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A cooling system able to reduce the Relative Humidity

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ABSTRACT

A cooling system based on a heat exchange obtained passing an air flow through a recycled car radiator immersed in a water reservoir was studied. Four trials were performed to solve the problems progressively emerging. Results showed that air temperature decreased from 36°C to 17°C, when the water temperature in the tank, where the radiator was immersed, was 16 °C. In half an hour, the ambient temperature of an empty climatic chamber of 25 m^3 was decreased from 36.0°C to 30.5°C, when a flow of 98 m^3/h of air at 17°C was introduced in the environment. In the same time, relative humidity (R.H.) in the chamber was reduced from 85.0% to 67.2% as a consequence of humidity the air lost by condensation in the radiator. Notwithstanding the effect was positive, it appeared, at beginning, as a problem because the water formed by condensation was impairing the airflow in the radiator. The problem was solved draining the water to a container situated to a lower level than the radiator. A second problem due to oxidising of the radiator could not be directly solved, but a substitution with a cheap aluminium tube was tested as possible. The cooling system was showing two secondary positive effects: the capability of reducing R.H of the air, contemporary to its cooling, and an extra production of pure water that could be very useful for family welfare. The water produced was depending on temperature and relative humidity of the air. As much as 480 ml/day were produced when air was 35°C and 90% R.H. A last trail showed that, when rabbits were present in the climatic chamber, the system was able to reduce the ambient temperature (-5°C), but the control of R.H. was only partial.

INTRODUCTION

Cooling systems based on the principle of humidifying the air are not suitable for hot humid climates. In these conditions they loose efficacy because of the low humidity gradient and, for the same reason, the capability of rabbits to loose body temperature through the increasing of respiratory rate is impaired (Finzi, 1990).

It was observed that in the Mediterranean area it is not uncommon that dwellings have water cistern reservoirs, made according to a very old technology of Arab origin. Cisterns are built underground and receive waters collected on wide surfaces during the rainy period. In the underground reservoirs in North Africa, water temperature was measured to be about 16 to 21°C, the same as inside pits at 4 m depth, as observed in Centre Africa.

It was then tested the chance of reducing air temperature passing it through an heath exchanger immersed in the water reservoir, before introducing it in a close ambient to improve environmental animal keeping conditions.

MATERIAL AND METHODS

Four trials have been performed with the idea of developing a model similar to the one illustrated in figure 1.

<u>In the first trial</u> an air flow (28°C; 80% R.H.) was forced through a heat exchanger immersed

in a tank containing water at the temperature of 18°C. To keep limited the cost, a recycled car radiator was utilised as heat exchanger. Temperature and relative humidity were recorded at the device exit as a measure of the efficiency of the cooling system.

In the second trial, to solve the problem of water condensation in the radiator impairing the airflow, as observed in the first trial, condensed water was diverted to a container situated at a level lower than the radiator. Since the system was producing water, it was decided to test the quantity of water that could be produced, both to give the right dimension to the container and to know the amount of pure water available for the family as a by-product of the cooling system. A climatic chamber was then set at three different temperatures (25, 30 and 35°C) combined with three different levels of R.H. (80, 85 and 90%). These were prudential values, since a R.H. higher then 90% was constantly observed in summer nights in North Africa (Finzi, 1987) and is also common in wet tropical areas. The air was forced from the chamber through the radiator by a pump (6 cm at the mouth, speediness at the mouth 9.6 m/s, flow 97.7 m^3/h). The temperature of the water in which the radiator was immersed was 11°C. The water produced by condensation of the air humidity was measured after three hours and reported to 24 hours.

A third trial was performed utilising a cheap aluminium tube (8 cm diameter, 2 m length; the cost was only 4.2 U.S. dollars) to avoid the problem of radiator rusting and resistance to the passage of the air. It was utilised the same pump of the previous trials. The air was aspired from the climatic chamber (4.4 x 2.4 x 2.4 m) initially set to an ambient temperature and R.H of 35°C and 85% respectively. The air was then reintroduced in the chamber after cooling in a tank containing water at 16°C. Data were corrected for the natural cooling of the chamber after being brought to the experimental conditions.

