proportion of this nitrogen is returned to the rumen in the form of salivary urea, the nitrogen loss to the animal must represent an appreciable proportion of the dietary intake. This approximate calculation emphasizes the need for more accurate estimations of nitrogen loss in animals receiving different diets and particularly in animals maintained under normal conditions of husbandry. Attempts are now being made to obtain this information.

SUMMARY

1. A technique is described for taking repeated samples of portal blood in the sheep.

2. Changes in the rumen-ammonia concentration of sheep fed on various diets were paralleled by changes in portal-blood ammonia concentration.

3. At the maximum rumen-ammonia level attained as a result of feeding (60 m-moles/l.), an increase in ammonia concentration was not detected in peripheral blood.

4. When this concentration was exceeded by adding ammonium acetate solution to the rumen, ammonia was present in peripheral blood.

5. As the concentration of ammonia in peripheral blood exceeded 0·6–0·9 m-mole/l. toxic symptoms developed.

The authors wish to acknowledge the technical assistance of Mrs E. N. Hills, Mr F. Hills and Mr P. Wright.

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Studies on the Portal Blood of Sheep

2. ABSORPTION OF VOLATILE FATTY ACIDS FROM THE RUMEN OF THE SHEEP

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The nutritional significance of the volatile fatty acids (VFA) acetic, propionic and butyric, which are produced during ruminal digestion, is well recognized, and much information is available on the relative quantities of individual acids which arise under different feeding conditions (cf. Phillipson & Cuthbertson, 1956). Several groups of workers have studied the rates of absorption of these acids from the sheep rumen and the conflicting conclusions which have emerged no doubt reflect the different conditions under which the observations were made (Gray, 1947, 1948; Kiddle, Marshall & Phillipson, 1951; Masson & Phillipson, 1951; Johnson, 1951). Earlier workers studied the absorption of VFA from the rumen of anaesthetized sheep, but observations on conscious sheep were made by Pfander & Phillipson (1953), although as in the previous investigations the rate of disappearance of VFA added to the rumen was used as a measure of their absorption.

A more direct method of assessing the amounts of VFA and other metabolites which are absorbed from the rumen and other parts of the alimentary tract lies either in the analysis of the blood draining individual organs or in the analysis of portal blood. The study of rumen absorption by the examination of the blood draining that viscus has not attracted a great deal of attention since the now classical work of Barcroft, McAnally & Phillipson (1944). This approach has, however, been adopted by

Schambye & Phillipson (1949) and Schambye (1951), who used the London-cannula technique to obtain successive samples of portal blood from conscious sheep maintained under stall-fed conditions. This enabled them to follow the changes in concentration of rumen, portal and arterial VFA when the sheep were fed on various diets. The results provided useful information on the relative concentrations of the total VFA in portal blood compared with the corresponding concentrations in the rumen, but owing to the limitations of the London-cannula technique sufficiently large samples of portal blood could not be obtained for the complete analysis of the VFA. This information itself is of sufficient interest to justify a renewed attack on rumen–portal absorption problems, but in view of recent developments in our knowledge of the metabolic activities of rumen epithelium (Pennington, 1952) the need for detailed analyses of portal blood has assumed even greater importance. The development of methods for the complete analysis of the VFA in 10–20 ml. of blood (Annison, 1954*b*), which were based on the vapour-phase chromatographic method of James & Martin (1952), made possible a detailed study of the VFA produced and absorbed during rumen fermentation, provided frequent samples of portal blood could be obtained. For this purpose a method of catheterizing the portal vein in sheep was developed which allowed the repeated withdrawal of relatively large volumes of blood (Lewis, Hill & Annison, 1957).

With these techniques, observations have been made on the VFA content of portal and peripheral blood and of rumen contents of sheep maintained under animal-house conditions and fed on various diets. In addition, the absorption of the individual acids, acetic, propionic and butyric, has been investigated together with the changes brought about in circulating glucose and ketone bodies when these individual acids were placed in the rumen.

A preliminary communication of some of this work was given to the Biochemical Society (Annison, Hill & Lewis, 1955).

