

Potential toxicity and feed value of onions for sheep

E.L. Fredrickson^{a,*}, R.E. Estell^a, K.M. Havstad^b, W.L. Shupe^a, L.W. Murray^b

^aUS Department of Agriculture, Agricultural Research Service, Las Cruces, NM, USA

^bNew Mexico State University, Las Cruces, NM, USA

Accepted 14 September 1994

Abstract

The feeding, ruminal effects and potential toxicity of cull onions bulbs (*Allium cepa*) was compared to whole sorghum grain for growing wethers. In Expt. 1, 56 Polypay × Rambouillet wethers (avg. initial BW of 32.7 ± 0.88 kg) were assigned randomly to one of four dietary treatments (dry matter basis): (1) 50% whole sorghum grain (CON); (2) 33% sorghum:17% onions (17%); (3) 17% sorghum:33% onions (33%); and (4) 50% onions (50%). The remaining 50% was pelleted alfalfa (19% CP). All wethers were group fed (seven wethers per pen; two replicates per treatment) for 6 weeks. Weight gain during the trial did not differ ($P > 0.05$) among treatments. Packed cell volume tended to be less ($P = 0.057$) for the 33% and 50% onion groups during weeks 1 and 2, and was less ($P < 0.0001$) for the same groups during week 3 (34, 33, 29 and 29% for CON, 17, 33 and 50%, respectively). Serum lactate dehydrogenase was increased ($P < 0.05$) at weeks 3 and 6 in sheep on the 33% and 50% onion treatments. During Expt. 2, 15 ruminally cannulated wethers were individually fed diets similar to those Expt. 1, except onions were fed to replace sorghum grain to provide 0, 25 and 50% of the dietary DM as onions. Ruminal fluid ($P > 0.05$) and particulate passage ($P > 0.05$) were not altered by feeding onions. Water intake by drinking decreased ($P < 0.0001$) as percentage of onions in the diet increased, whereas total water intake (drinking and fed) increased ($P < 0.0001$). Effects of onions on volatile fatty acid concentrations and ruminal pH were minimal ($P < 0.05$), whereas ruminal ammonia-N concentration was greater ($P < 0.05$) in wethers fed onions. We conclude that under conditions similar to those in our study, onions can be fed safely to sheep with weight gains comparable to those from whole sorghum grain.

Keywords: Sheep; *Allium cepa*; Digestion

1. Introduction

In the United States, 2.39 million metric tons of commercial onion bulbs (*Allium cepa*) are produced each year (USDA, 1991). In some areas, 15 to 40% of the onions produced are culled for various reasons, and entire crops are sometimes culled when production exceeds market demand. Discarding cull onions can be problematic because of increasing landfill restrictions.

Moreover, onions left in the field promote pathogens that can damage future onion crops, and non-destructive disposal of onions can result in pilfering that negatively affects onion markets. Feeding cull onion bulbs to livestock is one method of cull onion disposal that may benefit both livestock and onion producers. This practice is common in some onion-growing regions, but not in others. Onion poisoning is a major concern and limits more extensive use of onion bulbs by livestock producers.

* Corresponding author.

Although onions are low in fiber and high in sugars, they also contain dipropyl disulfide and *S*-methyl-L-cysteinyl sulfoxide (SMCO) which are thought to cause hemolytic anemia and potentially death (Gruhzit, 1931; Williams et al. 1941; Cheeke and Shull, 1985). Onion toxicity has been described in dogs (Sebrell, 1930), horses (Pierce et al., 1972), cattle (Koger, 1956; Hutchinson, 1977) and sheep (James and Binns, 1966; Van Kampen et al., 1970; Kirk and Bulgin, 1979). Of these species, sheep seem most resistant to onion toxicity (Cheeke and Shull, 1985). Studies examining onion toxicity have focused on cases in which animal death occurred; however, few studies of the chronic effect of onion feeding on animal health and productivity are available. Onions also have fungicidal and bactericidal properties that alter rumen microbial populations (Mazen et al., 1984; Abdel-Salam et al., 1982). These activities, in conjunction with high water content, may alter patterns of ruminal digestion. Our objectives were (1) to compare the feeding value of onion bulbs to sorghum for growing wethers, (2) characterize animal toxicosis should it occur and (3) determine whether onions affect ruminal fermentation and passage rates.

2. Materials and methods

2.1. Expt. 1

Fifty-six Polypay ram lambs (average body weight 32.7 ± 0.88 kg) were used in a completely random design arranged into two replicates of four treatments each. Lambs were assigned randomly to the following dietary treatments (dry matter basis): 0% onions/50% sorghum; 17% onions/33% sorghum; 33% onions/17% sorghum; and 50% onions/0% sorghum. Lambs were limit fed to provide 38 g dry matter \cdot kg $BW^{-1} \cdot$ day $^{-1}$, with alfalfa pellets constituting the remaining 50% of the diet. Lambs were limit fed in 2.5 m \times 5 m pens (seven lambs/pen). Water and trace mineral salt (95 to 99% NaCl, containing not less than 0.35% Zn, 0.43% Fe, 0.2% Mn, 0.033% Cu, 0.007% I and 0.005% Co, Akzo Salt Inc., Clarks Summit, PA, USA) were available at all times. Approx. 1/3 of each pen was covered to provide shade. Whole sorghum grain and onions (chopped into quarters), were weighed and fed twice daily at 08:00 and 16:00 in one

of two feed bunks (0.6 m \times 2.4 m). Alfalfa pellets were fed in the other feed bunk. For 21 days before initiation of the study, lambs were incrementally adapted to and maintained on a 50% sorghum/50% alfalfa diet.

On days 0, 7, 14, 21, 28, 35 and 42, all lambs were weighed just prior to the 08:00 feeding. At this time, blood samples were obtained via jugular venipuncture into sterile serum separator tubes. Blood samples were allowed to clot at ambient temperature (20 to 26°C) for 30 min, and serum was obtained by centrifugation at $2000 \times g$ for 15 min at 4°C. Serum was then stored at -20°C . Serum samples obtained on days 0, 7, 21 and 42 were analyzed for serum constituents using an automated multichannel analyzer (Southwest Medical Laboratories, Las Cruces, NM, USA). After serum sample collection, two heparinized microhematocrit capillary tubes (Fisherbrand, Fisher Scientific, Pittsburgh, PA, USA) were filled with whole blood. Packed cell volume (PCV) was then measured after centrifugation for 10 min (micro-capillary centrifuge, model MB, International Equipment Corp., Boston, MA, USA).

