JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Estimation of Bovine Carcass Composition by the Urea Dilution Technique

S. W. Kock and R. L. Preston

J ANIM SCI 1979, 48:319-327.

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://jas.fass.org/content/48/2/319

American Society of Animal Science

www.asas.org

Downloaded from jas.fass.org at Fagro on August 15, 2011

ESTIMATION OF BOVINE CARCASS COMPOSITION BY THE UREA DILUTION TECHNIQUE

S. W. Kock[1] and R. L. Preston[1]

University of Natal, Pietermaritzburg, So. Africa and Washington State University[2], Pullman 99164

SUMMARY

One hundred and thirteen beef type steers of varying live weight and degrees of fatness were used to study the reliability and usefulness of urea space measured at varying times after urea infusion for estimating body composition in the live animal.

Urea space measured 12 min following urea infusion proved to be the best time as judged from correlation coefficients with rib soft tissue composition and carcass specific gravity; overall correlations with rib water, protein and fat, and carcass specific gravity were .84, .73, -.84 and .68, respectively. This was true also when the cattle were divided into groups according to age, cold carcass weight or fatness. Urea space, therefore, appears to be a reliable and practical measure for estimating body composition in the live animal.

When the data were arranged into four almost equal groups on the basis of increasing cold carcass weight, significant relationships between percentage of fat in the rib and urea space at 12 min were obtained in all the weight groups, indicating that urea space provides a valid estimate of carcass composition in all weight groups. Significant relationships between carcass specific gravity and urea space at 12 min were obtained in all but the lightest carcass weight group (mean rib fat content of approximately 14 to 15%). The percentage of fat in the rib was also strongly correlated with carcass specific gravity in all but the lightest carcass weight group. The results, therefore, provide good evidence that light weight carcasses or carcasses with a low degree of fatness do not give very reliable results with the specific gravity technique.

(**Key Words:** Live Composition, Urea Space, Carcass Composition, Specific Gravity, Rib Composition, Cattle.)

INTRODUCTION

Various methods which include the use of subjective visual appraisal, live animal measurements, ultrasonic probes, dilution techniques and ^{40}K for estimating body composition of the live animal have been developed. Each of these methods has given satisfactory results under particular conditions, yet each suffers from distinct disadvantages such as operating cost and time, accuracy and reliability of the method and the usefulness of applying such a technique under practical conditions.

Donovan and Brenner (1930) demonstrated that equilibrium was reached within 3 min in blood following intravenous injection of urea and within 15 min in cellular and free water of the human body. Other workers reported that the urea molecule equilibrates with body fluids within 1 hr in dogs (Painter, 1940) and within 12 to 15 min in cattle (Preston and Koch, 1973; Bennett *et al.*, 1975). Soberman *et al.* (1949) pointed out that test substances, acting as tracers for body composition estimates, should show an even and rapid distribution throughout the body water, should be nontoxic, not foreign to the body and not cause any physiological disturbances. Furthermore, tracer substances should be accurately and easily measured in either whole blood or plasma and they should not be selectively stored, secreted or metabolized. In studies with humans, San Pietro and Rittenberg (1953) reported that urea appeared to meet all the requirements of a satisfactory tracer, and urea space and deuterium oxide space were similar in size. In their study, urea was used as a marker to determine the dilution of the chemical in the water of the

[1] Departments of Animal Science.

[2] Scientific Paper No. 4972, College of Agriculture Research Center, Washington State University, Pullman.

Downloaded from jas.fass.org at Fagro on August 15, 2011

animal's body. Urea space may be defined as the volume of water with which urea equilibrates. If it is assumed that urea space is related to empty body water, then urea space measurements may be used as a predictor for estimating body composition in cattle. In 1973, Preston and Kock published data illustrating the significant relationships between urea space measurements and percentage of empty body fat and percentage of empty body water in cattle. The major purposes of this study were: (i) to determine the time at which to measure urea space after infusion to accurately estimate body composition, (ii) to determine the relationship between carcass specific gravity and rib composition, and (iii) to estimate body composition in live cattle using the urea infusion technique.

