstein was touching the figure of 10 tons but under tropics and subtropics the average production was 3 to 4 tons. Under tropical and sub-tropical conditions, the more the country developed, the better was the management, and the higher was the milk production. Under tropical and subtropical zones there is a need to select animal not only for the production genetic merit but also for resistance to environmental and physiological stresses, and for that, it is suggested to model the genetic components to the environmental stress factors for selection. It is assumed that in the near future global warming effect would be more disastrous in the tropics. To avoid this mishap, considering an integrated approach by using improved cooling capability, efficient nutritionformulation andassisted techniques such as proxy indicators for adaptability, quantitative trait loci (QTL), gene chip and marker assisted selection are supposed to enhance the production combined with adaptability of Holstein under hot environmental conditions.

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