FOOD, FLUORIDE, AND FLUOROSIS IN DOMESTIC RUMINANTS IN THE DUNGARPUR DISTRICT OF RAJASTHAN, INDIA

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SUMMARY: Toxic effects of chronic fluoride (F) exposure in the form of osteo-dental fluorosis were observed in domestic ruminants in the Dungarpur district of Rajasthan, India. These animals included cattle (*Bos taurus*), buffaloes (*Bubalus bubalis*), camels (*Camelus dromedarius*), sheep (*Ovis aries*), and goats (*Capra hircus*) inhabiting areas having about the same mean 1.5–1.7 ppm F concentration in the drinking water. Evidence of osteo-dental fluorosis was present mostly in the mature animals but varied widely, with the highest prevalence of dental and skeletal fluorosis in mature ruminants being 55.9% and 48.3%, respectively, among 288 buffaloes, followed by 48.0% and 39.8% in 392 cattle, 10.7% and 8.4% in 356 goats, 7.3% and 5.6% in 248 sheep, and 5.3% and 5.3% in 38 camels. Among immature ruminants, osteo-dental fluorosis was not observed among 34 goats, 28 sheep, and 12 camels. However, among 43 immature cattle and 37 buffalo calves, the dental and skeletal fluorosis rates were 51.1% and 18.6% and 62.2% and 21.6%, respectively. Such variations of F toxicity in these ruminants may be due to differences in F exposure and ameliorating factors, such as differences in the levels of calcium, ascorbic acid (vitamin C), and other protective nutrients found naturally in their food. Additional factors causing variation in fluorotoxicosis may also be involved.

Keywords: Animal fluorosis; Dietary calcium; Dietary vitamin C; Dungarpur district; Environmental fluoride; Forage nutrients; Osteo-dental fluorosis; Rajasthan; Ruminants in India.

INTRODUCTION

Chronic exposure to fluoride (F) in drinking water causes ill health in the form of fluorosis, not only in humans but also in domestic animals.[1-5] The primary manifestation of fluorosis is mottling of teeth (dental fluorosis) and osteosclerosis of the skeleton (skeletal fluorosis). Besides these, non-skeletal fluorosis or toxic effects of F in soft-tissue or organ systems, viz., gastro-intestinal disturbances, neurological disorders, reproductive dysfunctions, and teratogenic effects have been reported in man[6] and animals.[7] The prevalence and severity of these chronic F effects are also influenced by several determinants besides the amount of F, duration of exposure, and frequency of intake.[6-7]

In India, chronic fluorotoxicosis (fluorosis) among domestic ruminants has been studied mostly in cattle (*Bos taurus*) and buffaloes (*Bubalus bubalis*).[8-10] Except for a few reports,[7-11] fluorosis in horses (*Equus caballus*), donkeys (*E. asinus*), camels (*Camelus dromedarius*), goats (*Capra hircus*), and sheep (*Ovis aries*), has had limited study in India. Although fluorotoxicosis can develop in any animal from chronic exposure to F in water, the severity varies among species, animals, and their habitat. A recent study also indicated a contributory role of food and its nutrient composition in ameliorating F toxicity in goats and sheep.[12] In the present preliminary study the sample sizes differed widely, but the mean water F

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concentration ranged narrowly between 1.5 and 1.7 ppm. Consequently, this investigation concentrated on ascertaining and correlating food nutrients and F intoxication in the above-mentioned ruminants living in a diverse F endemic area having the same or similar F concentrations in their drinking water sources.

MATERIALS AND METHODS

The ten villages of Ahada, Bhiluda, Kshetrapal, Mehrawada, Munged, Navagaon, Navatapara, Saroda, Sidri, and Vasi in the Dungarpur district of Rajasthan, India, were selected for the study. As already noted, the drinking water in these villages averages between 1.5 and 1.7 ppm F.[13] Osteo-dental fluorosis was observed in native domestic animals, all of which had lived in these villages since birth. Included were 435 cattle (*Bos taurus*) and 325 buffaloes (*Bubalus bubalis*) with mature designations above 3 years of age and immature below age 3; 50 camels (*Camelus dromedarius*) with these designations above and below age 5; and 276 sheep (*Ovis aries*) and 390 goats (*Capra hircus*) with their age designations above and below one year of age. For this study, house-to-house surveys were made in early morning and late evening hours when animals were available. The herds in the fields were also examined during the daytime. In these animals F estimation of urine and blood was not investigated. Osteo-dental fluorosis assessments were based on clinical signs only.

