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THE GOAT
IN
THE DESERT ENVIRONMENT

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FOREWORD

There has been a long-drawn controversy over the proper place of the goat in agro-systems round the world. Indeed, until recently, the goat was perhaps the most maligned livestock species, being held responsible for over-exploitation of the natural vegetation resources of almost all types of eco-systems. However, the goat seems to have lately regained some of the lost ground and there appears now an awareness of its considerable production potentialities, particularly in marginal lands.

The sizable goat population of the desert areas of Western Rajasthan has rightly attracted the attention of the scientists working in the Divisions of Plant and Animal Studies at CAZRI. While the range scientists are monitoring the impact of the goat on range vegetation, the animal scientists have been mainly looking into the goat's peculiar physiological characteristics. In particular, the desert goat's water use economy—a matter of vital importance from the survival point of view—has been investigated in depth and comparative studies on the desert sheep have been conducted.

I am glad that Dr. P.K. Ghosh and Dr. M.S. Khan of the Division of Animal Studies, CAZRI, have collated some of their research findings on the desert goat's water use efficiency, and on the strength of these evidences and other relevant considerations, have attempted to provide, for the first time, a quantitative basis for a reassessment of the goat's role and production potentialities in the desert eco-system. It is hoped that the information in this monograph will be of use to animal production specialists and desert development agencies.

H.S. Mann,
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THE GOAT IN THE DESERT ENVIRONMENT

INTRODUCTION

From prehistoric times, the goat's potential for extracting nutrients from areas which are unable to support larger livestock has been recognised and utilized. It is well established now that the goat eventually became closely integrated with the life of early man, at 'east by the eighth millenium B.C.

There is mention of goat sacrifices in the Bible. Curtains made of goat hair were used in the ancient Jewish temples and tanned goat skins served for tent coverings. Certain communities at a specific season, drive a goat into the desert and left it to die of starvation there as a mark of atonement for sins committed by the tribe.

Among the many sculptures of the goat found the world over, the earliest goat statues known is the pair recovered from the great death pit of the royal cemetery of Ur (ca. 2400 B.C.) (FAO, 1970). There are indications that even at very early times people were aware of the goat's antics to reach tempting leaves and shrubs. The animals were perhaps deliberately used at one time to reduce bush growth in the course of land clearance for agricultural activities, but one can well imagine the concern which may have been felt when uncontrolled goats in great numbers turned their attention to the remaining trees and bushes.

Goat seals of a later period have been discovered in Crete; in the Near East and in Egypt. Examples of goats painted on pots dating back to Ca. 3000 B.C. have been found in Mesopotamia, although there is, as yet, no evidence as to whether they were then domesticated.

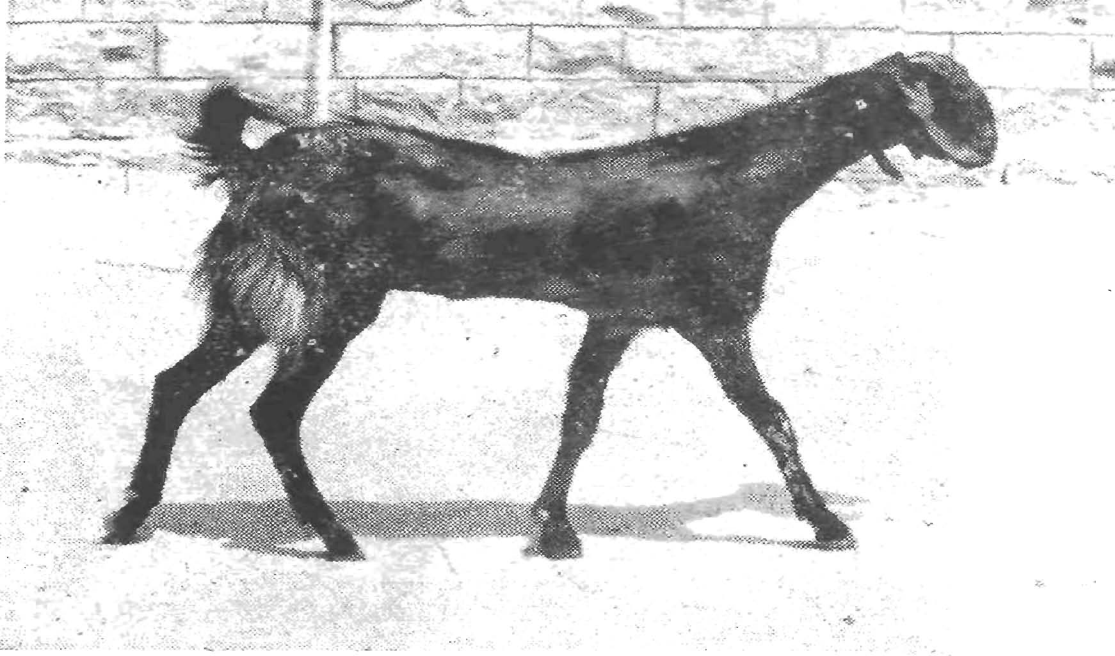
Through the ages, the goat has significantly contributed to human thought and vocabulary, numerous examples of which may be cited. For example, the isle of capri, the goatee, the scapegoat, to smell like a goat, a capricious person, the Capric, caprylic and caproic acids, etc. etc. are all derived from the goat and one or the other of its characteristics. Incidentally, it was in 1758 that Linnaeus had first assigned the goats to the genus *Capra*.

While the goat has long been recognised to be of importance to our social, religious and economic life, it has unfortunately been branded as an agent of desertification. This needs re-evaluation on the basis of scientific and economic facts rather than by relying on myths. Since when the goat entered the desert scene in Rajasthan is still a matter of conjecture for the archaeologists (Allchin, 1979). However, it seems probable that the goat has been thriving here well at least since the era of Harappan culture. The story of the goat's successful occupation of the desert niche in western Rajasthan has been told in this monograph.

