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EFFECTS OF SUNLIGHT EXPOSURE AND WATER RESTRICTION ON WATER BALANCE IN GOATS OF JENEPONTO – SOUTH SULAWESI

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ABSTRACT

Water balance in 5 does of Kacang goat originated from Jeneponto was studied under the condition of sunlight exposure and water restriction. The study was conducted in dry season with 4 consecutive treatments of 10 d with 4-5 d of adjustment period between two treatments: (1) indoor and unrestricted water; (2) indoor and restricted water; (3) 10 h outdoor –and unrestricted water; (4) 10 h outdoor – restricted water. Daily intakes of food and water, urine and faecal output, rectal temperature, respiration rate, and some haematology values were determined. The animals were placed in individual cages and fed with chopped native grass and multinutrient block unrestrictedly. The outdoor environment with direct exposure to sunlight was attributed to solar radiation in addition to a higher daily maximum air temperature (39.3 ^{O}C) than that of the indoor environment (30 ^{O}C). The plasma volume of the goats was significantly increased in the outdoor environment. Water restriction either in indoor or outdoor environment resulted in a significant lower the plasma volume compared to that of unrestricted water in the same environment. The hematocrit value was higher in the indoor that in the outdoor environment and water restriction in the same environment increased the hematocrit value. The intake and utilization of organic matter were not significantly affected by a higher daily maximum of the air temperature in the outdoor environment. Water restriction either in the indoor or outdoor environment resulted in reducing the intake and utilization of organic matter simultaneously with reducing the amounts of water loss through urination, defication and evaporation. However, the relative importance (% of total water exchange) of each evenue of water loss in the same environment was not significantly altered by water restriction. The importance of evaporation the outdoor environment was higher significantly in, while the other avenues were reduced significantly. The findings suggest clearly that sunlight exposure with unrestricted water resulted in a positive water balance of the Jeneponto goat without a significant change in the amount of digestible organic matter. The goat appeared to be able to withstand in the harsh environment by expanding plasma volume and increasing body temperature. On the other hands, water restriction resulted in a negative water balance and reducing the intake and the amount of digestible organic matter either in the indoor and outdoor environment.

Keywords : goat, sun exposure, water restriction, water balance, organic matter digestion.

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INTRODUCTION

Environmental stress resulted from high air temperature or water restriction or combination of both have long been recognized as important constraints for animal production in many parts of Indonesia. In South Sulawesi-Indonesia, Jeneponto is famous as the hottest and driest regency with the annual rainfall is less than 200 mm for only 63 rainy days and daily temperature fluctuates between the minimum of 17 °C and the maximum of 42 °C. This climate condition may have a negative effect on animal production directly and indirectly. However, the population of goats are more dense compared with the other regencies. Apparently, this small ruminant species has well adapted to cope and thrive in the harsh environment (climatic, nutritional and water availability) of Jeneponto.

Determination of daily water exchange between animals and their environment is important for estimating their water requirement as well as for evaluating their adaptability and productivity. Concerning the actual condition of Jeneponto, some questions intrigue about physiological strategies of animals. Goats have been found to be frugal in using water. In the Australian arid zone during summer, Dawson, et al (1975) observed that on the unit body weight basis the goats used more water than kangaroos and less than sheep, for the purposes of thermoregulation. Goats have also been found to have a slightly lower metabolic rate than sheep (MacFarlane and Howard, 1972). McDowell and Woodward (1982) reviewed that goats appear to have a lower metabolic rate production, higher tolerance to dehydration, less susceptibility to respiratory alkalosis resulted from high respiration rate and fewer metabolic disorders than cattle and sheep. These traits could favor the goat's survival in a hot climate, especially where water resouces are restricted.

Although the goat population constitute a prominent domestic animal in Jeneponto, the physiological strategies evolved in this animal for successful occupation of this regency have not been studied yet. Clearly, there is a need for understanding the adaptive mechanisms of this species in order to this valuable animal for more efficiently employed to boost the economy of Jeneponto regency. The present study was to investigate water balance and "millieu interiour" adjustment of the Jeneponto goats under the conditions of sunlight exposure (solar radiation and high temperature) and water restriction.

