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# Heat Stress in Dairy Cows (A Review)

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**Abstract** Heat stress is an important disadvantageous factor that reduce the dairy farm profitability and conduce to significant decrease in milk yields in dairy cows and some metabolical disorders. The objective of this review is to known the heat stress metabolism, its causing factors and its preventative methods for increase the herds profitability through managmental and nutritional procedures.

**Keywords** Heat, Temperature, Panting, Sweating, Moisture

## 1. Introduction

Heat Stress is an important affecting factors that negatively affect on dairy cattle performance and productivity traits, especially in hot climate or summer in very areas of the world. Heat stress can affect on lactating and dry cows performance and health. Lactating cows especially during peak of milk production, can experience heat stress and dry cows, especially during transition period, can experience heat stress.

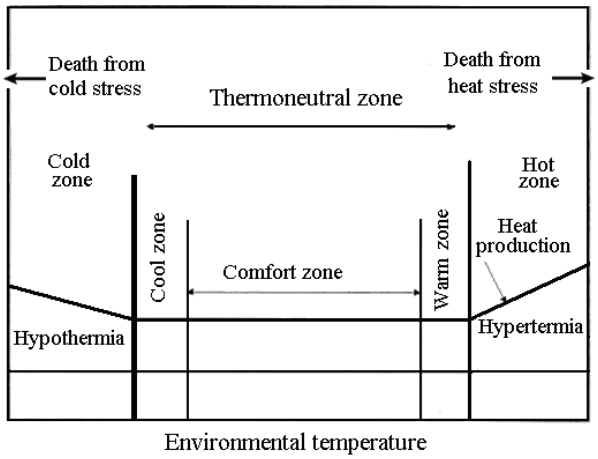


**Figure 1.** Schematic figure of thermoneutral zone and comfort zone(Adapted from curtis, 1981)

A common time for experience adverse effects of high temperatures is during transport(Fiore et al, 2009). Transport is a multiafected stressor that can create or exacerbate existing heat loads. Truck design can influence the environmental impact on animals. Handling of cows, increases cows body temperature. Cows are adversely affected any time the ambient temperature is more than their thermoneutral zone, which ranges from 25℃. Because that heat stress conduce to some disadvantageous affect on livestocks, many researchers work about heat stress in dairy cows.

**Thermoneutral zone**

Thermoneutral zone is defined as the zone of minimal heat production at rectal temperature. Out of this zone, some disturbances will be observed. Figure 1, illustrate this concept.

## 2. Dissipation of Heat from Body

All of negative heat stress affects on animals, is a results of body temperature increase. Body temperature increase, obtained from body metabolism after feeding and can be an useful mechanism under cool winters.

Body temperature(BT) results from the balance between heat production (HP) and heat loss (HL). In high-producing cows, the HP is higher, and the effect of a hot environment is more pronounced. The body temperature of high-producing cows rose to a higher level than that of low-producing cows, because of the higher metabolic rate and heat production of the more productive cows. In hot climate or at summer, we must not consider only the temperature, because that environments humidity is an important affecting factor in heat stress. Air moisture can influences the rate of evaporative heat loss from dairy cows through both skin and the respiratory tract. Humidity can affects on the HL from a dairy cows under high temperature conditions, therefore dairy cows performance, falls markedly in hot and humid summers.

Dairy cows can dissipate body heat through conduction, convection, radiation and evaporative cooling.

Conduction is based upon the principal that heat flows from warm to cold. This method of heat loss requires that a cow have physical contact with surrounding objects. When a cow wades into a pool, she is cooled by conduction.

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Convection occurs when the layer of air next to the skin is replaced with cooler air.

Radiation of body heat can occur when the ambient temperature is significantly cooler than the cow. At cool temperatures, dairy cattle are efficient at radiating heat. The level of radiant heat from the roof of a livestock barn(cal/cm2/min) is very high in summer, and its effect on milk production is very important. Black cows do feel the effects of heat stress earlier than white cows, but radiate heat better at night and hence recover more rapidly.

Evaporative cooling occurs when sweat or moisture is evaporated from the skin or respiratory tract. This explains why dairy cattle sweat and have increased respiration rates during heat stress. High humidity limits the ability of the cow to take advantage of evaporative cooling.

Thermal environments have several aspects, including air temperature, humidity, air movement, and radiation rate.

One of important factors in heat stress is wind. Wind affects the heat loss from the body surface of an animal by the processes of convection and evaporation.