MATERIALS AND METHODS

Experimental Animals. One hundred and fifteen steers of crosses between British breed types (Hereford and Sussex) and dual purpose breed types (Simmental) from two separate groups, were used in this experiment. The first group consisted of 56 weanling calves with live weights ranging from 150 to 270 kg (mean of 210 kg). The second group was comprised of 59 older animals (approximately 20 months of age) with live weights ranging from 220 to 445 kg (mean 330 kg).

Eight weanling animals were randomly selected for slaughter at the commencement of the trial. The remaining 48 weanlings were randomly allotted to six sub-groups of eight animals each. Two weanling calves were lost during the experimental period (one died from peritonitis, the other from *Anaplasma marginale*), leaving a total of 46 animals for this group. Likewise, eight randomly selected yearlings were slaughtered at the commencement of the trial. The remaining 51 yearlings were randomly allotted to three sub-groups of eight animals each and three sub-groups of nine animals each.

Feeding and Feed. All animals were allowed 6 m^2 pen space per head during the feeding period. All groups were fed a commercially available diet *ad libitum* (Meadows "Complete Steer Fattening Concentrate")[3]. Daily feed intake was recorded for each group.

Slaughter Procedure. Eight animals from the weanling group were slaughtered 56 days after the initial group, and thereafter groups of eight animals were slaughtered every 14 days, with the final group being slaughtered after 126 days of feeding. Eight animals of the yearling group were slaughtered 28 days after the initial slaughter date, and thereafter groups were slaughtered every 14 days, with the final group being slaughtered after 98 days of feeding.

The weight of each animal was determined on each of the last 2 days prior to slaughter and the average weight was used as final live weight. Weights were determined after withdrawal of feed and water for 12 hours.

Urea Space Measurements. Urea space measurements for each animal were determined 1 day prior to slaughter of each group using a technique described by Preston and Kock (1973). In brief, a polyethylene catheter (Clay Adams, PE 200) was inserted into the jugular vein through a No. 12 needle. The needle was then removed and the catheter closed with a stopper. A solution containing 20% urea dissolved in .9% saline was administered through the catheter over a 2-min period. The volume injected was accurately calculated to provide 130 mg urea/kg live weight. The catheter was flushed with 5 ml saline and immediately thereafter with a heparin solution (100 units/ml saline) to prevent clotting between samplings. Blood samples (heparinized) were collected through the catheter prior to infusion and at 6, 9, 12, 15 and 18 min after the mean infusion time.

The blood was centrifuged and the plasma was frozen for subsequent urea analysis. Methods described by Fawcett and Scott (1960) and Searcy *et al.* (1961) were used to determine plasma urea nitrogen.

The following formula was used to calculate urea space as a percentage of live weight: Urea space (%) = Volume infused[a] × concentration of solution[b] ÷ PUN[c] ÷ live weight in kg, where a = volume of urea infused (ml); b = concentration of urea solution infused (mg urea-N/100 ml) and c = difference in plasma urea nitrogen taken from blood sample prior to and after urea infusion (mg urea-N/100 ml).

Carcass Measurements. Animals were slaughtered by conventional means at the local municipal abattoir and the carcasses were split into halves. After a chilling period of approximately 24 hr, carcass weights and specific gravity were determined according to methods described by Garrett and Hinman (1969). The right sides of the carcasses were quartered between the 10th and 11th ribs according to

Downloaded from jas.fass.org at Fagro on August 15, 2011

customary South African trade procedures. The weight of each quarter was then determined in air and again under water using a balance positioned over a cylindrical tank (diameter, 120 cm; height 200 cm). Temperature of the water was lowered to approximately 4 C by adding ice. Both the temperature of the carcasses and of the water were accurately determined to correct under water weights to 4 C based on density changes of water with varying temperature.

Sampling Procedures. The eighth to 10th rib section of the fore quarter of the right side of each carcass was removed, weighed and placed in plastic bags. Naudé (1972) determined with a high degree of accuracy the relationships between the composition of this cut (eighth to 10th rib) and whole carcass composition, the correlation coefficients for percentage muscle and fat being .95 and .97, respectively. Six hours later, soft tissue from the rib was completely dissected from the bone. Bone and soft tissue weights were separately recorded for each rib. The soft tissue which included muscle, fat and connective tissue was thoroughly ground, placed in a plastic bag and frozen for subsequent analyses.