These herbivorous domestic animals have different food and feeding habits. The cattle and buffaloes are basically grass eaters while the camels, sheep, and goats in this region prefer to feed on fresh, delicate leaves, pods, small fruits of trees, and shrubs. Hence their mouths, teeth, and bodies are well adapted according to their food and feeding habits.

OBSERVATIONS AND DISCUSSION

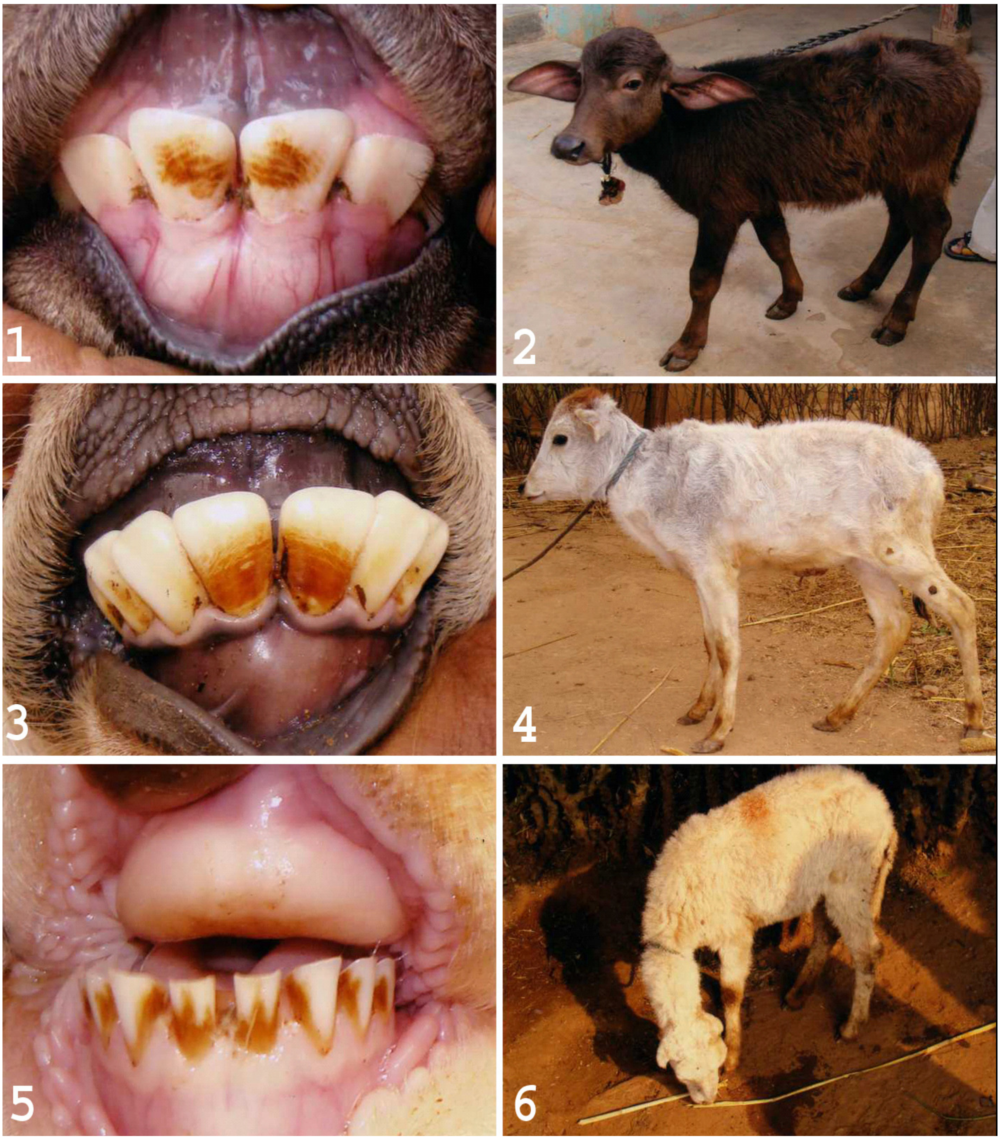
Among the different mature ruminant species living in the areas studied, buffaloes showed the highest (55.9%) prevalence of dental fluorosis, followed by cattle (48.0%), goats (10.7%), sheep (7.3%) and camels (5.3%) (Table1).

