Effect of Different Levels of Organic Acids Supplementation on Feed Intake, Milk Yield and Milk Composition of Dairy Cows during Thermal Stress

Amjed Ali¹, Sarzamin Khan*,¹, Muhammad Mobashar¹, Muhammad Inam¹, Iftikhar Ahmed¹, Nazir Ahmed Khan¹ and Mubarak Ali², ³, Hamayun Khan⁴

¹Department of Poultry Science, the University of Agriculture, Peshawar-Pakistan.
²Animal Nutrition Group, Wageningen University, P.O. Box 338, 6700, AH Wageningen, the Netherlands.
³Wageningen UR Livestock Research, P.O. Box 65, 8200 AB Lelystad, the Netherlands.
⁴Department of Animal Health, the University of Agriculture, Peshawar, Pakistan.

ARTICLE INFO

Article No.: EB11091313
DOI: 10.15580/GJAS.2013.11.EB11091313

Submitted: 09/11/2013
Accepted: 22/11/2013
Published: 29/11/2013

*Corresponding Author
Sarzamin Khan
E-mail: dr.zaminaup@gmail.com

Abbreviation: DMI, dry matter intake; Hb, haemoglobin; PCV, packed cell volume; SNF, solid not fat; TS, total solids; THI, Temperature Humidity Index.
INTRODUCTION

Thermal stress is the sum of external forces to a homoeothermic animal that acts to shift body temperature from the resting state. Thermal stress reduces feed intake, milk yield, growth rate and reproductive performance which lead to major economic losses to the dairy farmers especially in tropical countries. It also affects cellular physiology and systemic metabolism leading to reduction in dry matter intake (DMI) and milk production due to changes in the physiology, energy metabolism and endocrine profiles of dairy cows (Yousef, 1985; Baumgard and Rhoads, 2007; Collier et al., 2008). Sanchez et al. (1994) reported 20 to 40% decrease in DMI at 40°C compared to cows in a thermo neutral comfortable environment. Thermal stress depresses digestion of dietary nutrients reducing the effectiveness of converting feed energy units into production energy units (Fuquay, 1981). The lactating dairy cows are more sensitive to thermal stress because they produce much more metabolic heat and accumulate the additional heat from radiant energy than the non-lactating ones (Blackshaw and Blackshaw, 1994; West, 2003). The cow's comfort zone is between -0.5 to 20°C, however it varies between the breeds (Prasad et al., 2012). The upper critical limit temperature limit can reach up to 25 to 26°C (West, 2003). The environmental temperature is not the only factor, relative humidity is also important to describe the cow's comfort zone. The combined effect of temperature and humidity is quantified as Temperature Humidity Index (THI). The normal THI level of 72 is optimal to maintain the milk production of dairy animals (Prasad et al., 2012).

In the tropics, green fodder is not available during the prolonged summer period, and cows are mostly fed on low quality dry roughages, crop residues and agro industrial by products (Khan et al., 2009, 2012; Habib et al., 2013). These feeds are higher in ligno-cellulose content and lower in fermentable carbohydrates resulting in lower production of volatile fatty acids and rumen fermentation efficiency. Organic acids supplementation improves the utilization of dietary nutrients in the gastrointestinal tract of dairy cows. Moreover, organic acids can reduce the toxic metabolites, colonization of pathogens and endocrine changes in the cow's body during heat stress. The supplementation of organic acids improves the bioavailability of protein and uptake of minerals like magnesium, calcium, phosphorus and zinc (Hinton et al., 1988; Thompson and Hinton, 1997). Organic acids such as fumeric acid, citric acid, formic acid etc. have been used as growth promoters to enhance the digestibility of feed. Supplementation of organic acid can also improve milk quality. Feeding of orange extract reduced somatic cell count in high producing cows during moderately to hot summer season (Soderstrom, 2012).

During summer months (June to August), the temperature in most parts of South Asian Countries such as Pakistan increases above 40ºC, due to which the productivity of imported Holstein Frisians and their cross breeds reduces significantly due to less feed intake and changes in the metabolism. Moreover, most of the dairy animals are raised under small holder production systems. Because of these smaller production systems, the environmental interventions are very limited due to high cost involved.

The present study was therefore designed to investigate the effect of different levels of organic acids solution in the drinking water on the feed intake, milk yield, milk composition and the somatic cell count (SSC) of milk of dairy cows during thermal stress conditions. In addition, effect of different levels of organic acids on the blood haemoglobin (Hb) and packed cell volume (PCV) of heat-stressed dairy cows was also investigated.