Analyses of Rib. Procedures for the analysis of the soft tissue (bone was not analyzed) were similar to those described by Morris and Moir (1963). After thawing and thoroughly mixing each sample, duplicate 100 g samples were placed in previously dried 250 ml beakers and dried at 95 to 100 C for 48 hr, by which time a constant weight had been attained. The loss in weight on drying was considered to be water. The sample-containing beakers were rewarmed in an oven to approximately 60 C, placed in a hood and the contents immediately covered with petroleum ether. After approximately 15 min the ether was decanted. This procedure was repeated three times on each sample, after which excess ether was evaporated at 95 to 100 C. The loss in weight due to petroleum ether extraction provided a preliminary fat value. The residue was ground through a Wiley mill using a 1 mm screen. Duplicate samples of the powdered material were used to determine dry matter, residual fat, nitrogen (Kjeldahl procedure) and ash, using AOAC (1965) procedures. The composition of the soft tissue from each rib was then calculated using the appropriate weight and analytical data.

RESULTS

The mean cold carcass weights of the weanling and yearling cattle used in the experiment, together with standard errors (SE) and ranges, are given in table 1. Data relating to the chemical composition of the rib cuts, carcass specific gravity estimates and the results of the urea infusions which were carried out, are also included.

The results in table 1 indicate that the precentage of urea space at various times after urea infusion of the weanling group gradually increased in mean value from 48.0% at 6 min to 59.2% at 18 min following urea infusion. The yearling group of cattle shows a similar increase in mean percentage urea space with time, although the values are somewhat lower than in the weanling group; mean values ranged from 44.0% at 6 min to 57.3% at 18 min after urea infusion. This increase in urea space with time after urea infusion indicates further dilution perhaps in the rumen water and probably elimination by the kidney. The range of percentage urea space at various times after urea infusion also shows a gradual increase with time for both the weanling and yearling group of cattle.

Optimum Sampling Time after Infusion

Effects of Age of Animal. The results in table 2 show the correlation coefficients between urea space (as a percentage of live weight at various times following urea infusion) and the chemical constituents in the rib of weanling and yearling cattle. The correlation coefficient between urea space and the percentage of water in the rib was highest at 12 min after urea infusion, i.e., .91 and .76 respectively, for weanling and yearling cattle, and .84 overall. Similar relationships were observed with percentage of protein and fat in the rib.

The data presented in table 3 give the relationships between urea space and the carcass specific gravity. Again, the correlation coefficient between urea space and carcass specific gravity was highest when calculated from the 12-min post-infusion data. This holds for both weanlings and yearlings. Although the numerical values of the correlation coefficient are not as high (.77, .71 and .68, respectively, for the weanling, yearling and overall groups), findings support the results obtained with the various rib constituents.

Effect of Cold Carcass Weight. The mean

Downloaded from jas.fass.org at Fagro on August 15, 2011

TABLE 1. MEANS, STANDARD ERRORS AND RANGES OF COLD CARCASS WEIGHT, RIB COMPOSITION, CARCASS SPECIFIC GRAVITY AND UREA SPACE[a] AT VARIOUS TIMES AFTER UREA INFUSION FOR WEANLING AND YEARLING CATTLE

