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SIMPLE EVAPORATIVE COOLING METHOD REDUCES BACTERIAL CONTENT OF TRADITIONALLY MARKETED CAMEL MILK IN ISIOLO COUNTY, KENYA

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ABSTRACT

Milk marketing is important for many pastoralists to generate income, especially poor households residing near towns. Milk is typically collected in plastic containers using unhygienic methods at pastoral settlements. It is then transported—often over long distances—to market on foot, by pack animals, or automobiles. Despite the challenges of ambient heat and lengthy transportation periods, pastoralists or traders do not attempt to cool marketed milk and thus reduce the risk of spoilage. Spoilage of marketed milk is an important problem that limits urban demand and endangers human health. There is a need to find simple and cost-effective means in such situations to improve milk quality and benefit producers and consumers. The study objective was to determine the effects of using water-soaked hemp (burlap)—wrapped around 3.0 litres plastic containers—on reducing the temperature and enhancing chemical qualities of marketed camel milk, a key commodity in Africa's dry lands. The work was undertaken in north-central Kenya in a milk catchment incorporating pastoral settlements at Kulamawe and the market destination of Isiolo town. An experimental design that mimicked the daily milk collection and transport procedures was used. Pairs of plastic containers—with or without moistened hemp—were carried first by donkeys and then by lorry on eight market runs during the dry season. Samples of milk were taken at the early morning milking at Kulamawe and again after arrival at the Isiolo market in the late afternoon. Milk was analyzed for temperature, resazurin reactivity at 10 and 60 minutes (i.e., R10 and R60), and total bacterial count (TBC). Effects of milk container placement during transport, treatment, and time on milk attributes were assessed using an analysis of variance for a randomized complete block design, with blocks based on eight instances of milk being transported to market. A factorial treatment structure also incorporated time as a repeated measure. On average, milk took 7.4 hr to cover 80 km to market. Compared to the controls, upon arrival at market, the moistened hemp treatment significantly reduced ($p \leq 0.028$) milk temperature by 10% and total bacterial count by 43%. It also significantly increased ($p \leq 0.023$) R10 and R60 milk-quality values. This simple and readily adoptable intervention can therefore reduce risks of milk spoilage along such a value chain under similar field conditions.

Key words: Appropriate Technology, Value Chains, Pastoralism

INTRODUCTION

Livestock production remains the economic mainstay for pastoralists living in Africa's dry rangelands. In addition to using livestock for food production and asset accumulation, pastoralists market animals and dairy products to urban consumers. It is often the poorest pastoralists, in terms of livestock holdings, that sell dairy products because they have fewer options to generate income [1-3]. Regular sales of milk can be preferable to selling household assets such as a goat or a calf. Income from the sale of small quantities of milk can allow purchase of more calories per unit as maize meal, for example, illustrating how favorable terms of trade can promote basic survival. Sales of dairy products are particularly important to destitute pastoral women [1, 2].

Sustaining milk marketing by pastoralists, however, is fraught with challenges [4]. Seasonal patterns of rainfall, forage production, water availability, and livestock births largely determine the patterns of milk yields, off-take, and sale volumes; these are typically highest in the later stages of major rainy periods and lowest in the later stages of the major dry period. Problems of locally high stocking rates and resultant over use of forage can limit feed consumption by lactating animals, further reducing milk production.

Recent studies of urban dwellers who consume dairy products supplied by local pastoralists also illustrate demand constraints [5]. For example, residents of the rangeland town of Moyale, Kenya, have concerns over the quality of local milk offered for sale, including unsatisfactory color and taste. They also noted the health risks of drinking spoiled or adulterated milk. Moyale consumers indicated a willingness to pay at least 20% more for milk of a higher quality over what is typically found in the marketplace. This illustrates a possible financial benefit for pastoral producers and traders if the quality of marketed milk could be improved [5].

