International Journal of Food Engineering

Volume 8, *Issue* 1 2012 *Article* 16

Design and Performance Assessment of a Low Cost Evaporative Cooler for Storage of Camel Milk in Arid Pastoral Areas of Kenya

Francis O. Wayua, *Kenya Agricultural Research Institute*
Michael W. Okoth, *University of Nairobi*
John Wangoh, *University of Nairobi*

Recommended Citation:
Wayua, Francis O.; Okoth, Michael W.; and Wangoh, John (2012) "Design and Performance Assessment of a Low Cost Evaporative Cooler for Storage of Camel Milk in Arid Pastoral Areas of Kenya," *International Journal of Food Engineering*: Vol. 8: Iss. 1, Article 16.
DOI: 10.1515/1556-3758.2323

Design and Performance Assessment of a Low Cost Evaporative Cooler for Storage of Camel Milk in Arid Pastoral Areas of Kenya

Francis O. Wayua, Michael W. Okoth, and John Wangoh

Abstract

A low-cost charcoal evaporative cooler was designed and tested for the storage of camel milk in an arid pastoral area of northern Kenya. The cooler, 0.75 m3 in capacity, was made of galvanised iron frame reinforced with wire mesh inside and out, leaving a 10 cm-wide cavity which was filled with charcoal. A water reservoir linked to the cooler at the top through a perforated pipe kept the charcoal continuously wet through drip system. A wind driven fan on the roof enhanced air movement through the charcoal walls by sucking out the air in the cooler. The cooler was evaluated for temperature and product response. The inside temperature was 1-11°C lower than outside temperature and inside humidity was 0-49% higher than outside. During the hottest time of the day (14.00 hrs) when cooling was most needed, the cooler consistently maintained an average temperature drop of 10.5±0.4°C below ambient temperature, which varied from 29-32°C. This reduction in temperature was 35.6% and statistically significant ($p \leq 0.05$). During this time, cooling efficiency varied between 74.2 to 86.7%. Temperature of camel milk inside the cooler did not significantly increase ($p > 0.05$) between morning time and evening time. However, temperature of control milk at ambient conditions significantly ($p \leq 0.05$) changed over the same period, from 22.6±0.08°C to 28.1±0.08°C. Milk inside the cooler was also significantly cooler ($p \leq 0.05$) than control milk in the evening, with a net temperature reduction of 27.0%. Total bacterial count changed from 31.4±2.1 x 104 cfu/ml to 43.1±1.9 x 104 and 1638±81 x 104 cfu/ml for test and control milk, respectively, after storage for 10 hours. As an inexpensive alternative to mechanical refrigeration, evaporative cooling technology is promising and suitable for rural application in arid pastoral areas without grid electricity, to minimise risk of milk spoilage at collection points and retail level, and thereby encourage organised women groups to get involved in milk marketing as a source of income.

KEYWORDS: design, performance, evaporative cooler, camel milk storage, arid areas, Kenya

Author Notes: Please send correspondence to Francis O. Wayua, e-mail: fwayua@yahoo.co.uk.
This study was funded by the Kenya Arid and Semi Arid Lands Research Programme. Sincere gratitude to the pastoral households and milk traders in Isiolo county, Kenya for their participation.
Francis O. Wayua, Kenya Agricultural Research Institute, National Arid Lands Research Centre, Marsabit Michael W. Okoth, Department of Food Technology and Nutrition, College of Agriculture and Veterinary Sciences, University of Nairobi John Wangoh, Department of Food Technology and Nutrition, College of Agriculture and Veterinary Sciences, University of Nairobi

INTRODUCTION

Camel (*Camelus dromedarius*) milk is one of the key foods available in arid and semi-arid lands (ASALs) of Kenya where it covers a substantial part of the nutritional needs of the inhabitants. Camels are reliable milk producers with a long lactation period and maintain milk production throughout the long dry spells when milk production from cattle and goats is scarce (Farah, 1996). The annual camel milk production in Kenya is estimated at 338.3 million litres, valued at USD 107.1 million (Musinga *et al*., 2008). Most of this milk is consumed locally, though with increasing urbanisation, peri-urban camel milk marketing has evolved as an important income source for pastoralists in the ASALs. However, despite the importance of camel milk, ease of deterioration is a major problem, mainly due to improper postharvest handling and high ambient temperatures in the production areas. As a result about 30-45% of the total camel milk produced goes to waste (Kuria *et al*., 2009), resulting into massive losses by producers and traders. These losses occur during milking and postharvest operations such as handling, storage, transportation, selling in wholesale and retail marketing and domestic storage at the household level. With high postharvest milk losses, the development and deployment of a solution is urgently needed to reverse the trend. The reduction in temperature (maintenance of cold chain) is the most important factor in reducing loss and maintaining milk quality (Walstra *et al*., 2006). Low temperatures decrease physiological, biochemical and microbial activities, which are the causes of quality deterioration (Walstra *et al*., 2006). However, there are no cooling facilities in the ASALs, and mechanical refrigeration is not an option as the ASALs do not have access to grid electricity.

