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PROCEEDINGS OF THE NUTRITION SOCIETY

ABSTRACTS OF COMMUNICATIONS

The Four Hundred and Eleventh Meeting of the Nutrition Society was held in the Agricultural and Food Science Centre, The Queen's University of Belfast, Newforge Lane on Wednesday and Thursday, 10/11 *April* 1985, *when the following papers were read:*

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Effects of a novel β-adrenoreceptor agonist (BRL 26830A) on young and adult Sprague–Dawley rats. By K. J. MCCRACKEN[1,2] and S. COWAN[1], [1]*Department of Agricultural and Food Chemistry, The Queen's University of Belfast, Newforge Lane, Belfast BT9 5PX* and [2]*Department of Agriculture for Northern Ireland*

Arch & Ainsworth (1983) reported that once-daily dosing with the β-adrenoreceptor agonist BRL 26830A caused a reduction in the body lipid content of genetically obese adult mice and rats but had little effect on their lean counterparts. Calculations indicate that heat production was increased by approximately 7% in the obese strains. Two experiments are now reported in which the effects of BRL 26830A (Beecham Pharmaceuticals, Epsom, Surrey) were studied on young male and adult female Sprague–Dawley rats.

In Expt 1, twenty male rats (initial weight 100 g) were allocated to one of four treatments (C, Control; CT, given 1 ml water by tube once daily; D, 60 mg BRL 26830A/kg diet; DT, 1 mg BRL 26830A by tube once daily) and offered a synthetic diet (crude protein (nitrogen × 6·25), 175 g/kg; fat, 100 g/kg; gross energy, 18·5 MJ/kg) for 24 d. In Expt 2, twelve adult female rats (mean initial weight 387 g) matched for litter and weight were allocated to treatment C or D and given the same diet for 21 d. Metabolizable energy (ME) intake was measured and energy retention (ER) was determined from carcass crude protein and fat gain. Heat production (HP) was calculated by difference. Room temperature in both experiments was 24°. The results were subjected to analysis of variance.

Treatment . . .	C	CT	D	DT	SE of a difference	Statistical significance ($P<$)
ME intake (kJ/kg $W^{0·75}$ per d)	1065	1079	1087	1095	22·5	NS
ER (kJ/kg $W^{0·75}$ per d)	287	294	238	278	21·2	NS
HP (kJ/kg $W^{0·75}$ per d)	778	785	850	817	15·8	0·01
Gross efficiency	0·27	0·27	0·22	0·26	0·016	0·05
IBAT (g/kg carcass)	2·46	2·59	2·43	2·43	0·296	NS
KID (g/kg carcass)	24·5	26·2	12·3	16·8	2·33	0·001

NS, not significant

The ME intake (850 kJ/kg body-weight $(W)^{0·75}$), ER (225 kJ/kg $W^{0·75}$) and HP (625 kJ/kg $W^{0·75}$) of the adult female rats were unaffected by the drug. In the young rats ME intake was unaffected by treatment, but ER of the D group was reduced by 18% (P=0·052) and HP was increased by 9% ($P<$0·01) compared with the controls. These effects were entirely due to decreased fat gain there being no treatment differences in carcass crude protein or weight gain. Gross efficiency (ER/ME) was significantly ($P<$0·05) reduced in the D group. The weight of interscapular brown adipose tissue (IBAT) was unaffected by treatment but kidney-fat (KID) weight was reduced by the drug ($P<$0·001).

The results confirm the lack of effect of the drug on lean, adult rats but provide unequivocal evidence of a thermogenic response in growing animals. Although the daily intake of the drug was similar in D and DT groups it would appear that the response was greater when the drug was incorporated in the diet.

Arch, J. R. S. & Ainsworth, A. T. (1983) *American Journal of Clinical Nutrition* **38**, 549–558.

