Erratum to “Effects of particle size and dry matter content of a total mixed ration on intraruminal equilibration and net portal flux of volatile fatty acids in lactating dairy cows” (J. Dairy Sci. 93:4223–4238)

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An error was made in calculation of the flux data presented in this paper. Fluxes are presented as whole-blood fluxes but, because of a programming error, are, in fact, plasma fluxes. The errors do not, in general, affect the conclusions of the paper. The corrected text and tables are presented below, with corrections in bold font. The authors apologize for this error.

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Abstract (page 4223):

Consequently, reduced FPS affected the intraruminal equilibration of VFA between mat and ventral rumen with an estimated turnover rate of isobutyrate increasing from $66 \pm 3\%/h$ with long particles to $81 \pm 3\%/h$ with short particles.

Results: (pages 4230–4231):

Net Portal Fluxes

Net portal blood flux of oxygen, carbon dioxide, and net portal plasma flux of glucose, L-lactate, and BHBA were not affected by treatment or time ($P = 0.15$ to 0.83 ; Table 7). The net uptake of oxygen in the PDV was on average $2,134 \pm 58$ mmol/h. The corresponding net release of carbon dioxide from the PDV was $2,591 \pm 353$ mmol/h. There was PDV release of glucose from 0.5 to 1.5 h after feeding and net uptake was observed outside this time period.

The net portal blood fluxes of all VFA increased ($P < 0.01$) after feeding. The net portal blood flux of total VFA was on average $4,113 \pm 119$ mmol/h and increased from $3,256$ to $5,012 \pm 322$ mmol/h from 0.5 h before to 2.5 h after feeding. There were no effects of treatments on net portal fluxes of VFA ($P = 0.25$ to 0.99).

Net Hepatic Fluxes

Net hepatic blood flux of carbon dioxide, acetate, and the net hepatic plasma flux of glucose were not

affected by treatments or time ($P = 0.28$ to 0.99 ; Table 7). The net hepatic blood fluxes of oxygen, propionate, butyrate, isobutyrate, valerate, isovalerate, caproate, and net hepatic plasma fluxes of L-lactate and BHBA increased after feeding ($P < 0.01$ to 0.02). The net hepatic flux of glucose was on average 645 ± 19 mmol/h and was not affected by time ($P = 0.31$). The net hepatic uptake of L-lactate, propionate, isobutyrate, and valerate relative to the net hepatic production of glucose was 25.4 ± 2.2 , 69.5 ± 3.3 , 2.3 ± 0.09 , and $4.1 \pm 0.25\%$, respectively, accounting for $> 98\%$ of hepatic glucogenic precursors on a net basis.

Medial Ruminal Turnover and Fractional Absorption Rates of VFA

The turnover of the medial ruminal isobutyrate pool calculated from the net portal flux of isobutyrate and the medial ruminal isobutyrate pool increased 15.4 ± 4.6 percentage units/h from 66 to $81 \pm 3\%/h$ ($P = 0.01$) with decreasing total ruminal pool (Table 8). The same trends were observed for medial turnover of acetate and butyrate ($P = 0.06$). An FDM $\times$ time interaction affected the values of propionate, **butyrate**, and isobutyrate ($P = 0.01$, **0.04**, and 0.02 , respectively), **all** higher before feeding with dry diets. The FDM did not affect ($P = 0.26$ to 0.49) the medial ruminal pool turnover.

Even though the turnover rate of the medial pool of isobutyrate increased with short particles, no effects of treatments were observed for the CFAR from the ventral pool of isobutyrate, acetate, propionate, or butyrate. Nor were there observed time effects for acetate, propionate, butyrate, and isobutyrate corrected ventral rumen fluid fractional absorption rates.