As an alternative, introduction of simple and low cost evaporative coolers at different stages starting from farm to the retail market should be the solution. Evaporative cooling is achieved when warm dry air is blown across a wetted medium. Sensible heat in the air is utilised to evaporate water in contact with the air, resulting in a drop in air dry bulb temperature and a corresponding increase in relative humidity. The process is adiabatic because sensible heat of the air is converted to latent heat in the added vapour (El-Refaie and Kaseb, 2009). It is a simple technology which has been applied in cooling fruits and vegetables (Tilahun, 2010), and works perfectly well provided the outside air is dry and desert-like, as found in the ASALs of Kenya. There are indications it may be used to cool milk along the marketing chain (Farah *et al*., 2007). Because of its simplicity, acceptable level of efficiency and low running cost, the technology may have a positive impact not only in providing access to marketing but also improving frequency of milk collection from scattered pastoral production areas. This may increase the financial gain of producers and traders by reducing postharvest losses. However, the advantages of the technology are yet to be exploited in the ASALs of Kenya. Currently there is no information on the design and performance of evaporative coolers on milk storage in Kenya's ASALs, where milk is one of the significant outputs from the pastoral production system. Therefore, this study aimed to develop and test simple evaporative charcoal milk cooler for the storage of camel milk in arid pastoral areas of Kenya. Although the evaporative cooler may not be as efficient as a refrigerator, it is hoped that it will be useful in camel milk storage and marketing in the rural pastoral areas considering their socioeconomic status.

MATERIALS AND METHODS

Study area

The study was carried out in Isiolo, Kenya, which is situated north of the Equator at coordinates 00.35°N and 37.58°E and altitude of 1890 m above sea level. The area is characterised by unreliable and erratic rainfall with precipitation ranging from 237 to 698 mm per annum, high ambient temperatures (>25°C), sparsely distributed vegetation dominated by *Cactus* and *Acacia* species, and bushy woodlands. Camels are the most abundant livestock species in this area, with camel milk marketing being an important income earning opportunity for the pastoral households.

Design and construction of evaporative cooler

A charcoal evaporative milk cooler was designed and fabricated, with inner dimensions being 1.00 m long x 1.00 m wide x 0.75 m high (Figs. 1 and 2). A pilot study in the area indicated that the daily quantities of marketed milk by individual traders ranged from 40 to 160 litres (Wayua, unpublished data). The capacity of the cooler was, therefore, chosen in relation to the daily quantities of marketed camel milk in the region. The target was to cool approximately 200 litres of milk per producer/trader to temperatures less than 10°C, which is necessary to reduce microbial milk spoilage (Walstra *et al*., 2006) in the ASALs, characterised by high ambient temperatures (>25°C). The frame was constructed from 25 mm x 25 mm x 4 mm angle iron, reinforced with 3 mm thick steel wire mesh and chicken wire inside and out, leaving a 10 cm wide cavity which was filled with charcoal. The cooler was provided with a side door which opened outwards. The charcoal walls were on all four sides. Charcoal was selected as the pad material because it has a very porous structure that can hold water, is light, durable for repeated wetting and drying, is inexpensive and locally available in the study area, essential requirements for a good pad material (Gunhan *et al*., 2007).

A water reservoir (white 50 litre plastic tank) linked to the cooler at the top through a perforated pipe (holes 3 mm diameter, 10 cm apart) maintained the charcoal walls uniformly wet by water being properly distributed along the upper edge of the walls through a drip system. The water flow rate from the reservoir was measured by a flow meter and its flow rate adjusted by a manual valve. Water seeps through the charcoal walls and evaporates at the wall outer surfaces, keeping the storage space temperature below ambient temperature consistently during the cooler operation. Any excess water dripping from the bottom was collected into a water reservoir and re-used. To prevent heat absorption from the ground, the base of the cooler was made of galvanised iron sheet with a layer of water-soaked charcoal underneath. Four caster wheels of 15 cm diameter were fixed at each corner of the framework to make the unit portable.