SOME ASPECTS OF THE ORIGIN OF THE GOAT

Despite the lack of definitive genetic work it seems on the basis of comparative morphology, supplemented by some data from breeding experiments that the wild Bezoar goat (*Capra aegagrus*) of south west Asia may be regarded as the sole progenitor of the majority of modern domestic goats. There is good reason to believe that the Markhor goat (*Capra falconeri*) of north-west India (undivided), especially the Suleman Markhor of Baluchistan, has entered into the provenance of certain breeds in India and perhaps in the Near East, and it is also possible that the Abyssinian *Ibex* has a place in the ancestry of the Nubian goats of North and East Africa.

It appears, therefore, that the goat was domesticated somewhere in south-west Asia, within the range of the wild Bezoar. There is no evidence that the Bezoar inhabited a much greater area in early Neolithic times when it first came under man's care. It may be that the centre of domestication lay in the eastern rather than the western part of the south-west Asian upland because the greatest number and variety of primitive breeds with long, coarse, black hair occurs today



(Fig. 1)

(Fig. 2)

in the Indus lowland and the adjacent mountains to the west. Here too the ranges of the Bezoar and the Markhor come together.

BREEDS OF GOAT IN THE RAJASTHAN DESERT

The goat breeds of Rajasthan have not yet been specifically categorised. The two main types found in the state are : brown or white, with usually small hair, small ear and short tail (Fig. 1) and black or black and white, with shiny black coat, usually of long hair and with a short tail and long ears (Fig. 2). The other types of goats found in the region are rather non specified breeds, e.g. the Kutchi, Sirohi and Zalawadi, etc. (Singh and Chaudhry, 1974). Within these breeds are some other non-specified breeds like the Barmeri, the Parbatsar and the Mehsana type. This classification of the non-specified breeds is, in fact, based on the regionality of the animals rather than on their specific characters.

ADAPTATION TO THE ENVIRONMENT

Within the desert region the availability of potable water determines whether the rearing of animals will be a valid economic proposition. Like all other homeothermic animals, both the goat and the sheep of the Rajasthan desert need water to maintain homeostasis, including a constant body temperature. Since these animals have to bear a very high load of solar radiation and thermal energy when they graze or browse in the bare fields during the day, their body heat gain from external sources must be considerable. This, when added to the internal metabolic heat gains, must present a formidable problem of heat dissipation, particularly under conditions of insufficient water supply. Being large surface dwelling animals the goats can not obviously take advantage of the rodents' behavioural strategy of intermittently retiring to a moist and cool burrow to avoid the heat and desiccation. They have to fight the effects of heat and water stress mainly on physiological grounds. To begin with, the desert goat's usually long sleek coat of hair provides insulation against penetration of thermal energy into the body. The goat of this desert is also a very thrifty animal in respect of water expenditure (Khan and Ghosh, 1979).

1. Feed intake

The relationship between feed and water intake has been studied in several species of mammals. It has been observed that water and feed intake are interdependent–there being voluntary reduction in one whenever the other is restricted. The normal feed consumption of goats and sheep vary considerably. The average dry matter intake of adult goats, weighing about 35 kg, is about 1.5 kg/day while the sheep of approximately the same body weight consumes about 1.0 kg/day. When the quantity of drinking water is reduced by any degree in sheep, steers and cows, the dry matter intake is drastically reduced. However, the goat and camel have been found to be rather unusual in this regard.

After 4 days of absolute water deprivation, the feed consumption in the Barmer goat of this region has been observed to be only reduced by 40 per cent while the Marwari sheep under the same environmental conditions had almost ceased taking food on the 3rd day of water deprivation, the reduction in the feed consumption being almost 98 per cent (Khan *et al.*, 1980a). Macfarlane *et al.* (1961) had also reported that the intake of feed ceased after maintaining sheep for two days without water. Maloiy and Taylor (1971) have reported that under water restriction at 85 per cent of their initial body weight, the feed consumption of African goats was reduced by 58 per cent and 33 per cent under simulated desert conditions at 22° C and 22–40° C respectively. The black Sinai goat also can continue to eat even at a loss of 30 per cent of its body weight. The camel, however, continues eating at its normal level during water deprivation upto 20% and 30% loss in body weight (Schmidt-Nielsen, 1964).

2. Water intake

Data on normal water intake of the goat during different seasons have been presented in Table 1. The normal average intake of water during the summer, winter and the post-monsoon season in Barmer goats is 8.27, 6.33 and 5.63 l/100 kg body weight/day respectively. Maloiy and Taylor (1971) recorded that the African goats consume water at the rate of 8% of their body weight when water is available *ad-lib*. The findings of these authors are generally in agreement with our own. Under similar environmental and management conditions, the Marwari sheep of the Rajasthan desert consumed water at the rate of about 13% of body weight per day during summer (Purohit, 1972). In winter water intake in these sheep and goat breeds becomes almost similar, viz. about 6-7% of body weight. However water intake 1 kg of food (*Khejri* or *Prosopis cineraria* leaves) intake has recently been found to be nearly twice in Marwari sheep than in the Barmer goat (Bohra, 1980).

The hardiness of the desert goat is reflected in its response to externally imposed water restriction conditions. The average daily water consumption of the Barmer goat watered daily *ad-lib.*, 75 per cent water restricted and watered *ad-lib.* on every 4th day have been depicted in Table 1. As was expected, the water consumption

Table 1. Water intake (1/100 kg body weight/day) in Barmer goat

Seasons	Watered *ad lib.* (n=6)	Watered ¼ the normal (n=6)	Watered *ad lib.* every 4th day (n=6)
Post-monsoon	5.63 ± 0.20	1.49 ± 0.05	2.82 ± 0.15
Winter	6 33 ± 0.35	1.70 ± 0.08	2.60 ± 0.16
Summer	8.27 ± 0.37	2.26 ± 0.09	3.40 ± 0.19

during summer in each experimental group was more than during winter and the post-monsoon season. Obviously, the higher intake of water during summer is a reflection of the much greater need for body water replenishment in this season. Analysis of variance of the data on water consumption during different seasons has indicated that the differences between seasons and between treatments are highly significant (Table 2).

