Agricultural Sciences in China
2011, 10(10): 1618-1623

Available online at www.sciencedirect.com
ScienceDirect

October 2011

Studies on Wool-Eating Ailment in Guizhou Semi-Fine Wool Sheep

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Abstract

The clinical symptoms of a disorder which is known locally as "wool-eating ailment" in Guizhou semi-fine wool sheep in the Weining County of Guizhou Province, China, are poor weight gain, lost appetite, pica, emaciation, and wool-eating. The mineral composition of forage, and samples of blood, liver and wool from Guizhou semi-fine wool sheep in affected ranches were compared with those from the unaffected areas. The mean concentration of iron in forage from affected pasture was significantly higher than that from the unaffected pasture. The mean concentration of sulfur in forage from the affected and unaffected pasture was similar and within normal ranges. The mean concentration of sulfur in blood, liver and wool from the affected Guizhou semi-fine wool sheep was significantly lower than that from the unaffected sheep while the content of iron in blood, liver and wool from the affected sheep was significantly higher than that from the unaffected sheep. Oral administration of calcium sulfate prevented and cured the disease. We concluded that the disease of Guizhou semi-fine wool sheep in the Weining County is due to S deficiency caused by the high Fe in forages.

Key words: Guizhou semi-fine wool sheep, sulfur, iron, calcium sulfate, wool-eating

INTRODUCTION

For several consecutive years prior to 2007, wool-eating disease has caused much harm to Guizhou semi-fine wool sheep in Weining County of Guizhou Province, China. The local farmers suffer seriously from this problem. The affected animals repeatedly bite off the wool from their own bodies or from others. The bitten sheep have a sparse wool or even naked skin. The affected animals gradually become thin and lose their appetite. The more seriously affected ones have difficulty in keeping up with the herd and appeared to die of exhaustion. The disease usually occurs during November and June, the peak time is between January and April. The incidence is estimated at 20-25% and the mortality may reach 40%.

As regards to the main sign of the disease, wool-eating, the available literature contains only some simple suggestions, such as that it is associated with a wool ball in the stomach of lambs, for which there is no treatment except surgical operation (Ah and Li 1955). There is also the suggestion that ticks transfer from adult sheep to lambs at shearing, causing itching, so that the lamb gnaw its skin and swallow much wool, which then become the wool ball and causes indigestion, colic or internal obstruction (Shi 1974). More recently, Liu (1980) reported that wool balls in a stomach of lamb occur because of plucking or scratching, when the lamb mistakenly swallows its own or its mother' fleece. Li and Yang (1994) defined wool-eating or wool-plucking as type of allotriophagia that occurs in sheep,

Received 8 October, 2010 Accepted 25 April, 2011
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doi:10.1016/S1671-2927(11)60159-4

especially in lambs. They considered that a deficiency of minerals, such as calcium (Ca), phosphorus (P), sodium chloride (NaCl), copper (Cu), manganese (Mn) or cobalt (Co), or a vitamin or protein deficiency might be the cause of the disease. Fleece-eating in sheep and goats in Haizi area of Gansu Province, China has been reported by Huang and Chen (2001) and Huang (2002). From the results of the preliminary epidemiological and clinical observations, it was suspected fleece-eating might be a local nutritional and metabolic disease associated with mineral deficiency. However, the wool-eating in Weining County of Guizhou Province was clearly quite different from these as regards its local prevalence, the age range affected, the clinical signs and the pathogenesis.

Iron (Fe) in forage is a commonly recognized contributor to sulfur (S) deficiencies in ruminants. Fe combines with S to form an iron sulfide complex, rendering S unavailable for absorption (Suttle 1999). The objectives of this study were to investigate: 1) wool-eating ailment which is a secondary S deficiency caused by the high Fe in forages, and 2) the effect of calcium sulfate ($CaSO_4$) supplementation on the prevalence of wool-eating ailment.

MATERIALS AND METHODS

Study area

The Weining County of Guizhou Province is located at 26°36´-27°26´N latitude and 103°36´-104°45´E longitude, at an average elevation of 2 200 m above sea level. The annual precipitation is 962 mm. The average atmospheric temperature is 10-12°C. The grassland vegetations are mainly *Puccinellia* (*Chinampoensis ohuji*); Siberian Nitraria (*Nitraria sibirica* Pall); floriated astragalus (*Astragalus floridus*); poly-branched astragals (*A. polycladus*); falcate whin (*Oxytropis falcate*); Ewenki automomous banner (*Elymus nutans*); common leymus (*Leymus secalinus*); and june grass (*Koeleria cristata*).