A fourth trial was then performed, introducing in the chamber 16 or 8 rabbits at the weight of 2.1 kg, as a mean (density: 1.32 and 0.66 kg /m^3 respectively), maintaining the experimental conditions as in the previous experiment.

RESULTS AND DISCUSSION

In the first trial air temperature and R.H were sensibly reduced. The temperature of the air decreased from 28 to 20°C (-28.6%) and R.H. decreased from 80 to 63% (-21%). But the efficacy was impaired by an immediate problem. In fact the cooling of the air in the radiator produced a condensation of the humidity and the water that was formed had the effect of blocking the normal airflow.

In the second trial, when the condensed water was collected in the container, the airflow was regular and continuous. Water produced is shown in figure 2. As it can be observed, water condensation depended mainly on the original air temperature. The output increased from 235 g as a mean, at the temperature of 25°C to 451 g at the temperature of 35°C. The difference (+91.2%) was highly significant ($P<0.01$). When air temperature was 35°C, water produced varied significantly ($P<0.05$) from 416 g (when R.H. was 80%) to 480 g (R.H. 90%). But when air temperature was 25°C the differences were limited (from 226 to 246 g) and not significant.

The main negative result was rusting of the radiator, spoiling the water contained in the tank. As a consequence, if a way is not found to avoid rusting, the method is useful only when water is not collected for drinking use. This can be done preparing specific reservoirs with water coming from rivers, canals or oases. Another point to be considered is that radiators are

perfect heat exchangers but airflow is rather limited. This can be avoided setting more radiators in parallel.
Data of the third trial are reported in figure 3. Decreasing of air temperature and relative humidity was sensible and immediate. After 30 minutes, temperature decreased from 36.0 to 30.5°C (-15,3%; P<0.01) and R.H. from 85.0 to 67.2% (-20.9%; P<0.01). Later on temperature and R.H remained practically constant.
In the fourth trial the effect of cooling was limited by the presence of the animal dissipating heat and humidity in the air. Figure 4 shows that the effect was less immediate than with an empty chamber. After 2 hours the cooling system was able to lower the ambient temperature by 5°C (-17.2%), when the chamber contained 8 animals. When the animals where 16, the ambient temperature was 1°C higher. The figure shows also that the system was not sufficient to lower the R.H. in the ambient. This is due to the presence of the animals and to the fact that when temperature is lowered, R.H. increases if absolute humidity is not reduced in the same time. Anyhow R.H. stabilised after 90 minutes and a lower level of 7.6% (90.0% vs. 97.3%) was observed as an effect of cooling (8 rabbits). The difference was only 2% higher when rabbits were 16.

conclusions

The experiments show that it is possible to develop a cooling system based on a heat exchanger immersed in an underground water reservoir. The system is particularly suitable for tropical countries and is able also to reduce relative humidity in the breeding ambient, improving the animal well-being. Pure drinkable water is generated as a by-product and can contribute to family welfare.
Wasted car radiators are very efficient as heat exchangers, but they are easily rusting. They can be used only when artificial reservoirs are dug for the purpose. In case cheap aluminium tubes are available and can efficiently replace radiators. Many heat exchangers can be put in parallel when a higher fresh air output is requested.
Results encourage starting with field trials, while some important points need still to be analysed. Temperature and R.H. of the ambient, flow of the air to be cooled, dimensions of the reservoir and increasing of water temperature are related. Thus the efficiency of the cooling system in the lung run and, in case, the maximum of hours/day the system can properly work must be tested.