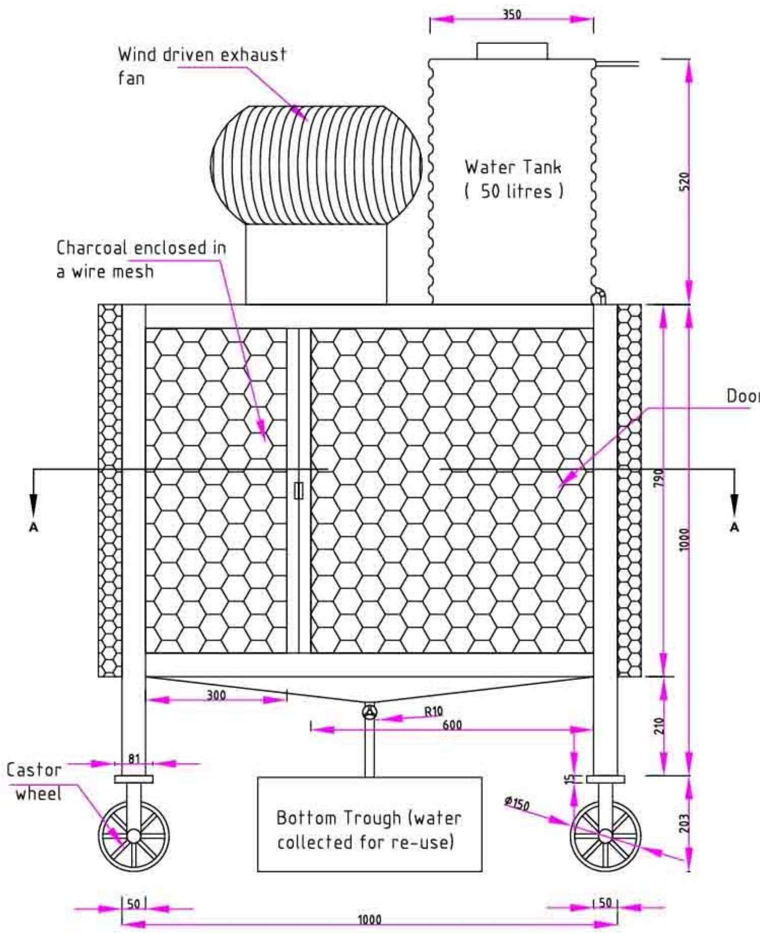

Fig.1. Front view of the drip type charcoal evaporative cooler (all figures in mm)