MATERIALS AND METHODS

Experimental design and measurements

The solution of organic acids was prepared by dissolving 80g citric acid, 90g phosphoric acid, 50g lactic acid and 10g copper sulphate in one litre of distilled water. Copper sulphate was used for stability and preservation of the solution. Twelve Holstein Friesian cows (mid-lactation, 3 to 4 years old, average body weight of (400±50kg) were used in the present study. The cows were blocked on the basis of parity and milk production into four groups (three cows per group), and offered water without (control) or with organic acids solution at the rate of 0.5, 1 and 1.5 ml per litre of drinking water. The experiment was continued for 45 days including two weeks adaptation period. The study was conducted during the summer months of July and August, 2012. The rations for the experimental animals were formulated according to the guide lines of NRC (2001) for dairy cows. The cows were offered maize fodder (dry matter, 18%; crude protein, 9%) as a basal diet, and 10 kg/animal dry ration (60% concentrate+40% wheat straw). The concentrate was consisting of cottonseed cake (25%), maize gluten (20%), mustard seed cake (8%), wheat bran (45%) and di-calcium phosphate (2%). For record keeping, separate feeding and water troughs were provided for each animal. Feed intake, temperature and relative humidity of the farm were recorded on daily basis. The cows were milked twice daily (morning and evening) and daily milk yield per cow was recorded.

Sample collection

For analysis of milk composition and SCC, milk samples were taken weekly from 4 consecutive milking. The morning and evening milk samples were pooled (1:1 ratio) separately to obtain two composite milk samples. Blood samples from the experimental animals were taken weekly to study the effect of different levels of organic acids solution on the blood Hb and PCV of dairy cows.
Chemical Analysis

The milk samples were mixed thoroughly and were analyzed for lactose, fat, protein, ash, solid not fat (SNF) and total solids (TS) according to the method of AOAC (1990). The SSC in the milk samples was checked according to the method described by Sears et al. (1993). Blood PCV and Hb were determined through Micro-capillary method and Sahli's haemometer procedure, respectively.

Statistical analysis

The effect of organic acids addition on milk yield, composition and the SSC, and on the blood Hb and PCV was determined using PROC MIXED procedure of statistical analysis (SAS, 2009) using the following model.

\[ Y_{ijk} = \mu + B_i + O_j + e_{ijk} \]

where, \( Y_{ijk} \) is the depended variable; \( \mu \) is the overall mean; \( B_i \) is the random effect of block/replication, \( O_j \) is the fixed effect organic acids; \( e_{ijk} \) is the random error. Values are presented as least square means with the standard error of the means.

RESULTS AND DISCUSSION

Feed intake

Data on feed intake of the dairy cows supplemented with different levels of organic acids solution are summarized in Table 1. The supplementation of organic acids in the drinking water significantly increased (\( P<0.05 \)) feed intake of dairy cows. Higher feed intake was recorded for cows offered with 1.5ml organic acids solution per litre of water, while lower feed intake was recorded in cows offered with plain water (control), during the thermal stress conditions. The increase in feed intake with the addition of organic acids in the present study was similar to the findings of Wing et al. (1988). Moreover, a parallel increase in feed intake was observed with the increasing dose of organic acids solution (Wing et al., 1988; Castillo et al., 2004; Bampidas and Robinson, 2006). During thermal stress, the feed intake of dairy cows decreases, and the extent of reduction depends on the period of thermal stress. The production of volatile fatty acids especially acetic acid reduces during heat stress which results in less feed intake and feed efficiency (Prasad et al., 2012). In contrast, Emery et al. (1961) reported that lactic acid supplementation to the diet reduced feed intake. Lactic acid makes rations less palatable which result in low feed intake. The higher feed intake in the present study could be related to the use of lactic acid in combination with other organic acids (citric acid, phosphoric acid and copper sulphate) and to the use in the drinking water instead of feed. The higher feed intake could also be related to the positive effect of the mixed organic acids solution on the ruminal fermentation and metabolism of dairy cows. Similarly, Castillo et al. (2004) stated that high levels of organic acids may be beneficial as feed additives for ruminants because they have effects on ruminal fermentation analogous to ionophores.