## 3. Effects of Heat Stress in Dairy Cattle

Heat stress affect on dairy cattle in several ways and finnaly cause to decrease animal milk production and performance.

Some of most important results of heat stress in dairy cattle include:

1. Some behavioral signs such as Seek shade, refuse to lie down, Incoordination, inability to move,
2. Increased respiration rate and laboured breathing, or panting,
3. An increase in heart rate,
4. Excessive salivation,
5. Increased sweating,
6. Crowding around water sources, and increased water intake,
7. Decreased blood flow to internal organs,
8. Some changes in digestion of food, such as reduced or absent rumination (chewing of cud) and Slower feed passage rate throught digestive tract,
9. Decreased dry matter intake and feed intake,
10. Decreased milk production, and milk quality,
11. Change in body hormones level,
12. Poor reproductive performance,
13. Lower calves birth weight,
14. Increase the maintenance energy requirements.

This events done step by step and finally conduce to decline in animal production(Fig 2).

1. Panting:

Panting or rapid breathing is one of first results of heat stress and is in observative and nonobservative form, Rapid breating with close mouth or low depth breating and rapid breating with open mouth or high depth breating that can observe. This mechanism, can increase the dairy cows requirements by 20%. During the panting period high volume of carbone dioxide excreted and this conduce to a disturbance in acid-base balance. This event especially around the parturition is very risk factor for incidence of hypocalcemia and milk fever.

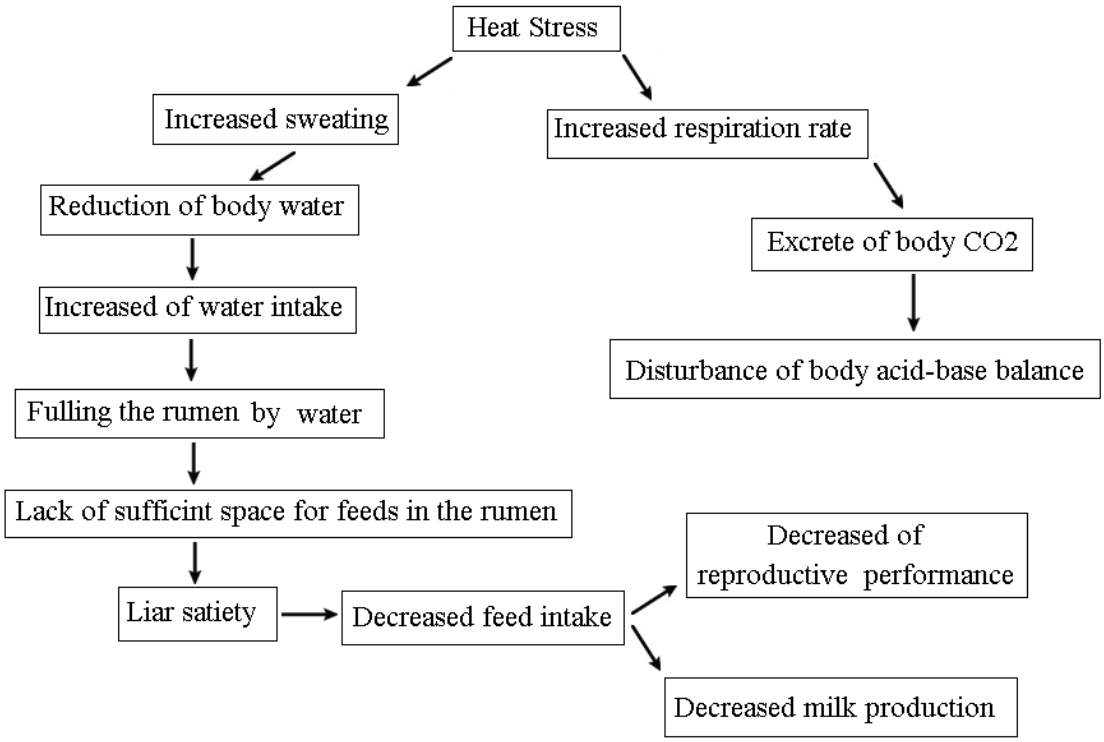


**Figure 2.** Some important results of heat stress in dairy cows

2. Increasing the sweating:

This mechanism is a effective action for excrete the excessive heat from body. Altought this mechanism conduced that body heat excrete, but this led to excrete a lot of body electerolytes such as potassium and this conduce to an acid-base imbalance in body. Water, sodium, potassium and chlorine are important constituents of sweat, and sweating is a major, if not the most important, thermoregulatory mechanism used to dissipate excess body heat. Addition of sodium bicarbonate or simply the addition of salt to the ration may also be useful to prevent ruminal acidosis.