Antigen absorption and immunological response in weanling rabbits given casein or ovalbumin. By J. R. NOTLEY and M. J. GIBNEY*, *Department of Nutrition, University of Southampton, Southampton SO9 5NH*

The antigenicity of a dietary protein depends partly on its molecular structure and partly on its access to peripheral lymph tissue. Accordingly, dietary proteins may vary in antigenicity as a result of varying numbers of antigenic determinants or its extent of macromolecular absorption. To determine the relative importance of these factors, we fed weanling rabbits *ad lib.* on milled stock diets, repelleted to contain 100 g of either casein or ovalbumin/kg. In the first experiment, circulating antibodies (IgG) to either ovalbumin or casein were measured at weaning or at 3 or 6 weeks post-weaning using a micro ELISA technique. The results are summarized in the Table:

Age post-weaning (weeks) . . .	Serum IgG (% reference anti-serum)					
	0		3		6	
	Mean	SE	Mean	SE	Mean	SE
Casein (*n* 5)	0·55	0·05	0·91	0·27	1·33	0·29*
Ovalbumin (*n* 5)	0·17	0·04	10·5	1·3*	47·4	21·7*

*Significantly different from week 0 ($P<0·05$).

In a second study, rabbits (*n* 5) were given similar diets, with 100 g of either casein or ovalbumin/kg. Circulating levels of casein or ovalbumin were measured by ELISA at weaning and at 1, 3, 5 and 14 d thereafter. The concentration of casein in serum showed a transient rise over the period of study (mean with SE): 5 (1), 59 (34), 102 (34), 1192 (961) and 597 (195) ng/ml for days 0, 1, 3, 5 and 14 respectively. None of these values differed significantly. In contrast, the levels of detectable ovalbumin showed a marked rise, the comparable values being (mean with SE): 22 (20), 8300 (5564), 17 135 (10 623), 13 324 (5756) and 46 (22·0) ng/ml. The maximum value, at day 3, was significantly greater than that at days 0 or 14 ($P<0·05$). No significant elevation in circulating IgG antibodies to either antigen was detected until day 14.

These results show that the immunological response to dietary antigen varies between antigen source. Whilst antigenicity may depend on molecular structure, the quantity of protein entering circulation is the primary immunogenic factor.

This work was funded by the Agricultural Research Council.

*Present address: Department of Clinical Medicine, Trinity College Medical School, St James' Hospital, Dublin 8, Irish Republic.

Effect of cafeteria-feeding on body composition of adult female Sprague–Dawley rats. By K. J. MCCRACKEN[1,2] and H. GILLIAN BARR[1], [1]*Department of Agricultural and Food Chemistry, The Queen's University of Belfast, Newforge Lane, Belfast BT9 5PX* and [2]*Department of Agriculture for Northern Ireland*

Increased food intake, weight gain and energy retention of female rats given a cafeteria diet were reported by Barr & McCracken (1984). The present paper describes the changes in body composition which occurred when Sprague–Dawley rats from three physiological states (U, unmated; N, non-lactating; L, lactating) were offered low-fat chow (C) or a cafeteria diet (CAF) for 42 d. The treatments before the experimental period were as described by Barr & McCracken (1984). The rats were aged approximately 180 d at the start of the feeding period.

Before weaning of the lactating group the rats were blocked within each physiological state and allocated to dietary treatment or slaughtered (S) (S and C, *n* 5; CAF *n* 10 animals from each state). At slaughter, interscapular brown adipose tissue (IBAT), kidney depot fat (KID) and extra-uterine depot fat (EXT) were weighed and returned to the carcass before analysis for protein, fat and ash. The results were analysed as 3×3 factorial. The LS group was considerably different in composition from the US and NS groups and the values are shown in parentheses in the Table. However, the statistics relate to the main effects since, only in the case of body water was the interaction statistically significant.

	S				SED	Statistical significance
	U/N	(L)	C	CAF	(*n* 15)	(*P*<)
Carcass weight (g)	335	(319)	371	473	12·9	0·001
Protein (g)	57·3	(57·2)	62·1	66·2	1·35	0·001
Fat (g)	64·3	(23·7)	83·8	176·3	10·7	0·001
Water (g)	199	(225)	206	212	3·8	0·01
IBAT (g)	0·54	(0·41)	0·75	1·24	0·086	0·001
KID (g)	11·6	(2·7)	15·2	28·0	1·77	0·001
EXT (g)	11·0	(4·1)	14·1	24·8	1·83	0·001
Body energy (MJ)	3·9	(2·3)	4·8	8·5	0·52	0·001

Carcass protein weight increased during the 42-d period. The major change in body water was a return to normal levels in the rats which had lactated but there was also a significant ($P<0·05$) increase in body water of the U and N groups given the cafeteria diet. The changes in weight of IBAT, KID and EXT in C and CAF rats were in proportion to each other and to total fat. Cafeteria-feeding induced high rates of weight gain (3·3 g/d), mainly due to fat deposition, and caused large increases in body energy and energy content per unit body-weight compared with C and S rats.