MATERIALS AND METHODS

Experimental animals and surgical procedures

Clun Forest sheep, each with a permanent rumen fistula and an exteriorized loop of the carotid artery, were kept in the animal house for at least 2 months before any experiments were carried out, and received the following diets in the daily amounts shown: hay (1 kg.), sheep 1; hay (800 g.) and casein (150 g.), sheep 2; alkali-washed straw (600 g.; for details of preparation see Annison, 1956), starch (100 g.) and casein hydrolysate (100 g.), sheep 3. During this initial period the animals were trained to consume the whole of their ration over a period of 1–2 hr., and so provide a somewhat exaggerated picture of the normal ruminal events.

A polythene catheter was placed in the portal vein at a subsequent operation and a series of experiments carried out. Details of the surgical technique are described elsewhere (Lewis *et al.* 1957). The time taken for complete recovery varied with individual sheep, the most frequent post-operative complication being reluctance to consume the whole of the daily ration in a short period, an essential feature of the experiments. Hence in some of the experiments part of the diet was added directly to the rumen through the rumen fistula.

Chemical determinations

Volatile fatty acids. Blood was analysed for VFA by the procedure of Annison (1954*b*), in which individual VFA are separated by vapour-phase chromatography (James & Martin, 1952). Since a minimum of 10 μmoles of VFA was required for chromatography, 15 ml. of arterial blood or 10 ml. of portal blood was used. Rumen VFA were examined as described earlier (Annison, 1954*a*).

Blood reducing sugar. The method of Somogyi (1952), coupled with the colorimetric procedure of Nelson (1944), was employed.

Ketone bodies. The method of Greenberg & Lester (1944), as modified by Pennington (1952), was used.

Ruminal administration of volatile fatty acids

The VFA were 'laboratory reagent' quality (British Drug Houses Ltd.) and were homogeneous when examined by vapour-phase chromatography. The acids were titrated with 2N-NaOH to pH 6·0, and added to the rumen in a concentration of 1 m-mole/ml., unless stated otherwise. Since the portal-vein catheters remained patent for only a limited time (1–3 weeks), experiments were carried out with the shortest possible time interval between them, consistent with the good condition of the animal. The sheep were not allowed access to food on the days when experiments were carried out. The sheep used for these experiments were fed on a diet of chopped hay (1 kg./day).

RESULTS

Absorption of volatile fatty acids under normal feeding conditions

Several series of observations were made over periods of 8–10 hr. on the concentrations of VFA in the portal and peripheral (arterial or venous) blood, and rumen contents, of sheep 1–3 (Expts. 1–3 respectively). Samples were withdrawn immediately before feeding, and at intervals of 1 hr. throughout the experiment. Earlier work (Annison, 1954*b*) had shown that the concentration of VFA in the sheep rumen declined steadily for 24–48 hr. after feeding, indicating that the increases in rumen VFA levels observed in the present studies were due to the ruminal fermentation of the food eaten during the experiments. Uneaten food was removed after 2 hr. The total VFA concentrations in portal and arterial blood, and rumen contents, are shown in Fig. 1, and the amounts of individual acids are shown in Tables 1–3. In Expt. 1, portal- and

arterial-blood samples were examined for their haemoglobin content to check for possible variations in the plasma:red cell ratio, which may have influenced the analytical results, since in sheep blood the VFA are not distributed equally between red cells and plasma (Annison, 1954*b*). Good agreement was found between the haemoglobin content of samples taken at the same time. Glucose and ketone-body estimations were also made on the blood samples withdrawn in Expts. 2 and 3 (Fig. 2).

There was good correlation between the total VFA concentrations in rumen contents and portal blood in two of the three experiments reported (see Fig. 1). Examination of the individual acids indicated a low concentration or complete absence of butyrate from portal blood, although comparatively large amounts were present in rumen contents. In addition, ketone-body levels were significantly higher in portal than in arterial blood (Fig. 2). These results obtained *in vivo* confirm that considerable quantities of butyrate are metabolized by rumen epithelium, as was shown by the *in vitro* studies of Pennington (1952), who found that butyrate was utilized by rumen epithelium with the production of ketone bodies. Kiddle *et al.* (1951) demonstrated that the amount of butyrate relative to the levels of acetate or propionate in blood draining the rumen was much less than would be expected from the relative concentrations of the three acids in the rumen.

Blood-glucose concentrations in portal and arterial blood showed little variations throughout the sampling periods, the portal–arterial differences being negligible. These results confirm those of Schambye (1951).