Table 2. Analysis of variance of water intake (1/100 kg body weight/day) in Barmer goat in different watering groups during post-monsoon, winter & summer

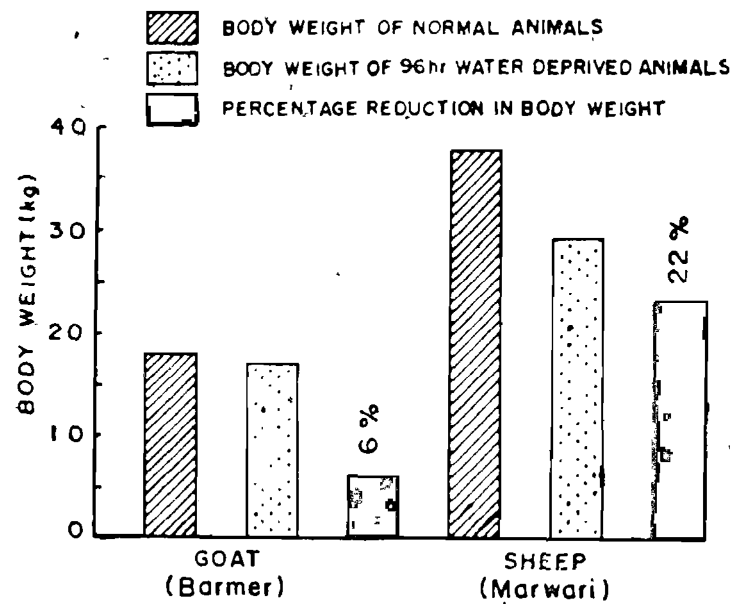
variation	d.f.	s.s.	M.S.S.
Between seasons	2	18.2293	9.1146***
Between treatments	2	239.9149	119.9574***
Seasons x treatments	4	8.2139	2.0534***
Error	45	19.0000	0.2666

***highly significant ($P<0.01$)

3. Maintenance of body weights

Of the various physiological responses during stress as revealed by various experiments is the loss in body weight of dehydrated animals During summer, an equal number of Marwari sheep and Barmer goats of comparable body weights were kept without water for 4 days. The Barmer goat, on an average lost only 1.5% of its body weight per day while the Marwari sheep had lost as much as 6% per day under the same experimental conditions (Fig. 3).

EFFECT OF WATER DEPRIVATION FOR 4 DAYS IN SUMMER ON DESERT SHEEP AND GOAT.



(Fig. 3)

However, it will be proper here to mention that, apparently, the maintenance of body weight during water stress depends, to a large extent, on the actual inital weight of the animals, at least in the desert goat. When absolute water deprivation was imposed for 4 days on goats weighing about 40 kg each, the animals lost about 3% of their body weights per day (Khan *et al.*, 1979a). It seems that young animals with low body weights put more resistance to water deficiency conditions than old animals with high body weights. Reports from Australia indicate that during water deprivation Shorthorn cattle lose about 8% of body weight per day, the Merino sheep about 4-5% per day and the camels about 2% per day. This would put the Barmer goat in a category very similar to that of the camel in respect of body weight maintenance during absolute water deprivation.

When maintained under intermittent or partial watering schedules during summer, the desert goats usually gain in body weight. Interestingly, the goats which were provided with only a quarter of their normal daily water intake, did not show any loss in body weight. The growth rate as a percentage of body weight (per cent G. R.) during summer showed an increase of 0.27 per cent in the control and 1.65% in 75% water restricted animals over the initial body weights (Table 3). It has been estimated that with a flock of

Table 3. Body weight changes in normal and water deprived Barmer goats

Groups		Body weights	
		May	June
Watered *ad lib.*	Mean	22.17	22.23
(n=6)	S.E.	0.50	0.46
	C.V.	5.50	5.04
	% G.R.		+ 0.27
Water one-quarter of	Mean	20.58	20.92
the normal intake	S.E.	0.43	0.49
(n=6)	C.V.	5.05	5.83
	% G.R.		+ 1.65

100 adult goats about 171 l of water/month may be saved, or 400 goats may be kept on the water ration of 100 without any ill effect, by limiting the daily intake of the animals to a quarter of what they would normally drink (Khan *et al.*, 1978b).

After the monsoon till the next summer season, Barmer goats receiving only a quarter of their normal daily water intake also did not show any ill effect either on body weight or on their general performance. The percentage increase in body weight of desert goats over the period September 1977 to June 1978 was 59.24 for the control group, 58.56 for the 75 per cent water restricted animals and 47.47 for the animals watered on every fourth day (Table 4). The average water consumption of the 4th day watered animals was about 3 l/100 kg/day, while the daily watered control group had an average intake of about 6 l/100 kg/day. Apparently these animals, when

Table 4. Changes in body weight in normal, water restricted and intermittently watered Barmer goats

Groups		Seasons	
		Post-monsoon	Summer
		September* (1977-78)	June
Watered *ad lib.* daily (n=6)	Mean	25.54	40.67
	S.E.	0.62	0.84
	% G.R.	—	+ 59.24
½ of normal water intake daily (n=6)	Mean	23.63	37 47
	S.E.	0.96	0.96
	% G.R.	—	+ 58.56
Watered *ad lib.* every 4th day (n=6)	Mean	26.71	39 39
	S.E.	0 29	0.90
	% G.R.	—	+ 47.47

*For 12 days only.

watered every 4th day, perform better than the Marwari sheep, which under similar conditions of water restriction reportedly lost, on average, 6 per cent of their body weight per day (Purohit *et al.* 1972; Taneja, 1966; Ghosh *et al.*, 1976). However, it has been observed that intermittent (twice a week) watering in sheep does not in any way affect either body growth or productivity (Abichandani and Ghosh, 1980). Studies conducted on Marwari and Magra sheep of this region from September 1974 to May 1975 and again from January, 1976 to June, 1976 had indicated that watering twice a week not only lead to considerable saving of drinking water but also does not adversely affect body growth. Also wool production and lambing performance are apparently not affected.