Table 1: Feed intake and milk yield of dairy cows supplemented with different levels of organic acids during summer heat stress

<table>
<thead>
<tr>
<th>Organic acids(^1) (ml/litre of water)</th>
<th>Feed intake (kg/day) Mean</th>
<th>SEM(^2)</th>
<th>Milk yield (kg/day) Mean</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SEM(^2)</td>
<td>Mean</td>
<td>SEM</td>
</tr>
<tr>
<td>0</td>
<td>31.3b</td>
<td>0.94</td>
<td>10.4c</td>
<td>0.99</td>
</tr>
<tr>
<td>0.5</td>
<td>35.4a</td>
<td>2.71</td>
<td>11.8b</td>
<td>0.98</td>
</tr>
<tr>
<td>1.0</td>
<td>36.0a</td>
<td>2.38</td>
<td>12.5b</td>
<td>0.81</td>
</tr>
<tr>
<td>1.5</td>
<td>37.3a</td>
<td>2.84</td>
<td>13.4a</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Mean values of feed intake and milk yield with different superscripts (a-c) are significantly (\( P<0.05 \)) differed. \(^1\) Mixed solution of organic acids: containing 80g citric acid, 90g phosphoric acid, and 50g of lactic acid and 10g of copper sulphate per litre of distilled water.

Milk yield

During thermal stress, the constant exposure of dairy cattle to high temperature causes high body temperature, reduction in feed intake, alterations in endocrine profiles which ultimately lead to decrease in milk production (Prasad et al., 2012). In the tropical countries, thermal stress is considered as a main factor which causes decline in milk production during summer months (Prasad et al., 2012). Milk production can decrease between 10 to 35% during prolonged thermal stress period (Schneider et al., 1984; St-Pierre et al., 2003). Collier et al. (2008) reported reduction in milk yields due to decrease in energy metabolism. The utilization of digestible energy in dairy cows was 60% at 21 °C but it decreased to 40% after 7 days exposure to 32°C. During heat stress period, a negative
correlation was found between milk production and THI (Linville and Pardue 1992).

Data on milk yield of the dairy cows supplemented with different levels of organic acids solution are summarized in Table 1. The results show that the milk yield significantly (P<0.05) increased with the use of the organic acids solution in the drinking water during thermal stress. The higher level (1.5ml) of organic acids solution results in higher milk production (Table 1). The increase in the milk yield might be due to increase in microbial efficiency and microbial nitrogen production, and the less methane production the rumen (Newbold et al., 2005; Sniffen et al. 2006; Khampa and Wanapat, 2007). Wing et al. (1988) evaluated the possible use of citrus molasses distillers as a source of organic acids for dairy cows and found increase in DMI and milk yield without any negative effect on the milk composition and body weight of the cows.

Milk composition

Thermal stress not only decreases the milk production but also causes negative influence on the milk composition (Prasad et al., 2012). The different levels of organic acids supplementation affected the composition of milk. In the present study, the use of organic acids solution in the drinking water significantly (P<0.001) increased the contents of fat, protein, lactose, SNF and total solids in milk (Table 2). In contrast, Piquer et al. (2009) and Ebtehag et al. (2011) reported a decline in milk fat content by the inclusion of whole citric fruits and organic acids, respectively compared to the control ration. However, Wang et al. (2009) observed that dairy cows supplemented with organic acids showed no effect on milk composition. The significant (P<0.05) increase in the milk fat content in the present study might be due to the supplementation of organic acids in the drinking water instead of using in the feeds which can depress feed intake due to lower palatability. In the present study, the milk protein increased at high level of organic acids used in the drinking water (Table 2). El-Nour et al. (2009) and Piquer et al. (2009) also found that organic acid supplementation increased milk protein. However, this increase was quantitatively very small. In the present study, the high protein content might be attributed to high feed intake and the beneficial effect of the mixture of organic acids. The increase in lactose content in milk with organic acid supplementation is consistent with the findings of El-Nour et al. (2009). The content of SNF in milk increased (P<0.05) with the use of organic acids in the drinking water. In the present study, the total solids content in milk increased with supplementation of organic acids. The results of present study are supported by Piquer et al. (2009) reported that the total solids content of milk was significantly (P<0.05) increased by the use of organic acids.

Somatic cell count

Data on the SCC of milk from cows offered with various level of organic acids solution is summarized in Table 3. The SCC significantly (P<0.05) decreased in cows supplemented with organic acids as compared to cows offered with plain water. The decrease in milk SCC content is consistent with the findings of Soderstrom (2012). These findings suggest that organic acids can be used as preventive measures against mastitis infection which cause major economic losses to dairy business.

### Table 3: Effect of different levels of organic acids\(^1\) supplementation on blood haematology of dairy cows during summer stress.