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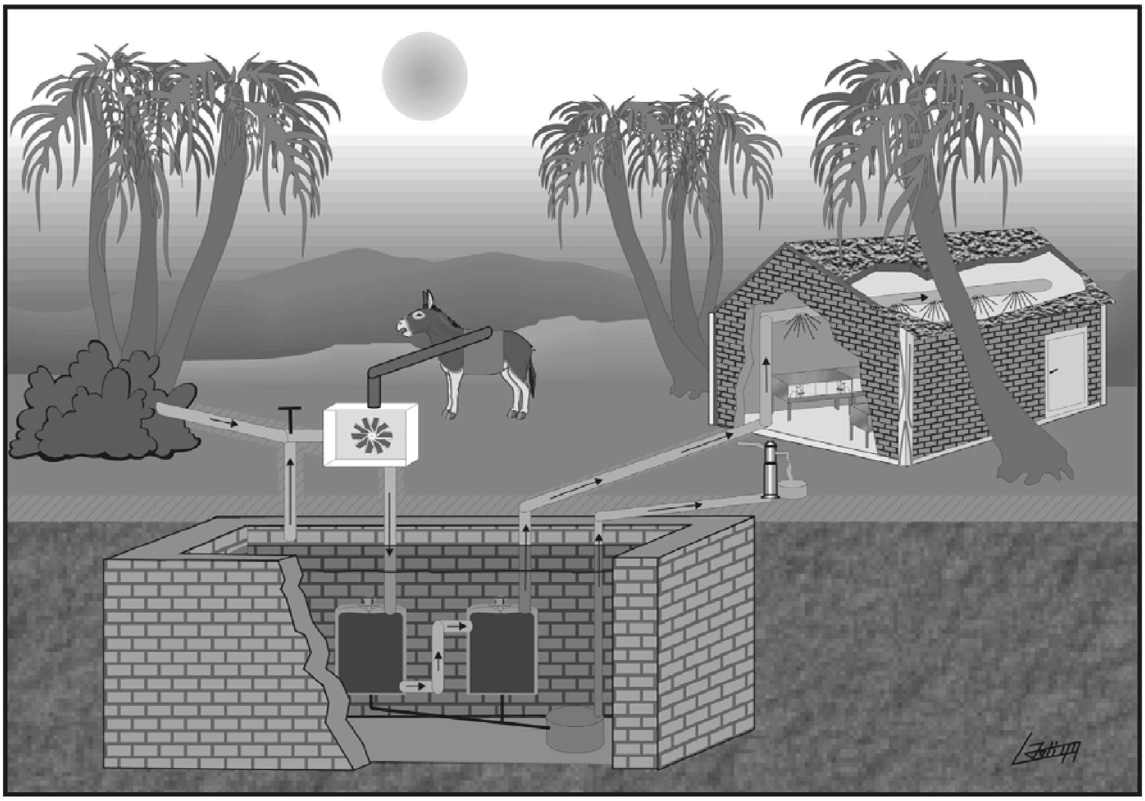

Fig. 1. General traits of the cooling system.