4. **Kidney function : Urine output and glomerular filtration rate**

In desert animals, the role of the kidneys during water stress is of the greatest importance, for the more concentrated urine an animal can produce, the more desert adapted it is. Deficiency of water triggers off the release of the hormones which act on loops of Henle in the kidneys, which in turn reabsorbs more and more water back into the system to compensate for the water lost to the body from evaporative cooling. Of the three desert animal species viz., the goat, camel, and the sheep, the kidneys of the former two are very strong in reabsorbing much of the filtered water and thus make very concentrated urine. During absolute water stress, for four days, the desert goat reduces its urine output drastically (Fig. 4). It is evident from the Figure that on the 4th day of water deprivation, the average urine output was only about 150 ml per day. The camel, the most celebrated among desert animals also cuts down its urine output sharply during water stress (Schmidt-Nielsen, 1964). Though, the desert sheep also reduces its urine output under similar situations, it is not capable of reducing it to the extent the goat and the camel can do.

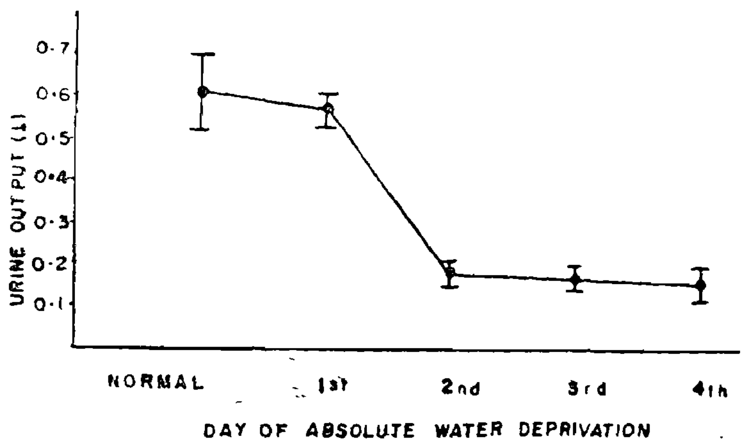
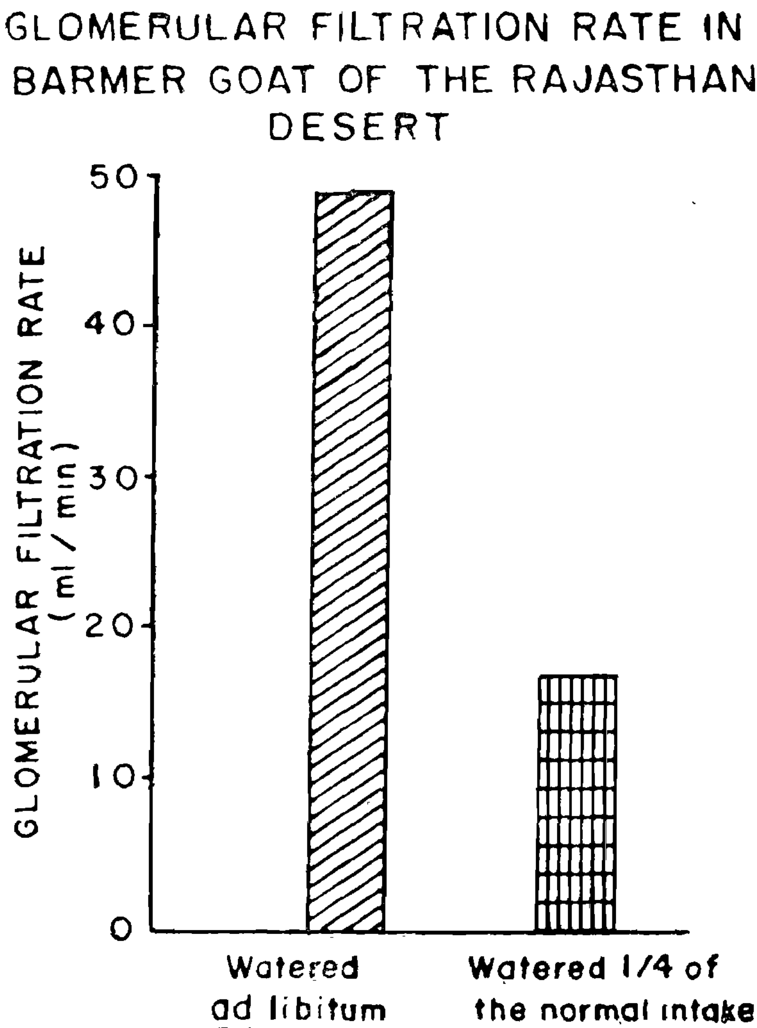


Fig. 4. 24 h urine output in normal and water deprived Barmer Goat

Glomerular Filtration Rate (GFR) in Barmer goats receiving a quarter of their normal daily water intake during summer was reduced to 1/3 of the normal (Fig. 5; Khan *et al.*, 1979b). In other words, when faced with water crisis, the goat has the ability to reabsorb almost 70 per cent of the urine water into its system, thereby conserving water to the maximum for maintenance of its internal environment. Water restriction in the sheep and the camel also reportedly result in reduced GFR (Macfarlane *et al.*, 1961; Maloiy, 1972). Recently, T.J. Dawson (personal communication) working at the University of New South Wales, Australia, has recorded a decrease in GFR of kangaroos from 48 to 25 ml/min as a result of water restriction.