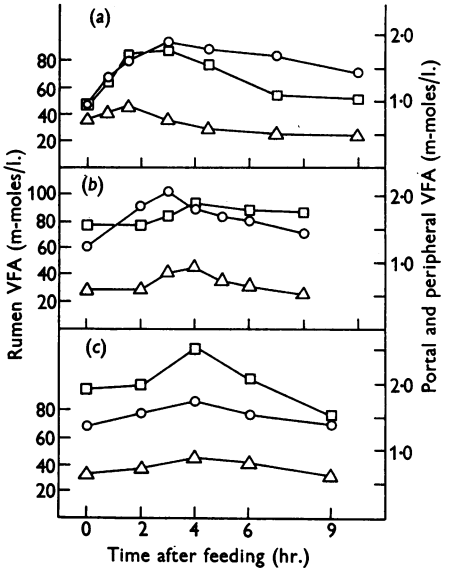

Fig. 1. Changes in total volatile fatty acid (VFA) levels in rumen contents (○) and in portal (□) and peripheral (△) blood of sheep receiving rations of hay (*a*), hay and casein (*b*) and casein hydrolysate and chopped straw (*c*).

Table 1. *Volatile fatty acid content of samples of rumen contents, portal blood and arterial blood, from a sheep on a diet of hay*

Time after feeding (hr.)	Sample	Total VFA concn. (m-moles/l.)	Molecular percentage of VFA						
			Formic	Acetic	Propionic	*iso*-Butyric	*n*-Butyric	*iso*-Valeric + 2-methyl-butyric	*n*-Valeric
0	Rumen contents	47	0	66	28	1	5	0	0
0·75		67	0	64	29	1	5	0	1
1·5		80	0	64	29	1	4	1	1
3		94	0	58	29	2	7	3	1
4·5		89	0	68	26	1	4	1	0
7		84	0	61	30	1	6	1	1
10		72	0	60	32	1	5	1	1
0	Portal blood	0·96	6	83	11	0	0	0	0
0·75		1·30	4	83	13	0	0	0	0
1·5		1·67	5	79	17	0	0	0	0
3		1·78	4	75	21	0	Trace	0	0
4·5		1·53	4	81	15	0	0	0	0
7		1·10	7	82	11	0	Trace	0	0
10		1·05	5	84	11	0	0	0	0
0	Carotid blood	0·73	5	95	0	0	0	0	0
0·75		0·82	5	95	0	0	0	0	0
1·5		0·92	4	96	0	0	0	0	0
3		0·71	5	92	3	0	0	0	0
4·5		0·58	6	92	2	0	0	0	0
7		0·52	4	96	0	0	0	0	0
10		0·51	5	95	0	0	0	0	0

Table 2. *Volatile fatty acids present in samples of rumen contents, portal blood and jugular blood, taken simultaneously from a sheep on a diet of hay and casein*

Time after feeding (hr.)	Sample	Total VFA concn. (m-moles/l.)	Molecular percentage of VFA						
			Formic	Acetic	Propionic	*iso*-Butyric	*n*-Butyric	*iso*-Valeric + 2-methyl-butyric	*n*-Valeric
0	Rumen contents	62	—	—	—	—	—	—	—
2		92	0	69	25	0	4	1	1
3		103	0	68	28	0	4	1	1
4		90	—	—	—	—	—	—	—
5		85	0	65	30	0	3	1	1
6		81	—	—	—	—	—	—	—
8		72	0	69	29	0	2	0	0
0	Portal blood	1·56	5	88	7	0	0	0	0
2		1·57	5	87	8	0	0	0	0
3		1·70	4	88	8	0	0	0	0
4		1·85	4	87	9	0	0	0	0
6		1·79	4	88	8	0	0	0	0
8		1·77	4	90	6	0	0	0	0
0	Jugular blood	0·60	7	93	0	0	0	0	0
2		0·60	8	92	0	0	0	0	0
3		0·85	7	93	Trace	0	0	0	0
4		0·94	6	93	1	0	0	0	0
5		0·73	7	93	Trace	0	0	0	0
6		0·66	6	94	0	0	0	0	0
8		0·52	8	92	0	0	0	0	0

Table 3. *Volatile fatty acids found in samples of rumen contents and portal and jugular blood taken from a sheep receiving a diet of casein hydrolysate and chopped straw*