3. Increased water intake:

Sweating of dairy cows in hot climate, conduce to a lot of loss of body water and this due to increasing water requirements of cows. Therefore first mechanism after sweating is an increase in water intake. High-yielding dairy cows may drink up to 200 litres per day. Water quality and cleanliness of the water troughs should be checked daily.

4. Decreasing the blood flow of internal organs:

Decreasing the blood flow of internal organs conduce to lower activity of digestive tracts organs such as rumen and intestines and frequently volatile fatty acid production in the rumen is decreased. Lower activity of digestive organs conduce to slower movement of feed particles and this conduce to rumen fulling and finally, cows appetite will be decresed.

5. Feed intake depression:

Increasing the water intake during heat stress, conduce to digestive tract fulling and then an insufficient space for feed consume, and consequently cows cant consume sufficient feed for meet their needs and finally some nutrient deficiency will be created. Forthermore decreased feed passage rate conduce to doubling the digestive tract fulling effect and finally cows cant consume sufficient feed. Feed intake, depend on the severity of heat stress may reduced by 8-12% or more. Feed intake started to decreased at 24℃ or more.

Depression in feed intake due to reduction in animal production and performance and some metabolic deficiencies.

6. Milk production depression:

Effects of heat stress on milk production have been studied extensively. Milk production decline is the most negative economic affects of heat stress(Smith, 1996) that reduced the dairyman benefits. Milk production depression at hot climate, stated in many researchs. Johnson(1965) suggested that milk yield depression started at above 27℃.

Toda et al at 2002 suggested a equation for calculating the relathionship between environment temperature and milk yields depression in hot climates. According this equation, a significant relationship exists between the level of milk yield (X, kg/day) and the decline in milk yield with each increase in daily mean environment temperature (Y, kg/day/℃) as follows:

$Y = -0.04*X + 0.18$ ($r = -0.53$, $P = 0.03$).

This equation shows that the decline in milk yield seen in lactating Holstein cows with each increase in ET of one degree C was 0.6 kg/day in cows producing 20 kg milk/day, 1.0 kg/day in cows producing 30 kg/day, and 1.4 kg/day in cows producing 40 kg/milk/day.

It is estimated that for every 1 kg decrease in dry matter intake, 2 kg of milk production are lost. Therefore milk production in dairy cattle that rear in moderate or cool climate, is more than hot climate cows milk production. Althought depend on the dairy herd management, milk production depression may be varied. In well-cooled dairies, heat stress typically decreases milk yield by 10-15%, and in non-cooled management systems, milk yield can decrease by 40-50% during severe conditions (West, 2003).

7. Milk composition changes:

Another heat stress effects on dairy cows is milk composition changes. Decreased in milk fat and protein is the most important milk composition changes under heat stress condition.

8. Body hormones level changes:

Cattle that rear without any shade in hot climate, usually have a lower level of estrogen than those with access to shade. There were other hormonal changes as well, which meant that cows suffering from heat stress had a lower conception rate.

9. Poor reproductive performance and fertility depression:

All of heat stress results can affect on cows reproductive performance and fertility. Heifers that rear under heat stress condition, usually has a significant delay in maturing and has a delay in first ovulation. Decline in fertility in hot environments is closely related to an increase in body temperature(BT).

10. Lower calves birth weight:

Heat stressed pregnant cows consume lower feed and especially in late pregnancy, cows nutrient requirements can not meet and lower nutrients is available for fetus growth and finally calves birth weights is lower than normal condition.

11. Increaseing the Maintenance energy requirements:

Maintenance energy requirements of dairy cows will increased during heat stress and this is because that high energy levels is required for heat loss from body during heat stress and this is called energy expenditure of heat stress.

# 4. Measuring of Heat Stress

Accurate measurement of heat stress in dairy cows is complicated, because the responses of cows to heat stress, affect not only on the energy balance, but also on water, sodium, potassium and chlorine metabolism.