Cull onion bulbs were obtained weekly from a local packer to ensure a constant degree of freshness. Onions were sampled daily and composited by week. Dry matter (DM) content of onions was determined by chopping and freeze drying an aliquot of the composite samples. Alfalfa pellets and sorghum grain also were sampled daily and composited by week before oven drying at 50°C for 48 h. Lyophilized onion samples, and oven-dried alfalfa and sorghum were ground to pass a 2-mm screen in a Wiley mill and analyzed for DM, ash and N (AOAC, 1990). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) content of the onion bulbs and alfalfa were determined using nonsequential procedures (Goering and Van Soest, 1970). Neutral detergent fiber of sorghum was assessed using modifications of the NDF procedure (Van Soest et al., 1991) for samples that contain resistant starch. Starch content of the onions and sorghum grain was analyzed according to procedures described by MacRae and Armstrong (1968).

S-substituted L-cysteine sulfoxide derivative concentrations were obtained using a slight modification of a technique described by Schwimmer and Weston (1961). In brief, pyruvate is cleaved from *S*-substituted L-cysteine sulfoxide by allinase-type enzymes when

onion tissue integrity is destroyed by blending. The concentration of pyruvate is then determined colorimetrically after complexing with 2,4-dinitrophenylhydrozone. 1 mol of pyruvate is produced per mol of *S*-substituted *L*-cystiene sulfoxide present. In these analyses, four bulbs were composited per replicate with four replicates assayed per week.

Data were analyzed using the GLM procedure of SAS (SAS Institute, 1985) as a split-plot in time. The whole-plot was a completely random design with level of onions as treatments, pen as whole-plot experimental unit, and animal within pen as subsample. The split-plot factors were time, time \times treatment and time \times pen nested within treatment. Treatment effects were evaluated by an *F* test when time \times treatment interactions were not significant ($P > 0.05$). When significant interactions were detected, data were analyzed by week using the design specified for the whole plot. Differences among treatment means were separated using predicted difference, while orthogonal contrasts were used to determine whether linear, quadratic and cubic effects occurred (SAS Institute, 1985).

2.2. Expt. 2

To determine the effect of feeding onions on ruminal digestion, 15 ruminally cannulated (7.6 cm inside diameter) Rambouillet \times Polypay wether lambs (average body weight 48 ± 0.8 kg) were individually assigned to one of three treatments (dry matter basis): 0% onions/50% sorghum; 25% onions/25% sorghum; or 50% onions/0% sorghum. The remaining 50% of the diet consisted of the alfalfa pellets described in Expt. 1. Sorghum used in this experiment was the same as for Expt. 1, whereas the onions were from weeks 5 and 6 in Expt. 1. As in Expt. 1, onions were chopped into quarters before feeding. Wethers were limit fed equal amounts at 07:00 and 17:00 to provide $30 \text{ g of DM} \cdot \text{kg BW}^{-1} \cdot \text{day}^{-1}$. Wethers were maintained in individual indoor pens ($1.22 \times 2.44 \text{ m}$), with free access to water and trace mineral salt (as in Expt. 1). Water intake was measured daily during the sampling period.

After a 21-d adaption period, each lamb was dosed intraruminally with 50 ml of Co-EDTA (Uden et al., 1980) as a ruminal fluid-phase marker immediately before feeding at 07:00. Ruminal fluid was obtained from the dorsal sac at $-2, 0, 1, 2, 4, 6, 8, 12, 24$ and

36 h relative to the 07:00 feeding. Ruminal fluid pH was measured before being acidified with 1 ml 7.2 N H_2SO_4 and frozen at -20°C .

In the laboratory, ruminal samples were thawed at room temperature and a 50-ml aliquot was centrifuged at $10\,000 \times g$ for 12 min. Supernatant fluid obtained at 0, 1, 2, 4, 6, 8, 12, 24 and 36 h after dosing was analyzed for Co concentration by atomic absorption spectrophotometry with an air-plus-acetylene flame (McCollum and Galyean, 1985). Fluid passage rates were calculated by regressing the natural logarithm of cobalt concentration on time after dosing. Ruminal fluid volume was estimated by dividing the dose by marker concentration in the rumen extrapolated to the time of dosing. Volatile fatty acid (VFA) concentrations were measured by gas chromatography using 2-ethyl butyric acid as an internal standard (Goetsch and Galyean, 1983). Ruminal ammonia-N concentration was determined colorimetrically using a phenol-hypochlorite assay (Broderick and Kang, 1980).

Ruminal particulate-phase dynamics were evaluated with ytterbium-labeled alfalfa (the same pelleted alfalfa fed to the wethers). Pelleted alfalfa was soaked in deionized water until all pellets disassociated, dried at 45°C for 48 h and then immersed in a solution that contained 2.5 mg Yb/liter deionized water for 24 h (McCollum and Galyean, 1985). Labeled alfalfa was then rinsed thoroughly, air dried at 40°C for 48 h, and dried at 50°C for 24 h. Each wether was ruminally dosed with 15 g (DM basis) of water-saturated, labeled alfalfa at 07:00 on day 23. Feces was obtained rectally at 0, 4, 8, 12, 16, 24, 32, 36, 42, 48, 54, 60, 72, 84, 106 and 120 h after-dosing and frozen at -20°C . Fecal samples were dried at 50°C for 96 h and ground to pass a 2-mm screen. Ytterbium was extracted from fecal samples using EDTA (Hart and Polan, 1984), and Yb concentration was measured by atomic absorption spectrophotometry (nitrous oxide-plus-acetylene flame). To estimate particulate digesta kinetics, fecal Yb concentration data were fitted to a one-compartment model (Krysl et al., 1988).

Expt. 2 was analyzed as a completely random design. Analyses were completed using the GLM procedure of SAS (SAS Institute, 1985). In the case of a significant *F* test, means were separated by predicted difference (SAS Institute, 1985).