Experiment 1

To determine the pathogenesis of wool-eating ailment, studies were conducted in April (2008 and 2009; n=2 per treatment). Sixty Guizhou semi-fine wool sheep (wethers) of 2 years old were selected for study, consisting of: 1) 20 affected sheep were selected from the affected Shoupu pasture (SP), 2) 20 affected sheep were selected from the affected Liangshui pasture (LS), and 3) 20 healthy sheep were selected from the unaffected pasture as a control (C). The animals used in these experiments were reared with acceptable practices as outlined in the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching Consortium* (2001). Blood samples, 10 mL of each, were taken from the jugular vein of all the above animals, using 1% sodium heparin as anticoagulant, kept cool at the collection site, and subsequently transported to the Animal Nutrition Laboratory, Bijie University, China, for further preparation and analysis. Wool was also sampled from each animal's neck and washed as described by Salmela (1981) and his Colleague. Liver biopsy collections were performed by a trained technician using techniques previously described (Arthington and Corah 1995) and approved by the Institute of Zoology, Chinese Academy of Sciences, and the Institutional Animal Care and Use Committee of China. Samples of forage were cut from each pasture. To reduce soil contamination, the herbage samples were cut 1-2 cm above ground level. The forage samples were dried at 60-80°C for 48 h.

Forage nitrogen (N) and *in vitro* organic matter digestibility (IVOMD) analysis were conducted at the Forage Evaluation Support Laboratory, Bijie University, China. For N analysis, samples were digested using a modification of the aluminum block digestion procedure described by Gallaher *et al*. (1975). Sample weight was 0.25 g, catalyst used was 1.5 g of 9:1 K_2SO_4:$CuSO_4$, and digestion was conducted for at least 4 h at 375°C using 6 mL H_2SO_4 and 2 mL of H_2O_2. N in the digestion was determined by semiautomated colorimetry (Hambleton 1977). For IVOMD analysis, a modification of the two-stage technique (Tilley and Terry 1963) was used as previously described (Moore and Mott 1974). Rumen fluid was obtained from donor Guizhou semi-fine wool sheep consuming hay and provided with 150 g of soybean meal 1 h prior to collection.

P and S were determined by nephelometry (Wen *et al*. 1983) and Fe, Cu, Co, and Ca levels were determined by atomic absorption spectrophotometry using a Perkin-Elmer AAS 5000 (Perkin-Elmer, Norwalk, CT), while selenium (Se) was assayed using the modified fluorometric procedure described by Whetter and Ullrey (1978). Molybdenum (Mo) was determined using flameless atomic absorption spectrophotometry (Perkin-Elmer 3030 graphite furnace with a Zeeman background correction). Mo concentrations in tissue are difficult to determine accurately, and extra steps are necessary to produce reliable data. When the graphite furnace is used for the determination of Mo concentration, "memory" or carryover effects can occur after a sample is run. This happens when the intense heat of the graphite furnace allows the carbon in the graphite tube to combine with Mo in the sample to form Mo carbides (Perkin-Elmer). Special steps were taken to eradicate this effect. After each sample was run, two blanks (deionized water) were run to reduce the effects of "memory". Accuracy of analytical values was checked by reference to the certified values of elements in the National Institute of Standards and Technology Standard Reference Material Bovine Liver SRM1577(7).

Experiment 2

Forty affected Guizhou semi-fine wool sheep from Shoupu pasture (SP) and Liangshui pasture (LS) were allocated to one of two treatments, consisting of: 1) 20 affected Guizhou semi-fine wool sheep were fed 50 mg d^{-1} of $CaSO_4$ for 80 d. Sulfate treatments were formulated into a corn meal carrier and were offered 0.8 kg per capita, three times weekly; 2) 20 affected Guizhou semi-fine wool sheep were grazed in control pasture for 80 d. Jugular blood were collected on 0, 20, 40, 60, and 80 d. Mineral elements were analyzed as described in experiment 1.

Statistical analysis

Analysis of variance was performed using the general linear model procedure of SAS (SAS Inst. Inc., Cary, NC) for completely randomized model. Forage data were analyzed as a split-plot in time with plot as the whole-plot treatment and harvest as the subplot. Mineral status in experiment 1 was evaluated using pasture as experimental unit. The model included the effect of treatment and pasture and the interaction for treatment ×pasture. Treatment means for both forage and animal data were compared using single-df orthogonal contrasts. Comparisons made included the affected pasture *vs*. control (SP pasture and LS pasture *vs*. C pasture) and affected pasture (SP pasture *vs*. LS pasture). In experiment 2, S treatments were delivered to pens; therefore, average S concentration in blood for the pen was used as the experimental unit. For multiple measure of S content in blood, a split plot design was used with pen as the whole-plot treatment and time as the subplot. Treatment means were compared using least significant differences using the error associated with time×pen (treatment) interaction.

