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Traditional fodder storage systems used in India's western hot arid zone as a drought-proofing mechanism

Sushil Kumar[a,*,#], Arun Kumar Misra[b] & Venkatesan K[c]
[a]ICAR-Central Arid Zone Research Institute, Regional Research Station, Bhuj 370 105, Gujarat, India
[b]ICAR-Central Arid Zone Research Institute, Jodhpur 342 003, Rajasthan, India
[c]ICAR-Central Arid Zone Research Institute, Regional Research Station, Jaisalmer 345 001, Rajasthan, India
[*]E-mail: sushilangrau@gmail.com

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The aim of the study was to record the customary methods of storing fodder that farmers in India's hot and dry regions have used. In addition to using a questionnaire, key informant interview schedules, and secondary sources to gather data on fodder storage systems, the study employed a cross-sectional survey approach to obtain primary data from pastoral families. *Karai* and *Pachawa* are the traditional fodder storage systems being used in the hot arid zone to store fodder for use in drought years. These are low cost and durable fodder storage systems made with locally available materials using indigenous knowledge since time immemorial. *Karai* is made in the conical shape and especially used for storing small fodder cuttings. However, *Pachawa* is made in circular or square or rectangular and used for storing fodder as it is (uncut). These traditional systems are exceptionally good to store the dry fodder for a longer period (1-10 years) with minimal deterioration in fodder quality.

Keywords: Fodder quality, Hot arid zone, *Karai*, *Pachawa*, Traditional fodder storage system

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About 18.8% of the total land area of the world is arid. With 31.7 million hectares (m ha) of hot arid regions and 7.0 m ha of cold arid regions, arid region makes up about 12% of India's geographical area[1]. The majority of the hot arid region in India, which accounts for almost 90% of the total area, is located in the north-western states of Rajasthan (19.6 m ha), Gujarat (6.22 m ha), Haryana, and Punjab (2.75 m ha)[2]. The hot arid zone in the southern states of Andhra Pradesh and Karnataka, including Maharashtra, comprises tiny pockets spanning an area of 3.13 m ha. The primary limitations for agricultural development in the hot arid zone are adverse meteorological conditions, including insufficient and unpredictable rainfall, frequent droughts, high temperatures, strong winds, excessive evapotranspiration, and limited water supplies[3]. Pastoralism is often the most common practice in arid regions.

The human population in the hot arid zone is less than the animal population of which the Kachchh is the classic example, where livestock population (17.07 lakh) is greater than human (15.26 lakh) population[4]. Farmers involved in animal husbandry consider the proper availability of excellent feed, whether green or dry, as vital to their livelihoods. Aside from the limited cultivation of fodder crops, livestock owners in the hot desert zone satisfy their needs for fodder through a combination of crop residues, fodder trees and bushes, grazing on resources on public and private property[5], cultivable fallows, and croplands following harvest. The availability of appropriate quality feed and fodder, which is frequently much lower than required, is very important for livestock production in the region. According to one estimate, green fodder is available in the country's western arid zone at 26.83% of the required amount, dry fodder at 12.41%, and concentrates at 5.86%. During the drought, things get worse, especially in the arid areas[6]. During the scarcity period, the cost of feed and fodder become very high, which are beyond the reach of most of the poor farmers. In such circumstances, there is a significant decrease in the output of animal products, a significant exodus of cattle from the area, and fewer

*Corresponding author
[#]Present address: ICAR-Central Agroforestry Research Institute, Jhansi-284003, Uttar Pradesh, India

options for subsistence, particularly for the most vulnerable members of society[5].

Agricultural leftovers and the natural flora found in fallow areas and uncultivated lands serve as the primary sources of feed in the hot arid zone. The permanent grazing pastures, referred to as *Orans*, frequently face severe deterioration and extensive encroachment. In a typical year with average rainfall, agricultural leftovers such as bajra (pearl millet) stover, dry leaves, and the plants of green gram, moth bean, cluster beans, and wheat straw serve as the primary source of animal feed. In addition to grasses, there are other options for animal feed, such as pala (the leaf fodder of *Ziziphus nummularia*), loong (the leaf fodder of *Prosopis cineraria*), and wheat straw. However, the total crop loss during the intense drought phase significantly diminishes the availability of agricultural leftovers[7]. The drought has had a serious impact on the regeneration and growth of natural vegetation. This is mostly due to the lack of moisture and the increased occurrence of browsing, lopping, and cutting of trees and shrubs for fodder and fuel. Hence, the livestock keepers of the hot arid zone of India always use some kind of traditional methods, they had acquired from their forefathers, for fodder storage as a drought-proofing mechanism to overcome the fodder scarcity problem during the drought period[8]. It is believed that these traditional fodder storage methods might have been evolved by practice since long back and being adapted for storing fodder in the hot arid zone but not yet well documented. Therefore, this study was aimed at documenting the traditional fodder storage methods and assess the quality of the stored fodder.