Making substantive improvements to the quality of milk marketed by pastoralists, however, appears daunting. Milk collection occurs under unsanitary conditions at pastoral settlements—often unhealthy animals are milked in crowded, traditionally constructed kraals

by people with unwashed hands using unwashed containers. Fresh milk can thus be quickly inoculated with bacteria at the start. In the process of collecting and mixing milk from multiple households, it can be adulterated via dilution with water or other substances to alter volume or appearance. The milk then begins an often arduous journey to market. While distances covered may not always be great, the poor roads and infrequent vehicular traffic mean that containers are exposed to sunlight and warm temperatures for long periods of time, creating perfect conditions for bacteria to multiply and render the product unsatisfactory in just a few hours. This situation is the antithesis of the primary requirements for dairy product preservation, namely storage under cool temperatures and hygienic handling to reduce the risks of oxidation and contamination. It is notable that prospects for milk refrigeration in pastoral lands are virtually nil because there is no capacity for rural development of modern dairy

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facilities. There is also little in the way of effective food safety regulation or monitoring of products in open markets to protect urban consumers.

Extensive work on bovine milk marketing and hygienic handling in higher-potential areas of Kenya has occurred [6]. Similar studies, however, have not been reported for milk processing and marketing in lower-potential areas. In the Isiolo County of north-central Kenya, camels (*Camelus dromedarius*) are a common source of marketed milk and became the focus of our work on how we might improve milk markets in the rangelands. The key intervention was how to promote milk cooling while in transit. The study was inspired by observations that long-distance truck drivers in the region commonly use water-soaked, fabric pouches to keep drinking water cold via evaporative cooling and convection; such containers are suspended on the outside of moving vehicles. This study adopted the same principle to the local transport of milk.

Given that most local milk is mixed and transported in plastic containers, and fabric made of hemp (for example, sisal or burlap) is cheap and readily available, our research objective was to assess the effects of wrapping plastic milk containers in water-soaked hemp on the temperature and chemical and bacteriological attributes of marketed camel milk.

METHODOLOGY

Study area

Research was conducted in the Kulamawe milk catchment in Isiolo County. The environment is described in detail elsewhere [7]. The catchment has an arid climate. Vegetation consists of abundant thorn bush with sparse grass cover, and the volcanic terrain is rocky. Rainfall is delivered on a bimodal basis with the long rains occurring in April to May and the short rains occurring in October to November. There is a cool dry season from June to September and a warm dry season from December to March. The Kulamawe site is home to several hundred pastoral households, dominated by Sakuye, Gabra and Boran ethnic groups. Households occur in scattered settlements - henceforth referred to as *manyattas* - that include assorted huts (framed with sticks and covered with animal skins or plastic sheeting) and livestock corrals constructed with bush fencing. The main destination for marketed milk is Isiolo town, the county administrative centre and home to over 140,000 residents [8].

On average, the Kulamawe catchment supplies about 1000 litres of camel milk to Isiolo town per day. This volume increases in rainy periods and decreases in dry periods. When excess supply occurs, milk is forwarded to markets in Nairobi. Milk destined for Isiolo from Kulamawe originates from dozens of settlements and is transported by donkey to a central collection point. It is then transferred to a lorry for the road trip to an Isiolo market that specializes in camel milk. When surplus milk goes to Nairobi it is transported by public bus. Here, however, we are only concerned with the Isiolo market.

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Research design

The study was conducted using paired, 3 litres plastic containers with screw-top lids. The containers were identical to each other and similar to what the people normally use for milk collection and transport. However, unlike local containers, the containers used for research were new and thoroughly washed prior to use. One container of each pair was unaltered (the control) while the other was completely wrapped in water-soaked hemp. The latter is henceforth referred to as "hemped" (Figure 1). Four matched pairs of containers were used on each of eight daily market runs from neighboring *manyattas* to the Isiolo market.

Days selected were randomized within a five-week period during dry periods in 2008-9. All eight containers received the same mixed milk. Mixed milk was collected immediately after the early morning milking between 0600 and 0830 h in traditional vessels and pooled in a 50.0 litres aluminum can prior to being allocated among the plastic containers. It cannot be assumed that the milk was protected from inoculation or adulteration from foreign matter, as producers were asked to abide by their "normal" collection and processing procedures. So it is most correct to assume that the milk was "initially inoculated and adulterated to the typical degree."

Figure 1: The 3 litre plastic milk containers, with and without moistened hemp. (Photo credit: AO Adongo Contact: adongoam@yahoo.co.uk)

The eight containers were systematically loaded on donkey packs so that variation in exposure to sunlight would be minimized. Two control and two hemped containers were placed on each side of the donkey for a 10 km trip (Figure 2). This trip took 1.5 h on average to complete.

