In Vivo Prediction of Body Composition in Cattle from Urea Space Measurements[1] (37470)

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In studies on the exchange of urea between the blood and tissues of humans, it was shown that infused urea was mixed in the blood within 3 min and diffused into cellular water as well as into the free water of the body within 15 min (1). At that time, the concentration of urea in the blood equals that in the tissues. In dogs, injected urea (iv) reached equilibrium between blood and tissues in about 1 hr (2), although inspection of the "typical" curve presented in this paper revealed that equilibrium was reached within 30 min. The amount of body water available in the dog for solution of urea (urea space) was similar to that found by direct desiccation. Therefore, measurement of urea space allows estimation of body water.

Test substances should possess certain properties to be acceptable as a measure of total body water (3) as follows: (a) even and rapid distribution throughout the body water; (b) there should be no toxic manifestation or physiologic effect; (c) it should not be selectively stored, secreted or metabolized; (d) an accurate and convenient estimation of its concentration in the plasma or blood should be available; and (e) it should not be a substance that is foreign to the body. San Pietro and Rittenberg (4) state that urea appears to meet all of these requirements. They measured urea space in human subjects using ^{15}N tagged urea and obtained identical results, within experimental error, compared to body water measured using deuterium oxide. Similar conclusions were reached using ^{14}C tagged urea in cats (5).

Preston (6) attempted measuring urea space in sheep by following plasma urea concentration over a period of 5–8 hr following urea infusion. Urea space was calculated by extrapolation of the plasma concentration curves back to the time of urea infusion. These measurements did not yield consistent results, perhaps because of the variability in the formation of endogenous urea as well as its diuretic effect (7).

The work reported here relates urea space measurement to body composition in cattle following the observation that infused urea mixes in the total body water within 9–10 min and gives a plasma urea value which is nearly the same as that obtained when plasma urea disappearance curves are extrapolated back to time of injection, thus precluding some of the above problems.

Methods. Urea infusions via a polyethylene catheter (Clay Adams, PE 200) introduced into the jugular vein through a No. 12 needle were performed on several cattle. The infusion solution contained 20% urea dissolved in 0.9% saline and was administered over a 2 min period. The volume injected was accurately measured; the quantity of urea injected approximated 130 mg/kg live weight. Jugular blood samples were taken prior to and at varying times after the mean infusion time. Plasma was removed following centrifugation for urea analysis (8, 9). The coefficient of variation between determinations on the same sample was ± 1.0%.

In preliminary work with 12 cattle, it was established that distribution of the urea in the body was completed within 9–10 min af-

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TABLE I. Means, Standard Deviations and Ranges of the Data.

Item	Mean	SD	Range
Live wt (kg)	340	129	169–492
Empty body wt (kg)	316	131	147–480
Initial PUN[a] (mg/100 ml)	12.1	5.7	3.9–21.8
Change in PUN (mg/100 ml):			
T_9	14.8	1.1	12.7–17.0
T_{12}	13.7	1.0	12.1–15.9
T_{15}	13.0	1.0	11.6–14.5
Sp gr of carcass	1.0600	0.0170	1.0405–1.0875
Empty body fat (%)	23.0	8.5	9.3–32.7

[a] PUN = plasma urea nitrogen.

ter injection, based on observing a rapid decrease in plasma urea concentration for the first 9–10 min, followed by a nearly linear decrease in urea concentration (log basis) over the next 6–8 hr. Since simultaneous samples from two catheters (one used for urea infusion) placed in opposite jugular veins gave equal plasma urea values, the same catheter was used for infusion (after flushing with 5–10 ml saline) and for removing blood samples. A heparin solution (100 units/ml saline) was placed in the catheter to prevent clotting between samplings.

The study reported in this paper presents data from 12 steers after establishing the above procedure. Their data characteristics are shown in Table I. After removing feed and water the evening before, the steers were weighed and urea was infused. Jugular samples were taken immediately before and at 9, 12 and 15 min following urea infusion. Within 3 days, the steers were slaughtered and empty body composition was estimated from specific gravity of the carcass (10). The validity of these equations has been confirmed in our laboratory. Urea space at various times after urea infusion was calculated by dividing the amount of injected urea by the increase in plasma urea concentration from the blood sample taken immediately prior to urea infusion. Also urea space was calculated by extrapolating to zero time the change in plasma urea (log basis) observed at 9, 12 and 15 min after infusion; these times will be referred to as T_0, T_9, T_{12} and T_{15}, respectively. Urea space was expressed as a percentage of live weight and percentage of empty body weight (live weight less the contents of the gastrointestinal tract), estimated from carcass weight (10).