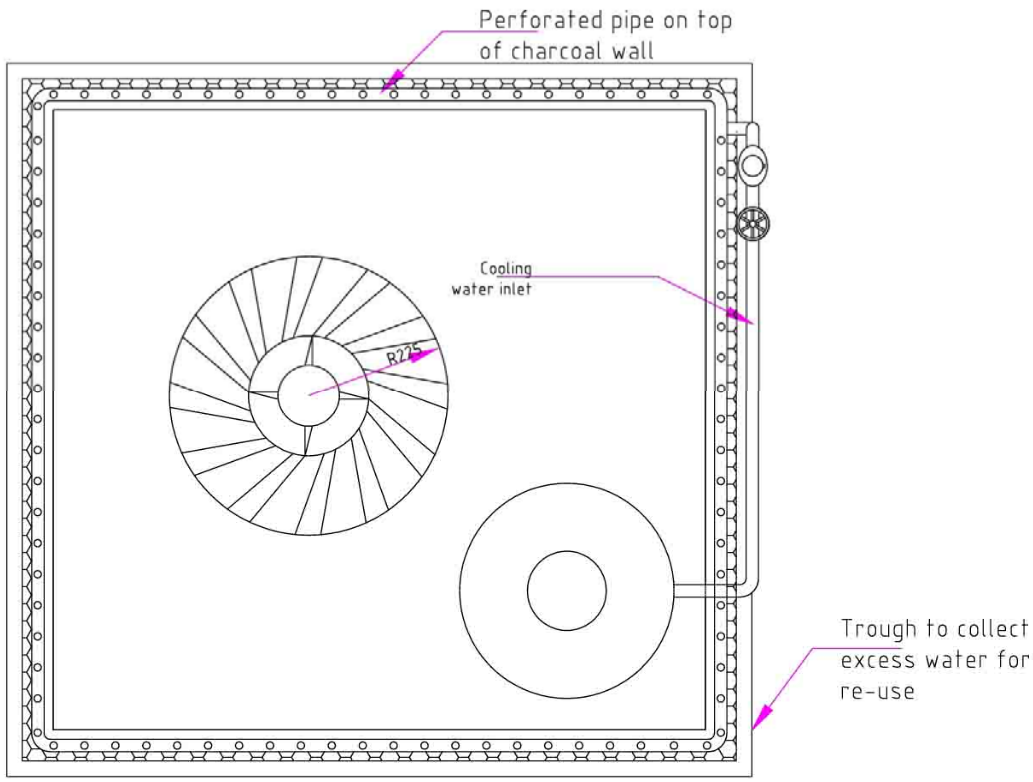

Fig.2. Plan view of charcoal evaporative cooler

The roof was made of galvanised iron sheet (painted white) over which was placed grass thatch to prevent overheating of the cooler interior by direct solar radiation. An opening of 0.30 m diameter was left at the centre of the roof to accommodate a wind-driven turbine ventilator (Cyclone® SuperEco, Steel Structures Ltd., Nairobi, Kenya) which enhanced air movement through the charcoal walls by sucking out air from the cooler. The ventilator consisted of a number of vertical curved vanes in a spherical dome (0.25 m in height) mounted on a frame. A shaft and bearings connected the top moving section to a base duct. The ventilator works on the principle that when wind blows on the aerofoil vanes the resulting lift and drag forces cause it to rotate. This rotation produces a negative pressure inside which extracts warm air that has risen to the top of the cooler to the outside, therefore, drawing new cool air through the wet charcoal walls (Khan *et al*., 2008). In the absence of wind, the ventilator works on the principle of stack effects (Khan *et al*., 2008). The ventilators are inexpensive to run and can be used in remote locations without electricity supply.

Performance assessment

The cooler was evaluated for both temperature and product response. Experiments were conducted in the warm dry season as this was thought to be the period when cooling intervention could be most useful. The cooler was located under a tree and in an area with good ventilation so that the fullest advantage of evaporative cooling could be harnessed. The experimental procedures focused on the cooler's performance within 12 hours over a 15 day period. The patterns of storage temperature, relative humidity and camel milk quality changes in both the cooling chamber and ambient conditions were investigated.

Temperature and relative humidity measurement

Temperature and relative humidity were measured by digital thermo-hygrometer (0°C to 60°C, Model No. ETH529, Brannan Thermometers, Cleator Moor, Cumbria, England). One thermo-hygrometer was mounted inside the cooler (at the centre) and another was outside in close proximity to the cooler. A glass thermometer and a wall hygrometer were positioned near each thermohygrometer for occasional checking of readings. The charcoal walls were fully and uniformly moistened and water was just at the point of dripping from the bottom. The door was closed and readings recorded after 20 minutes. Subsequent readings were done at hourly intervals during the day-time from 07.00 hours to 18.00 hours for 15 consecutive days. The average cooler and ambient temperature and relative humidity were calculated from the 15 days data separately for each time. The cooling efficiency (η) of the cooler, indicating the extent to which the dry bulb temperature of the cooled air approaches the wet bulb temperature of the ambient air was calculated as defined in Eq.1 (Olosunde *et al*., 2009):

$$\eta = \frac{T_a - T_1}{T_a - T_{wb}} \text{ x } 100\% \qquad (1)$$

where T_a is the ambient air dry bulb temperature (°C); T_{wb} is the ambient air wet bulb temperature (°C); and T_1 is the cooled air dry bulb temperature (°C).

Camel milk storage demonstration application

Camel milk samples were collected from camel herds of the indigenous breed (*Camelus dromedarius*), which were fed all year round exclusively by grazing on natural pastures. On two successive weeks, three bulk camel milk samples (3 litres each) were collected at milking time in sterile 3 litre plastic containers and brought to the study site within 1 hour. A box containing ice was used to provide cold storage during transportation to the study site. Each of the milk samples was divided into two equal amounts—test (put inside the cooler) and control (ambient storage).

Quality of test and control milk was monitored through measurement of temperature, pH and titratable acidity at hourly intervals, and total bacterial counts (TBC) at 07.00 hours and 18.00 hours. Milk temperature was measured using digital K-Type thermocouple thermometer (type HI 9043, Hanna Instruments, Padova, Italy). pH was determined using pH meter (Model HI, Hanna Instruments, Padova, Italy). The instrument was first calibrated using buffers of pH 4.0 and 7.0. Then the pH of the samples was measured by dipping the electrode of the pH meter into portions of milk samples in a beaker. Between samples, the electrode was rinsed with deionised water and wiped with tissue paper. Titratable acidity, expressed as percentage of lactic acid, was determined by titrating 10 ml of milk with 0.1 N sodium hydroxide using a phenolphthalein indicator to an end-point of faint pink colour. Total bacterial counts were determined using plate count agar (Oxoid, CMO325, Basingstoke, England) incubated at 37°C for 48 hours (APHA, 1992). Each analysis was done in triplicate and the figures averaged.

