THE EFFECT OF UREA SUPPLEMENTATION OF HIGH GRAIN RATIONS ON THE METABOLISM OF FATTY ACIDS IN THE RUMEN OF SHEEP AND CATTLE

E. PAYNE* and J. G. MORRIS*†

Summary

When rations containing, basically, sorghum grain were supplemented with urea, it was found that the urea affected the concentrations of certain fatty acids in the rumen and depot fat. On a ration of grain/sorghum silage similarly supplemented, isovaleric acid increased. There was a small affect of urea on the level of linoleic acid in the rumen of sheep which, however, was not significant at the 5 per cent level. When the levels of fatty acids in the omental fat of steers fed grain/sorghum silage plus urea were examined, it was found linoleic acid was significantly decreased. The influence of urea supplementation of high grain rations upon volatile fatty acid utilization and hydrogenation of unsaturated fatty acids is discussed.

I. INTRODUCTION

Urea as a non-protein source of nitrogen is widely used as a supplement in the feeding of animals. The effects of urea added to the ration of ruminants on the fatty acid metabolism of the microflora does not appear to have been studied by many workers. Coombe and Tribe (1962) reported that urea ***in*** vivo increased the concentration of total volatile fatty acids (VFA) in the ruminal fluid, and Ottova and Hatleova (1963) found a similar effect in ***in vitro*** studies. More recently, Satapathy and Leffel (1966) have reported that lambs given urea had higher total VFA and propionate concentrations in their ruminal fluid than lambs not receiving urea. While the VFAs have received some attention, there do not appear to have been any reports on the effect of the dietary addition of urea on long chain fatty acid (LCFA) metabolism in the rumen.

This paper reports some preliminary observations on the effects of urea supplementation of grain-fed cattle and sheep on the VFA and LCFA in the rumen and the LCFA in the omental fat.

II. MATERIALS AND METHODS

(a) *Experimental*

(i) *Volatile Fatty Acids*

Three sets of observations were made in which sheep or cattle were fed rations composed of either sorghum grain, sorghum silage, or paspalum hay containing 1.6, 1.0, and 1.1 per cent N, respectively, on a dry matter basis.

*Animal Research Institute, Yeerongbilly, Brisbane.
†Present address: Dept. of Animal Science, University of California, Davis, California, U.S.A.

In the first experiment, eight ruminal-fistulated Merino x Border Leicester wethers were given a ration of 80 per cent sorghum grain and 20 per cent paspalum hay (500 g/day). Four of the sheep had 8 g of urea mixed into their feed daily, while the other four acted as controls. Ruminal samples were taken pre-feeding and 4 h post-feeding.

In the second experiment, the same design was used except the eight wethers were given a ration of 500 g sorghum grain and 300 g wet sorghum silage daily.

In the third experiment, four rumen-fistulated steers were each given a ration of 1.8 kg sorghum grain and 4.5 kg paspalum hay once daily and, in addition, two of the steers received 60 g of urea. Samples of rumen contents were taken at 4, 8 and 24 h after feeding.

(ii) *Chain Fatty Acids*

The direct effect of urea on the composition of the LCFA's in the rumen was examined on samples taken from sheep in the first experiment.

The effect of urea on the composition of the LCFA in omental fat was measured on samples from Hereford steers fed sorghum grain and silage rations in the ratios of 60/40, 80/20 and 100/0 as described by Morris (1966) for periods of 103 to 155 days. Comparisons were made between the composition of the omental fat recovered from these steers at slaughter and that from a group of steers slaughtered prior to the grain feeding. Samples of fat were obtained from only some of the animals in each group.

(b) *Analytical Methods*

The total VFA concentrations in the rumen fluids were measured by the steam distillation method of Markham (1942). The molar percentages were measured on this distillate by the method of Emery and Koerner (196 1) except that 5 per cent formic acid was added to overcome the "ghosting" effects referred to by Erwin, Marco and Emery (1961).

The LCFA of omental fat and rumen contents were measured by gas chromatography of the methyl esters on 20 per cent diethylene glycol succinate on Embacel (May and Baker). The LCFA of rumen contents were extracted by the method of Garton, Lough and Vioque (1961).

III. RESULTS

(a) *Volatile Fatty Acids*

The total VFA concentration was not significantly affected by the addition of urea to any of the sheep rations (Table 1). The results for the cattle are not shown as some of the values were missing.