MATERIALS AND METHODS

There were 5 does of goat originated from Jeneponto, aged 1.5 – 2 y were used. Their body weights were 16.92 ± 1.44 kg at the commencement of the study and decreased to 15.30 ± 1.25 kg at the end of the study. The experiment was conducted in the dry season and the animals were individually placed in the metabolisme cages. Feed (chopped native grass and urea-molasses multinutrient block) was provided *ad libitum* throughout the experiment.

There were 4 treatment periods of 10 days. Prior to collecting data of each period, the animals were allowed to acclimatize (for 4-5 d) to the treatment conditions until daily intakes of food and water were more or less constant, and attained a steady state at a certain body temperature (± 0.2 ^{O}C) and respiration rate (± 10 per minute) .

Total daily water exchange was calculated as a sum of water drunk, performed water and metabolic water. Performed water of ingested food consisting the native grass and UMMB was calculated separately. The amount of metabolic water of each animal was estimated in accordance with Brody (1945). Evaporative water loss was estimated by subtracting the sum of fecal and urinary water loss from the total daily water exchange.

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Evaporated water from drinking water in the vessel was corrected daily. Urine and faecal outputs of each animal were monitored 3 times daily along each period. Standard proximate analyses were used to determine the contents of crude protein, ether extract, crude fiber, nitrogen-free extract and ash of the food and faecal samples.

Rectal temperatures and respiration rates were monitored 4 times daily : 06.00 am, 11.00 am, 02.00 pm and 04.00 pm. Respiration rates were determined by counting flank movements. Air temperature of the indoor and outdoor environments were monitored using max-min thermometer. Plasma volume was determined in the last day at 04.00 pm. in each period by using dilution technique of Evan Blue (T1824) in accordance with the procedures of Williams, et al (1991).

The experiment was arranged as a repeated measure experiments, and "SYSTAT for Windows version 6" was used for variance analysis of the data (Wilkinson, 1996). The significant differences between mean values were tested in accordance with the procedures of Newman-Keuls (Winer, 1971).

RESULTS AND DISCUSSION

Sunlight exposure was particularly attributed with solar radiation and a higher daily maximum ambient temperature of the outdoor (39.3 ^{o}C) compared to that of the indoor environment (30 ^{o}C).

The daily maximum rectal temperature of the goats was significantly higher in the outdoor (41.8 ± 0.2 ^{O}C) than that in the indoor environment (39.9 ± 0.1 ^{O}C) (Table 1). However, water restriction did not significantly change these maximum rectal temperatures in either the indoor or outdoor environment. The maximum rate of respiration was significantly higher in the outdoor than that in the indoor environment. Increasing the respiratory rate to a maximum level in the indoor environment was about 4 times of the minimum level, while it was 6 times in the outdoor environment.

Panting and evaporation from respiratory tract seem to be the most important mechanism for heat loss in goat during heat load, (which discharge only small amount of sweat. An experiment reported by Whittow (1971) indicated that at 40^{o}C, the maximum cutaneous evaporation rate of goat is only 50 g/m^{2}/h. Under the condition of maximum cutaneous evaporation rate, increasing respiration rate appeared to be the most important mechanism for dissipating the excessive heat. The hyperthermia observed during direct exposure to sunlight was associated with a remarkable rise in respiration rate, particularly during the hottest time of the day (afternoon). These present results are in agreement with those reported by several investigators (McDowell and Woodward, 1982; El-Nouty, et al., 1988).

It is well known that water plays a central role, by way of evaporative cooling, in the mechanisms used for heat dissipation. Accordingly, homeostatic mechanism of body fluid plays an important role to balance the requirements of water. The result of the present experiment indicated that the plasma volume of the goat in the outdoor was significantly higher than that in the indoor environment. Water restriction decreased the volume significantly either in the indoor or outdoor environment. On the other hand, the hematocrit value was significantly lower in the outdoor than that in the indoor environment, and water restriction in the same environment resulted in an increased hematocrit value (Table 1).