Table 1. Prevalence of dental and skeletal fluorosis in ruminants living in areas with 1.5–1.7 ppm F in their drinking waters

Ruminant Species	Mature ruminants		Immature ruminants	
	DF	SF	DF	SF
Cattle (*Bos taurus*)	188/392 (48.0)	156/392 (39.8)	22/43 (51.1)	8/43* (18.6)
Buffaloes (*Bubalus bubalis*)	161/288 (55.9)	139/288 (48.3)	23/37 (62.2)	8/37* (21.6)
Camels (*Camelus dromedarius*)	2/38 (5.3)	2/38 (5.3)	– /12 (0.0)	– /12 (0.0)
Sheep (*Ovis aries*)	18/248 (7.3)	14/248 (5.6)	– /28 (0.0)	– /28 (0.0)
Goats (*Capra hircus*)	38/356 (10.7)	30/356 (8.4)	– /34 (0.0)	– /34 (0.0)
	407/1322 (30.8)	371/1322 (28.1)	45/154 (29.2)	16/154** (10.4)

Figures in parentheses indicate percentage. DF, dental fluoroisis; SF, skeletal fluorosis.
Comparison *vs* corresponding mature ruminant group: * $p < 0.05$; ** $p < 0.001$ (χ^2-test).

Among immature animals, only calves of grass eaters (buffaloes and cattle) showed evidence of dental fluorosis (buffalo calves, 62.2%; cattle calves, 51.1%) (Table 1 and Figures 1 and 3).



Figures 1-6. Calves of buffalo (Figure 1) and cattle (Figure 3) under 2 months of age exhibiting severe dental fluorosis, hind leg lameness, intermittent diarrhoea, and wasting of body muscles as signs of skeletal fluorosis. Mature sheep showing moderate dental (Figure 5) and skeletal fluorosis (Figure 6).

On the other hand, none of the predominantly plant eating immature ruminants—calves of camels, kids (goats), and lambs (sheep)—showed any definite signs of dental fluorosis (Table 1). In general, the severity of dental fluorosis was also higher in grass eaters (Figures 7 and 8) compared to their plant eater counterparts (Figures 5, 9, and 10).

Among the mature animals, the prevalence of skeletal fluorosis was also higher in buffaloes (48.3%) followed by cattle (39.8%), goats (8.4%), sheep (5.6%, Figure 6), and camels (5.3%). None of the immature plant eaters appeared to be afflicted with skeletal fluorosis. However, the grass eating calves of buffaloes and cattle showed evidence of skeletal fluorosis: 21.6% and 18.6%, respectively (Table 1 and Figures 2 and 4).

Figures 7-10. Severe dental fluorosis in a mature cow (Figure 7) and a buffalo (Figure 8). Moderate dental fluorosis in a camel (Figure 9) and a goat (Figure 10) living in areas with 1.5-1.7 ppm F in their drinking waters.

From this survey, it appears that 1.5–1.7 ppm F in drinking water is sufficient to cause fluorotoxicosis or fluorosis in these ruminant species. However, the prevalence and severity of fluorotoxicosis in these animals obviously involves several other determinants besides exposure to and frequency of F intake.[8,10,14] Among the mature and immature camels, goats, and sheep, the severity of F toxicosis was relatively less, indicating that, despite the presence of sufficient F in the drinking water to cause fluorosis in the buffaloes and cattle, other factors apparently are at play that counteract or ameliorate the toxic effects of F, and many of these occur naturally in the food or food chains. Camels and small ruminants (goats and sheep) in our area predominantly feed on small delicate fresh leaves, pods, and small fruits of trees and shrubs. Hence their mouths, and teeth, are also modified or adapted accordingly. The most common trees and shrubs found in the study area on which these animals are dependent for their food are listed in Table 2.

Table 2. Calcium and vitamin C content (mg/100 g or % dry wt) in edible parts[a] of common plants in areas studied

S. No.	Name of Plant	Common Name	Calcium (% dry wt)	Vitamin C (mg/100 g)	Ref.
1	*Prosopis juliflora*	Vilayati babool	L-1.01-2.25% P- 0.30-0.50%	- -	15 16
2	*Prosopis cineraria*	Khejri	F-414 L-2.73 (5% DM) P-0.41	F - 523	17 18 19
3	*Acacia nilotica*	Babool	F-0.64% L-2.53%	- -	20
4	*Zizyphus mauritiana*	Ber	F-4 L-1.08%	F - 76	17 21
5	*Zizyphus jujuba*	Ber	F-106.3-117.5 L - 3612.7-4961.3%	F - 309.3-364 -	22
6	*Zizyphus nummularia*	Jungli/ Jhar ber		F - 85	19
7	*Capparis decidua*	Kair	F-55	F - 7.8	17
8	*Cordia dichotoma*	Indian cherry	F-55	-	17
9	*Ficus religiosa*	Peepal	L-1.9	-	23
10	*Ficus bengalensis*	Bargad	F-1.8	-	23
11	*Tamarindus indica*	Imali	S-248.56 Pu-35-17 Fl-35.5	Pu-0.7-3.0 Fl-13.8 L-3.0	24 25
12	*Cymamopsis tetragonolobus*	Guar	P-130	P-49	19
13	*Pithecellobium dulce*	Keekar	F-42	F-133	26
14	*Emblica officinalis*	Amala	F-0.05%	F-600	27

[a]F = Fruits; Fl = Flowers; L = Leaves; P = Pods; Pu = Pulp; S = Seeds.