Container placement became even more important when they were transferred to a lorry for the remaining 70 km journey to Isiolo. Paired containers were systematically placed in an open lorry bed in a fashion intended to capture variation in the exposure of containers to the circulating air associated with vehicle movement. For example, treated containers on the periphery of the lorry bed would receive more breezes that could initially cool the milk rapidly, but with an associated risk that the hemp would dry out faster. Treated containers in the interior of the lorry bed would be less exposed to breezes and hence at lower risk of the hemp drying out.

Figure 2: Placement of 3 litre plastic containers, with and without moistened hemp, on a donkey pack for transport from *manyattas* to a central collection point. **(Photo credit: HK Walaga Contact: hkwalaga@yahoo.com)**

Control containers were expected to be less affected by breezes regardless of their position on the lorry bed. Container placement on the lorry bed were thus referred to as either more exposed (ME) or less exposed (LE), and this was factored into the experimental design. Containers were not allowed to touch others to avoid associative effects on temperature. The hemp was only soaked at the very beginning of each trial, prior to loading on the donkey packs. Arrival at the Isiolo market typically occurred after 1430 h. Overall, the lorry portion of the trip took 5.9 h on average. Total transit time (donkey + lorry) for eight market runs averaged 7.4 ± 0.1 (SE) h.

Sampling

Two milk samples were taken from each container; one soon after initial milk collection and mixing and another after arrival at the Isiolo market. Single observations of milk temperature were taken with a thermometer for each container at the same times. Ambient air temperatures were taken with a thermometer at roughly 2.5-hr intervals throughout the full transit period. Qualitative observations of hemp moistness were made hourly. There were four containers and eight milk samples for each of eight milk runs for a grand total of n = 64 observations per analysis. Each sample was collected in 50 ml in a sterile, screw-cap universal bottle. Bottles were placed in a cool box where they were frozen at 4°C and transported to the Isiolo District Hospital laboratory for analysis.

Laboratory analyses

Two standard diagnostic procedures were used to assess milk quality attributes before and after treatment. The resazurin test indicates bacteriological quality of milk. Resazurin is a dye that imparts a blue color to milk. Blue changes to pink when resazurin is reduced to resofurin, and pink changes to white when resofurin is reduced to dihydroresofurin [9]. One (1) ml of resazurin was mixed with 10 ml of milk. This was incubated in a water bath at 38°C and checked after 10- (R10) and 60-min (R60) intervals. The color of samples was read in a comparator with a tube of milk lacking resazurin as a control. Results were scored into one of five color/quality classes [9]. These classes ranged from a score of 0 (white for very poor milk quality), 1 (light pink for poor milk quality), 2-3 (pink for adequate milk quality), 4 (violet for a milk quality acceptable for pasteurization) and 5-6 (blue-lilac for milk quality good for pasteurization). Assessment of bacteria load involved serial dilutions of milk samples using peptone water (Himedia, 0000046823, Mumbai, India) and total bacterial counts (TBC) were determined using plate count agar (Oxoid, CM0325, Basingstoke, England) incubated at 37°C for 48 h [11]. Results were expressed as colony-forming units per ml (cfu/ml). Each analysis was done by averaging figures from duplicate subsamples.

Statistics

Effects of container placement, treatment and time on milk temperature, total bacterial count, R10 and R60 were assessed using analysis of variance; each response was analyzed separately. The design was a randomized complete block design with eight blocks defined by runs, a 2x2 factorial treatment structure, and time as a repeated measure. Runs were a random effect. Placement (less exposed/more exposed), treatment (control or hemped), and time (AM or PM) were treated as fixed-effects factors. All interactions of time with placement and treatment also were included as fixed effects. Based on graphical assessment of residuals, TBC was square-root transformed, and R10 and R60 were converted to proportions on a 0-6 scale and log transformed prior to analysis to better meet assumptions of normality and homogeneity of variance. For transformed variables, back-transformed standard errors

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for means were estimated using the delta method. Data analyses were computed using the MIXED procedure in SAS/STAT software Version 8 in the SAS System for Windows [10].