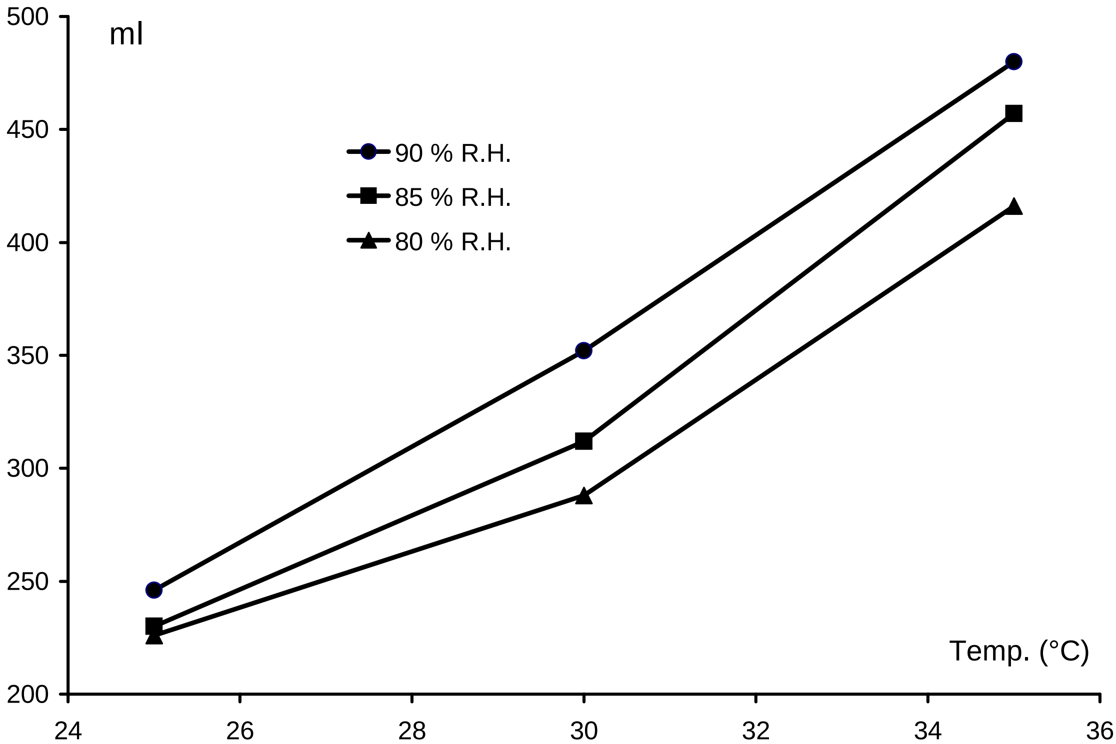

Fig. 2. Water production in 24 hours, according to air temperature and relative humidity (RH)