Heat Stress severity, can measured by using a temperature humidity index(THI). Both ambient temperature and relative humidity are used to calculate a single index that called THI(Table 1). Signs of heat stress become evident in dairy cows when the THI exceeds 72. Figure 3 shows the different heat stress affects on dairy cows.

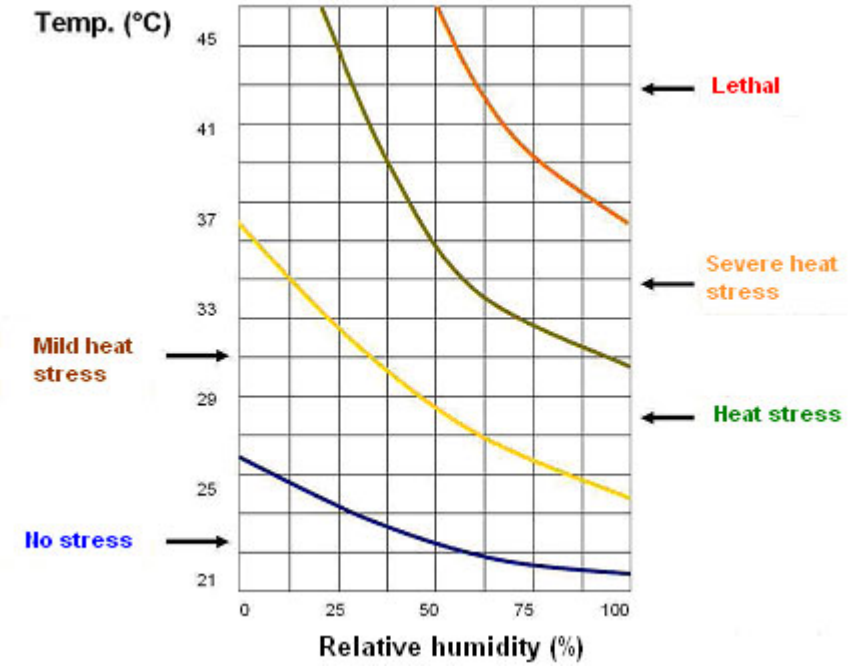


**Figure 3.** Different levels of heat stress and its affect on cows

**Table 1.** THI determining by use of Relative humidity and Tempertaure

| Temperature | Relative humidity | | | | | | | | | | | | | Stress level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | |
| 75 | No stress | | | | | 72 | 72 | 73 | 73 | 74 | 74 | 75 | 75 | Mild |
| 80 | 73 | 73 | 74 | 74 | 75 | 76 | 76 | 77 | 78 | 78 | 79 | 79 | 80 | Moderate |
| 85 | 76 | 77 | 78 | 78 | 79 | 80 | 81 | 81 | 82 | 83 | 84 | 84 | 85 | |
| 90 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 86 | 87 | 88 | 89 | | Severe |
| 95 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | |
| 100 | 86 | 87 | 88 | 90 | 91 | 92 | 93 | 94 | 95 | 97 | 98 | 99 | | |
| 105 | 89 | 91 | 92 | 93 | 95 | 96 | 97 | | | | | | | |

Heat stress severity, depend on the THI levels can divide to four levels (Table 2). According to this table, four main form of THI is exist that at worst condition, almost most cows in the herds will be dead.

**Table 2.** Heat stress severity

| THI | Heat stress severity |
|---|---|
| 72-78 | Mild stress |
| 79-88 | Moderate stress |
| 89-98 | Severe stress |
| More than 98 | Very severe stress |

Farmers can purchase a thermometer/hygrometer and measure the severity of heat stress. Measuring of heat stress can help the farmers for maintaining cows at optimal temperature and prevent from negative results of heat stress.

## 5. Methods of Heat Stress Prevention

Reducing and prevention of heat stress in dairy cattle, requires a multi-disciplinary approach. It involves breeding of dairy cattle for improved heat tolerance and improved nutrition for the animals, and improved structural design and environmental control for their housing(Armstrong, 1993).

Breeding of dairy cows for improved heat tolerance is a long term procces and is not practical way in most dairy farms in short period of time. Therefore we must focus on short term ways of reducing the heat stress.

Prevention of increase in body temperature in hot environments, can be approached in three ways (Shibata 1996):

- Lowering the environmental temperature by modifying the structure of the shed where the cattle are kept, or by introducing cooling facilities.
- Increasing heat loss from animals by sprinkling them with water, using fans and so on.
- Increasing the efficiency of feed energy utilization, and reducing the heat increment of animals by feeding strategies.