3. Results and discussion

3.1. Expt. 1

The chemical composition of feeds is presented in Table 1. Starch concentration in onions was likely overestimated because onions contain approx. 19 g of glucose (monomeric form) per 100 g DM (Shallenberger and Birch, 1975). Other sugars found in relatively high concentrations in onions are fructose and sucrose, which constitute approx. 9 and 7 g per 100 g DM, respectively (Shallenberger and Birch, 1975).

Using the procedures described by Schwimmer and Weston (1961), 1 mol of pyruvate and 1 mol of ammonia are generated per mol of either SMCO, *S*-propyl-L-cysteine (SPCO) or cycloalliin (3-methyl-1,4-thiazane-5-carboxylic acid-1-oxide) present in the sample. The products of allinase reactions are generally methyl and propyl esters of methyl and propyl thiosulfenic acids (Schwimmer and Weston, 1961). These and other products of SMCO and SPCO degradation are thought to be responsible for the antithrombotic (Morimitsu et al., 1992), antiasthmatic (Bayer et al., 1989), anticholesterol (Sendl et al., 1992), and antibiotic and antifungal (Block, 1985; Fenwick and Hanley, 1985) properties of onions and related species. Furthermore, these compounds and their products are largely responsible for the flavor, odor and pungency of onions (Whitaker, 1976). Our low pyruvate concentrations (Table 1) indicate that the onions we fed were mild (Schwimmer and Weston, 1961), which is characteristic of onion varieties planted in southern New Mexico.

In vitro incubation of SMCO in adapted ruminal fluid yields dimethyl disulfide and methanethiol (Smith et al., 1974). Although not tested, SPCO may undergo a similar ruminal hydrolytic reaction to yield dipropyl disulfide, which is a major volatile component of fresh onions (Ohta and Osajima, 1992). Dimethyl disulfide and dipropyl disulfide are oxidants that appear to gradually deplete red blood cell (RBC) concentrations of reduced glutathione. Oxidative damage to hemoglobin and precipitation of the damaged hemoglobin into Heinz bodies eventually occurs, and damaged erythrocytes are removed by the spleen (Hutchinson, 1977; Jain, 1986). Alternately, these disulfide compounds may decrease activity of glucose-6-phosphate dehydrogenase (Smith et al., 1982; Abdo et al., 1983) resulting in decreased production of reduced glutathione. Again, a decrease in reduced glutathione production would result in hemoglobin oxidation, Heinz body formation and possible hemolytic anemia. Other volatile dialkyl disulfides in onions (Ohta and Osajima, 1992) may affect RBC metabolism similarly, but have not been examined as yet.

During this 6-week study, treatment did not influence body weight ($P > 0.10$) or average daily gain ($P > 0.10$; 0.14 kg day^{-1}). When examined across time (Fig. 1), average daily gain (ADG) during the first 7 d was less ($P < 0.05$) for lambs eating 50% onions and tended ($P = 0.06$) to be less for lambs eating 33%

Table 1
Dry matter (DM; g/100 g) and chemical composition of feed DM

	DM	g/100 g DM					starch	Pyruvate $\mu\text{mol/g}$ DM
		Ash	CP ^a	NDF ^b	ADF ^c	ADL ^d		
Onions								
Mean	12.7	5.2	8.8	9.9	9.3	1.2	50.3	41.3
SD ^e	2.46	0.31	0.63	1.34	1.68	0.19	1.9	9.53
Alfalfa pellets	94.1	10.2	19.1	49.9	35.9	8.3		
Sorghum grain	90.1	1.5	8	14	6.3	2.5	72.5	

^aCP = crude protein ($\text{N} \times 6.25$).

^bNDF = neutral detergent fiber.

^cADF = acid detergent fiber.

^dADL = acid detergent lignin.

^eSD = standard deviation of the mean.

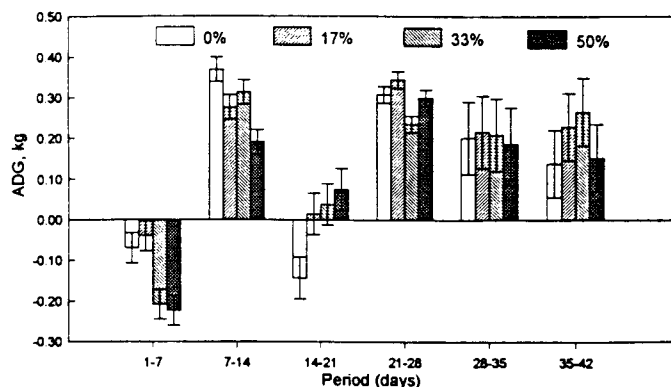


Fig. 1. Average daily gain (ADG) and standard error of the least-squares means of ram lambs fed either 0, 17, 33 or 50% of their dietary dry matter as onions.

onions compared with to lambs eating 0 and 17% onions. Average daily gain was less during week 2 ($P < 0.05$) for lambs fed 50% onions compared with the 0 and 33% treatments. Differences in ADG during the first 14 days appeared to result from an initial rejection of onions as a novel feed; this rejection subsequently waned, and animal preference for onions became obvious. For the remainder of the experiment there were no feed refusals and a dry matter intake of $38 \text{ g of DM} \cdot \text{kg BW}^{-1} \cdot \text{day}^{-1}$ was sustained. During the course of the study, maximum ambient air temperatures were in excess of 38°C , and minimum temperatures greater than 20°C . We attribute the low ADG or weight loss during days 14 to 21 to periodic rains that increased humidity and effective ambient temperature and would be expected to decrease ADG.