Materials and Methods

Study area

The study was conducted during 2014-16 in the hot arid zones of Rajasthan and Gujarat. Two districts from each state *i.e.,* Jodhpur and Jaisalmer from Rajasthan and Bhuj and Banaskantha from Gujarat were selected based on drought proneness, scarcity of fodder and operation of fodder/cattle camps. The districts are known for their typical arid climate; experiences scanty and highly-erratic rainfall with an average annual precipitation of 300-500 mm with a high coefficient of variation[9]. The livestock-centric agriculture systems are dominant in the region and more often especially during severe drought period livestock sector remains the only main source of livelihood of the inhabitants[10]. The climate in the chosen research sites is defined by infrequent and unpredictable rainfall, elevated potential evapotranspiration, significant variations in both diurnal and yearly temperatures, intense solar radiation, low levels of humidity, and strong wind speeds. The yearly precipitation varies from around 100 mm in the far western region to 500 mm in the eastern and south-eastern areas[9], whereas 65% of the annual rainfall coefficient of variation corresponds to potential evapotranspiration above 2000 mm. The majority of the precipitation (80-85%) occurs during the southwest monsoon period, which spans from June to September. The monsoon rains commence in early July and typically recede by the beginning of September in the hot arid region of northwest India. The area encounters significant variations in temperatures. The air temperature has a rapid rise starting in April and reaches its highest point from May to mid-June. Nevertheless, the summer season has a range of maximum temperatures between 39 and 45°C, with unusual spikes reaching up to 49°C. The region natural vegetation is characterised by a scarcity of plant life, consisting mostly of permanent and annual grasses, herbaceous plants, shrubs, and tiny trees. Shrubs and trees are slow growing in nature, while the annual grasses are fast growing and complete their life cycle in a short span of the favourable rainy season. Most of the vegetation cover is degraded due to over-exploitation.

Methodology

The primary data on fodder resources, storage practices and livestock was collected through various methods like Participatory Rural Appraisal (PRA) techniques, formal and informal discussions, case studies, etc. The study attempted to explore the traditional fodder storage and conservation systems being adopted by the livestock keepers in the hot arid zone as a drought-proofing mechanism to maintain the fodder supply for the livestock in the event of monsoon failure. Survey of the districts (Kachchh and Banaskantha of Gujarat and Jodhpur and Jaisalmer of Rajasthan state) covered under the study was performed with the consultation of local gaushalas, non-government organizations (NGOs) and religious trusts who manage Community Property Resources such as gauchars (common grazing lands) and orans (sacred groves). To identify traditional fodder storage and conservation systems, types of fodder availability and sources of fodder, focus group discussion (FGD)

were conducted followed by household interviews of randomly selected villages. Two traditional fodder storage structures (*Karai* and *Pachawa)* were selected from each taluka for detailed investigation. Fodder samples from each structure were selected and pooled for analysis of proximate principles as per the standard procedure[11]. Fodder stored over different durations (1-5 years old) were collected and analysed for quality parameters to ascertain the changes in fodder quality, if any, with passing time. The details of selected locations (districts, blocks/talukas, and villages), their demographic characteristics are given in Table 1.

Results and Discussion

The socio-economic profile of the selected respondents is presented in Table 2. Results revealed that average family size and livestock holding per household was more in Rajasthan than in Gujarat. The number of small ruminants was significantly higher in Rajasthan than Gujarat whereas large ruminants were more in Gujarat.