Item	Weanlings			Yearlings			Overall		
	Mean	± SE	Range	Mean	± SE	Range	Mean	± SE	Range
Cold carcass weight (kg)	173.0	4.64	105.0 - 261.5	227.7	7.01	138.0 - 349.0	201.5	4.95	105.0 - 349.0
Rib soft tissue composition:									
Water, %	61.8	.88	43.0 - 72.0	59.4	.86	42.5 - 69.0	60.5	.62	42.5 - 72.0
Protein, %	17.4	.13	14.3 - 19.0	17.2	.16	14.5 - 19.6	17.3	.10	14.3 - 19.6
Fat, %	19.8	1.00	8.0 - 41.9	22.4	1.04	10.7 - 42.5	21.5	.73	8.0 - 42.5
Ash, %	.8	.02	.6 - 1.2	.8	.02	.6 - 1.2	.8	.01	.6 - 1.2
100 (S.G.[b] - 1)	7.42	.08	5.65 - 8.50	7.47	.12	5.50 - 9.27	7.45	.07	5.50 - 9.27
Urea space (%) at various times after urea infusion (min)									
6	48.0	.62	39.7 - 55.3	44.0	.55	34.0 - 52.2	45.9	.45	34.0 - 55.3
9	51.7	.62	42.8 - 61.1	48.5	.53	38.0 - 56.1	50.0	.43	38.0 - 61.1
12	53.8	.58	44.4 - 62.7	51.7	.51	42.6 - 59.2	52.7	.39	42.6 - 62.7
15	56.4	.59	46.0 - 63.8	54.5	.51	44.7 - 62.8	55.4	.39	44.7 - 63.8
18	59.2	.66	48.9 - 68.7	57.3	.56	46.3 - 69.1	58.2	.43	46.3 - 69.1
No. of animals	54			59			113		

[a]Percent of live weight.

[b]S.G. = Specific gravity.

Downloaded from jas.fass.org at Fagro on August 15, 2011

TABLE 2. CORRELATIONS BETWEEN UREA SPACE[a] AND THE CHEMICAL CONSTITUENTS IN THE RIB OF WEANLING AND YEARLING CATTLE

Time after urea infusion (min)	Weanlings				Yearlings				Overall			
	Water	Protein	Fat	Ash	Water	Protein	Fat	Ash	Water	Protein	Fat	Ash
6	.82	.77	-.83	.55	.62	.52	-.60	.42	.72	.60	-.71	.46
9	.86	.79	-.87	.58	.68	.57	-.67	.42	.77	.64	-.76	.50
12	.91	.80	-.91	.64	.76	.69	-.76	.52	.84	.73	-.84	.58
15	.86	.76	-.86	.60	.72	.63	-.71	.44	.80	.67	-.79	.52
18	.80	.70	-.81	.60	.68	.60	-.68	.40	.75	.64	-.75	.51

[a]Percent of live weight at various times after urea infusion.

cold carcass weight for all the carcasses in the experiment was 201.5 kilograms. A total of 61 carcasses were below and 52 were above the mean cold carcass weight. The cold carcass weight of these two groups averaged 163 kg and 246 kg, respectively (table 4). The highest correlation coefficient between urea space and rib fat percentage was at 12 min following urea infusion for both light and heavy carcass groups (table 5). For the light weight carcass group this correlation coefficient was -.71 and for the heavy carcass group -.82.

When urea space was correlated with carcass specific gravity the results presented in table 6 clearly show a high correlation (r = .78) at 12 min after urea infusion, but only for the heavy carcass group. The correlation for the lighter carcass group (r = .36) is much less satisfactory.

Effect of Fat Content of the Rib. The animals were also divided into thin and fat cattle (table 4) by using the overall mean of 21.5% fat in the rib cut as the dividing point. Division of animals into thin and fat categories did not bring about a pronounced change, from grouping according to cold carcass weight.

The results presented in table 5 indicate high correlations within both thin and fat cattle between urea space and rib fat percentage. Best results were obtained at 12 min after urea infusion, giving correlation coefficients of -.67 for thin and -.75 for fat cattle, respectively.

The relationship between urea space and carcass specific gravity was satisfactory for fat cattle, but not so for thin cattle. The low correlations for thin cattle support previous findings obtained with the light weight carcass group (table 6).

It is clear that urea space measurements calculated from plasma samples drawn 12 min after urea infusion show the highest correlation coefficients between urea space and rib fat percentage regardless of whether the animals were grouped according to age, cold carcass weight or fatness.

Similarly, urea space measurements estimated from plasma samples taken 12 min after urea infusion are strongly correlated with carcass specific gravity estimates (table 6), at least for carcasses obtained from weanlings, yearlings, cattle with heavy carcasses, and fat cattle. The correlation coefficients are numerically smaller for cattle with a light carcass weight and for thin cattle.