Average packed cell volume within dietary treatments was altered ($P < 0.05$; 35, 35, 32 and 33% for 0, 17, 33 and 50% onions, respectively) when main effects are compared. Lambs fed the 33 and 50% onion diets had lower PCV than lambs fed 0 or 17% onions. This linear ($P < 0.01$) relationship provides evidence that hemolysis occurred as a result of feeding onions. Across time (Fig. 2), RBC hemolysis (as measured by PCV) with onion diets was evident by day 14 ($P = 0.055$), reached a nadir by day 21 ($P < 0.0001$) and appeared to diminish by day 28 ($P = 0.18$). With the exception of two wethers in week 3 fed 50% onions (PCV = 20 and 23%), all animals were within the normal range (27 to 45%; Jain, 1986). A small decrease in blood PCV across time for the control sheep may have resulted from increasing temperatures and a subsequent increase in water intake, which can lower blood

PCV (Jain, 1986). Of the serum constituents, only sodium tended to differ ($P = 0.058$; 143, 142, 142 and 141 mEq/L for 0, 17, 33 and 50% onion treatment, respectively) among treatments. Increased water consumption can cause a decrease in serum Na concentration (Carlson, 1989), which could affect serum osmolality.

Time \times treatment interactions existed ($P < 0.05$) for serum albumin, triglycerides, bilirubin and lactate dehydrogenase (LDH), hence, data were examined by week. Differences across sampling times in bilirubin ($P < 0.05$; Fig. 2) and LDH ($P < 0.05$; Fig. 2) indicate that RBC hemolysis was evident on days 21 and 42. Lack of agreement in PCV, bilirubin and LDH data as indicators of hemolysis at 42 d may reflect differences in the sensitivity of techniques, increased erythropoiesis to compensate for loss of mature RBC, and/or increased mean corpuscular volume (MCV). Others (James and Binns, 1966; VanKampen et al., 1970; Kirk and Bulgin, 1979) have shown decreased PCV, hemoglobin, red cell count and blood urea nitrogen with an increase in RBC volume. Furthermore, our PCV data agrees with observations of Kirk and Bulgin (1979) that PCV of ewes fed cull onions ad libitum differed from controls at 21 days, but differences were not observed thereafter. Jain (1986) also noted reticulocytosis during remission from onion toxicosis in beef cattle that would suggest onion poisoning causes a regenerative anemia. Reticulocytosis and increased MCV may mask RBC destruction; however, a narrower range of LDH and bilirubin concentrations suggests that lambs adapt to onion toxicants.

Treatment means for albumin and triglycerides (Fig. 2) differed on days 21 and 42. Especially in the case of triglycerides, these differences most likely reflect nutritional status. Nonetheless, increased serum albumin concentrations are viewed to be the result of dehydration (Kaneko, 1989); therefore, differences may reflect differences in extracellular fluid volume.

3.2. Expt. 2

Effects of feeding onions on ruminal fluid dynamics are shown in Table 2. Ruminal fluid dilution rate, ruminal fluid volume, outflow rate and turnover time did not vary ($P > 0.05$) among wethers fed either 0, 25 or 50% onions. Likewise, ruminal particulate passage rate, dry matter fill and retention time did not differ

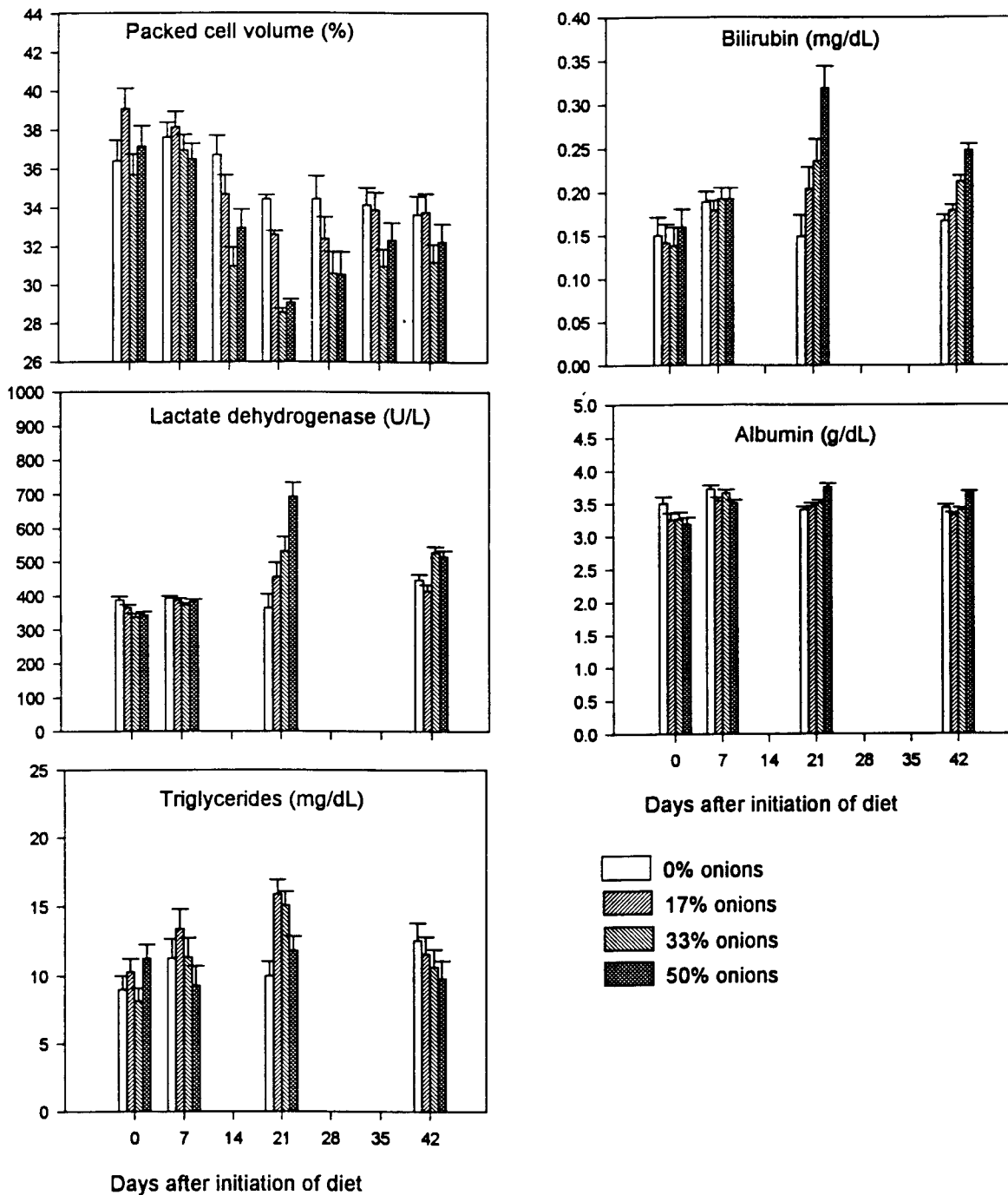


Fig. 2. Least-squares means and standard error of packed cell volume, serum lactate dehydrogenase activity and bilirubin, albumin and triglyceride concentrations of blood obtained from ram lambs fed either 0, 17, 33 or 50% of their dietary dry matter as onions.