Among the commonly used fodder, the lion's share of the fodder requirement of the livestock in the region is met with sorghum and pearl millet-based sources. The availability of excellent quality feed in sufficient quantities is of major importance for sustainable livestock production[12] not only in the arid zone but also across all the climatic situations. The quality of fodder heavily depends on types of fodder and its source, storage condition and duration of storage. The composition of the fodder stored in *Karai* and *Pachawa* for the period 1-5 years are presented in Table 3. Analysis of the stored fodder samples indicated the nominal change in fodder quality with increasing storage period in *Karai* and *Pachawa*. Except for crude protein content, the chemical makeup and nutritional qualities of stored dry fodder do not change much. This is logical, as nitrogen is sensitive to heat and solar radiation. It is important to understand that the quality of stored fodder is not solely determined by storage circumstances. Other factors, including as the kind of stover fodder and when it is harvested, as well as packing methods and drying conditions, also have a significant role.

Traditional fodder storage systems

The farmers of the hot arid zone of India always store some dry fodder in the form of *Karai* or *Pachawa* for at least 2-3 years at their farm. The occurrence of drought results in a serious shortage of animal feed, leading to the necessity of selling valued animals in a state of suffering. In years with abundant rainfall, surplus fodder from crops such as sorghum, pearl millet, wheat, barley, or any other crop is conserved for years with unfavourable conditions. The crop residues of cereals are stored in huge structures called '*Karai* (small fodder cuttings) or '*Pachawa* (fodder used as it is) which are made of agricultural stalks or branches, and can be either conical with a circular base or rectangular with hut-like top and base. These traditional fodder storage structures are made of the locally available material such as *Saccharum*

Table 1 — Demographic characteristics of selected locations (as per 2011 census)

	Rajasthan						
	Jodhpur				Jaisalmer		
Tehsil/block	Luni	Phalodi	Mandore	Jodhpur	Pokaran	Fatehgarh	
Villages	Lunawas Khara	Purkhawas	Digawari	Mandore	Ketookalan	Bhadriya	Bhadli
Total geographical area (ha)	1398	1580	1481	2284	1838	20856	3233
No. of Households	402	187	158	601	355	261	236
Net cultivated area (ha)	1211	1221	508	NA	1071	51	1681
Rainfed area (ha)	1171	1221	508	NA	1030	51	1681
Irrigated area (ha)	40	0	0	NA	41	0	0

	Gujarat									
	Banaskantha				Kachchh					
Tehsil/block	Dhanera		Deesa	Vav	Bhuj	Lakhpat			Anjar	Mundra
Villages	Raviya	Jadiya	Baiwada	Khimana Padar	Kukma	Lakhpt	Dayapar	Kaiyari	Bhalot	Baroi
Total geographical area (ha)	1257.6	2289.4	1741.6	1594.2	1829.3	2947.7	4755.3	2739.7	1079.6	1126.7
No. of Households	453	914	864	416	1636	108	856	47	197	3856
Net cultivated area (ha)	NA	2131	1396	834	1221	NA	1700	104	495	712
Rainfed area (ha)	NA	579	131	834	942	NA	1650	104	485	547
Irrigated area (ha)	NA	1452	1265	0	79	NA	50	0	10	165

bengalense (Sarkanda), *Leptadenia pyrotechnica* (Khimp), and *Clerodendrum phlomidis* (Arna) etc. to control the entry of rainwater into the stored fodder[13]. The details of traditional systems used by the farmers of study sites are given below:

Karai

Karai is a traditional method used to store fodder in the western region of the extremely dry and hot arid zone, which includes parts of Rajasthan and Gujarat. This technique involves the secure preservation of small fodder cuttings for a duration of up to 10 years. The *Karai* is constructed at a short distance from the human settlement using materials that are readily found in the area. The design ensures that the stored fodder is protected from sunlight, rains, strong winds, as well as potential damage from humans and animals. The *Karai* is constructed in a conical shape, with a diameter of 3-4 m at the base and a height of 8 m (Fig. 1). Pearl millet and mustard straw are stored at the base of *Karai* to protect the stored fodder from termite infestation. The upper part of the *Karai* is adorned with a jhumpi crafted from pearl millet stalk, which is renewed every three years. In order to protect against both domestic and wild animals, a trench about 0.5 m in width and 1-1.5 m in depth is constructed around *Karai*. The small fodder cuttings stored in *Karai* are fed to livestock during the severe drought period when there is a wide-spread scarcity of fodder.