The increase in the plasma volume was apparently in proportion to the thermoregulatory requirement of the Jeneponto goat. This response may be interpreted as a strategy of the Jeneponto goat to cope with the outdoor environment (higher temperature and solar radiation) in which drinking water was provided unrestrictedly. There are two basic receptors sensing the plasma volume changes, volume- and baro-receptors in the atria. MacFarlane (1982) indicated that the mechanism of this response begins with a fall in blood volume brought about by increasing respiration rate – water evaporation. Pressure change is sensed by baroreceptor and this combines with a change of plasma sodium concentration detected by macula densa and juxtaglomerular apparatus of the kidney, to release renin, the enzyme which generates angiotensin I, and this in turn loses a dipeptide to become angiotensin II (Reid, et al., 1978). This stimulates the adrenal cortex to release aldosteron, which then to decrease sodium excretion through urination, as well as in saliva. With sodium retention in the plasma, water is kept in the plasma and extra-cellular space, which then resulted in increasing the plasma volume.

Additionally, the increase in plasma volume may also be attributable with an increase in plasma protein mass (colloidal osmotic pressure, COP), which provides the water retaining force of the plasma compartment (Horowitz and Samueloff, 1985). The possible increase in COP augmented water passage from the extra-vascular to intravascular compartment which then resulted in expansion of the plasma volume as observed in this study.

The exposure of animals to heat is known to cause a great loss of body water, which lead to a water deficit if not replaced by drinking water as occurred in this study. Under such conditions, maintaining the increased plasma volume despite the body water deficit is necessary to maintain adequate circulation required for heat dissipation processes. This is accomplished through the dilatation of the peripheral vessels, which take place in the hot outdoor environment to dissipate heat to the surrounding. Such a vasodilatation may cause a decreased hydrostatic blood pressure below the blood colloidal pressure, so that more extra vascular fluid passes to the intravascular fluid compartment.

The increase in plasma water may also come from the digestive tract, since the digestive tract of ruminants contains considerable amounts of water, particularly in the rumen. However, absorption of water from the rumen is relatively slower compared with the lower part of the digestive tract (von Engelhardt, 1970). Therefore, even though there was a possibility of an increased flow rate of rumen fluid resulted from increasing water intake, but the increase was apparently proportional to an increased rate of water absorbed from the lower part of digestive tract.

The significant increase in plasma volume would apparently be concomitant with increasing extra-cellular fluid volume (ECFV). A previous result reported by Taymour et al. (1984) indicated that heat load with free access to drinking water resulted in an increased TBW of the goats, and the most increase of TBW is due to the enlargement of the ECFV. Similar results were also indicated by other studies (Shebaita and El-Benna, 1982; El-Nouty, et al, 1988). The increase in TBW in a hot environment may be an adaptive mechanism for heat tolerance, since it will allow the animal to store a great amount of heat during the hot hours of the day and dissipate it during the cool hours of the night.

The most common strain resulted from exposing herbivore to excessive heat load is an elevated body temperature (Finch, 1984), as indicated also by the Jeneponto goat in the present study. Widely known that a raised body temperature results in depressing food intake. However, a higher body temperature of the Jeneponto goat in the outdoor environment had apparently no affect whatsoever on the amount of organic matter consumed and digested as long as water provided unrestrictedly.

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This physiological aptitude of the Jeneponto goat seems to be similar to those found in the desert-adapted goats, such as the Bedouin goat and Baladi goat, two famous breeds for their capacities to cope with a harsh hot desert condition (Shkolinik, et al., 1972; Brosh, et al., 1988; El Nouty, et al., 1988; Mualem, et al., 1990). The changes in vascular volume may be resulted from a delay and reduction in the increase of plasma renin activity and anti-diuretic hormone which then results in increasing plasma osmolality (Morimoto, 1990). The importance of the above response is to maintain the appetite which is attributed to the ability for supplying a sufficient blood flow to the digestive tract (Maltz, et al., 1984). Silanikove (1985) indicated that the ability of desert goats to maintain higher feed intake during heat load than that of the close related non-desert ones which was related to the superiority of the former to alleviate a rise in plasma osmolality.