Time after feeding (hr.)	Sample	Total VFA concn. (m-moles/l.)	Molecular percentage of VFA						
			Formic	Acetic	Propionic	*iso*-Butyric	*n*-Butyric	*iso*-Valeric + 2-methyl-butyric	*n*-Valeric
0	Rumen contents	68	0	59	24	3	11	2	1
2		78	0	63	22	2	10	2	1
4		87	0	61	25	2	9	2	1
6		77	0	63	24	2	9	1	1
9		70	0	64	25	1	8	1	1
0	Portal blood	1·91	7	84	7	0	2	0	0
2		1·98	8	82	8	0	2	0	0
4		2·49	6	84	8	0	2	0	0
6		2·09	7	84	7	0	2	0	0
9		1·55	7	83	8	0	2	0	0
0	Jugular blood	0·66	12	88	0	0	0	0	0
2		0·74	12	88	0	0	0	0	0
4		0·94	11	89	0	0	0	0	0
6		0·83	10	90	0	0	0	0	0
9		0·64	14	86	0	0	0	0	0

Addition of sodium butyrate to the rumen

In a preliminary experiment, 300 m-moles of sodium butyrate in 150 ml. of water, pH 6·0, was added to the rumen of a sheep fasted for 24 hr. Samples of rumen contents, portal blood and venous blood were then taken at intervals, and examined for total VFA, butyrate, glucose and ketone bodies. The results are shown in Figs. 3 and 4. The main points of interest were: (1) the low concentration of butyrate in portal blood when the concentration of butyrate in the rumen was high (40 m-moles/l.); and (2) the markedly enhanced levels of ketone bodies in portal blood compared with those of peripheral blood during the first 2 hr. of the experiment.

At this stage it was decided to investigate the effects of slowly increasing the concentration of butyrate in the rumen. Sodium butyrate (five doses of 50 m-moles each) was added to the rumen of a sheep through the fistula at intervals of 1 hr.; a further 100 m-moles was added 1 hr. later. Samples of rumen contents, portal and arterial blood were taken immediately before the first dose, 30 min. after the second dose, and 30 min. after each further dose of butyrate. The rumen contents were analysed for VFA, and blood samples for VFA, ketone bodies and blood sugar. The results are shown in Table 4 and Fig. 5*C*. Good correlation between butyrate concentrations in the rumen and in the portal blood was observed, but most of the portal butyrate was removed by the liver, since only a small amount appeared in arterial blood. Although concentrations of ketone bodies in portal blood showed considerable increases as the rumen and portal-blood levels of butyrate rose, there was only a rough correlation between rumen butyrate and portal-blood ketone levels. Portal blood- and arterial blood-sugar concentrations rose slightly throughout the dosage period.

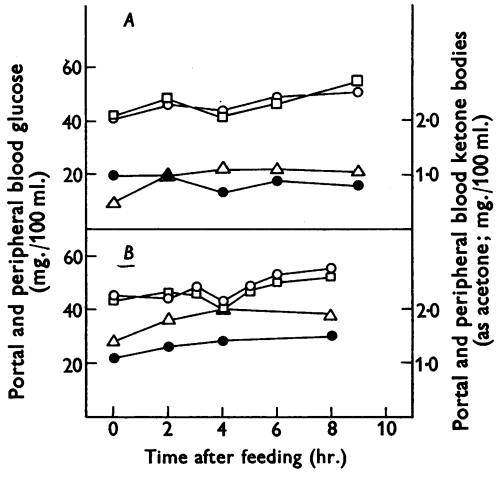

Fig. 2. Glucose and ketone-body concentrations in the portal and venous blood of sheep receiving diets of hay and casein (*A*) and chopped straw and casein hydrolysate (*B*). ○, Portal glucose; △, portal ketones; □, venous blood glucose; ●, venous blood ketones.

Since the pH of rumen contents influences the rate of absorption of VFA (Gray, 1948), control experiments were made to investigate the pH changes in the rumen of a sheep dosed with sodium butyrate under the conditions of the experiments. During the dosage period the pH of the rumen fluid, measured by a glass electrode, varied between 6·3 and 6·8, a change which is unlikely to affect appreciably the rate of absorption of the acid. Similar experiments with sodium acetate and sodium propionate indicated that the pH of the rumen contents remained within the pH range 6·0–7·0 under these conditions, which suggested that the following absorption experiments were not carried out under grossly unphysiological conditions.