Payback calculation

Payback period was calculated by considering the equivalent savings in additional marketed milk that could have otherwise been wasted, as defined in Eq. 2 (Tilahun, 2010):

$$\text{Simple payback (in years)} = \frac{\text{initial cost}}{\text{cost saving per year}} \quad (2)$$

Data analysis

Analysis of variance on a randomised complete block design was carried out according to the general linear model procedure of SPSS®, version 17.01 (SPSS, 2008) to compare pH, acidification, and TBC. Mean separation was done by the Student-Newman-Keuls test, with a probability of $p \leq 0.05$. Simple linear regression with groups was carried out in GenStat Version 7.2.0.220 (GenStat, 2007) to compare temperature variation inside the cooler and at ambient conditions.

RESULTS AND DISCUSSION

Temperature and relative humidity variation

Temperatures recorded within each 12 hour period of the 15 days of test varied with the hour of the day but showed significantly ($p \leq 0.05$) reduced cooler temperature when compared with ambient (Fig. 3).

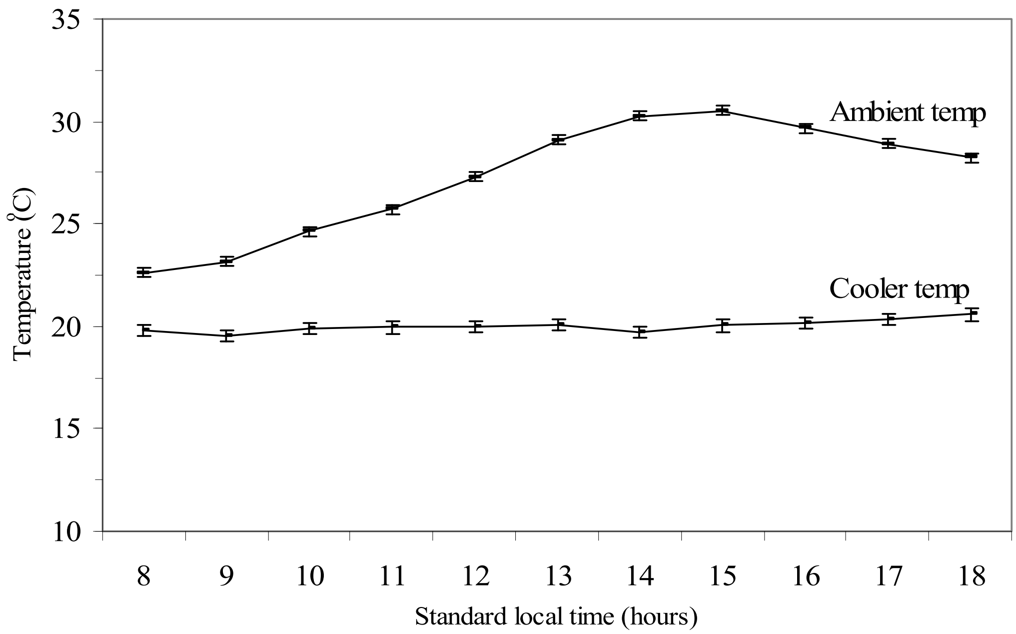

Fig. 3. Average hourly variations of temperature (temp) for ambient and cooling chamber. Data are means of 15 replications; bars are standard errors

The evaporative cooling system maintained the average temperature approximately constant during the daytime, while the average ambient air temperature continuously increased during 08.00 hours to 14.00 hours and thereafter decreased from 15.00 hours to 18.00 hours (Fig. 3). Similar results were observed by Tilahun (2010) during evaporative cooling storage of fruits and vegetables. A drop of 1-11°C from ambient condition was observed in the dry bulb temperature, indicating possible reduction in postharvest losses of milk due to microbial spoilage. Temperature reduction was higher during the hottest time of the day (14.00 to 15.00 hrs) when cooling was most needed. During this time, the cooler consistently maintained an average temperature drop of 10.5±0.4°C below ambient temperature, which varied from 29 to 32°C. This reduction in temperature was 35.6% and statistically significant ($p \leq 0.05$), hence indicates possible reduction in postharvest milk spoilage due to microbial activity. However, microbial activity may only be significantly reduced at 10°C or below (Walstra *et al*., 2006). Whereas such temperatures can be achieved by refrigerators, the theoretical minimum temperature that can be reached by evaporative coolers is the wet bulb temperature (El-Refaie and Kaseb, 2009).

Similarly, the data presented in Fig. 4 show that the evaporative cooling system maintained the relative humidity approximately constant when compared with the ambient relative humidity that was fluctuating during the experiment.