Brosh et al. (1988) showed data of voluntary feed intake of the Bedouin goat maintained outdoor in the desert summer and indicated that it was depressed during hot hours of the days, and it was resumed in the afternoon. In general, ruminants given a choice will prefer to eat during cooler hours, i.e., during the afternoon and at night (Finch, 1984). Apparently, during hot hours of the days, the rumen is primarily used as a water reservoir when it is most required and primarily as a container of fermentation processes in the afternoon and during the night. Under hot condition with unrestricted water provided the goats of Jeneponto may possibly maintain the fluid balance between the inflow of fluid into and outflow of fluid out from the rumen. In addition to restore osmolality and to increase volume of the plasma, this condition was apparently maintaining appetite, feed intake and its digestibility. The expanded plasma volume may possibly be maintained during the hot hours of the day, which is an indication of a positive balance of water.

However, the organic matter intake of the Jeneponto goat was significantly reduced by water restriction. Although there was a significant increase in the digestibility of organic matter, the absolute amount of digestible organic matter was significantly lower compared to that when water was provided unrestrictedly.

There is an indication of various ruminant species (dairy and beef cattle, sheep and goat), that water restriction results in a reduction in feed intake but an increase in digestibility (Silanikove, 1992). The increased digestibility of the goat in the present experiment seems to be attributable with the increase in the mean retention time of feed particles in the gut, and the goat was apparently able to balance their water economy at a lower level. Under this condition, plasma tonicity and electrolyte concentration may be in steady state throughout. It is suggested that the change in appetite and digestibility may be mediated by food-related drinking phenomena (Kraly, 1984). Consequently, variation in one of the variable (food or water) will lead to proportional changes in the other. Reduction in feed intake leads to reduce metabolic rate which then to reduce water losses. Therefore, the proportional response to water restriction was to allow the goat to establish a new steady state at a lower level of water balance either in the indoor or outdoor environment.

However, it is unlikely that the reduced feed intake could be regarded as a single factor responsible for the increase in the retention time, particularly in the outdoor environment. Apparently, it may also be related with a decreased secretion rate of the thyroid hormones (T3 and T4) (Abdullah and Falconer, 1977). These hormones have been reported to exert a major impact on rumen motility and on passage rate (Christoperson, 1985). Additionally, More et al (1983) reported that water restriction decreased thyroxin secretion rate (TSR) in direct proportion to reduce energy intake. Although the maximum rectal temperature of the goat in the outdoor was higher than that in the indoor environment,

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decreasing feed intake resulted from water restriction would apparently decrease the endogenous heat production.

In the indoor environment and unrestricted water provided, the daily total water exchange of the goat was about 181.58 ± 4.38 ml / kg $^{0.82}$ / d. It was increased to 284.44 ± 8.81 ml / kg $^{0.82}$ / d in the outdoor environment. Water restriction was to decrease their daily water exchanges to 107.20 ± 4.26 and 159.98 ± 4.89 ml / kg $^{0.82}$ / d in the indoor and outdoor environments respectively. Urinary, faecal and evaporative water losses (g / kg $^{0.82}$/d) were significantly reduced by water restriction either in the indoor or outdoor environment. However, as the proportion of the total water exchange, water restriction did not virtually change the losses either in the indoor or outdoor environment. Under heat stress, the goat reduced markedly the proportions of the water loss through urination and defecation, whereas the loss through evaporation was increased significantly.

In conclusion, the present study elucidates that there is not a simple physiological mechanism explaining the remarkable tolerance of the Jeneponto goat to sunlight exposure (solar radiation and heat loads) and to low water availability. The Jeneponto goat could be able to withstand and to develop in the harsh environment based on their own mechanisms of heat and water balances by expanding plasma volume and increasing body temperature without alteration in the amount of digestible organic matter. Regarding management, it may apparently be possible to have high production of the Jeneponto goat. In the areas where water is scarce and daily maximum temperature is high, high production of the Jeneponto goat may be achieved by utilizing water as efficiently as possible but still fulfill the requirement, and by feeding management to reduce high endogenous heat production during hot hours of the days.

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