Addition of sodium propionate to the rumen

Propionate was added to the rumen of a sheep in doses of 50 m-moles, at 1 hr. intervals, with the final addition of 100 m-moles as described for butyrate: samples of blood and rumen contents were removed for analysis at the same time intervals. The results are shown in Table 4 and Fig. 5*B*. Close correlation between portal and rumen levels was again found and considerable quantities of propionate 'spilled over' into the arterial blood.

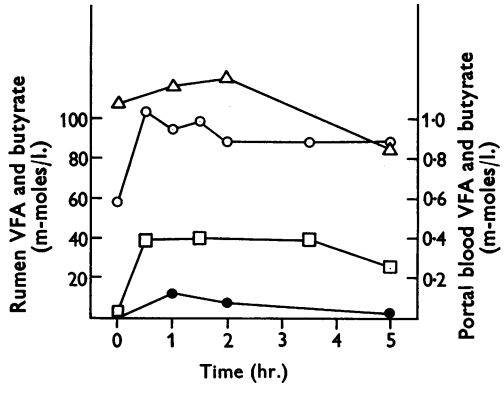

Fig. 3. Total VFA concentrations in rumen contents (○) and portal blood (△), and butyrate levels in the rumen (□) and portal blood (●), when butyrate was put into the rumen.

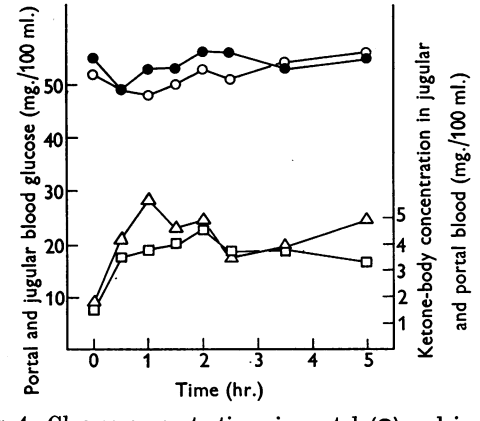

Fig. 4. Glucose concentrations in portal (●) and jugular (○) blood, and ketone-body levels in portal (△) and jugular (□) blood, when butyrate was put into the rumen.

Table 4. *Changes in the concentrations of volatile fatty acids, glucose and ketone bodies in rumen contents, and portal and arterial blood, after addition to the sheep rumen of successive doses of acetate, propionate or butyrate*

Volatile fatty acid added	Time added (hr.)	Amount added (m-moles)	Time of sample (hr.)	Volatile fatty acids (m-moles/l.)			Blood glucose (mg./100 ml.)		Ketone bodies (mg./100 ml.)	
				Rumen	Portal	Carotid	Portal	Carotid	Portal	Carotid
Acetate	0	50	Before dose	38	1·98	1·37	59	59	4·6	4·0
	1	50	1½	51	1·85	—	57	—	4·8	—
	2	50	2½	67	2·37	—	60	—	5·2	—
	3	50	3½	49	2·08	1·40	60	54	2·6	2·0
	4	50	4½	53	2·80	—	67	—	2·8	—
	5	100	5½	59	3·58	1·60	72	70	3·2	2·7
Propionate	0	50	Before dose	44	1·90	1·20	64	62	3·0	3·6
	1	50	1½	50	2·20	—	69	—	3·2	—
	2	50	2½	54	2·19	—	73	75	3·2	—
	3	50	3½	60	2·09	1·31	75	—	3·9	2·9
	4	50	4½	53	1·83	1·62	78	—	3·0	—
	5	100	5½	60	2·22	1·70	76	80	2·8	2·1
Butyrate	0	50	Before dose	58	1·61	1·35	48	48	2·4	2·4
	1	50	1½	76	1·77	—	54	—	6·9	—
	2	50	2½	80	1·89	1·35	58	53	4·1	3·5
	3	50	3½	92	2·41	—	62	—	5·2	—
	4	50	4½	92	2·31	1·98	58	58	5·9	6·1
	5	100	5½	116	2·92	2·32	70	60	9·3	8·2