Definition of Urea Space at 12 Min after Infusion. Results presented to this point

Downloaded from jas.fass.org at Fagro on August 15, 2011

TABLE 3. CORRELATIONS BETWEEN UREA SPACE[a] AND THE CARCASS SPECIFIC GRAVITY OF WEANLING AND YEARLING CATTLE

Time after urea infusion (min)	Weanlings	Yearlings	Overall
6	.73	.55	.53
9	.74	.62	.60
12	.77	.71	.68
15	.73	.68	.65
18	.69	.66	.63

[a]Percent of live weight at various times after urea infusion.

indicate that urea space measurements showed the highest correlation coefficients with percentage fat in the rib and carcass specific gravity measurements from plasma samples drawn 12 min after the mean urea infusion time. Estimates of urea space were best made from plasma samples taken at the 12-min post-infusion time. As a matter of convenience the abbreviation US-12 will be used henceforth to designate urea space determined from plasma samples taken at this time.

Relationship between the Fat Percentage of the Rib and Urea Space. From the results obtained in this study, the least-squares regression line of percentage fat in the rib on urea space was computed from 113 animals as: Rib fat % = 102.2 - 1.5368 (% US-12), with r = -.84. A multiple linear regression analysis including live weight and urea space did not significantly increase the correlation coefficient over that obtained with urea space alone (-.85 *vs* -.84).

Relationships between the Constituents of the Rib and Carcass Specific Gravity. Correlations between rib composition and carcass specific gravity based on age, cold carcass weight and fatness of cattle are presented in table 7. It is evident from the results that light carcasses and those classified as thin, generally show low correlations between carcass specific gravity and the constituents of the rib. Such correlations are higher for carcasses from yearlings, for heavy carcasses and for carcasses from fat cattle.

Relationships between Rib Composition, Carcass Specific Gravity and Urea Space Measurements. The data recorded in table 8 give the correlation coefficients between fat percentage in the rib, carcass specific gravity and urea space after dividing the carcasses into four groups on the basis of increasing cold carcass weight.

It appears from the results presented in table 8 that: (a) the correlations between percentage fat in the rib and US-12 were high for all groups, (b) the correlations between carcass specific gravity *vs* US-12 or percentage fat in

TABLE 4. MEANS, STANDARD ERRORS AND RANGES OF COLD CARCASS WEIGHT AND FAT PERCENTAGE OF THE RIB IN LIGHT AND HEAVY CARCASSES, AND IN THIN AND FAT CATTLE

Item	Light	Heavy	Thin	Fat
No. of carcasses	61	52	60	53
Cold carcass weight (kg):				
Mean	163	246	174	232
SE	3.12	5.57	5.20	6.53
Range	105.0–201.5	201.6–349.0	105.0–288.0	150.0–349.0
Rib fat (%):				
Mean	16.9	26.1	15.3	27.7
SE	.67	.98	.44	.77
Range	8.0–33.4	11.0–42.5	8.0–21.1	21.5–42.5

Downloaded from jas.fass.org at Fagro on August 15, 2011

TABLE 5. CORRELATIONS BETWEEN UREA SPACE[a] AND FAT PERCENTAGE OF THE RIB ON A BASIS OF COLD CARCASS WEIGHT AND FATNESS OF CATTLE

Time after urea infusion (min)	Cold carcass weight		Fatness		Overall
	Light	Heavy	Thin	Fat	
6	-.51	-.61	-.55	-.57	-.71
9	-.64	-.74	-.60	-.65	-.76
12	-.71	-.82	-.67	-.75	-.84
15	-.67	-.76	-.63	-.70	-.79
18	-.61	-.74	-.60	-.65	-.75

[a]Percent of live weight at various times after urea infusion.