Clearance of Ruminal VFA and Intraruminal Fluid Flow

The intraruminal flow of fluid through the medial mat was 142 ± 30 L/h and not affected by dietary treatments or time ($P = 0.32$ and 0.54 , respectively; data not shown). The clearance of ruminal acetate from the medial to ventral ruminal pool was on average 44.2 ± 1.1 L/h and was not affected by dietary treatments

or time (Table 8). The medial to ventral pool clearance of propionate, butyrate, and isobutyrate was on average 38.6 ± 1.0 , 43.6 ± 1.4 , and 33.2 ± 0.8 L/h, respectively. Medial butyrate clearance increased ($P < 0.01$) from 34.1 to 48.4 ± 3.2 L/h after feeding. The medial clearance of propionate and isobutyrate were affected by an FDM $\times$ time interaction ($P = 0.02$ and 0.04 , respectively), reflecting greater clearance with dry diets before feeding.

Ventral pool to blood clearances of acetate, propionate, butyrate, and isobutyrate were not affected ($P = 0.23$ to 0.89) by treatments and were on average 65.7 ± 2.1 , 59.1 ± 2.0 , 66.9 ± 2.5 , and 49.2 ± 1.6 L/h, respectively. The ventral pool clearance of butyrate increased ($P < 0.01$) from 43.7 to 76.4 ± 5.7 L/h after feeding.

Discussion (pages 4236–4237):

Rate of reticuloruminal VFA absorption relies on the rate at which VFA are supplied from the ruminal mat to the reticulorumen epithelia. Because of the large volume of the rumen, the cow cannot rely on passive diffusion to facilitate the intraruminal equilibration. The mixing of ruminal contents through ruminal motility is therefore crucial for effective VFA absorption. Controlling the reticulorumen motility may be a route for the cow to control VFA absorption. In acute ruminal acidosis, the frequency of primary reticuloruminal contractions is reduced or even absent, reducing the mixing and passage of ruminal content to the omasum (Crichlow, 1988). Through this action, the cow may affect the rate at which ruminal VFA flows from the medial to the ventral pool and consequently downregulate the absorption of VFA from the reticulorumen. The FPRC was not affected by dietary treatments in the present study; however, because of the reduced ruminal mat together with the shorter particles, the relative movement of ruminal fluid by the contractions might increase, affecting the intraruminal equilibration of VFA. With the setup used we cannot measure the amplitude of the contractions and therefore cannot account for any frequency $\times$ amplitude (work) effect. However, the flow from the medial to the ventral pool (142 ± 30 L/h) of ruminal fluid was not affected by the size of the medial pool. Thus, intraruminal fluid flow and thereby intraruminal VFA flow seems not to be dependent on the size of the ruminal mat.

The overall values of net portal flux of VFA were in agreement with previous studies using dairy cows receiving corn silage-based rations with the same DMI as in the present study (Kristensen and Raun, 2007). Changing the physical characteristic of the ruminal

mat was expected to affect the rate of fermentation and intraruminal turnover, consequently affecting the net portal flux of VFA; however, this was not observed. The best estimate of corrected absorption was evaluated to be isobutyrate because of the limited PDV metabolism and high portal blood recovery of ruminal infused isobutyrate (Kristensen and Harmon, 2004b). Isobutyrate was therefore evaluated to be the best VFA marker in relation to intraruminal turnover and corrected flux using the ruminal VFA model (Figure 2). The model is constructed under the assumption that VFA is primarily absorbed from the ventral ruminal pool and that VFA equilibrates from the medial mat to the ventral pool with the same rate that VFA is absorbed. The experimental design enables us to measure the real time dynamic of VFA between ruminal pools and the VFA exchange between ventral ruminal pool and portal blood. The ruminal CFAR links the corrected flux of specific metabolites to the ruminal pool of interest, thereby describing the pool turnover rate. The CFAR of the total pool of VFA has previously been studied in vivo under intact (Krehbiel et al., 1995; Resende Júnior et al., 2006; Penner et al., 2009) and washed (Dijkstra et al., 1993; Kristensen and Harmon, 2004a,b) rumen conditions. The present study used ventral ruminal pool and corrected flux to estimate the CFAR and can therefore not directly be related to these studies. No effect ($P = 17$ to 0.95) was revealed when calculating the CFAR of acetate, propionate, butyrate, and isobutyrate (430 ± 17 , 392 ± 17 , 426 ± 17 , and $324 \pm 12\%/h$, respectively) because the ventral ruminal pool and corrected flux of these metabolites were not affected by dietary treatments. However, the effect of FPS on the medial pool of isobutyrate was clear when calculating the intraruminal turnover. The turnover of isobutyrate increased ($P < 0.01$) as the medial pool decreased with short particles; the same trend was observed for acetate and butyrate ($P = 0.06$). This shows that the effect of dietary particle size is related to the turnover of the medial pool and that the size of the mat affects the retention of isobutyrate. It can be hypothesized that this effect is the same for other VFA because the estimated fluid flow through the mat was not affected.