($P > 0.05$) among diets (Table 2). Ruminal pH was decreased by all diets within 1 h after feeding. This decrease persisted longer ($P < 0.05$; Fig. 3) in diets with a greater proportion of sorghum grain (0 and 25% onions). A pH below 6.2 is indicative of a concentrate diet with readily fermentable carbohydrates, and inhibits growth of cellulolytic bacteria (Ørskov, 1982).

Within 2 h after feeding, ruminal ammonia-N concentrations were 2-fold greater in wethers fed onions than in wethers receiving no onions (17, 39 and 35 mg/100 ml for 0, 25 and 50% treatments, respectively; Fig. 3). At 4, 6 and 12 h after feeding, ruminal ammonia-N concentrations did not differ ($P > 0.05$) among treatments, but at 8 h after feeding, ruminal ammonia-N

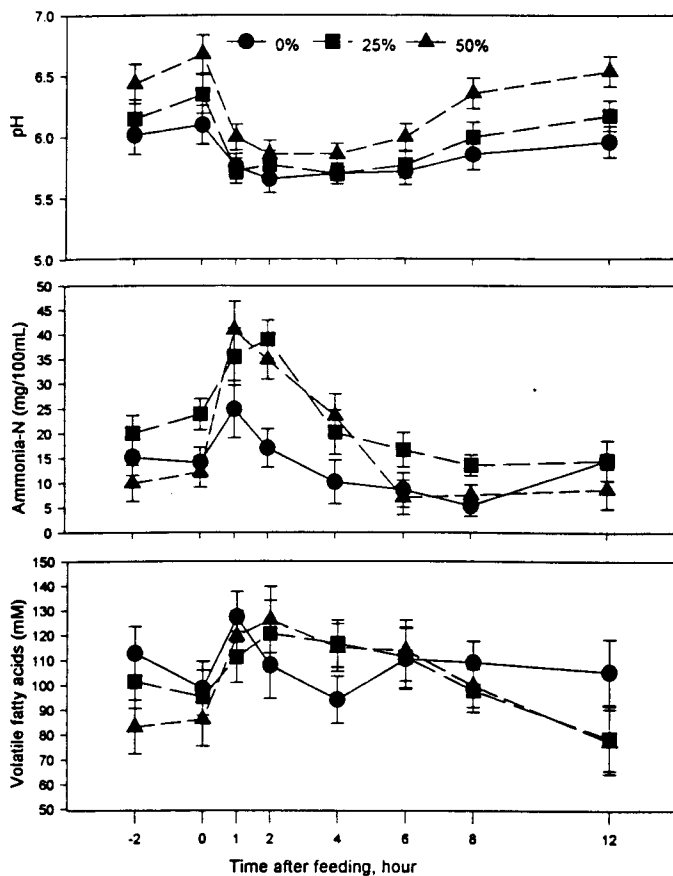


Fig 3. Least-squares means and standard error of ruminal pH, ammonia-N and total volatile fatty acid concentration of wethers fed either 0, 25 or 50% of their dietary dry matter as onions.

concentrations were greater ($P < 0.05$) in wethers fed 25% onions than in wethers fed either 0 or 50% onions

(5, 14 and 8 mg/100 ml for 0, 25 and 50% treatments, respectively).

Total VFA concentrations did not differ ($P > 0.05$) among treatments (Fig. 3), which suggests that ruminal microbial populations were not greatly affected by feeding onions. Mazen et al. (1984) reported an increase in ruminal fungal populations, whereas Abdel-Salam et al. (1982) observed a decrease in ruminal protozoa populations in sheep fed onion tops. The molar proportion of acetate also did not differ ($P > 0.05$) among treatments; however, proportions of propionate and butyrate differed ($P < 0.05$; Fig. 4). Butyrate proportions were greater ($P < 0.05$) in wethers fed onions from 1 through 6 h after feeding. Conversely, propionate proportions differed ($P < 0.05$) only at 8 and 12 h after feeding, being least ($P < 0.05$) in wethers fed onions. This result, coupled with differences in pH at 8 and 12 h, suggests that fermentation of readily fermentable carbohydrates persisted longer in wethers fed 50% of their diet as sorghum grain. The higher simple sugar content of onions may have produced this effect, a conclusion which is supported by observations that concentrate diets generally result in greater ruminal proportions of propionate (Van Soest, 1982) and lower ruminal pH (Ørskov, 1982) than forage-based diets. Of the minor VFA (data not reported), only valerate proportion differed ($P < 0.05$) among treatments. Wethers receiving no onions had slightly greater ruminal fluid concentrations of valerate than

Table 2
Ruminal fluid and particulate dynamics in wethers fed three levels of onions

	Percentage onions in diet ^a			SE ^b
	0	25	50	
Fluid dynamics				
Dilution rate (%/h)	8.7	8.9	9	0.84
Volume (l)	11	9.7	9.3	1.3
Volume (l/kg BW)	0.22	0.2	0.2	0.028
Particulate dynamics				
Particulate passage rate (%/h)	4.1	4.3	4.1	0.47
Undigested DM fill (g/kg BW)	13.7	12.2	14.2	1.34
Ruminal retention time (h)	29.2	28.9	30.5	3.06
Intestinal retention time (h)	15.1	12.3	11.6	1.51
Total tract retention time (h)	44.4	41.2	42.1	3.34

^aOnions were substituted for whole sorghum grain in a diet containing 50% sorghum grain and 50% alfalfa pellets.

^bStandard error of least-square means, $n = 5$.