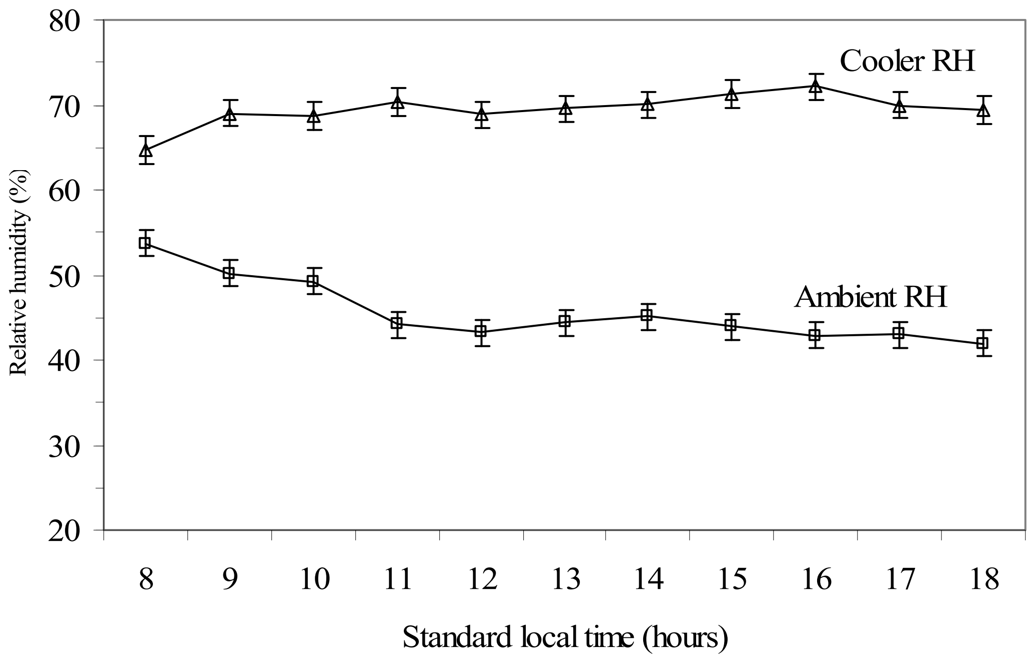

Fig. 4. Average hourly variations of relative humidity (RH) for ambient and cooling chamber. Data are means of 15 replications; bars are standard errors

The evaporative cooling system significantly increased ($p \leq 0.05$) the relative humidity of the air. The results agree with the finding of Tilahun (2010) during evaporative cooling storage of fruits and vegetables. However, unlike fruits and vegetables, milk weight and quality are not adversely affected by low relative humidity.

Cooling efficiency

The average cooling efficiency followed the same pattern of average ambient temperature, continuously increasing from 08.00 hours to 14.00 hours and thereafter decreasing from 15.00 hours to 18.00 hours (Fig. 5). Cooling efficiency was highest when cooling was most needed during the hottest time of the day (14.00 hours). The daily variation of cooling efficiency recorded for the 15 consecutive days at 14.00 hours was 74.2-86.7%, which agrees with values for cooling efficiencies reported by Olosunde *et al*. (2009) during evaporative cooling storage of fruits and vegetables.

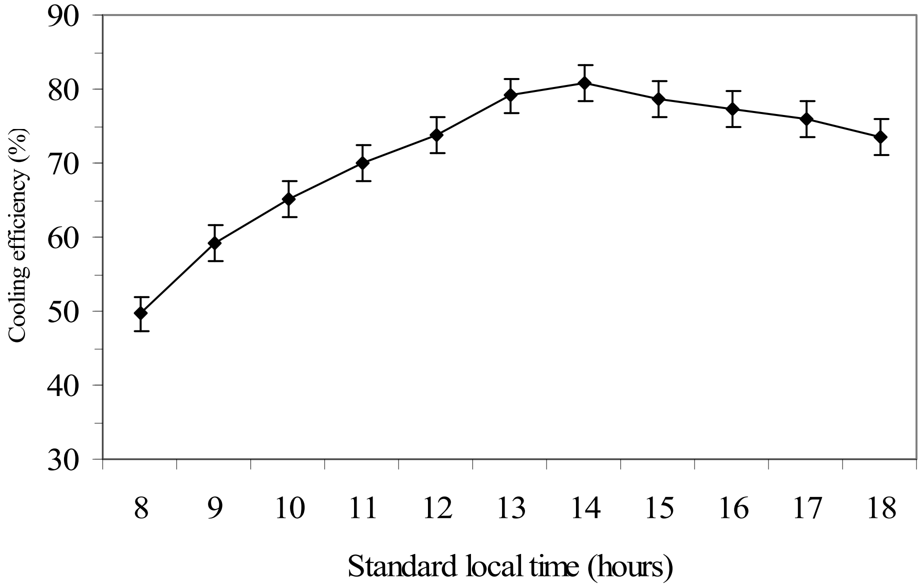

Fig. 5. Average hourly variations of cooling efficiency for the evaporative cool chamber. Data are means of 15 replications; bars are standard errors

Cooler application for camel milk storage

The acidity (expressed as percent lactic acid), pH and TBC of raw camel milk destined for treatment and control were within the normal range for raw camel milk (Table 1) but deteriorated upon storage in ambient conditions. This is consistent with the findings of Younan (2004) who reported that good quality raw camel milk is produced but it deteriorates rapidly as it enters the informal marketing chain.