Medial to ventral ruminal clearance and ventral rumen to portal blood clearance of acetate, propionate, butyrate, and isobutyrate were not affected by dietary treatments because no effects were detected on the ruminal concentrations or corrected flux of these metabolites. The clearance describes the VFA dynamic of the rumen in relation to the mixing of ruminal contents and exposure of the VFA to the epithelia for absorption. The medial ruminal clearance of isobutyrate indicates

that 33.2 ± 0.8 L/h of medial ruminal fluid was cleared of this metabolite, whereas 49.2 ± 1.6 L/h of ventral ruminal fluid was cleared. In relation to the ruminal

pool sizes, this indicates the incomplete equilibration of the mat with the ventral ruminal fluid.

Tables (pages 4233–4234):

Table 7. Blood plasma flow in the portal vein, hepatic vein, and hepatic artery and net portal flux and net hepatic flux of oxygen, carbon dioxide, and metabolites in dairy cows fed 2 levels of TMR DM and 2 levels of forage particle size

Item	Short		Long		SEM (n = 4)	P-value ¹			
	Dry	Moist	Dry	Moist		FPS	FDM	FPS × FDM	Time
Blood plasma flow, L/h									
Portal	1,433	1,262	1,322	1,335	50	0.71	0.15	0.10	0.04
Hepatic vein	1,499	1,488	1,475	1,482	69	0.83	0.98	0.90	0.01
Hepatic artery	66	226	153	147	63	0.95	0.25	0.22	0.71
Net portal blood flux, mmol/h									
Oxygen	-2,358	-2,043	-2,190	-1,932	178	0.44	0.15	0.85	0.29
Carbon dioxide	3,678	2,783	2,313	1,999	612	0.14	0.37	0.70	0.62
Acetate	3,022	2,672	2,843	2,859	274	0.99	0.56	0.52	<0.01
Propionate	942	834	896	862	85	0.92	0.43	0.67	<0.01
Butyrate	276	261	282	262	31	0.91	0.58	0.93	<0.01
Isobutyrate	31.1	29.3	29.9	30.9	2.1	0.99	0.89	0.49	<0.01
Valerate	54.7	47.4	49.5	45.0	5.5	0.52	0.28	0.83	<0.01
Isovalerate	18.3	15.5	16.3	16.7	1.4	0.79	0.42	0.29	<0.01
Carproate	61.0	47.7	49.2	43.0	7.7	0.31	0.23	0.64	<0.01
Net portal plasma flux, mmol/h									
Glucose	-34.9	-16.1	-11.9	-46.7	15.9	0.82	0.63	0.12	0.83
L-Lactate	169	142	145	128	17	0.29	0.22	0.76	0.40
BHBA	209	178	162	209	22	0.73	0.72	0.12	0.26
Net hepatic blood flux, mmol/h									
Oxygen	-2,334	-2,578	-2,305	-2,287	190	0.45	0.69	0.43	<0.01
Carbon dioxide	1,725	1,174	1,862	1,592	879	0.63	0.43	0.83	0.31
Acetate	10	390	239	159	131	0.99	0.28	0.11	0.53
Propionate	-871	-759	-824	-795	80	0.95	0.40	0.62	<0.01
Butyrate	-220	-198	-221	-207	28	0.87	0.54	0.89	<0.01
Isobutyrate	-28.9	-26.5	-27.6	-28.8	1.9	0.89	0.73	0.37	<0.01
Valerate	-51.9	-45.1	-48.5	-43.9	4.9	0.61	0.23	0.92	<0.01
Isovalerate	-14.6	-10.3	-11.0	-12.0	1.7	0.60	0.36	0.16	<0.01
Carproate	-60.9	-48.5	-49.8	-43.6	7.5	0.30	0.25	0.67	<0.01
Net hepatic plasma flux, mmol/h									
Glucose	701	630	620	631	52	0.46	0.57	0.45	0.31
L-Lactate	-340	-297	-247	-275	49	0.27	0.89	0.49	0.01
BHBA	273	298	290	234	44	0.60	0.76	0.38	0.02