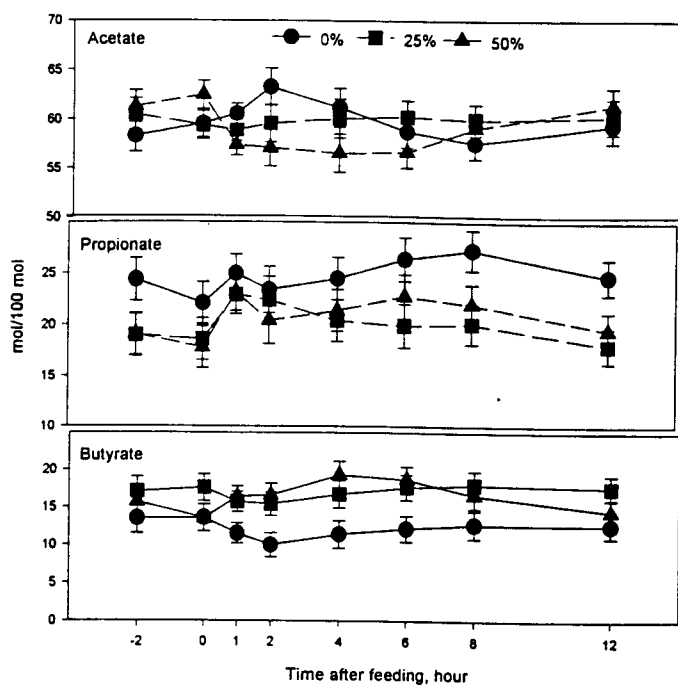


Fig. 4. Molar proportions and standard error of the least-squares means of ruminal acetate, propionate and butyrate in ruminal fluid obtained from wethers fed either 0, 25 or 50% of their dietary dry matter as onions.

those fed onions (1.4, 1.2 and 1.2 mol/100 mol for 0, 25 and 50% treatments, respectively).

Water intake by drinking decreased ($P < 0.0001$) as the percentage of onions in the diet increased (0.09, 0.07 and 0.04 l kg BW⁻¹ day⁻¹ for 0, 25 and 50% treatments, respectively). A decrease in consumption of free water with increasing amounts of dietary onions was apparently a compensatory mechanism for the increased water concentration of the diet. Total water intake per unit of body weight was greater ($P < 0.0001$) for wethers consuming onions (0.09, 0.13 and 0.13 l kg BW⁻¹ day⁻¹ for 0, 25 and 50% treatments, respectively).

Preparation of onions may affect toxicant dosages. When onion cells and organelles are ruptured, allinase enzymes are released that lyse SMCO and SPCO into volatile sulfide and pyruvate components (Virtanen, 1965). The volatilization of sulfide compounds should decrease onion toxicity. This observation is important when interpreting studies that have examined onion toxicity in ruminants. For example, Lincoln et al. (1992) fed onions to calves for 119 d in incremental amounts up to 25% of the diet (DM basis) without observing clinical anemia. The onions in their trial were crushed before mixing with other ingredients. With

time, crushing should substantially decrease sulfur-containing compounds, whereas feeding sliced or whole onions may yield different results. The greater resistance to onion toxicity generally observed with sheep may result from the greater degree of mastication exhibited by sheep by cattle. Lincoln et al. (1992) concluded that onions have a feed value similar to barley.

Under the conditions of the present study, it seems that onions can be fed safely without negatively affecting ruminal fermentation or animal production. Indeed, feeding onions resulted in weight gains similar to those obtained from feeding whole sorghum grain. However, when onions are fed, caution should be exercised. The onions used in this study were low in SMCO and SPCO. Comparisons of toxicosis with other studies are difficult because SMCO and SPCO concentrations were not quantified in other studies. Furthermore, there may be important nutrient/toxicant interactions. Personal observations of livestock producers that have fed onions suggest that feeding onions in conjunction with feeds that contain moderate to high concentrations of protein generally decrease animal losses from onion toxicity. Conversely, producers that feed onions in conjunction with low-quality feeds often experience death losses from onion toxicity. Dietary protein is important for synthesis of enzymes and availability of cofactors needed for phase II detoxification reactions; these interactions need to be examined further. The effect of abundant dietary sulfides from cull onions on molybdenum and copper availability and thiamine activity also should be examined.

Acknowledgements

This research was partially funded by the New Mexico Dry Onion Commission. The authors also wish to acknowledge the excellent technical assistance of Linda Kiehl, Roy Libeau and Marisa Wall, and the comments of M.L. Galyean and John Thilsted.

References

- Abdel-Salam, M.N., Amer, A.A., Gazia, N. and Mottelib, A.A., 1982. The effect of feeding post-harvesting remnants on sheep rumen microfauna. *Assiut Vet Med. J.*, 10: 141–145.