The data were analyzed by standard linear regression analyses.

Results. Table II shows the overall correlations between percentage empty body fat and percentage urea space; all correlations were highly significant ($p < 0.01$). It is of interest to note that the correlations were higher at T_9, T_{12} or T_{15} than at T_0. Also, the correlations were higher for urea space expressed as a percentage of empty body weight than when expressed as a percentage of live weight. When a plot of these data at T_{12} was examined (Figs. 1 and 2), three steers appeared to deviate markedly when urea space was expressed as a percentage of live weight. Their data are not included in

TABLE II. Correlations Between Urea and Empty Body Fat Percentage (All Steers Included).

Time after urea infusion (min)	Urea space (%)	
	Live wt[a]	Empty body wt[b]
0[c]	—0.75	—0.84
9	—0.84	—0.90
12	—0.88	—0.93
15	—0.83	—0.91

[a] Urea space calculated as a % of live weight.

[b] Urea space calculated as a % of empty body weight.

[c] Estimated by extrapolating the log of the change in plasma urea observed at 9, 12 and 15 min back to zero time.

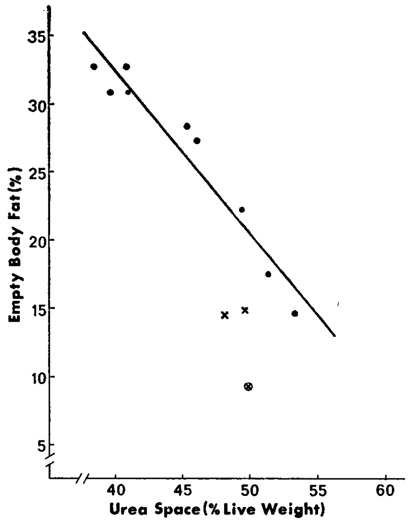

FIG. 1. Relation between urea space (% live wt) and empty body fat in cattle.

the calculation of the regression line shown in Fig. 1. When body weight changes were noted for a period of 6 wk prior to making these measurements, all three steers had lost weight whereas the others had gained weight. In two of these steers, this was probably due to a greater gastrointestinal fill since expressing the data as a percentage of empty body weight (Fig. 2) appeared to bring these two steers in line with the others. In the case of one steer, however, it still deviated from the others when urea space was expressed as a percentage of empty body weight. This steer was affected with chronic bloat and was not included in the calculation of the regression line shown in Fig. 2.

Two types of steers were included, namely six heavy and six light weight steers. When the data within each type were examined, highly significant correlations ($p < 0.01$) were observed in the heavy weight cattle between percentage empty body fat and urea space (% of live wt) at T_9, T_{12} and T_{15} (—0.97, —0.92 and —0.94, respectively), but not at T_0 (—0.63). When urea space was expressed as a percentage of empty body weight, these correlations were again significant ($p < 0.05$). Within the light weight group, however, the correlations between percentage empty body fat and urea space as a percentage of live weight were nearly zero; when urea space was expressed as a percentage of empty body weight, they were higher but nonsignificant. The three steers mentioned above were in the light weight group and were included in the above correlations.

Discussion. These results indicate that fat composition in cattle can be estimated *in vivo* by measuring urea space. When urea space is expressed as a percentage of live weight, using the data from nine steers, the prediction equations are:

T_{12}: % empty body fat =
79.59 —1.185 (% urea space) ($r = -0.96$),
T_{15}: % empty body fat =
81.50 —1.162 (% urea space) ($r = -0.96$).

When urea space is expressed as a percentage of empty body weight, using the data from eleven steers, the prediction equations are:

T_{12}: % empty body fat =
73.01 —0.976 (% urea space) ($r = -0.96$),
T_{15}: % empty body fat =
75.82 —0.983 (% urea space) ($r = -0.95$).

Body weight is reported to be correlated with body composition in cattle (11). The overall correlation between live weight and percentage empty body fat in this study was 0.94 ($p < 0.01$). The correlations within each weight group were 0.44 and 0.76, respectively, for the light and heavy weight groups, neither

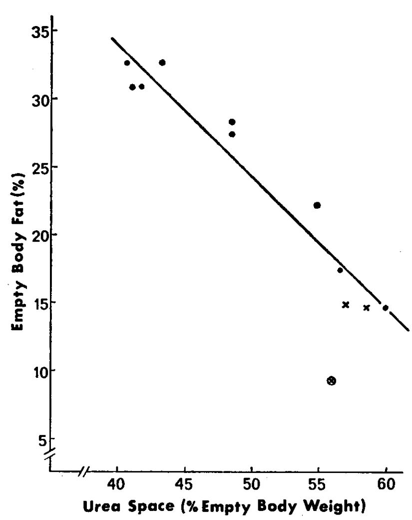

FIG. 2. Relation between urea space (% empty body wt) and empty body fat in cattle.

of which were significant. Thus, live weight was highly correlated with percentage empty body fat when all cattle were included, but in the case of the heavy weight steers, urea space was more highly correlated with percentage empty body fat than was live weight. When a multiple correlation was run using body weight and urea space (% of live wt) at T_{12} on nine steers, the multiple correlation coefficient (0.98) was not significantly increased over that observed between urea space at T_{12} and percentage empty body fat (—0.96).