RESULTS

From 2001, the local government allocated both the pastures and stocks to each family for use in all four seasons, in an attempt to improve the local herder's productivity. Therefore, all the animals had to be grazed on the same pasture throughout the year. As a result, wool-eating had occurred in Guizhou semi-fine wool sheep. Clinical symptoms of S deficiency in Guizhou semi-fine wool sheep include poor weight gain, lost appetite, pica, emaciation, and wool-eating.

The forage nutritive values in experiment 1 are given in Table 1. No treatment differences were detected in forage S, N and IVOMD values. The contents of trace elements in forage are given in Table 2. The Fe contents in forages from the affected areas were significantly higher ($P<0.01$) than those from the control samples. Other mineral contents in forage samples were within the normal ranges in all areas. The concentrations of mineral elements in the blood samples are shown in Table 3. The S contents in the blood of the affected Guizhou semi-fine wool sheep were significantly lower than those of the control animals ($P<0.01$). The Fe contents in affected animals were significantly higher than those in healthy sheep.

The concentrations of mineral elements in wool samples are shown in Table 4. The S content of wool in the affected sheep was significantly lower than that from the healthy animals ($P<0.01$). The concentration of Fe from the affected Guizhou semi-fine wool sheep was significantly higher that of the control animals.

Table 1 Forage nutritive values in experiment 1

Item	SP (%)	LS (%)	C (%)	Pooled SEM	SP & LS *vs.* C (*P*-value)	SP *vs.* LS (*P*-value)
IVOMD	43.3	43.1	42.5	5.98	0.921	0.936
Sulfur	0.23	0.25	0.24	0.03	0.933	0.936
Nitrogen	2.37	2.45	2.38	0.13	0.903	0.912

SP, Shoupu pasture; LS, Liangshui pasture; C, control. SEM, standard error of the mean. The same as below.

Table 2 Forage trace element values in experiment 1

Item	SP (%)	LS (%)	C (%)	Pooled SEM	SP & LS *vs.* C (*P*-value)	SP *vs.* LS (*P*-value)
Cu	11.5	11.3	11.2	2.9	0.927	0.916
Mo	1.23	1.28	1.21	0.13	0.931	0.936
Se	0.13	0.11	0.12	0.03	0.932	0.932
Co	1.36	1.33	1.35	0.12	0.911	0.913
Zn	88.1	87.8	88.6	7.83	0.926	0.923
Fe	1 723	1 703	323	65	<0.001	0.913
Mn	58.1	58.3	57.9	5.92	0.925	0.931

Table 3 Concentrations of mineral elements in the blood samples in experiment 1

Item	SP (%)	LS (%)	C (%)	Pooled SEM	SP & LS *vs.* C (*P*-value)	SP *vs.* LS (*P*-value)
Cu	0.38	0.36	0.37	0.01	0.931	0.916
Mo	0.13	0.12	0.12	0.03	0.933	0.936
Se	0.12	0.13	0.15	0.13	0.613	0.932
Co	0.69	0.68	0.71	0.27	0.731	0.933
Zn	7.83	7.81	7.91	1.89	0.932	0.956
Fe	657	649	389	65	<0.001	0.987
Mn	0.53	0.54	0.56	0.13	0.896	0.933
S	226	213	489	47	<0.001	0.833

Table 4 Concentrations of mineral elements in wool samples in experiment 1

Item	SP (%)	LS (%)	C (%)	Pooled SEM	SP & LS *vs.* C (*P*-value)	SP *vs.* LS (*P*-value)
Cu	6.85	6.76	6.89	0.76	0.931	0.929
Mo	0.47	0.46	0.49	0.03	0.873	0.912
Se	0.43	0.45	0.41	0.13	0.756	0.897
Co	0.13	0.12	0.15	0.03	0.856	0.968
Zn	76	77	75	17	0.918	0.936
Fe	923	957	423	76	<0.001	0.918
Mn	18.9	19.1	18.7	2.5	0.933	0.927
S	2 156	2 218	6 879	317	<0.001	0.865

Other values were within normal ranges.

The contents of mineral elements in the liver are given in Table 5. The concentrations of S were significantly lower in the affected animals than in the healthy sheep. Fe contents in the affected animals were significantly higher than the healthy animals. There were no significant differences in other elements between the affected and unaffected animals.