- Abdo, K.M., Timmons, P.R., Graham, D.G. and Abou-Donia, M.B., 1983. Heinz body production and hematological changes in the hen after administration of a single dose of *n*-butyl mercaptan and *n*-butyl disulfide. *Fundam. Appl. Toxicol.*, 3: 69–75.
- AOAC, 1990. Official Methods of Analysis, 15th edn. Association of Official Analytical Chemists, Washington, DC, 1141 pp.
- Bayer, T.H., Breu, W., Seligmann, O., Wray, V. and Wagner, H., 1989. Biologically active thiosulfates and α -sulphinyl-disulfides from *Allium cepa*. *Phytochemistry*, 28: 2373–2377.
- Block, E., 1985. The chemistry of garlic and onions. *Sci. Am.*, 252: 114–119.
- Broderick, G.A. and Kang, J.H., 1980. Automated simultaneous determinations of ammonia and total amino acids in ruminal fluid and in vitro media. *J. Dairy Sci.*, 63: 64–75.
- Carlson, G.P., 1989. Fluid, electrolyte, and acid-base balance. In: J.J. Kaneko (Ed.), *Clinical Biochemistry of Domestic Animals*, 4th edn., Academic Press, Inc., New York, pp. 543–575.
- Cheeke, P.R. and Shull, L.R., 1985. Natural Toxicants In Feeds and Poisonous Plants. AVI Publ. Co., Westport, p. 279.
- Fenwick, G.R. and Hanley, A.B., 1985. The genus *Allium*. *Crit. Rev. Food Sci. Nutr.*, 23: 1–73.
- Goering, H.K. and Van Soest, P.J., 1970. Forage Fiber Analyses. Apparatus, Reagents, Procedures and Some Applications. ARS, USDA Agricultural Handbook No. 379, pp. 1–12.
- Goetsch, A.L. and Galyean, M.L., 1983. Influence of feeding frequency on passage of fluid and particulate markers in steers fed a concentrate diet. *Can. J. Anim. Sci.*, 63: 727–730.
- Gruhzit, O.M., 1931. II. Anemia in dogs produced by feeding disulfide compounds. *Am. J. Med. Sci.* 181: 815–820.
- Hart, S.P. and Polan, C.E., 1984. Simultaneous extraction and determination of ytterbium and cobalt ethylenediamine-tetraacetate complex in feces. *J. Dairy Sci.*, 67: 888–892.
- Hutchinson, T.W.S., 1977. Onions as a cause of Heinz body anemia and death in cattle. *Can. Vet. J.*, 18: 358–360.
- Jain, N.C., 1986. *Schalm's Veterinary Hematology*. Lea & Febiger, Philadelphia, 1221 pp.
- James, L.F. and Binns, W., 1966. Effects of feeding wild onions (*Allium validum*) to bred ewes. *J. Am. Vet. Med. Assoc.*, 149: 512–514.
- Kaneko, J.J., 1989. Serum proteins and the dysproteinemias. In: J.J. Kaneko (Ed.), *Clinic Biochemistry of Domestic Animals*, 4th edn. Academic Press, New York. pp. 142–165.
- Kirk, J.H. and Bulgin, M.S., 1979. Effects of feeding cull domestic onions (*Allium cepa*) to sheep. *Am. J. Vet. Med. Res.*, 40: 397–399.
- Koger, L.M., 1956. Onion poisoning in cattle. *J. Am. Vet. Med. Assoc.*, 129: 75.
- Krysl, L.J., Galyean, M.L., Estell, R.E. and Sowell, B.F., 1988. Estimating digestibility and faecal output in lambs using internal and external markers. *J. Agric. Sci. (Camb.)*, 111: 19–25.
- Lincoln, S.D., Howell, M.E., Combs, J.J. and Hinman, D.D., 1992. Hematological effects and feeding performance in cattle fed domestic onions (*Allium cepa*). *J. Am. Vet. Med. Assoc.*, 200: 1090–1094.
- MacRae, J.C. and Armstrong, D.G., 1968. Enzyme method for determination of alpha-linked glucose polymers in biological materials. *J. Sci. Food Agric.*, 19: 578–581.
- Mazen, M.B., Mottelib, A.A., Amer, A.A. and Abdel-Salam, M.N., 1984. Studies on fungal flora of ruminal juice of sheep gained after fed with certain field stubbles. *Assuit Vet. Med. J.*, 12: 87–93.
- McCollum, F.T. and Galyean, M.L., 1985. Influence of cottonseed meal supplementation on voluntary intake, rumen fermentation, and rate of passage of prairie hay of beef steers. *J. Anim. Sci.*, 60: 570–577.
- Morimitsu, Y., Morioka, Y. and Kawakishi, S., 1992. Inhibitors of platelet aggregation generated from mixtures of *Allium* species and/or *S*-alk(en)nyl-*L*-cysteine sulfoxides. *J. Agric. Food Chem.*, 40: 368–372.
- Ohta, H. and Osajima, Y., 1992. Volatile components recovered from fresh onion (*Allium cepa* L.) with combination of ethyl ether extraction and new cold trap apparatus. *J. Fac. Agric., Kyushu Univ.*, 37: 125–131.
- Ørskov, E.R., 1982. Protein Nutrition in Ruminants. Academic Press, New York. pp. 202.
- Pierce, K.R., Joyce, J.R., England, R.B. and Jones, L.P., 1972. Acute hemolytic anemia caused by wild onion poisoning in horses. *J. Am. Vet. Med. Assoc.*, 160: 323.
- SAS Institute, 1985. SAS User's Guide: Statistics. Statistical Analysis System Institute, Inc., Cary, NC. 956 pp.
- Schwimmer, S. and Weston, W.J., 1961. Enzymatic development of pyruvic acid in onion as a measure of pungency. *Agric. Food Chem.*, 9: 301–304.
- Sebrell, W.H., 1930. An anemia of dogs produced by feeding onions. *Public Health Rep.*, 45(21): 1175–1191.
- Sendl, A., Schliack, M., Löser, R., Stanislaus, F. and Wagner, H., 1992. Inhibition of cholesterol synthesis in vitro by extracts and isolated compounds prepared from garlic and wild garlic. *Atherosclerosis*, 94: 79–95.
- Shallenberger, R.S. and Birch, G.G., 1975. Sugar Chemistry. AVI Publ. Co., Westport, p. 51.
- Smith, R.H., Earl, C.R. and Matheson, N.A., 1974. The probable role of *S*-methylcysteine sulphoxide in kale poisoning in ruminants. *Biochem. Soc. Trans.*, 2: 101–104.
- Smith, R.H., Watt, W.B. Lawson, W.J. and Rice-Evans, C., 1982. Red blood cell membrane changes in a Heinz body anaemia (Kale anaemia). In: H. Peeters (Ed.), *Protides of the Biological Fluids*. Pergamon Press, Oxford, pp. 125–147.
- Uden, P.D., Colucci, E. and Van Soest, P.J. 1980. Investigation of chromium, cerium and cobalt as markers in digesta. Rate of passage studies. *J. Sci. Food Agric.*, 31: 625–632.
- USDA, 1991. Agricultural Statistics 1991. US Government Printing Office, Washington, DC, p. 156.
- Van Kampen, K.R., James, L.F. and Johnson, A.E., 1970. Hemolytic anemia in sheep fed wild onions (*Allium validum*). *J. Am. Vet. Med. Assoc.*, 156: 328–332.
- Van Soest, P.J., 1982. Nutritional Ecology of the Ruminant. O&B Books, Corvallis, OR. 374 pp.
- Van Soest, P.J., Robertson, J.B. and Lewis, B.A. 1991. Methods for dietary fiber, neutral detergent fiber and non starch polysaccharides in relation to animal nutrition. *J. Dairy Sci.*, 74: 3583–3597.
- Virtanen, A.I., 1965. Studies on organic sulphur compounds and other labile substances in plants. *Phytochemistry*, 4: 207–228.