### 5.1. Environmental Control and Management for Reducing Heat Stress

Shade, fans, mist and fan systems, and night grazing, are

presented as effective methods of modifying the environments of dairy cattle for prevention of heart stress in hot climate. Depend of the different climate, several different methods can apply(table 3). In every methods, we must cool cows and finally decline the cows body temperature. For better understanding, we breakdown the different areas to four climate that include very humid, mild humid, low humid and very dry climates.

Physical modification of the every environment is based on two concepts: Protecting the cows from the factors contributing to heat stress, and enhancing evaporative heat loss by the animal. Use of cooling system is a very effective procedure for reducing of heat stress affects on cows. The major objective of every cooling system is to reduce the air temperature inside the barn, to keep the cow's body temperature as close as possible to the normal.

In very humid climates, cattle don't able to excrete body temperature with sweating. Humidity in this climate, block the sweating mechanism of cows and we must cool animals with another methods that don't depend to sweating mechanism. To cool cows in a very humid climate, large water droplet is required to wet the skin of the cow. In hot and humid subtropical regions, evaporative cooling doesn't able act alone and requires the use of forced ventilation. Ventilation is a good procedure for free stalls housed cows. Ventilation conduce that hot air move and excrete from the house. If ventilation use beside the fog method, house temperature decline significantly and cows welfare will be increased. Sprinklers without fans, or fans without sprinklers, will not give an effective cooling system. Sprinklers, can installed on the roof or at every various place of barns.

Spray and fan systems can use for decline heat stress affects in humid areas. Natural air movement, or the use of fans, will also increase the evaporation rate. Fans are the most common type of cooling device used in many countries. Fans can increase the air movement and air movement increases the rate of heat loss from a cow's body surface, as long as the air temperature is lower than the cow's skin temperature.

In climates with a low relative humidity, fog or mist systems (fine spray) usage provides evaporative cooling. These systems cool the air around the dairy cattle.

In very dry climates dairy cattle can sweat and this sweating cause that most of body heat excreted. Therefore usage of shades is a proper recommendation for dry climates. Simple shade is the basic method in summer of protecting animals from direct solar radiation during the day. Shades reduced solar radiation negative affects. Cows housed in dry lot or pasture situations should be provided with solid shade. Shade will reduce the amount of radiant heat load the cattle would face, that is especially true with dark hided cattle. Natural shading (trees) is effective, but most often shades are constructed from metals that are conductor of heat and especially if their surface be dark, it can be stressor. This is because that dark materials can absorb the sunshine. This subject is worse for dark metals, because they fist absorb sunshine and then conduce to dairy cows body surface. Natural wind in open housed cows, can increase the heat loss from body, but air temperature must be lower than body temperature. If the air temperature is higher than the cows skin temperature, the skin will gain heat from the surrounding air. At air temperatures above 39℃ moving air becomes a source of heat stress for dairy cattle.

**Table 3.** Recommended methods for different humidity under heat stress

| Humidity condition | Recommended methods |
|---|---|
| Very humid | Use of large water droplet |
| Mild humid | Use of spray or fans |
| Low humid(Dry) | Use of Fog or Mist(Fine spray) |
| Very dry | Use of shade |

Another important managing factors in heat stress is transport time of cows. One effective recommendation is that transport done in early in the day (prior to 0600) in the summer or every hot climate.

**Late evening or Night grazing**

Because that heat stress usually observed under sunlight, therefore one of effective methods for decline the affects of sunlight is evening or night grazing in summer. Air temperature and the level of solar radiation begin to fall after about 3 pm. After 6 pm, usually in all regions, the sunlight is very low and is not stressfull for cows. When you can not send cows in evening or night to pasture, cows should always be ensured of sufficient shade and fresh water.

**Delaying the afternoon milking**

In hot climates or in summer, in large dairy farms, usually most of lactating cows, waiting a lot of time for milking and at this period of time, they experience the heat stress. Because that this cows yet don't milking, then their heat produce a significant levels of heat and this is stressfull for their. One of effective methods for prevention the heat stress, is create a delay in afternoon milking for 1-2 hours.

### 5.2. Free Water Availability

Providing access to water during heat stress period, is critical and it is a common method for heat stress eliminate in every climate and don't depend to humidity levels. Lactating cattle water requirements is more than dry cows. In normal condition, every dairy cow needs 4-5 kg water for each kg of milk produced. Therefore high producing dairy cows need more water than low producing dairy cows and this high producing dairy cows will be more disposable against detrimental affects of heat stress.