Pachawa/Pachasa

The hot and arid regions of western Rajasthan and Gujarat (Kachchh) specifically use the *Pachawa*, an indigenous method of storing fodder. The *Pachawa* used to have a fodder storage capacity of up to 1000 quintals. Its base can be either round, square, or rectangular in form (Fig. 2). The fodder stored in square or rectangular *Pachawa* is consumed gradually over time, whereas the fodder stored in circular *Pachawa* is chopped into pieces and stored in a room or covered location for further use or sale. The *Pachawa* is constructed on an elevated platform to

Table 2 — Socio-economic profile of respondents

Attributes	Rajasthan	Gujarat
Average family size	6.70	5.73
Male (%)	51.17	52.12
Female (%)	48.83	47.88
Average number of livestock/family	17	9
Small ruminants (%)	61	35
Large ruminants (%)	39	65

Fig. 1 — *Karai*

Table 3 — Quality composition of fodders traditionally stored in *Karai* and *Pachawa* (1-5 years)

Roughages/grasses	Organic matter (%)	Crude protein (%)	Ether extract (%)	Crude fibre (%)	Nitrogen free extract (%)	Total ash (%)
			1 year old			
Bajra stover	91.03	5.51	1.25	35.37	48.90	8.97
Sorghum straw	90.58	4.62	1.20	38.40	46.37	9.42
Moongbean straw	88.84	9.27	0.78	31.19	47.60	11.16
Mixed grasses	97.05	4.70	1.15	29.37	43.07	7.85
			2 year old			
Bajra stover	90.89	4.10	1.11	34.37	50.45	9.11
Sorghum straw	90.01	4.12	1.12	37.40	47.37	9.99
Mixed grasses	91.10	4.50	1.13	29.37	56.10	8.90
			3 years old			
Bajra stover	90.03	4.35	1.05	34.37	50.26	9.97
Sorghum straw	90.01	4.32	1.11	39.40	45.18	9.99
Mixed grasses	91.15	4.45	1.15	31.37	54.18	8.85
			5 years old			
Bajra stover	91.03	3.98	1.02	33.71	48.82	10.11
Sorghum straw	90.58	3.36	1.07	36.40	48.81	10.36
Mixed grasses	97.05	4.06	1.05	31.37	53.36	10.16

Fig. 2 — *Pachawa*

protect it from rainfall and is positioned away from the huts to reduce the likelihood of fire hazards. To prevent overturning, alignment of the *Pachawa* longest side is done parallel to the prevailing winds during construction. To protect it against termites, a layer of dry grasses, including mustard and sesame stalks, is sprinkled evenly over the elevated floor, with a thickness of 1-1.5 m. The *Pachawa* has a specified height range of 6-8 m and a width range of 4-5 m. Once it reaches a height of 6-8 m, the upper surface is shaped into an inverted "V" and covered with a thatched roof constructed from pearl millet stalks and other materials found in the surrounding area. The roof is rebuilt on a triennial basis. The roof cover is designed to encompass the whole area, ensuring that the stored fodder is shielded from rain. The *Pachawa* is also surrounded by dried branches of a thorny shrub that may grow up to 2-3 m tall. Additionally, there is an open trench that is 0.5 m wide and 1-1.5 m deep surrounding the *Pachawa* to ensure safety from both domestic and wild animals.

Conclusion

Livestock is an integral part of the arid farming systems as it plays a crucial role in risk-aversion mechanism for sustaining farm families when the crops fail due to climatic stresses. The *Karai* and *Pachawa* are the two most common traditional fodder storage systems made up of locally available materials. They are being used since time immemorial for storing dry fodder material in the hot arid zone of India. These systems are very durable wherein fodder is stored up to 12 years with minimal deterioration in fodder quality. The stored fodder is used as a drought-proofing mechanism and fed to livestock in the event of severe drought when other sources of fodder are unavailable completely.

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Conflict of Interest

The authors state that there are no conflicts of interest.

Declaration

Authors conducted focused group discussions with participants for data collection after obtaining their prior informed consent.

Author Contributions

SK: Conceptualization, documentation, data collection and writing-original draft. AKM: Formal analysis, supervision, editing and review. VK: Data tabulation and editing

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