RESULTS

The ambient air temperatures (n = 8; mean ± SE) were 24.4 ± 0.5°C during the morning milking at the *manyattas*, 28.2 ± 0.6°C at the Kulamawe central transfer point, 28.8 ± 0.5°C mid-way (~35 km) between Kulamawe and Isiolo, and 25.8 ± 0.6°C at the Isiolo milk market. This reflects the diurnal pattern where maximum temperatures were reached around mid-day.

Data for milk temperature, total bacterial count, R10, and R60 are shown in Figure 3(a-d). Each graph is based on n = 64 observations. They depict data that have been untransformed (Figure 3a) or back-transformed (Figure 3b-d). The solid lines represent the controls while the dashed lines represent the hemp-treated. All milk samples collected at the morning milking were statistically indistinguishable from each other in all measured attributes (AM pairwise tests; $p > 0.26$). Treatment, however, affected change from AM to PM in milk temperature (interaction $F_{1,28} = 15.51$, $p \leq 0.001$), R10 (interaction $F_{1,28} = 19.21$, $p \leq 0.001$), R60 (interaction $F_{1,28} = 5.78$, $p = 0.023$), and TBC (interaction $F_{1,28} = 5.39$, $p = 0.028$). Milk temperature increased for controls and decreased for hemped (Figure 3a). The R10 and R60 levels decreased in both the control and hemped samples, with a less pronounced decrease in the latter (Figure 3b and 3c, respectively). The TBC increased in both control and hemped samples, with a less pronounced increase in the hemped (Figure 3d). The overall decrease in mean milk temperature and mean TBC due to treatment, respectively, was 10% (that is, from 26.2 to 23.2°C) and 43% (that is, from 263 x 10^5 to 149 x 10^5 per ml). Treatment had a marked effect on elevating R10 values over two full scalar units from an “adequate” milk quality to an “acceptable” milk quality in the PM (Figure 3b). This magnitude of difference was not sustained, however, as samples began to converge to within one full scalar unit (that is, “very poor” to “poor” milk quality) after 60 min (Figure 3c).

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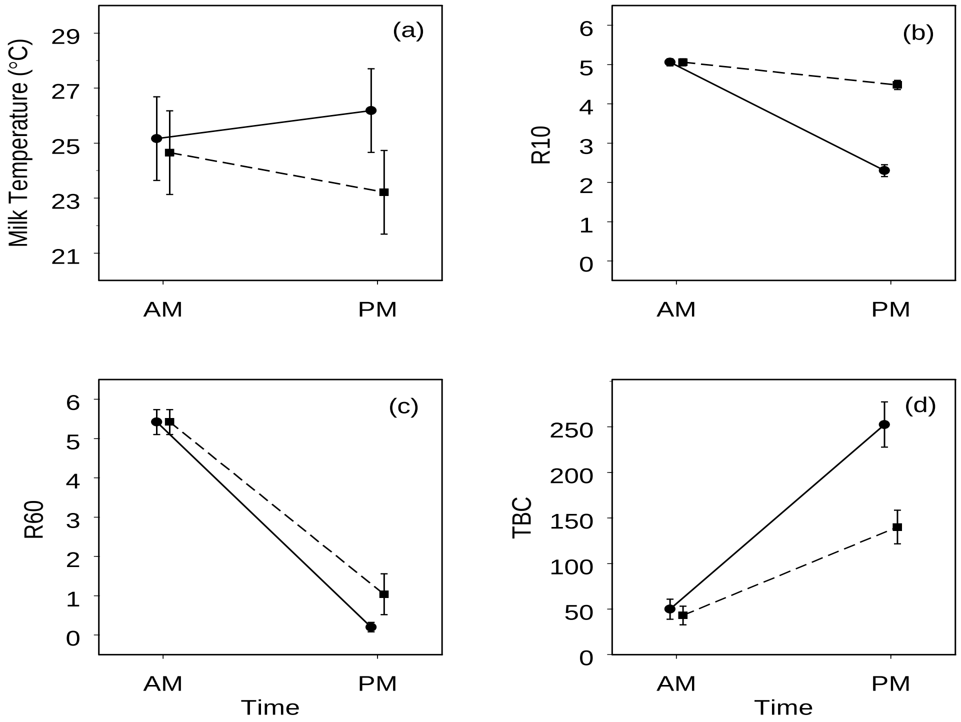

Figure 3: Interaction of treatment x time for: (a) milk temperature (*p* < 0.001); (b) resazurin reactivity at 10 minutes (R10; *p* < 0.001); (c) resazurin reactivity at 60 minutes (R60; *p* = 0.023); and (d) total bacterial counts (TBC; *p* = 0.028)

Because the treatment x time interactions were significant, main effects of treatment or time became irrelevant for interpretation. The third experimental factor, container placement, only approached significance for milk temperature ($p = 0.0793$), but was clearly non-significant ($p \geq 0.146$) for the other response variables.