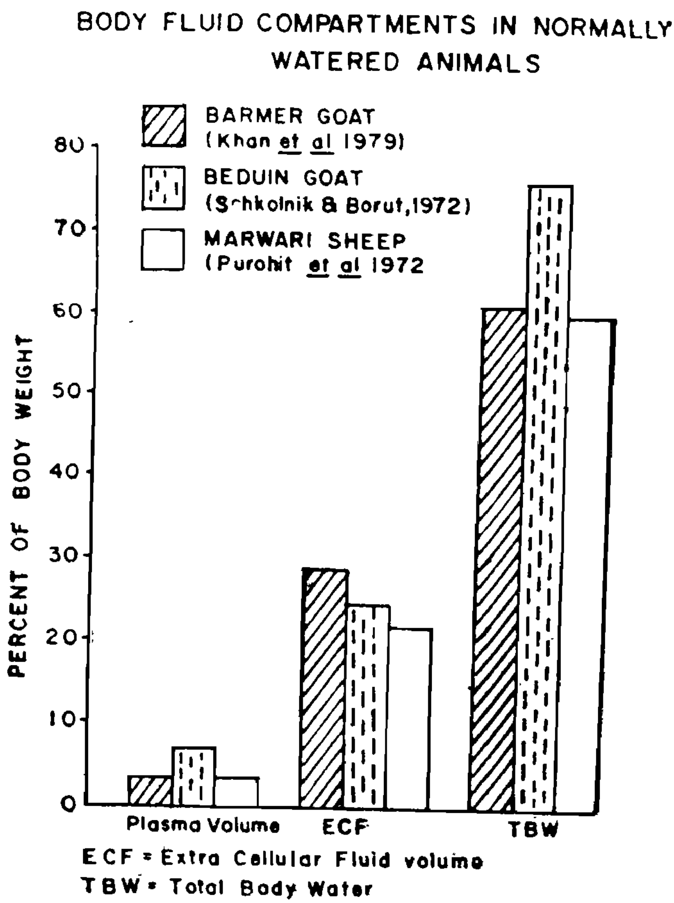


(Fig. 5)

5. **Body water distribution**

Maintenance of homeostasis is of prime importance for survival of mammals in the desert. Although most arid zone animals have learnt to live with less water and feed, some have apparently evolved superior behavioural and physiological adaptive mechanisms. The goat is obviously superior to the sheep for desert living. For any desert animal, the maintenance of circulatory volume is of great importance because of two obvious reasons : (1) to avoid circulatory failure which may occur if the blood gets thick, and (2) to dissipate the internal body heat through the circulatory medium.

The distribution of water in various body compartments in normally watered desert animals has been reported by several workers. The normal plasma volume (PV), extracellular fluid volume (ECF) and total body water (TBW) in Marwari sheep, Barmer goat and the Beduin goat have been shown in Fig. 6. The Marwari sheep and the Barmer goat of western Rajasthan have almost similar PV and TBW. However, the ECF, a very important water compartment for combating water stress, is significantly higher in the Barmer goat than in the Marwari sheep. In the Beduin goat PV and TBW are



(Fig. 6)

significantly higher, but the ECF lower, than in the Barmer goat. Such breed differences in goats with regard to various body water compartments may be attributed to the influence of different environmental and nutritional conditions. The camel apparently has higher levels of PV, cell and gut water and TBW than the Barmer goat or the Marwari sheep (Banerjee and Bhattacharjee, 1963).

During water restriction, water lost from an animal is drawn from various body water compartments, and the degree by which these compartments are depleted during dehydration differ from species to species. For example, in the Barmer goats 4 days of water deprivation brought down plasma volume by about 13% of normal (Table 5). However in the Marwari sheep, PV was reduced by 43% under similar conditions (Purohit *et al.*, 1972). The Australian Merino sheep also lost about 45% of PV after 5 days of absolute water deprivation (Macfarlane *et al.*, 1956). Interestingly, the camel reportedly lost less than 10% of its normal PV at a body weight loss of 20% due to dehydration (Schmidt-Nielsen, 1964). From these studies it may be concluded that there is apparently no mechanism in the sheep for sparing the circulatory water during dehydration, while an efficient mechanism exists in the goat and in the camel to achieve this end in times of water crisis. The actual mechanism involved in retaining plasma water in the goat and the camel appears to be associated with the retention of plasma proteins, particularly of albumin, in the vascular bed.

Unlike Macfarlane's Merinos (1956) and Purohit's Marwari sheep (1972) which had severe reductions in the ECF at the end of the dehydration regimes, the Barmer goat tends to conserve its ECF somewhat more efficiently, there being a reduction of ECF by only about 8% (Khan *et al.*, 1979a). Examination of the levels of cell and gut water in the goat and the sheep at the end of dehydration regimes has revealed that while in the goat the reduction is of the order of 41% , in the sheep it may be only to the extent of 30%. Cell and gut water is of special significance during periods of water stress in the goat because it is this water which is mainly relied upon by the circulatory medium of this animal for the maintenance of its normal volume (Khan *et al.*, 1979a). The cell and gut water may, thus, be considered as the "emergency water reservoir" which is used to avert circulatory failure in the goat. The inability of the sheep to use this

Table 5. Body fluid compartments in normally watered and water deprived Barmer goat

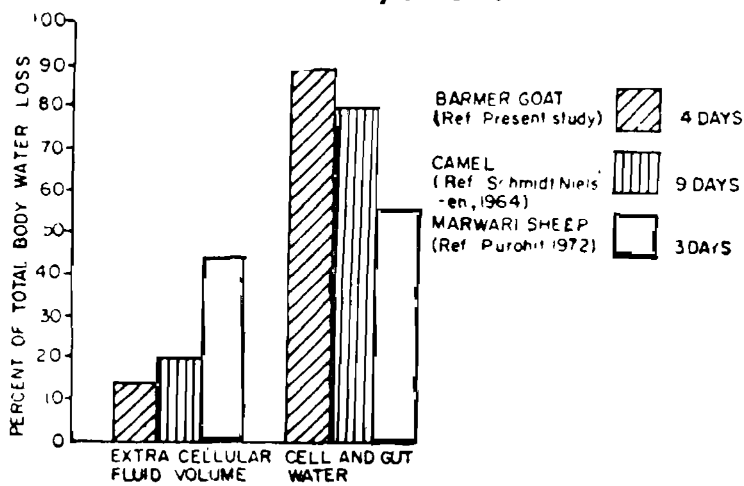
Character	Before water restriction (mean ± S.E.)	Day 4 of water restriction (mean ± S.E.*)	Change of complete water restriction from *ad-libitum* value (%)	Average amount of water lost (mean ± S.E.)	Per cent of the total body water lost
Body weight (kg)	40.10 ± 0.75	35.30 ± 1.08	− 11 97	–	–
Total body water (l)	24.46 ± 1.53	18.21 ± 1.09	− 25.55	6.24 ± 2.11	–
Plasma volume (l)	1.47 ± 0.03	1.28 ± 0.05	− 12.92	0.19 ± 0.07	3.04
Blood volume (l)	2.03 ± 0.07	1.93 ± 0 06	− 4.92	0.14 ± 0.05	2.24
Extracellular fluid volume (l) (thiocyanate space)	11.49 ± 0.22	10.62 ± 0.32	− 7.57	0.90 ± 0.28	14.42
Cell and gut water (l)**	12.96 ± 1.52	7.59 ± 1.03	− 41.43	5.58 ± 1.80	89.42
Interstitial fluid volume (l)	10.02 ± 0.19	9.33 ± 0 31	− 6.88	0.71 ± 0.27	11.37

*Significantly different from control animals ($P < 0.05$).