The evaporatively cooled storage maintained the camel milk 100% marketable for at least one day. The reason for this was attributed to the fact that the cooler was capable of reducing the temperature as required for short period milk storage during marketing. Under hot climate conditions of Kenya's ASAL with ambient temperatures more than 28°C, this perishable commodity would become unmarketable within 1 day (Younan, 2004).

Table 1. Effect of storage inside and outside the cooler on average temperatures (Temp.), acidity, pH, and total bacterial count (TBC) of camel milk collected in the morning from the herds in Isiolo[a]

Milk	Time							
	Morning (08.00 hrs)				Evening (18.00 hrs)			
	Temp. (°C)	Acidity (%)	pH	TBC (x10^4 cfu/ml)	Temp. (°C)	Acidity (%)	pH	TBC (x10^4 cfu/ml)
Inside cooler	22.6±0.1	0.14± 0.01	6.6± 0.02	31.4± 21.9	20.5±0.1*	0.21± 0.01*	6.3± 0.02*	43.1± 19.2*
Ambient	22.6±0.1	0.14± 0.01	6.6± 0.02	31.4± 21.9	28.1±0.1*	0.32± 0.01*	5.9± 0.02*	1638± 806*
Kenya Standards[b]	-[c]	0.14-0.18	6.4-6.7	0-20	-	-	-	-

[a]Figures are mean±standard error. Each number is the average of 45 milk samples and each in triplicate. Asterisk (*) indicates statistical significance between values within the same columns ($p \leq 0.05$).

[b]Kenya Standards for raw camel milk (KEBS, 2007)

[c] – = not applicable

The cooler improved the keeping quality of camel milk as was detected by the acidity, which was relatively constant during the storage period (0.14-0.21%) compared to control milk which showed higher acidity (0.14-0.32%). The results agree with the findings of Younan (2004) who noted that camel milk becomes sour within 12 hours at 25°C and within 8 hours under hot conditions (30°C). The results, however, differ from those of Yagil (1990) who reported that the acidity of camel milk stored at room temperature remains unchanged for 5 days then becomes sour within the next 2 days. The values of TBC for raw camel milk agree with those reported by Younan (2004) who found values of TBC between 10^2-10^4 cfu.ml^{-1} for camel milk in Kenya (from udders directly milked into a clean container) and thus grade I and II quality milk (KEBS, 2007). After storage for 10 hours TBC significantly increased 2.3-fold for the control milk ($p \leq 0.05$), which agrees with the finding of Younan (2004) who reported TBCs values of 10^5-10^8 cfu.ml^{-1} for bulk camel milk samples in Kenya stored for 24 hours without cooling. TBC remained within acceptable limits i.e. $\leq 10^5$ cfu.ml^{-1} (KEBS, 2007) for milk inside the cooler. Though not investigated in this study, the positive storage effect is expected to last for at most 4 days according to the findings of Younan (2004).

Payback calculation

Payback period was calculated using equation 2. The capital cost of the cooler was USD 1067 and discussions with traders in the region showed that the maximum amount of milk traded by individual traders was 160 litres. Assuming that each trader invests in one cooler, the additional quantity of marketed milk will be 40 litres (since the maximum capacity of the cooler is 200 litres). Assuming further that there are on average 50 milk traders (according to discussions with traders in the region) and that there are no risks of losses in the evaporative cooled storage, the maximum amount of additional marketed milk would thus be 50 x 40 litres = 2,000 litres of milk daily, valued at USD 0.4 per litre. Hence payback = USD 1067 /(2000 x 0.4) = 1.33 years. This means that, if farmers adopt the technology, it would take them at most 1.33 years to recoup their investments. Additional cost savings could be realised in larger scale operations. Tilahun (2010) found a payback period of less than 1.2 years for evaporative coolers for fruits and vegetables. Therefore, the use of evaporatively cooled system in camel milk storage should be promoted as an alternative technology for the producer households, retailers, wholesalers and traders of camel milk. The advantages of evaporative cooling over mechanical refrigeration systems are mainly due to low initial investment, low installation and maintenance costs (El-Refaie *et al*., 2009; Tilahun, 2010), and they can be used by micro and small-scale enterprises dealing with camel milk marketing. Mechanical refrigerators of the same capacity cost in excess of USD 1500 but require electricity, which is not available in ASALs. The cost of electricity needs to be factored in their daily operation.