<table>
<thead>
<tr>
<th>Organic acids (ml/litre of water)</th>
<th>Haemoglobin (g/dl) Mean (\text{SEM}^2)</th>
<th>Packed cell volume (%) Mean (\text{SEM})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>10.5(^c) 0.43</td>
<td>32.4(^c) 0.27</td>
</tr>
<tr>
<td>0.5</td>
<td>11.3(^b) 0.25</td>
<td>32.7(^b) 0.28</td>
</tr>
<tr>
<td>1.0</td>
<td>11.4(^b) 0.34</td>
<td>33.1(^a) 0.43</td>
</tr>
<tr>
<td>1.5</td>
<td>12.1(^a) 0.71</td>
<td>33.2(^a) 0.45</td>
</tr>
</tbody>
</table>

Mean values within the same column with different superscripts (a-c) are significantly (P<0.05) differed.

\(^1\) Mix solution of organic acids: citric acid (80g), phosphoric acid (90g), lactic acid (50g) and copper sulphate (10g) were solved in one L distilled water.

\(^2\) Standard error of the mean.
### Table 2: Effect of different levels of organic acids\(^1\) supplementation on milk composition (%) and somatic cell count of dairy cows during summer stress

<table>
<thead>
<tr>
<th>Organic acids (ml/litre of water)</th>
<th>Ash</th>
<th>Fat</th>
<th>Protein</th>
<th>Lactose</th>
<th>Solid not fat</th>
<th>Total solids</th>
<th>Somatic cell count per ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.92</td>
<td>3.79&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.32&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.54&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.34&lt;sup&gt;c&lt;/sup&gt;</td>
<td>220000</td>
</tr>
<tr>
<td>0.5</td>
<td>4.92</td>
<td>3.83&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.56&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.45&lt;sup&gt;b&lt;/sup&gt;</td>
<td>202083</td>
</tr>
<tr>
<td>1.0</td>
<td>4.92</td>
<td>3.83&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.36&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.57&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.64&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.48&lt;sup&gt;b&lt;/sup&gt;</td>
<td>179583</td>
</tr>
<tr>
<td>1.5</td>
<td>4.92</td>
<td>3.84&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.59&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>174583</td>
</tr>
<tr>
<td>Pooled SEM&lt;sup&gt;2&lt;/sup&gt;</td>
<td>0.71</td>
<td>0.025</td>
<td>0.028</td>
<td>0.031</td>
<td>0.030</td>
<td>0.041</td>
<td>4083</td>
</tr>
</tbody>
</table>

Mean values within the same column with different superscripts (a-c) are significantly (P<0.05) differed.

1 Mix solution of organic acids: citric acid (80g), phosphoric acid (90g), lactic acid (50g) and copper sulphate (10g) were solved in 1L distilled water. 2 Standard error of the mean. 3 Estimated for the least square mean values of milk composition across all groups.
Blood haemoglobin and packed cell volume

Data of the effect of different levels of organic acids on blood Hb and PCV is summarized in Table 3. The Hb content and PCV of blood significantly (P<0.05) increased with the use of organic acid in water during the thermal stress conditions. The results shows that the use of organic acids solution in the drinking water not only improve milk production and milk quality but also beneficial for the health of dairy cows.

CONCLUSIONS

The results of present study show that the supplementation of the organic acids solution in the drinking water improves the performance of dairy cows during thermal stress conditions. Feed intake and milk yield of dairy cows were significantly (P<0.05) during thermal stress conditions. Feed intake and milk composition during thermal stress. Moreover, the use of organic acids solution in the drinking water of dairy cows to minimize the SCC in milk of dairy cows. The results of this study suggest using organic acids supplementation of the organic acids solution in the drinking water improves the performance of dairy cows during prolonged thermal stress conditions. The results of present study show that the use of organic acids mixture in the drinking water improves the performance of dairy cows during thermal stress conditions. Feed intake and milk yield of dairy cows were significantly (P<0.05) increased with the addition of organic acids mixture in the drinking water. The use of organic acids mixture during thermal stress also shows positive effects on milk composition during thermal stress. Moreover, the use of organic acids increased Blood Hb concentration and decreased the SCC in milk of dairy cows. The results of this study suggest using organic acids solution in the drinking water of dairy cows to minimize the production losses and to improve the health of dairy cows during prolonged thermal stress conditions in the tropics.

LITERATURE CITED


Sears, P.M., Gonzalez, R.L.N., Wilson, D.J. and Han, H.R. 1993. Procedures for mastitis diagnosis and