**Cell and gut water = total body water – thiocyanate space.

water fully at times of water crisis, and its primary dependence on circulatory water for evaporative cooling and other essential purposes makes the sheep decidedly less desert worthy than the goat. A comparison of water use patterns in the camel, sheep and goat has been made in Fig. 7.

PERCENT CONTRIBUTION OF ECF AND CELL AND GUT WATER TO TOTAL BODY WATER LOSS IN WATER DEPRIVED DESERT GOAT, SHEEP AND CAMEL



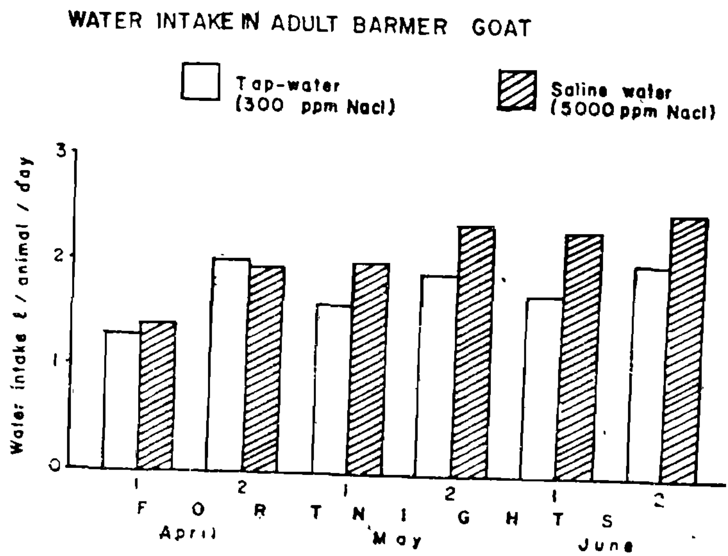
(Fig. 7)

In its overall physiological approach to the problem of dehydration the desert goat emulates the camel, and quite successfully so (Table 5).

6. Salinity tolerance

Salinity of the surface as well as of the ground waters is another major hazard of desert living. While total salt concentration upto a limit, say 500 parts per million, in the drinking water may be perfectly safe and acceptable to man and animals alike, total salt concentrations above this limit, or the presence of particular cations or anions in unphysiological proportions in the drinking water render it unsuitable for human and animal consumption. Over mineralization of drinking water is a real menace, and animals have to be either kept confined to grazing areas surrounding water holes or wells of known and acceptable water quality, or they have to be frequently driven over long distances while grazing, from one tolerably good water hole to another. In the former case, there is usually regional over-exploitation of plant resources leading to ecodegradation, and in the latter, the water need of the animals is sought to be met at the cost of maintaining energy surpluses for production purposes.

In common with other desert livestock, the goat is also subjected to these husbandry practices, but work done at CAZRI has revealed that the desert goat can, and do, tolerate a good deal more of salts in the drinking water than, at least, the desert sheep. The Rajasthan desert sheep do not possibly have sufficiently strong kidneys to excrete out high loads of salt. For Marwari sheep, 1% sodium chloride has been found to be the upper safe limit (Ghosh and Ram Ratan, personal communication). The salt-tolerance of the Barmer goat of this region is, on the other hand, quite remarkable. In an experiment conducted during summer (March to June), different groups of these animals were given saline drinking water having the following salt (NaCl) concentrations for a period of one month : 0.5%, 1.0% and 1.5%. The goats tolerated the 0.5% and 1.0% salt solutions without any apparent ill effects. The animals on the 0.5% salt regime were drinking more water (Fig. 8). This

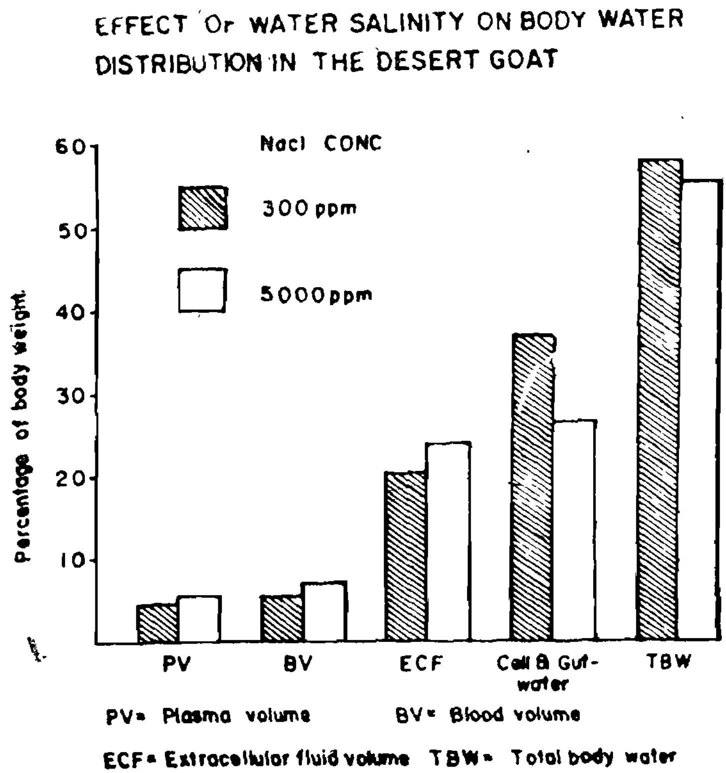


(Fig. 8)