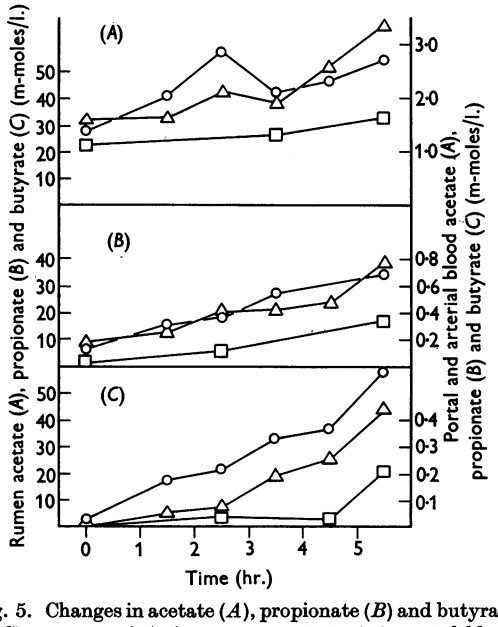

Fig. 5. Changes in acetate (*A*), propionate (*B*) and butyrate (*C*) concentrations in rumen contents (○), portal blood (△) and arterial blood (□), when aqueous solutions of these acids were added in successive doses to the rumen of sheep, in separate experiments.

Ketone-body concentrations in portal blood remained unchanged, but as with butyrate there was a slight increase in blood-glucose levels with insignificant portal–arterial differences, throughout the dosage period. Arterial blood ketone-body concentrations decreased to about one-half of the initial value.

Addition of sodium acetate to the rumen

The absorption of acetate from the rumen into the portal system was investigated by the same procedure as that described for propionate and butyrate. Increasing levels of acetate in the rumen were paralleled by those of portal blood (Fig. 5*A*), whilst blood-sugar concentrations increased slightly in both portal and arterial blood (Table 4). The portal and arterial ketone bodies decreased, although portal ketone bodies showed a slight increase in the first half of the dosage period.

DISCUSSION

The portal system drains the whole splanchnic area and thus contains VFA contributed by regions of the tract other than the rumen. Examination of the blood draining the different regions of the tract (Barcroft *et al.* 1944) revealed, however, that, apart from that from the rumen, only the blood draining the omasum and caecum contained VFA in significant amounts, and examination of the VFA of the contents of various regions of the tract (Annison, 1954*b*) indicated that only the rumen and caecum contained appreciable quantities. The concentration of VFA in the caecum is about one-quarter of that in the rumen, and since the caecum has only about one-tenth of the capacity of the rumen it is probable that the contribution of VFA from the caecum is relatively very small compared with

that of the portal blood. It is reasonable therefore to assume that any observations made on the portal blood will reflect changes occurring in the blood draining the rumen.

Sampling errors due to the possible occurrence of laminar flow in the portal vein have been discussed elsewhere (Lewis *et al.* 1957), but it would seem from a comparison of the general shape of the curves representing portal-VFA concentration and rumen-VFA levels that in most experiments errors due to this cause were not large enough to invalidate the results obtained. It is perhaps premature to discuss why there should be a close correlation between the rumen and portal VFA in some experiments and not in others, but it was felt that the occasional discrepancies observed did in fact represent a genuine phenomenon.

The demonstration that changes in the total VFA content of the rumen ingesta after feeding were paralleled by similar changes in the portal blood confirmed the findings of Schambye (1951), and in addition the detailed analyses provided information on the composition of the portal VFA compared with those of the rumen ingesta. Gray (1947), and Phillipson and his colleagues, have shown in experiments involving replacement of the rumen ingesta with mixtures of VFA at different pH levels that the rumen pH influences to a marked extent the relative rate of disappearance of VFA from the rumen. Thus at pH 7·2 the quantities of acetate, propionate and butyrate disappearing were similar (Elsden & Phillipson, 1948), whereas at pH 5·8 proportionately more butyric acid was lost from the rumen (Pfander & Phillipson, 1953). The exact significance of these findings in relation to the events occurring during normal fermentation is not very clear, since under these conditions there is a continual production and a varying concentration of VFA along with small changes in pH.

Little information on the relative rates of absorption from the rumen of acetic, propionic and butyric acids was obtained by comparing the quantities appearing in portal blood at known rumen concentrations. When rumen levels of each acid were plotted against portal concentrations, the results obtained throughout the whole study being used, a large scatter was observed with no apparent differences between acetate and propionate. Portal levels of butyrate, however, were always lower than those of acetate and propionate when compared at similar rumen concentrations, but this difference could be explained by the metabolism of butyrate by rumen epithelium and does not necessarily reflect a slower rate of absorption. The increase in rumen butyrate after the ruminal administration of 50 m-moles of acid at 1 hr. intervals, however, was much higher than that observed when acetate or propionate was given (Fig. 5), suggesting that under the conditions of these experiments butyrate was absorbed more slowly.