In experiment 2, Guizhou semi-fine wool sheep which had deficient initial mean blood S contents of 215 and 217 μg g^{-1} blood S were divided into two groups, which were supplemented with $CaSO_4$ or grazed in the control pasture, respectively. Blood S was increased in all affected Guizhou semi-fine wool sheep regardless of the way of treatment, however, the sheep supplemented with $CaSO_4$ were tended to have higher mean blood S values. During 80 d of supplementation, the rate of blood S repletion was 4.1 *vs*. 3.4 for supplementing $CaSO_4$ and grazing in C pasture, respectively. In all treated and control animals, some symptoms of recovery were evident in 20 d, with appetite and vigor improved.

DISCUSSION

From the results of the preliminary epidemiological and clinical observations, it is suspected that wool-eating disease might be a local nutritional and metabolic disease which is associated with a trace element deficiency.

Table 5 The contents of trace elements in the liver samples in experiment 1

Item	SP (%)	LS (%)	C (%)	Pooled SEM	SP & LS *vs*. C (*P*-value)	SP *vs*. LS (*P*-value)
Cu	117	116	123	21	0.773	0.943
Mo	3.43	3.28	3.57	1.23	0.941	0.936
Se	1.13	1.21	1.18	0.31	0.916	0.932
Co	0.68	0.63	0.693	0.23	0.793	0.712
Zn	73	77	72	17	0.812	0.827
Fe	823	791	323	83	<0.001	0.853
Mn	3.86	3.71	3.92	1.31	0.892	0.837
S	987	968	2147	69	<0.001	0.832

Table 6 The effect of supplementing S and grazing on C pasture S content of the blood in experiment 2

Time	SC (μg g^{-1})	GC (μg g^{-1})	Pooled SEM	SC *vs*. GC (*P*-value)
0	215	217	21	0.996
20	358	286	32	<0.001
40	537	485	31	<0.001
60	556	487	38	<0.001
80	587	488	37	<0.001

However, the veterinary staff did not succeed when they tried to use various microelement additives. This meant that other causes for this disease needed to be investigated. It is known that pica might be a natural response in animals to a mineral deficiency, so it seemed that the addiction to wool-eating in the Weining County might be related to a shortage of some macro-elements that are especially abundant in wool. One of the major components of wool is S, and it is known fact that S supplementation affects wool production, so, it is considered that wool-eating disease maybe due to S deficiency.

Wool has the highest content of S. This suggests that the wool sheep might need higher requirements than other animals. The S level more than 0.14% (dry matter) in forage is safe for wool sheep (Guo 2004). The optimum dietary S is recommended to be 0.25% (Zhang *et al*. 2008). In present study, the contents of S in the forage were optimal in the affected areas, but Fe levels were significantly higher than those of the unaffected area.

The concentration of S was very low in blood, but the Fe level was higher than normal. The concentration of S in blood depends on S of forage, because it can not be stored in organism (Suttle 1999; Luo *et al*. 2001). In sheep, blood S values less than (22.8±0.41) mmol L^{-1} are a sign of severe S deficiency (Yang 1998; Huang and Chen 2001). Therefore, our results showed that the S status of Guizhou semi-fine wool sheep in the affected regions were severely deficient.

The S content of wool is also a sensitive indicator for diagnosing S deficiency since, as previously reported in sheep, the values for wool S and blood S are positively correlated (Arthington *et al*. 2002). The mean S concentration in wool of sheep with wool-eating of (1.3±0.02)% is well below (2.61±0.24)% characteristic of S deficiency in sheep (Bird 1970; Suttle 1999). In addition, oral administration of $CaSO_4$ appears to prevent or cure the disease. The symptoms gradually disappeared whenever the affected sheep were grazed in the unaffected pasture. Once removed from the pastures containing high concentrations of Fe, sheep were able to rapidly respond to S supplementation while received $CaSO_4$ source tended to have higher mean blood S concentrations than animals grazed in control pasture (450 and 392 μg g^{-1}, respectively). Therefore, it is reasonable to conclude that the disease of Guizhou semi-fine wool sheep in the Weining County is due to S deficiency caused by the high Fe in forages.

Acknowledgements

This work was supported financially by the National Natural Science Foundation of China (40930533/D011004), the China Agriculture Research System (CARS-40-30), the Science Foundation of Bijie District Grant, China (200905), the Guizhou Provincial Key Technologies R&D Program, China (NY[2010]3041), and the Guizhou Governor Foundation, China (2009129).

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(Managing editor ZHANG Juan)