obviously has a physiological purpose. It is easier for the kidneys to handle large volumes of moderately concentrated urine than to excrete a small volume of highly concentrated urine. Drinking of 1.5% salt solution caused declines in both the water and feed consumptions of the animals. During summer, when the environmental heat load is very high, ordinarily almost half the quantity of ingested water is utilized for evaporative cooling of the body. If, under such circumstances, the water is highly mineralized, there is hardly enough water left in the body for the kidneys to utilise in getting rid of the salt load. Along with marginal declines in body weight, body fluid compartments of the 1.5% saline treated animals were also depleted and urine output fell considerably. These were in contrast to observations made on the camel maintained on 5.5% NaCl solutions (Maloiy, 1972). The camel tolerated the imposed salinity without any apparent ill effects. Experiments conducted at this Institute on the effects of salt intake on the body water distribution pattern in desert goats have revealed that the goat of this region handles salt loads more or less as the camel does. The Barmer goat not only excretes a highly concentrated urine but it also regulates its body water in such a way that as the circulating minerals increase due to saline intake, a large volume of water is drawn from the gastrointestinal tract to the circulatory system so that the circulatory fluid remains diluted to the optimum level (Fig 9), thereby avoiding circulatory failure. An expanded circulatory volume is a necessity when animals are confronted with either heat and water stress or salt stress, and the Rajasthan desert goat has obviously learnt well how to achieve this physiological feat in times of necessity.

THE HARDINESS OF THE GOAT

The desert goat, with its built-in physiological mechanisms to fight the twin problems of desert life, viz., heat and lack of water, has now come to be considered as one of the most important biotic factors of the desert ecosytems. Both sheep and goat inhabit the desert, but unlike the sheep, the goat has achieved more flexibility in adjusting its system to the high heat load and water deficiency conditions prevailing there (Ghosh and Khan, 1979). All desert dwelling large land animals, in general, had to learn to live with less water, the goat and the camel apparently outshining others in this respect.



(Fig. 9)

In view of the long-drawn controversy over the goat, studies have been conducted at CAZRI on desert goats to obtain further evidence on this issue. The findings clearly point to the animal's hardiness of a very high order, both in respect of tolerance of a reduced water intake and high salinity level in the drinking water. In comparison to the desert sheep, the goats of Western Rajasthan appear to be considerably superior in respect of their efficiency of niche utilization. The almost 70% increase in goat number during the decade 1961-71 (3.42 million vs. 5.81 million), compared to a mere 18.6% for sheep (4.35 million vs. 5.16 million), in the 11 arid districts of Rajasthan, is clear evidence of the goat's superior adaptive and reproductive faculties (Table 6). Quite apart from this impressive increase in the goat population, recorded during a period of recurring droughts, experimental data on the desert goat's water use economy further testify to its hardiness.

Thus, the population dynamics of the two species of animals in the two bioclimatic zones within Rajasthan desert point clearly to the goat's high degree of adaptability to hot arid conditions.

Table 6. Distribution of goat and sheep population in (million) Rajasthan

Zones		1961	1971	Increase (%)
Arid districts	Sheep	4.35	5.16	18.6
(11)	Goat	3.42	5.81	69.6
Semi-arid districts	Sheep	3.01	3.39	12.9
(15)	Goat	4 62	6.35	37.5

GOAT REARING FOR MEETING THE PROTEIN GAP IN THE COUNTRY

Malnutrition, particularly protein malnutrition, is fairly widespread in India. Traditional value systems and socio-economic factors have combined to lead to this unfortunate situation. The goat has a significant role to play in this context and Western Rajasthan with its vast spread of marginal lands harbouring an ever-increasing number of goats may indeed become the future "protein bank" of the country. This possibility needs to be examined in greater depth and with less bias than has hitherto been done by the planners.

Even now, Rajasthan, or more correctly Western Rajasthan, is a major supplier of goats to neighbouring Delhi, Punjab and Haryana, and to distant Bombay. It is, of course, difficult, under the present system of sedentary cum migratory animal husbandry prevailing in this region to come to a definite figure on the export of live goats out of the state for sale of mutton. However, estimates of nearly 2.5 lakh heads of goat annually going out of Jodhpur district alone have been made. The other districts of the state each have their own contributions to meet the nation's demand for more and more protein.

More than half (54%) the quantity of meat being annually consumed in India [about 721 thousand tonnes; Report of the National Commission on Agriculture (NCA), 1976] comes from sheep and goats. The demand is, of course, rising each year, and the NCA has estimated India's total meat requirement to range between 1.1 and 1.4 million tonnes by 1985 and between 1.6 and 2.1 million tonnes in 2000 A.D. An obviously optimistic NCA has also arrived at a projected increase in our per capita meat requirement from 1.25 kg in 1971 to something between 1.45 and 1.93 kg in 1985, and between 1.68 and 2.26 kg in 2000 A.D. That is, if every thing goes well with the family planning programme and agricultural and industrial production and if the per capita income rises. 'Even these significant total increases in meat consumption per capita will apparently fail to meet the physiological requirement of 30 g protein, as set forth by the Indian Council of Medical Research, for the meat eating population (estimated at 70% of the total population) in the country, assuming the proportion of meat proteins to be 30 per cent of the total requirement.

In any case, there seems to be a strong case for providing at least 1.6 kg of meat per person for the population as a whole by 1985. This obviously would call for a massive effort to raise mutton production. Since the Indian palate is tickled more readily by the leaner goat meat than the richer and more strongly flavoured mutton of sheep, goat production in India's arid and semi-arid areas will have to be stepped up considerably along scientific lines.

THE ECONOMICS OF GOAT REARING IN THE DESERT

The goat once provoked Mahatma Gandhi's adulation as the 'Poor Man's Cow'. Now it is likely to attract Schumacher's appreciation as the ideal biological system that conforms to his ideal of "Small is beautiful". Indeed, there are enough economic reasons which warrant a reassessment of the goat's position in our farming system. Several attributes easily place the goat in a favourable position. For example, (i) the goat is a small animal that requires a relatively short time to mature and so requires less feed between birth and production, (ii) they act as guides to their flock mates during migration and help the stockowners by keeping vigil during the night, and (iii) they provide milk to the growing lambs, the ewes usually being very low milk-yielders. The flock owners are also able to dispose off goats during any part of the year or during migration to get some money for meeting their day to day expenditure. Besides meat, goats are also utilized as a supplier of milk for the poorer sections of the people and goat hair is used for the manufacture of ropes, blankets, etc. Goat skins are valued for their use in the leather industry both at home and abroad. Products of the goat sector in western Rajasthan have been shown in Table 7.