The molar proportions of the VFA found in the rumen fluid from sheep and cattle given the various rations with and without urea are presented in Table 1. The only significant effect of urea was to increase the proportion of isovaleric acid in the ruminal fluid from sheep given the grain/sorghum silage ration, but not from sheep or cattle given the grain/paspalum hay rations. The proportion of isobutyric acid also was greater in the urea fed sheep given the grain/silage ration, but the difference was not signicant at $P < 0.05$ level. The proportion of n-valeric was less ($P < 0.07$) in the ruminal fluid from steers given urea than in those without urea.

TABLE 1

The effect of urea on the volatile fatty acid composition of rumen fluid of sheep and cattle on various rations

Animal	Ration	Total VFA m–equiv./l	% Composition of Volatile Fatty Acids					
			Acetic	Prioponic	Isobutyric	Butyric	Isovaleric	Valeric
Sheep	80% sorghum + 20% papsalum hay	86.1 ± 2.7	66.4 ± 1.9†	22.9 ± 2.3	0.71 ± 0.05	8.08 ± 0.56	1.62 ± 0.21	0.33 ± 0.08
	above + urea	86.5	66.0	21.9	0.61	9.47	1.70	0.29
Sheep	87% sorghum grain 13% wet sorghum silage	84.1 ± 3.0	59.7 ± 2.4	31.8 ± 2.6	0.38 ± 0.13	7.03 ± 0.62	0.73c ± 0.41	1.14 ± 0.29
	above + urea	87.5	59.3	28.3	0.70	7.45	3.09c	0.99
Cattle	28% sorghum grain		75.7 ± 1.1	13.3 ± 0.5	0.58 ± 0.08	9.42 ± 0.68	0.90a ± 0.13	0.13 ± 0.18
	72% paspalum hay		74.7§	13.8	0.60	10.20	0.73b	0.50
			77.5‖	12.8	0.65	7.65	1.38ab	0.15
Cattle	As above		74.6 ± 0.9	13.8 ± 0.4	0.52 ± 0.07	9.72 ± 0.56	0.92 ± 0.11	0.48d ± 0.14
	As above + urea		77.3	12.4	0.70	8.47	1.08	0.03d

Means in the same column with the same notation are different a, b = P < .05
c = P < .01
d = P < .07

†S.E. of difference between means.
‡4h after feeding.
§8h after feeding.
‖24h after feeding.

TABLE 2

The effect of urea on the long chain fatty acid composition of rumen contents of sheep maintained on a grain:paspalum hay ration

Treatment	Fatty Acid Composition (% by weight)					
	C14	C14:1	C16	C18	C18:1	C18:2
No urea	2.3 ± 0.1†	3.3 ± 1.3	19.9 ± 2.2	49.3 ± 7.0	13.6a ± 2.7	8.1a ± 2.0
Urea	2.4	7.1	21.2	57.4	4.8a	3.4a

Means in the same column with the same notation are different a = P < 0.6.
†S.E. of difference between means.

The proportion of isovaleric acid in the ruminal fluid from the steers was the only VFA significantly affected by the time of sampling.

(b) ***Long Chain Fatty Acids***

The most marked effect of urea on the LCFA composition of the ruminal fluid from sheep (Table 2) was to decrease the percentage of C18: 1 acid and Cl 8:2 acid but, because of low numbers of samples and between sheep variation, the difference was not significant (P < 0.06).

The addition of urea to the diet of steers significantly decreased the percentage of Cl 8:2 acid in the omental fat when there was a corresponding increase in Cl 8 and Cl 8: 1 acids. The percentage of C 18 acid in the fat also significantly decreased as the proportion of grain in the ration increased. Again, there was a corresponding though not significant increase in the percentage of C1 8: 1 acid in the omental fat. Similarly, a comparison of the fat from pasture-fed and grain-fed steers showed that the latter had a significantly greater percentage of Cl 8: 1 acid and a significantly lower percentage of Cl8 acid than the former (Table 3).

IV. DISCUSSION

In previous reports, in which an increased level of total VFA was found from the addition of urea to the diet, e.g., Coombe and Tribe (1962) and Satapathy and Leffel (1966), the basal level of nitrogen in the diet was considerably less than in the diets which we used. However, production responses to the addition of urea had been obtained with our diets (Morris 1966) which indicated that nitrogen was a limiting nutrient for maximum growth.