TABLE 6. CORRELATIONS BETWEEN UREA SPACE[a] AND CARCASS SPECIFIC GRAVITY ON A BASIS OF COLD CARCASS WEIGHT AND FATNESS OF CATTLE

Time after urea infusion (min)	Cold carcass weight		Fatness		Overall
	Light	Heavy	Thin	Fat	
6	.19	.57	.11	.46	.53
9	.28	.64	.19	.50	.60
12	.36	.78	.27	.61	.68
15	.37	.72	.25	.52	.65
18	.34	.71	.17	.47	.63

[a]Percent of live weight at various times after urea infusion.

the rib were high for the heavier, fatter carcasses but low for the lighter, thinner carcasses.

Relationships between the Chemical Components of the Rib. The results in table 9 indicate the relationships between the various chemical constituents of the rib for weanling and yearling cattle. The overall correlations between the percentage of water in the rib and its content of protein or of fat were high. In general, these relationships were somewhat stronger for the yearling than for the weanling group of cattle.

Discussion

Urea space measurements calculated from plasma samples drawn 12 min after urea infusion are best for estimating body composition, based on correlation coefficients with rib composition and carcass specific gravity, compared to other times following urea infusion.

TABLE 7. CORRELATIONS BETWEEN THE CONSTITUENTS OF THE RIB AND CARCASS SPECIFIC GRAVITY ON A BASIS OF AGE, COLD CARCASS WEIGHT AND FATNESS OF CATTLE

Rib constituents, %	Age		Cold carcass weight		Fatness		Overall
	Weanlings	Yearlings	Light	Heavy	Thin	Fat	
Water	.80	.90	.63	.87	.45	.87	.84
Protein	.64	.80	.54	.74	.34	.57	.75
Fat	-.80	-.90	-.65	-.87	-.48	-.87	-.84
Ash	.52	.63	.38	.63	.15	.54	.58

Downloaded from jas.fass.org at Fagro on August 15, 2011

TABLE 8. CORRELATION COEFFICIENTS BETWEEN PERCENTAGE FAT IN THE RIB, CARCASS SPECIFIC GRAVITY AND UREA SPACE IN FOUR GROUPS OF CARCASSES DIVIDED ACCORDING TO WEIGHT

	Group 1	Group 2	Group 3	Group 4
Variable	n[a] = 28 wt[b] = 142.5 kg RF[c] = 14.5% CSG[d] = 1.07881	n = 28 wt = 177.6 kg RF = 18.2% CSG = 1.07749	n = 29 wt = 210.8 kg RF = 24.5% CSG = 1.07233	n = 28 wt = 274.9 kg RF = 27.3% CSG = 1.06953
RF *vs* US-12[e]	-.80	-.79	-.77	-.81
CSG *vs* US-12	.24	.69	.84	.74
RF *vs* CSG	-.44	-.79	-.79	-.90

[a]n = number of carcasses.
[b]wt = mean carcass weight.
[c]RF = mean fat percentage in the rib.
[d]CSG = mean carcass specific gravity.
[e]US-12 = urea space at 12 min after urea infusion.

Figure 1 shows various "correlation pathways" between some of the compositional parameters involved between urea space and live animal composition. Considering that urea space gives consistently high correlations with rib soft tissue composition in thin as well as fatter cattle, urea space measurement in live cattle may be a good as well as practical estimator of carcass and live animal composition, although the direct correlation between urea space in live cattle and carcass or body composition remains to be measured.

The results of this study indicate that the specific gravity technique for estimating carcass composition is not as good with light weight carcasses and those with a low degree of fatness, compared to heavier, fatter carcasses, as indicated by the lower correlation with rib composition. Urea space appears to give a better estimate of body composition over an entire range of fat percentage than specific gravity and indicates that it may be a valid measure of live animal composition over a wide range of body fatness.