DISCUSSION

Wrapping 3.0 litres plastic containers with moistened hemp reduced milk temperature and TBC for the conditions depicted in this study. A modest temperature reduction of only 2.9°C was sufficient to yield a marked reduction in TBC. The R10 and R60 results provided additional confirmation that treatment improved the chemical and bacteriological status of the milk. That milk cooling can retard bacterial growth is, of course, common knowledge in dairy science. What we see as important here, in contrast, is that a simple procedure using locally available materials can enhance the quality of marketed camel milk under difficult conditions of warm ambient temperatures, extended transportation times, and unhygienic milk-handling practices. Despite some improvement in milk quality, it is important to note that the TBC levels we observed, overall, far exceeded the maximum concentrations (20 x 10^5 per ml) for human consumption by the Kenya Bureau of Standards [12]. Treatment resulted in TBC levels over seven-times higher than the maximum recommended concentration, while lack of treatment resulted in TBC levels over 13-times higher. Experience in this study is that consumers in the small towns of northern Kenya routinely consume very poor quality milk, either because they lack enough income to buy heat-treated milk, or because improved products are simply unavailable [5].

A conservative approach was taken by moistening the hemp only once when the containers were ready for transport by donkey. It was common for our observers to note that the moistened hemp appeared (at least superficially) to be dry by the mid-point of the lorry journey to Isiolo—and especially for the ME containers (Adongo and Wayua, unpublished data). It is noteworthy, however, that the single moistening was still sufficient to achieve an experimental effect under difficult ambient conditions.

This conservative approach was justified for several reasons. Considering the first quarter of the marketing chain (from the *manyattas* to Kulamawe), limitations of water supply - as well as the potential difficulties donkeys could have carrying water in addition to the milk (Figure 2) - may dictate that only an initial moistening of hemped containers is realistic. Milk is marketed daily by pastoralists - and in larger quantities than we were simulating - so obtaining enough water at *manyattas* to moisten many more containers may be challenging. For the last three-quarters of the marketing chain (from Kulamawe to Isiolo), it is much more likely that sufficient water could be obtained and transported with the milk by lorry to allow re-moistening of hemped containers as needed.

A more liberal approach for the study could thus have involved repeated moistening of hemped containers, with the expectation that further reductions in temperature and bacterial growth would be obtained compared to control milk. This points to the idea, given that the benefits of enhanced milk quality could translate into higher prices paid by consumers in the region [5], that various actors along the value chain could differentially profit from improvements in the quality of marketed milk. Traders seem best positioned to benefit from such a practice given their greater access to water and motorized transport. Pastoral producers could benefit if traders, in turn, offered a premium for milk that has been cooled starting at the *manyatta*. Other beneficiaries of improved milk quality include consumers in local towns. Research conducted with consumers in the border town of Moyale, Kenya, illustrated that the poorer residents had little choice but to purchase raw milk supplied by local pastoralists in open-air markets. Consumer concerns about product quality control and health risks have been previously noted [5]. Milk cooling could help ameliorate such risks.

CONCLUSIONS

Simple evaporative cooling techniques using appropriate technology, such as containers wrapped in water-soaked hemp, can improve the chemical and bacteriological quality of camel milk that is marketed in challenging rangeland environments. Similar interventions should also work with milk from other livestock species. Such techniques are suitable for extension to pastoral producers and traders. This can provide opportunity for scientists to work closely with citizens in an iterative process to determine the best practices for supplying milk to local markets. Further research is needed to determine what the maximum improvements in marketed milk quality are given the value-chain constraints. This prominently includes consideration of more liberal moistening regimes for hemped containers. In addition, improvements in milk quality need to be assessed with respect to local consumer demand. The market value of improved milk quality must be empirically determined. This could reveal more opportunities for market-driven interventions to expand.

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