Whitaker, J.R., 1976. Development of flavor, odor and pungency in onion and garlic. *Adv. Food Res.*, 22: 73–133.

Williams, H.H., Erickson, B.N., Beach, E.F. and Macy, I.G., 1941. Biochemical studies of the blood of dogs with *n*-propyl disulfide anemia. *J. Lab. Clin. Med.*, 26: 996–1008.

Résumé

Fredrickson, E.L., Estell, R.E., Havstad, K.M., Shupe, W.L. et Murray, L.W., 1995. Toxicité potentielle et valeur alimentaire des oignons pour le mouton. *Livest. Prod. Sci.*, 42: 45–54.

La consommation des bulbes d'oignons (*Allium cepa*), leurs effets sur la rumination et leur toxicité potentielle ont été étudiés chez le mouton en comparaison avec les graines entières de sorgho. Dans l'Expérience 1, 56 moutons Polypay × Rambouillet (poids vif initial de $32,7 \pm 0,88$ kg) ont été affectés au hasard à l'un des quatre traitements expérimentaux suivants (sur la base de la matière sèche): (1) 50% de graines entières de sorgho (CON); (2) 33% de sorgho/17% d'oignons (17%); (3) 17% de sorgho/33% d'oignons (33%); et (4) 50% d'oignons (50%). Les 50% restants étaient constitués de luzerne agglomérée (19% de protéines brutes). Tous les moutons étaient alimentés en groupes (7 moutons/loge; deux répétitions par traitement) pendant 6 semaines. La croissance pondérale durant l'essai ne différait pas entre les traitements ($P > 0,05$). Le taux d'hématocrite tendait à être plus faible ($P = 0,057$) dans les lots à 33 et 50% d'oignons au cours des semaines 1 et 2, et était inférieur ($P < 0,0001$) dans les mêmes lots pendant la semaine 3 (respectivement 34, 33, 29 et 29% dans les lots CON, 17, 33 et 50%). La lactate déshydrogénase sérique était augmentée ($P < 0,05$) durant les semaines 3 et 6 chez les moutons des lots 33 et 50% d'oignons. Pendant l'Expérience 2, 15 moutons munis d'une canule du rumen recevaient individuellement des régimes similaires à ceux de l'Expérience 1, sauf que les oignons remplaçaient la graine de sorgho de façon à apporter 0, 25 et 50% de la matière sèche alimentaire sous forme d'oignons. Le liquide du rumen ($P > 0,05$) et le passage de particules ($P > 0,05$) n'étaient pas altérés par la consommation d'oignons. L'ingestion d'eau de boisson diminuait ($P < 0,0001$) lorsque le pourcentage d'oignons dans le régime augmentait, alors que la quantité totale d'eau consommée (boisson et aliment) augmentait ($P < 0,0001$). Les effets des oignons sur les concentrations en acides gras volatils et le pH du rumen étaient minimes ($P < 0,05$), alors que la concentration en azote ammoniacal du rumen était plus élevée ($P < 0,05$) chez les moutons consommant des oignons. Nous en concluons que dans des conditions similaires à celles de notre étude, les oignons peuvent être distribués sans problème aux moutons et assurent des gains de poids similaires à ceux permis par des graines entières de sorgho.

Kurzfassung

Fredrickson, E.L., Estell, R.E., Havstad, K.M., Shupe, W.L. und Murray, L.W., 1995. Potentielle Toxizität und Futterwert von Zwiebeln für Schafe. *Livest. Prod. Sci.*, 42: 45–54.

Die Fütterung, die ruminalen Effekte und die potentielle Toxizität von aussortierten Zwiebelknollen (*Allium cepa*) wurden bei wachsenden Hammeln mit der Fütterung von Hirse verglichen. Im Experiment 1 wurden 56 Polypay × Rambouillet-Hammel (Anfangsgewicht $32,7 \pm 0,88$ kg) zufällig folgenden vier Behandlungen zugeordnet (Trockenmassebasis): (1) 50% Hirsegras (CON); (2) 33% Hirse/17% Zwiebeln; (3) 17% Hirse/33% Zwiebeln; (4) 50% Zwiebeln. Die restlichen 50% waren pelletierte Luzerne mit 19% Rohprotein. Alle Tiere wurden über sechs Wochen in der Gruppe gefüttert (7 Hammel je Box; 2 Wiederholungen je Behandlung). Die Gewichtszunahme unterschied sich zwischen den Behandlungen ($P > 0,05$) nicht. In der Tendenz ($P = 0,057$) war bei den Gruppen mit 33% und 50% Zwiebeln in der ersten und zweiten Woche die Gewichtszunahme geringer, in der 3. Woche dagegen niedriger. Die Serum-Laktat-Hydrogenase nahm in der 3. und 6. Woche bei den Schafen mit den Rationen von 3% und 50% Zwiebeln zu. Im Experiment 2 wurden 15 Hammel untersucht, die im Rumen eine Kanüle besaßen. Die Fütterung erfolgte wie im Experiment 1. Allerdings wurden die Zwiebeln so eingesetzt, daß sie Hirse zu 0%; 25% und 50% in der Trockenmasse der Ration ersetzten. Der ruminale Durchgang und die Teilchenpassage ($P > 0,05$) wurden durch die Ration nicht verändert. Die Wasseraufnahme durch Saufen ging zurück ($P < 0,0001$). Die Wirkungen der Zwiebeln auf die Konzentration freier Fettsäuren und dem pH-Wert im Rumen waren minimal ($P < 0,05$), wobei die ruminale $\text{NH}_3\text{-N}$ -Konzentration bei den Hammeln, die Zwiebeln erhielten, höher war. Es wird geschlossen, daß unter ähnlichen Bedingungen wie im Versuch Zwiebeln an Schafe ohne Nachteile verfüttert werden können. Es werden vergleichbare Zunahmen erreicht wie bei Hirsefütterung.