Edible parts of these plants, the leaves, pods, and small fruits are very rich in calcium (Ca) and ascorbic acid (vitamin C).[15-27] These two nutrients especially counteract F toxicity.[1,2,28,29] In this connection, the reversibility of dental fluorosis in man is still controversial, but reports suggest that its further advancement or development can be checked,[30,31] and these two nutrients especially can therefore be expected to help prevent or alleviate fluorotoxicosis. Furthermore, although immature animals have relatively greater sensitivity and susceptibility and less tolerance to F,[8-10] none of the immature camel calves, goats (kids), and sheep (lambs) in our survey were found to be afflicted with either dental or skeletal fluorosis. It is reasonable to conclude, therefore, that these particular animals are protected naturally from F toxicity owing to the presence of ample amounts of Ca and vitamin C in their diet, thus accounting, at least in part, for the lower prevalence and severity of osteo-dental fluorosis in these three ruminants.

In addition, differences in the sensitivity of camels, goats, and sheep to fluorosis may also be due to inherent differences in susceptibility to fluorotoxicosis and frequency of F intake. In this connection, it should be noted that many breeds of sheep and camels in general are better adapted to desert ecosystems and require less water for their survival than most other ruminants. Camels, for example, can survive without water for up to 30 days. Hence, they have comparatively less and irregular F exposure resulting in lower F toxicity. The food (grasses or fodder) of buffaloes and cattle was almost the same in the surveyed areas, but due to consumption of fluoridated water from different sources or variation in F exposure, the prevalence and severity of osteo-dental fluorosis can vary. Buffaloes in our survey are mostly confined in dwellings and drink F-containing ground water from wells and hand pumps (regular and more F exposure), whereas cattle generally remain in the fields during the day and drink surface waters (lakes, ponds, and canals) containing a lower concentration of F (irregular and less F exposure).

The significance of the present investigation is that it reports for the first time that ruminant species (cattle, buffaloes, camels, sheep, and goats) are roughly equally susceptible for F toxicity at low F concentration in drinking water as in the case of human beings, but the susceptibility is greatly influenced by the availability or presence of Ca and vitamin C nutrients in their food or food chains besides the amount, duration of exposure to and frequency of F intake, and other determinants.[12] These findings are potentially useful in controlling or ameliorating fluorosis in both man and domestic animals. They can also be seen as contributing significantly to our knowledge of fluorotoxicosis in animals. However, the question of a generally safe maximum permissible F concentration (1.0 or 1.5 ppm) in drinking water for animals still persists. To establish the role of Ca and vitamin C nutrients in ameliorating or helping to prevent fluorotoxicosis requires more surveys in different geographical areas having different F levels in drinking water sources with involvement of substantial numbers of diverse species of both mature and immature domestic animals.