¹FPS = forage particle size; FDM = feed DM; time = sample time (n = 8).

Table 8. Medial pool turnover, corrected¹ fractional absorption rate, and corrected¹ ruminal clearance of VFA in dairy cows fed 2 levels of TMR DM and 2 levels of forage particle size

Item	Short		Long		SEM (n = 4)	P-value ²			Time
	Dry	Moist	Dry	Moist		FPS	FDM	FPS × FDM	
Medial pool turnover, ³ /h									
Acetate	114.9	98.0	89.8	85.4	8.9	0.06	0.26	0.50	0.29
Propionate*	96.9	88.4	80.1	75.8	8.5	0.12	0.47	0.81	0.26
Butyrate*	97.5	94.8	84.6	76.7	7.3	0.06	0.49	0.73	0.06
Isobutyrate*	84.3	77.9	66.6	64.8	4.6	<0.01	0.44	0.64	0.67
CFAR ventral ruminal pool, ⁴ /h									
Acetate	499	346	442	414	77	0.95	0.27	0.44	0.14
Propionate	481	325	410	366	92	0.87	0.31	0.56	0.23
Butyrate	432	334	441	382	52	0.60	0.17	0.71	0.36
Isobutyrate	393	272	354	320	58	0.95	0.20	0.47	0.86
Medial to ventral clearance, ⁵ L/h									
Acetate	46.8	41.4	44.7	42.1	4.0	0.87	0.35	0.73	0.32
Propionate*	39.6	37.3	39.6	37.3	3.5	0.99	0.53	0.99	0.58
Butyrate	39.7	40.2	43.1	37.9	4.2	0.90	0.59	0.52	<0.01
Isobutyrate*	34.2	33.0	32.9	32.0	2.2	0.60	0.69	0.98	0.30
Ventral to blood clearance, ⁶ L/h									
Acetate	70.5	58.0	61.2	58.8	7.0	0.56	0.31	0.49	0.78
Propionate	66.8	53.4	55.9	52.4	9.1	0.53	0.38	0.60	0.79
Butyrate	64.2	57.2	63.0	56.6	6.0	0.89	0.29	0.96	<0.01
Isobutyrate	56.9	45.4	47.3	45.6	5.3	0.38	0.23	0.37	0.02

¹Corrected portal flux of acetate, propionate, butyrate, and isobutyrate (Kristensen and Harmon, 2004a,b).²FPS = forage particle size; FDM = feed DM; time = sample time (n = 4).³Medial pool turnover = corrected VFA flux/medial ruminal VFA pool.⁴Corrected fractional absorption rate (CFAR) = corrected VFA flux/ventral ruminal VFA pool.⁵Medial clearance = corrected VFA flux/medial ruminal concentration of VFA.⁶Ventral clearance = corrected VFA flux/ventral ruminal concentration of VFA.*FDM × time, $P < 0.05$.