The straight and branched chain four and five carbon VFA's which have been shown by several workers including Bentley ***et al.*** (1954) and Allison, Bryant and Doetsch (1962) to be essential nutrients for the growth of at least some of the cellulolytic bacteria, were with one exception, n-valeric, not significantly decreased bv urea supplementation. When protein in a ration was replaced by urea, a decrease in the concentration of branched chain VFA's of the rumen was reported by Bruggemann, Giesecke and Drepper (1962). However, as branched chain VFA's arise from the degradation of protein (el Shazly 1952), experiments in which protein is replaced by urea, e.g., Bruggemann, Giesecke and Drepper (1962) and Briggs ***et al.*** (1964), cannot assess effects of urea on VFA production and utilization. Furthermore, it appears that certain species of amylolytic bacteria are capable of synthesizing the branched chain skeletons (Bruggemann and Giesecke 1967) and as all our rations contained grain, branched chain VFA's may not be limiting nutrients for the microflora.

Though the main fatty acids in pasture and grains are linolenic and linoleic acids, it is well known that biohydrogenation of dietary unsaturated fatty acids

TABLE 3

The effect of urea and various proportions of sorghum grain on the fatty acid composition of omental fat of steers

Group	Ration	Fatty Acid Composition (% by weight) C14	C14:1	C16	C16:1	C18	C18:1	C18:2
Pre-treatment	Pasture (6)†	3.4 ± 0.4‡	1.0 ± 0.2	26.5 ± 1.2	2.5 ± 0.3	31.8b ± 1.3	30.7b ± 1.9	1.6 ± 0.3
Rest	> 80% grain (32) < 20% silage	3.5	1.1	26.6	2.8	16.0b	44.7b	2.6
No urea	> 80% grain (15)	3.8 ± 0.4	1.2 ± 0.1	28.1 ± 1.0	3.0 ± 0.2	15.1 ± 1.1	43.6 ± 1.6	3.4b ± 0.3
Urea	> 80% grain (17)	3.2	1.1	25.2	2.7	16.7	45.9	2.0b
Group 1	80% grain (13)	3.3 ± 0.4	1.0a ± 0.2	27.9 ± 1.3	2.8 ± 0.2	17.2b ± 1.4	42.6 ± 2.1	2.5 ± 0.3
2	90% grain (8)	3.5	1.1	26.3	2.7	16.9a	44.3	3.1
3	100% grain (11)	3.8	1.4a	25.8	3.0	13.7a, b	47.3	2.6

Means in the same column with the same notation are different a = $P < 0.05$
b = $P < 0.01$

†Number of individual analyses.

‡S.E. of difference between means.

occurs to a marked extent (Shorland et *al.* 1957; Ward, Scott and Dawson 1964).

It is suggested that the addition of urea to the grain/paspalum ration fed to the sheep and the grain/silage rations fed to the steers significantly increased hydrogenation of the dietary fat as evidenced by (i) the lower Cl 8: 1 and Cl 8:2 percentages in the ruminal ingesta of the sheep, and (ii) the lower Cl 8:2 concentration of the omental fat from the steers. The absence of a significant change in the C18:1 percentage in the omental fat is probably accounted for by the fact that this acid can also be synthesized by the ruminant (West and Annison 1964). The degree of hydrogenation is probably a reflection of the metabolic activity of the ruminal population rather than of any specific action of urea on hydrogenation. Sachan and Davis (1969) have shown that only certain ruminal bacteria are responsible for hydrogenation. It is conceivable that some of these organisms, e.g., *Butyrivibrio fibrisolvens,* may increase specifically, or, alternatively, the total flora may increase thus increasing hydrogenation. The effect of urea on the linoleic acid content or omental fat was not due to changes in the level of intake of grain, for addition of urea to the rations increased feed intake (Morris 1966).

The increase in Cl 8: 1 and decrease in Cl 8 LCFA content of the omentai fat of steers fed increasing levels of grain in the ration was related probably to the dietary intake of unsaturated LCFA. Roberts (1966) has reported that cattle fed high-concentrate rations had more Cl 8: 1 and less Cl 8 LCFA in the depot fat than cattle fed high roughage rations.

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