TABLE 9. CORRELATIONS BETWEEN CHEMICAL CONSTITUENTS IN THE RIB OF WEANLING AND YEARLING CATTLE

Variable X	Variable Y	Weanlings	Yearlings	Overall
Water	Protein	.82	.93	.87
Water	Ash	.71	.67	.69
Fat	Water	-.997	-.998	-.997
Fat	Protein	-.86	-.94	-.90

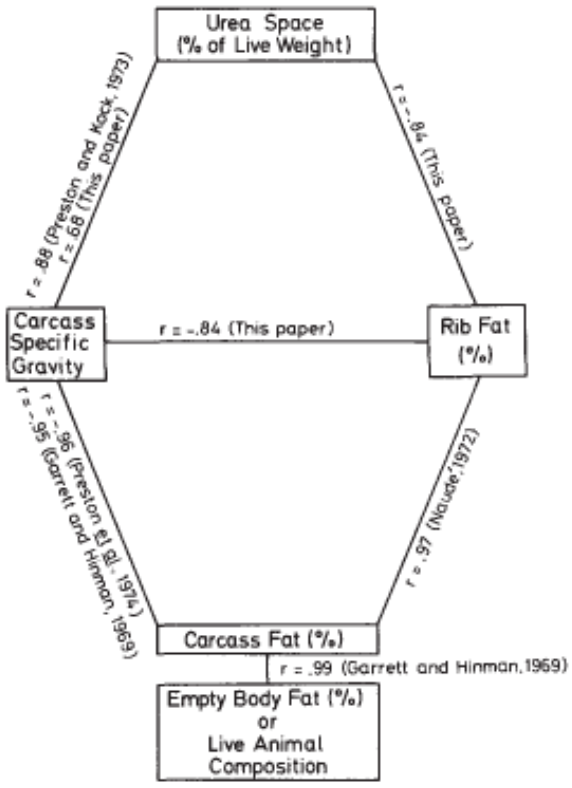

Figure 1. "Correlation pathways" from urea space to live animal composition.

Downloaded from jas.fass.org at Fagro on August 15, 2011

LITERATURE CITED

AOAC. 1965. Official Methods of Analysis (10th Ed.) Association of Official Agricultural Chemists. Washington, DC.

Bennett, G. L., L. A. Swiger and R. L. Preston. 1975. Predicting lean-fat composition from measures on live beef steers. Ohio Beef Day and Cattlemen's Roundup - 1975. Ohio Agr. Res. Dev. Center, Wooster, OH:19.

Donovan, H. and O. Brenner. 1930. The influence of the intravenous injection of urea on the exchange of substances between the blood and the tissues. Brit. J. Exp. Path. 11:419.

Fawcett, J. K. and J. E. Scott. 1960. A rapid and precise method for the determination of urea. J. Clin. Path. 13:156.

Garrett, W. N. and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. J. Anim. Sci. 28:1.

Morris, J. G. and K. W. Moir. 1963. Methods of determining the chemical composition of dead animals. *In* D. E. Tribe (Ed.) Carcass composition and appraisal of meat animals, p. 2–1 to 2–22, CSIRO, Australia.

Naudé, R. T. 1972. The determination of muscle, fat and bone in carcasses and cuts of young steers. S. African J. Anim. Sci. 2:35. (Eng. sum.).

Painter, Elizabeth E. 1940. Total body water in the dog. Amer. J. Physiol. 129:744.

Preston, R. L. and S. W. Kock. 1973. *In vivo* prediction of body composition in cattle from urea space measurements. Proc. Soc. Exp. Biol. and Med. 143:1057.

Preston, R. L., R. D. Vance, V. R. Cahill and S. W. Kock. 1974. Carcass specific gravity and carcass composition in cattle and the effect of bone proportionality on this relationship. J. Anim. Sci. 38:47.

San Pietro, A. and D. Rittenberg. 1953. A study of the rate of protein synthesis in humans. 1. Measurement of the urea pool and urea space. J. Biol. Chem. 201:445.

Searcy, R. L., G. S. Gough, J. L. Korotzer and L. M. Bergquist. 1961. Evaluation of a new technique for estimation of urea nitrogen in serum. Amer. J. Med. Tech. 27:255.

Soberman, R., B. B. Brodie, B. B. Levy, J. Axelrod, V. Hollander and J. M. Steele. 1949. The use of the antipyrine in the measurement of total body water in man. J. Biol. Chem. 179:31.

Downloaded from jas.fass.org at Fagro on August 15, 2011

Citations

This article has been cited by 1 HighWire-hosted articles:
http://jas.fass.org/content/48/2/319#otherarticles

Downloaded from jas.fass.org at Fagro on August 15, 2011