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REFERENCES

1 World Health Organization. Fluoride and human health, Monograph series No. 59. Geneva: World Health Organization; 1970.
2 Swarup D, Dwivedi SK. Environmental pollution and effects of lead and fluoride on animal health. New Delhi: Indian Council of Agricultural Research; 2002.
3 Choubisa SL, Pandya H, Choubisa DK, et al., Osteo-dental fluorosis in bovines of tribal region in Dungarpur (Rajasthan). J Environ Bio 1996;17:85-92.
4 Choubisa SL, Choubisa DK, Joshi SC, Choubisa L. Fluorosis in some tribal villages of Dungarpur district of Rajasthan, India. Fluoride 1997;30:223-8.
5 Choubisa SL. Endemic fluorosis in Southern Rajasthan, India. Fluoride, 2001; 34:61-70.
6 Susheela AK. Prevention and control of fluorosis in India. New Delhi: Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Development; 1993.
7 Choubisa SL. Osteo-dental fluorosis in domestic horses and donkeys in Rajasthan, India. Fluoride 2010;43:5-12.
8 Choubisa SL. Some observations on endemic fluorosis in domestic animals in Southern Rajasthan (India). Vet Res Comm 1999;23:457-65.
9 Choubisa SL. Dental fluorosis in domestic animals. Curr Sci 2008;95:1674-5.
10 Choubisa SL. Fluoridated ground water and its toxic effects on domesticated animals residing in rural tribal areas of Rajasthan (India). Int J Environ Stud 2007;64:151-9.
11 Choubisa SL. Fluorosis in dromedary camels in Rajasthan, India. Fluoride 2010;43:194-9.
12 Choubisa SL. Natural amelioration of fluoride toxicity (fluorosis) in goats and sheep. Curr Sci 2010;99:1331-2.
13 Choubisa SL, Sompura K, Choubisa DK, et al. Fluoride content in domestic water sources of Dungarpur district of Rajasthan. Indian J Environ Hlth 1995;37:154-60.
14 Wang JD, Hong JH, Li JP, Guo YH, Zhang JF, Hao JH. Effect of high fluoride and low protein on tooth matrix development in goats. Fluoride 2002;35:51-5
15 Pasiecznik N M. *Prosopis juliflora* (vilayati babul) in the dry lands of India: develop this valuable resource, don't eradicate it: a briefing paper for the Government of India, state governments and concerned ministries. HDRA, Ryton-on-Dunsmore, Conventry, UK: HDRA-the organic organisation (Henry Doubleday Research Association; 2002. Available from: http://www.dfid.gov.uk/r4d/PDF/Outputs/Forestry/Prosopis-PolicyBrief-2.pdf.
16 Shukla PC, Talpada PM, Pande MB. *Prosopis juliflora* pods – a new cattle feed source, Technical Bulletin. Anand, Gujarat, India: Animal Nutrition Department, Gujarat Animal University; 1984.
17 Rathore M. Nutritional content of important fruit trees from arid zone of Rajasthan. J Hortic Forest 2009;1:103-8.
18 Singh ND. Utilization of top feeds for sheep and goats. In: Proceedings of the National seminar on sheep and goat production. Avikanagar, India: Central Sheep and Wool Research Institute; 1981. p.1-16.
19 Goyal M, Sharma SK. Traditional wisdom and value addition prospects of arid foods of desert region of North West India. Indian J Trad Knowel 2009; 8:581-5.
20 Carter JO. *Acacia nilotica*: a tree legume out of control. In: Gutteridge RC, Shelton HM, editors. Forage Tree Legumes in Tropical Agriculture. St Lucia, Queensland, Australia: The Tropical Grassland Society of Australia; 1998. Chapter 7.2. p.279-90. (Originally published in 1994 by CAB International, Wallingford, Oxon, UK). Available from: http://betuco.be/coverfodder/Forage%20Tree%20Legumes%20in%20Tropical%20Agriculture%20FAO.pdf.
21 Mohamed AM, Somasundaram E, Alagesan A, et al. Evaluation of some tree species for leaf fodder in Tamil Nadu. Res J Agric Bio Sci 2006;2:552-3
22 San B, Yildirim AN, Polat M, Yildirim F. Mineral composition of leaves and fruits of some promising jujube (*Zizyphus jujuba* Miller) genotypes. Asian J Chem 2009;21:2898-02.
23 Ruby J, Nathan T, Balasingh J, Kunz TH. Chemical composition of fruits and leaves eaten by short note Fruit Bat *Cynopterus sphinx*. J Chem Eco 2000; 26:2825-41.
24 Pugalenthi M, Vadivel V, Gurumoorthi P, Janardhanan K. Comparative nutritional evaluation of little known legumes, *Tamarindus indica*, *Erythyrina indica* and *Sesbana bispinosa*. Trop Subtrop Agro Ecosyst 2004;4:107-23.
25 Morton J. Tamarind. Fruits of warm climates. Miami, FL: Julia F Morton;1987. p. 115-21. Available from: http://www.hort.purdue.edu/newcrop/morton/tamarind.html.
26 Duke JA. Handbook of energy crops [an electronic publication on the NewCROPS web site] 1983. Available from: http://www.hort.purdue.edu/newcrop/duke_energy/dukeindex.html.
27 Khan KH. Roles of *Emblica officinalis* in medicine: a review. Bot Res Intern 2009;2:218-28.
28 Chinoy NJ. Effects of fluoride on some organs of rat and their reversal, Proc Zool Soc (Calcutta) 1991;144:11-5.
29 Chinoy NJ, Reddy VVPC, Michael M. Beneficial effects of ascorbic acid and calcium on reproductive functions of sodium fluoride-treated prepubertal male rats. Fluoride 1994;27:67-75.
30 Sompura K. Study on prevalence and severity of chronic fluoride intoxication in relation to certain determinants of the fluorosis [PhD thesis]. Udaipur, India: Mohanlal Sukhadia University; 1997.
31 Choubisa SL, Choubisa L, Choubisa D. Reversibility of natural dental fluorosis. Adv Pharmacol Toxicol. In press 2011.