It is concluded that dairy cows water needs increase 1.2 to 2.0 times when cows are under heat stress.

Water temperature is important factor and if water temperature is high or moderate, dairy cattle needs to more water for eliminating the heat from body. Cool waters are more suitable for prevention of heat stress.

Water should be fresh, clean and potable. Availability of clean and cool water to cows leaving the milking parlor is beneficial for increasing water intake during times of heat stress. Access to an 2.5-metres water trough when cows are leaving the milking center is adequate for milking parlors

with 25 stalls or less per side.

Ideally, water should be available at every crossover between feeding and resting areas.

3-Prevention of heat stress throught Nutritional ways:

Nutrition is one of the most important factors that affect on heat stress. Changes in ration formulation and feeding programs can help reduce the negative effects of heat stress on the dairy cow. Changes in the ration should be made slowly and prior to the onset of hot weather.

Heat stress causes a decline in dry matter intake, the cow's energy and protein requirements in hot environments increase. Therefore, it is important to increase the energy and by-pass protein contents of diets in order to maintain the performance of dairy cows in a hot environment. First we must increase the DMI for compensate the DMI decreased in hot climate. Then we must use of high energy diets, throught the use of available grains or fat supplements. One special characteristics of fat is that their heat increments is very lower than another natural feeds. Use of fatty feeds, or the calcium salts of fatty acids, as way of improving the energy supply for dairy cows in summer, is effective method for eliminate the negative affects of heat stress on energy intake of dairy cows(Terada, 1996). Cows that fed such diets, have a lower body temperature(BT), panting and produce more milk. Among several protein supplements, fish meal is a good source of bypass protein. This protein supplement, led to lower body heat production and is very useful for cows in hot climate(Terada, 1996).

In hot climate and heat stress period, cows appetite depressed and every procedure that cause to elevate animal appetite, can help to decline heat stress negative affects. Use of some additional feeds or supplements such as molasses or citrus pulp, cause to increased animal appetite elevation. Molasses are very good select in hot climate, because in hot and dry climate, cows sweating cause that large quantities of body electerolytes such as potassium(Mallonee et al, 1985), excrete throught sweat and because that molasses are rich source of potassium, use of molasses can replace the excreted potassium and this cause to an elimination in acid-base imbalance.

One of the another nutritional procedures for prevention of heat stress, is increased feeding frequencies. In most dairy herds in the world, 3 times of feeding is a common methods for herds feeding. But if we increased frequencies of feeding from 3 times at day to 4 times at day, lower heat production in body produced and this lower heat product of body conduce to lower heat stress. Another important factors that conduce to more heat production in body, must be attention.

One of the most important affecting factors in incidence of heat stress is levels of low quality fiber in the ration. High levels of hays in ration, conduce to more heat increment and finally more negative effects of heat stress. Use of lower hays levels cause to lower heat increment and conduce to lower heat stress and a very important preventional method. Another recommedation is use of high-quality forages to reduce heat produced in digesting and assimilating feed. If high quality forages availability be low, use of fibrolytic enzyme can increase forages fiber digestibility(Atrian and Shahryar, 2012).

**Treatments of dairy cows under heat stress condition**

First immediate action for treatments of dairy cows, should involve housing the cow down with large volumes of cold water, minimising stress/physical exertion, placing her in the shade and provide air movement with increasing the ventilation rate.

Use of large volumes of intravenous fluids and electrolytes, rectal enemas or stomach tubing with water, can be benifical methods in some conditions. Use of sodium bicarbonate with ration is another effective method for treatment of heat stressed cows.

**Proper temperature for dairy cows**

Dairy cows have decreased mortality when their environmental temperature is between 14 and 24°C(Stull et al, 2008). According Hahn, In lactating Holstein cows, the comfortable temperature is within the range 4-24°C (Hahn 1981).

# 6. Conclosions

Heat stresss can affect negatively on animals production and healthy and we must reduce its affect on animal with several possible methods.

More researchs is needed to develop a more efficient and sustainable production system for dairy cows in hot environments. Use of managemental methods and nutritional ways for prevention the heat stress affects, finally reduce the heat stress affects in hot climates and increase the cows performance and consequently increase the herd profitability.

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