The analytical data providing the concentrations of propionate in the portal blood allow an estimate to be made of the actual amounts of propionate metabolized by the liver, since under normal circumstances this fatty acid is largely removed by the liver and very little appears in the peripheral blood (Annison, 1954*b*). If it is assumed that the level in portal blood 8–10 hr. after feeding was representative of the amount present for the remainder of the 24 hr. period, then when diets based on hay, casein and casein hydrolysate were fed, 32, 20 and 26 g. of propionate respectively were metabolized/24 hr. Portal-flow rates based on the results of Schambye (1956) were used in these calculations, i.e. 37 ml./min./kg., and the portal-propionate concentrations were corrected for any propionate found in peripheral blood.

The fact that butyric acid was absent or present in low concentrations in portal blood, although present in comparatively large amounts in rumen contents, confirmed the observations of Masson & Phillipson (1951). Since ketone-body levels were significantly higher in portal than in arterial blood the results indicated that considerable quantities of butyrate were metabolized by rumen epithelium with the production of ketone bodies, as was first shown by Pennington (1952).

There is a considerable amount of published data on the changes in blood sugar and ketone bodies which occur when acetate, propionate and butyrate are added to the rumen (Johnson, 1955; Clark & Malan, 1956). Propionate undoubtedly gives rise to glucose, but there is no convincing evidence that acetate affects blood-sugar levels in sheep. Although Potter (1952) found that sodium butyrate injected intravenously relieved insulin convulsions in lambs and caused a rise in blood sugar, no clear-cut effects of butyrate had been reported until Kronfeld (1956) showed that butyrate injected intravenously into sheep caused the blood sugar to either rise or fall, depending on the initial blood-sugar level. The butyrate (50 g.) was given over a period of 50 min. Several groups of workers have observed symptoms of distress when butyrate is administered intravenously (Jarrett, Potter & Filsell, 1952; Johnson, 1955), but the slow rate of injection was stated by Kronfeld to obviate this effect. The results of Kronfeld (1956) suggest that butyrate has a glucostatic action in sheep; it would be expected that accetate would have the same effect, since the metabolism of these substances follows similar pathways. There is no evidence on this point. The extra-hepatic tissues of sheep are not normally exposed to high concentrations of butyrate, the usual concentration in blood rarely exceeding 10 μmoles/l. (Annison, 1954*b*), a situation which

reflects the rates at which butyrate is metabolized by the rumen wall and the liver. The significance of Kronfeld's results is therefore difficult to assess, and it is possible that the effects observed were secondary to the pharmacological action of the high concentration of butyrate employed. The increases in blood sugar observed in the present experiments during dosage with acetate, propionate and butyrate are difficult to interpret, since they could have been due to excitement of the animal as a result of continued blood sampling, or to the administration of sodium (as the VFA salt), reported by Johnson (1955) to increase blood-sugar levels.

The concentrations of metabolites in the portal vein can only be translated into actual quantities absorbed from the alimentary tract if the portal-blood flow is known, and elegant methods of measurement have recently been devised for this purpose by Schambye (1956). Portal-flow rates on blood for which analytical figures are available have, however, not yet been reported. It is hoped to obtain information of this nature in future studies.

SUMMARY

1. A study was made of the changes in the concentrations of the individual volatile fatty acids present in the rumen, and portal and peripheral blood, of sheep fed on diets of hay, hay and casein, and of alkali-washed straw and starch. Considerable amounts of volatile fatty acids were absorbed from the rumen, and there was good correlation between the concentrations of total volatile fatty acids in portal blood and rumen contents.

2. Under normal feeding conditions there is a much lower concentration of butyrate, relative to the levels of acetate and propionate, in the portal system than in rumen contents. Concentrations of ketone bodies in the portal vein usually exceeded those in the peripheral blood. Only minor differences in portal and peripheral blood glucose were detected.

3. The absorption of the individual acids, acetic, propionic and butyric, from the rumen into the portal system was demonstrated, and the corresponding levels in peripheral blood were examined. Dosage with butyrate resulted initially in high ketone-body levels in portal blood, followed by a steady rise of concentration in peripheral blood.

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