In view of the known influence of gastrointestinal fill on the error of live weight measurement in ruminants (*e.g.*, up to 15% of the body wt), it is not surprising that urea space expressed as a percentage of empty body weight was more highly correlated with percentage empty body fat than when urea space was expressed as a percentage of live weight (Table II).

Since variations in fat composition are responsible for most changes in body composition, the relationship of urea space to empty body fat composition was studied in this work. Because specific gravity of the carcass was used to estimate body composition, the correlations between urea space and percentage empty body water would be similar to those reported for percentage empty body fat. Prediction equations for estimating percentage empty body water from urea space, expressed as a percentage of live weight, using the data from nine steers, are:

$$T_{12}: \% \text{ empty body water} = 13.25 + 0.9007 \text{ (\% urea space)},$$

$$T_{15}: \% \text{ empty body water} = 11.80 + 0.8830 \text{ (\% urea space)}.$$

When urea space is expressed as a percentage of empty body weight, using the data from 11 steers, the prediction equations are:

$$T_{12}: \% \text{ empty body water} = 18.25 + 0.7413 \text{ (\% urea space)},$$

$$T_{15}: \% \text{ empty body water} = 16.12 + 0.7466 \text{ (\% urea space)}.$$

These equations indicate that urea space measurements in cattle somewhat underestimate percentage empty body water. For instance, urea space as a percentage of live weight ranged from 40 to 55%, resulting in a calculated percentage empty body water ranging from 49 to 63%. The same was true for urea space expressed as a percentage of empty body weight.

The above findings indicate that urea space measurements can predict body composition in live cattle. Because of the ease of administration and the short time between infusing and sampling (*e.g.*, 12 min), this procedure should have experimental as well as practical value. Further work is required to determine the accuracy of the above regression equations, especially in lighter weight cattle. Also, the relationship between urea space and actual chemical composition needs to be determined since there is some error in predicting percentage empty body fat from carcass specific gravity. In our hands, the correlation between these two measurements is —0.96. It is not known at this time whether infused urea passes into the water of the gut; the short time interval between infusion and sampling probably excludes gut water from urea space as measured in this work.

Summary. Urea space was measured in cattle by infusing (iv) a known quantity of urea (approximately 130 mg/kg body wt) and withdrawing blood samples at varying times after infusion for plasma urea analysis. The relation between urea space determined at 12 or 15 min after urea infusion in 12 steers was highly correlated with percentage empty body fat and percentage empty body water.

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1. Donovan, H., and Brenner, O., Brit. J. Exp. Pathol. 11, 419 (1930).

2. Painter, E. E., Amer. J. Physiol. 129, 744 (1940).

3. Soberman, R., Brodie, B. B., Levy, B. B., Axelrod, J., Hollander, V., and Steele, J. M., J. Biol. Chem. 179, 31 (1949).

4. San Pietro, A., and Rittenberg, D., J. Biol. Chem. 201, 445 (1953).

5. Kornberg, H. L., Davies R. E., and Wood, D. R., Nature (London) 169, 502 (1952).

6. Preston, R. L., unpublished data.

7. Peters, J. P., Harvey Lect. 33, 112 (1937-38).

8. Fawcett, J. K., and Scott, J. E., J. Clin. Pathol. 13, 156 (1960).

9. Searcy, R. L., Gough, G. S., Korotzer, J. L., and Bergquist, L. M., Amer. J. Med. Technol. 27, 255 (1961).

10. Garrett, W. N., and Hinman, N., J. Anim. Sci. 28, 1 (1969).

11. Reid, J. T., Bensadoun, A., Bull, L. S., Burton, J. H., Gleeson, P. A., Han, I. K., Joo, Y. D., Johnson, D. E., McManus, W. R., Paladines, O. L., Stroud, J. W., Tyrrell, H. F., Van Niekerk, B. D. H., and Wellington, G. W., Nat. Acad. Sci. Publ. No. 1598, 19 (1968).

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