Up-scaling potential of the system

The system has high up-scaling potential, especially with non-test farmers in areas the technology was introduced and in neighbouring communities. The cooler was designed using locally available materials, is of low cost and can be locally fabricated by village artisans. The system can be operated by the local people and has potential of transforming peoples' lives if well promoted and adapted, as it can increase the quantity of milk sold and hence income from milk sales. Training is, however, important during up-scaling. Financial services also need to be made more accessible to pastoralist communities in order to provide capital for investing in evaporative coolers for milk preservation.

CONCLUSIONS AND RECOMMENDATION

Based on all parameters for measuring milk quality and temperature, this study has demonstrated that a charcoal evaporative cooler can significantly reduce milk temperature and the risk of milk spoilage for this arid pastoral area of Kenya, under these ambient conditions. As an inexpensive alternative to mechanical refrigeration, the evaporative cooler has potential for application in small-scale preservation of milk by producers and traders in remote ASALs without grid electricity. These low-cost and appropriate storage facilities should be installed at different centres throughout the hot ASALs in order to promote camel milk production on private, cooperative or public basis. They are proposed for application at farmer, retailer and wholesaler level along the market flow channel until the product reaches the consumer.

REFERENCES

APHA (1992). *Standard Methods for the Examination of Dairy Products* (16th Edn.), American Public Health Association, Port City Press, Baltimore, NY, 676pp.

El-Refaie, M. F. and Kaseb, S. (2009). Speculation in the feasibility of evaporative cooling. *Building and Environment*, 44: 826–838

Farah, Z. (1996). *Camel milk: Properties and products*, SKAT-Verlag, St. Gallen, Switzerland, pp 91.

Farah, Z, Mollet, M., Younan, M. and Dahir, R. (2007). Camel dairy in Somalia: limiting factors and development potential. *Livestock Science*, 110: 187–191.

GenStat (2007). GenStat 7th Edition (DE 3), Service Pack 1 Version 7.2.0.220. Laws Agricultural Trust, Hemel Hempstead, UK.

Gunhan, T., Demir, V. and Yagcioglu, A. K. (2007). Evaluation of the suitability of some local materials as cooling pads. *Biosystems Engineering*, 96 (3): 369–377.

KEBS (2007). Kenya Standard KS 2061: 2007: Raw whole camel milk – specification. Kenya Bureau of Standards, Nairobi, Kenya.

Khan, N., Su, Y. and Riffat, S. B. (2008). A review on wind driven ventilation techniques. *Energy and Buildings*, 40: 1586–1604.

Kuria, S. G., Omore, A., Thendiu, I. N., Mwangi, D. M., Ng'ang'a, A. B. and Kaitibie, S. (2009). Constraints of camel meat and milk marketing and strategies for its improvement in the arid and semi-arid northern Kenya. Paper presented at the conference, "Biophysical and Socioeconomic Frame Conditions for the Sustainable Management of Natural Resources", Tropentag, October 6-8, 2009, Hamburg, Germany.

Musinga, M., Kimenye, D. and Kivolonzi, P. (2008). The camel milk industry in Kenya: Results of a study commissioned by SNV to explore the potential of camel milk from Isiolo district to access sustainable formal markets. Final Report prepared by Resource Mobilisation Centre (RMC), Nanyuki, Kenya.

Olosunde, W. A., Igbeka, J. C. and Olurin, T. O. (2009). Performance evaluation of absorbent materials in evaporative cooling system for the storage of fruits and vegetables. *International Journal of Food Engineering*, Volume 5, Issue 3, Article 2.

SPSS (2008). SPSS for Windows, release 17.01 (SPSS Inc., Chicago, LA).

Tilahun, S. W. (2010). Feasibility and economic evaluation of low-cost evaporative cooling system in fruit and vegetables storage. *African Journal of Food, Agriculture, Nutrition and Development*, 10 (8): 2984-2997.

Walstra, P. J., Wouters, T. M. and Geurts, T. J. (2006). *Dairy Science and Technology*. 2nd ed. CRC Press, Taylor and Francis Group, Boca Raton.

Yagil, R. (1990). Camel milk: a review. *International Journal of Animal Science*, 2: 81-99.

Younan, M. (2004). Milk hygiene and udder health. In: Farah, Z. and Fischer, A. (Eds.), *Milk and meat from the camel: handbook on products and processing*, pp 67-76, ETH, Zurich.