Table 7. Productivity of goat in the arid zone of Rajasthan

Product	1961	1966	1971
Goat flesh (tonnes)	8685.93	9619.13	12245.52
Goat skin (million)	1.24	1.37	1.75
Goat hair (tonnes)	388.52	455.70	697.73

It has been observed that goat raising on the properly developed range land would be much more profitable than sheep or cattle raising. Theoretical considerations on the relative economics of the rearing of cattle, sheep and goats in the arid regions of Rajasthan while primarily maintained on free range grazing or browsing, with some supplementary feeding to the cattle during lactation, have led scientists of the Central Sheep & Wool Research Institute, Avikanagar, to infer that goats are 130% more economical than cattle and 123% more economical than sheep, whereas sheep are 7% more economical than cattle (Acharya and Patnayak, 1974).

Studies conducted elsewhere on the comparative economics of sheep and goats under range conditions have indicated that goats are 40% to 160% more economical than sheep.

Estimates made at the CAZRI indicate that a reasonably good indigenous goat should provide a small farmer an extra income of Rs 250/- per year, or a farmer with a flock of 20 goats should have a clear income of Rs 5,000/- per annum. This is besides the nearly 2 quintals of manure that each goat yields over a year, and the additional benefit accrued from the clearing of the fields of obnoxious weeds, and thorny bushes which are devoured by the goats. That the merit of the goat is catching up with planners at various levels is evidenced by the number of requests being received at the CAZRI from different social service organizations and business houses for information on the goat for use in their adopted villages or areas of operation. In view of the potentialities of the goat in rural reconstruction, the ICAR has recently established a Central Goat Research Institute near Mathura.

THE GOAT AND DESERTIFICATION

The goat has been the subject of a controvesy ever since the 1930's. Two conflicting views prevail as to the goat's role in land use : (i) the goat is the major cause of deforestation, rangeland destruction and soil erosion, and, as such, its propagation should be checked, and (ii) this animal is of considerable value as the "Poor Man's Cow" (some even calling it the "Walking Refrigerator") and as the major supplier of animal protein in our diet and, as such, should be included in a rational grazing programme. The proponents of the latter view hold that most of the world's deteriorated rangelands have been caused by over grazing by cattle and sheep, and the scrub vegetation left behind can only be utilized by goats. To categorically blame the goat for the vast destruction of the world's pasture and forest resources may, therefore, be unrealistic.

These differences of opinions have caused varying governmental approaches pertaining to the goats. For example, countries like Switzerland, Portugal, Egypt and Israel do not favour large, free-ranging goat flocks. On the other hand, France, Italy, Venezuela, Syria and Cyprus have no official bias operating againt the goat. In India, the National Commission on Agriculture has come down rather heavily on the goat and has recommended drastic reduction in its numbers in the desert areas.

When we sift the facts from the myths, however, a realistic assessment, absolving the goat of much of the crime supposedly perpetrated by it as the prime agent of ecodegradation, becomes possible. The goat, in fact, has for long been a victim of human ingratitude. In many cases, it has long since been banished to semi-arid and rocky regions where neither the cow nor the sheep can thrive easily. But such banishment of the goat to refractory sites only makes things difficult to reclaim such sites. An example of irrational condemnation of the goat is the blame put on them for initiating and accelerating soil erosion, whereas they may be only one of the factors involved. They are not necessarily even an integral part of the destructive chain because severe erosional damage may occur even in their total absence, As mainly browsers on shrubs, the goat not only manages to provide itself a diet of adequate protein and mineral contents, it also generally leaves the soil undisturbed. The sheep, on the other hand, because of their bifid upper lip, are able to graze closer to the ground than cattle or goats and in doing so, in dry weather and on loose soils. they frequently uproot the smaller grass species and thereby permanently damage the sward. These are generally overlooked.

Agricultural operations also frequently cause more soil erosion than is done by goats. This has been especially brought out in a report from Lebanon (FAO, 1970). Again another human activity, viz., more harvesting of wood for fuel or charcoal by unauthorised persons than the existing forests can support. Thus, even if all goats were removed from the forests and the adjacent areas, uncontrolled forest destruction would still continue at the present high rate. When foresters condemn the goat, they usually forget the more serious depradations caused by man himself to the vegetative cover of the earth. Certainly, when grazing or browsing cut-over forest areas, goats prevent tree regeneration by consuming the young shoots, but cattle and sheep also cause appreciable damage of the same nature in similar circumstances. Goats are also accused of damaging crops; but, in actual fact, the natural grazers, i.e. cattle and sheep, can often be even more destructive. With both forest and crop damage, the type of stock is usually a less important factor than the number of livestock, irrespective of species. It is a widespread lack of control and the careless management of the animals which are chiefly responsible for the destruction incurred.

What is needed, then, is to maintain a balance between the total number of goats (and other livestock) and the quantity of feed which is available for the combined population during the lean periods. In other words, the carrying capacity of the land has to be determined and respected. There is no sense in discriminating unjustly or unnecessarily against one particular species, the goat. In extreme situations where elimination of the goat from the eco-system is considered logical the probable effects of its disappearence on the existing vegetation and on the low level of animal production in the region should be carefully considered. It will be well to remember that where feed is scarce and of low nutritive value the larger animals are at a disadvantage because of their greater maintenance requirement. Smaller animals like the goat, with correspondingly lower maintenance needs, are often able to roam over larger areas to gather sufficient nutrients for both survival and at least the minimal production of meat and milk.

The goat has a strong justification to continue to exist as part of our agricultural practices, at least in such areas where the potential for sedentary agriculture is at best minimal. The controversy that has been ragging concerning the goat does not originate in the goat *per se*, but in the uncontrolled and continued overgrazing by this agile and inquisitive animal. The approach to contain the menace so far fallaciously believed to be posed by the goat should be to upgrade it and control its movements, rather than doing away with it.

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