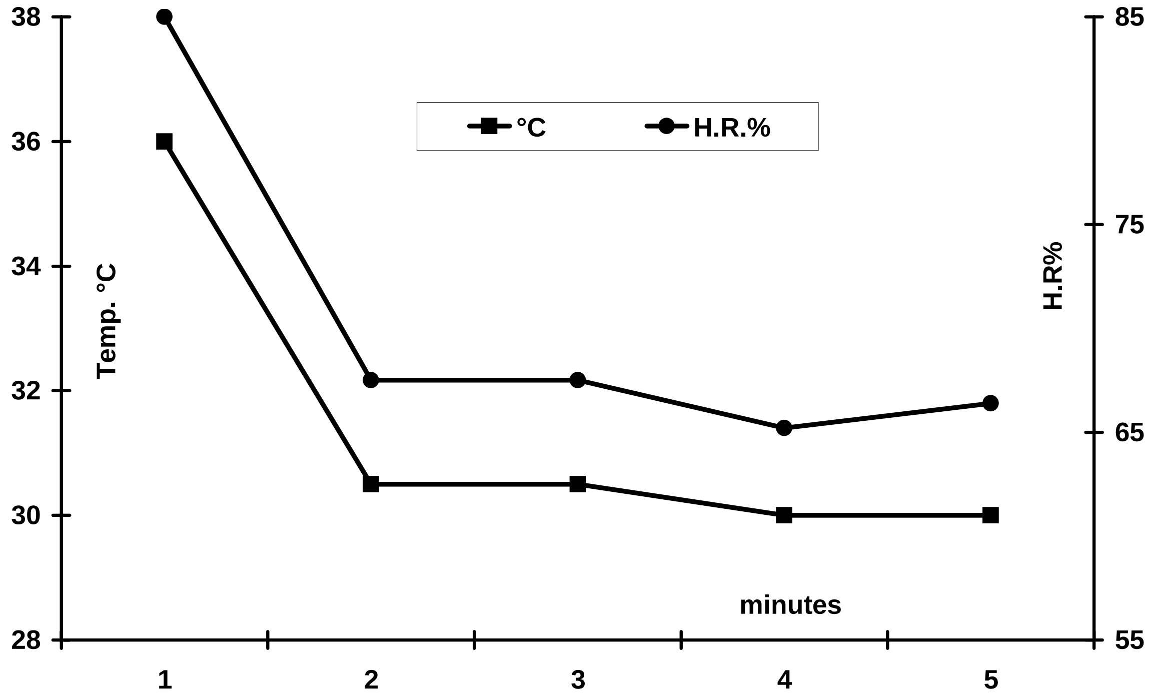

Fig. 3. Decreasing of ambient temperature and R.H. in the chamber, after reintroducing the air passed through the heat exchanger.

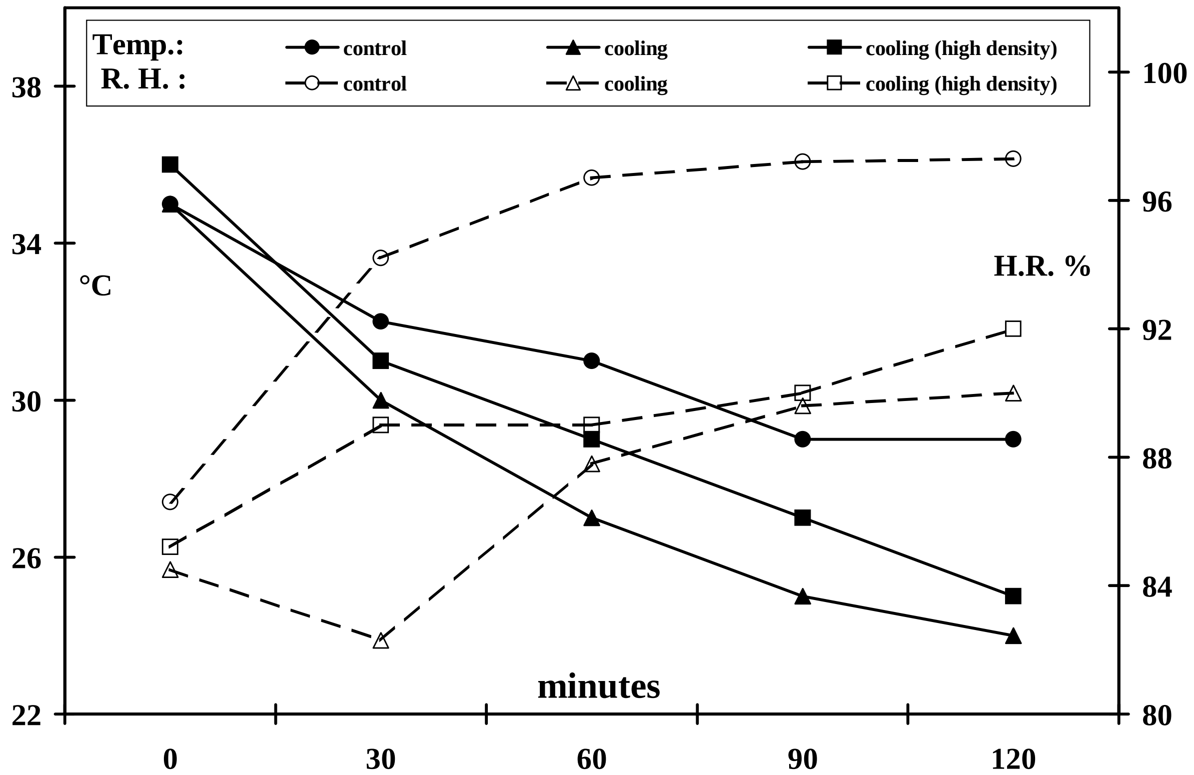

Fig. 4. Trend of temperature and relative humidity when rabbits are introduced in the chamber.