The results demonstrate that rats which have lactated rapidly replenish body fat reserves when allowed *ad lib.* access to a low-fat diet and that, irrespective of previous physiological state, offering a cafeteria diet induces gross obesity in normal female rats. They further illustrate the dangers inherent in estimating changes in body energy status from body-weight change.

Barr, H. G. & McCracken, K. J. (1984). *Proceedings of the Nutrition Society* **43**, 72A.

Changes in chemical composition of piglets weaned at 14 d of age. By K. J. McCracken, *Department of Agricultural and Food Chemistry, The Queen's University of Belfast, Newforge Lane, Belfast BT9 5PX* and *Department of Agriculture for Northern Ireland*

Whittemore *et al.* (1981) studied the changes in body composition of pigs weaned at 21 d of age and concluded that lipid catabolism to support anabolism of essential body tissues commenced when weight gains fell below 193 g/d. The associated estimate of 56 g lipid catabolism/d for no weight change is higher than would be predicted from consideration of the energy metabolism of the weaned pig.

In a study of digestive development of early-weaned pigs (McCracken, 1984), eight pigs were slaughtered at 14 d and thirty-two (eight suckled and twenty-four weaned) were slaughtered at 21 d of age. Weight gains ranged from 0 to 390 g/d. In subsequent work the carcasses were analysed for crude protein (nitrogen × 6·25), fat and ash. Energy content was calculated from protein and fat. Metabolizable energy (ME) intake was determined for the twenty-four weaned pigs.

The mean ME intake and weight gain of the weaned pigs were 2·5 MJ/d and 125 g/d respectively whereas the mean weight gain of the suckled pigs was 280 g/d. Linear regressions of the gain in protein (Pr), fat (F), water (W) and energy (E) and of ME intake against empty body-weight gain (EBW) yielded the following equations (SE in parentheses):

Pr (g)	= 0·149 EBW (0·0078)	− 0·167 (1·485)		r, 0·96
F (g)	= 0·186 EBW (0·0206)	− 14·2 (2·91)		r, 0·86
W (g)	= 0·607 EBW (0·0254)	+ 20·1 (4·82)		r, 0·98
E (kJ)	= 11·5 EBW (0·084)	− 710 (159)		r, 0·93
ME (kJ)	= 10·6 EBW (1·06)	+ 1172 (150)		r, 0·91

The relation between protein gain and EBW is similar to that reported by Whittemore *et al.* (1981) but that for fat gain is considerably different. The present equations indicate that net lipid catabolism did not occur until the daily gain fell below 76 g/d, corresponding to a mean ME intake of 2 MJ/d (0·640 MJ/kg body-weight$^{0·75}$ per d). Zero energy retention was associated with the retention of approximately 9 g crude protein/d and 60 g body-weight gain/d. The estimates of fat loss and water gain associated with zero body-weight gain are considerably lower than those of Whittemore *et al.* (1981).

McCracken, K. J. (1984). *Proceedings of the Nutrition Society* **43**, 109A.
Whittemore, C. T., Taylor, H. M., Henderson, R., Wood, J. D. & Brock, D. C. (1981). *Animal Production* **32**, 203–210.

Estimation of body fat by nuclear magnetic resonance imaging. By M. F. FULLER, *Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB* and M. A. FOSTER and J. M. S. HUTCHISON, *Department of Biomedical Physics and Bioengineering, University of Aberdeen, Foresterhill, Aberdeen AB9 2ZD*

Nuclear magnetic resonance (NMR) imaging has been developed primarily for its value in clinical practice. Only recently has its potential in the estimation of body composition in vivo been explored. The Aberdeen MkII imager, operating at 3·4 MHz (0·08 Tesla) has been used to examine the distribution of fat and muscle in a series of transaxial images of living pigs. One particular pulse sequence displaying an inversion recovery image has been found to give excellent contrast (6:1) between fat and muscle (Foster *et al.* 1984). It is not clear, however, how closely the interfaces between muscle and fat observed in the NMR images correspond to those in the living animal. This question was examined by a direct comparison in three sections taken from one of the pigs. The pig was anaesthetized during the imaging process and was afterwards killed. The body was frozen and sliced in the same transaxial planes as the images. Both cut faces at each slice were photographed with a size marker and the areas of the slices occupied by subcutaneous fat were estimated with a computer-linked planimeter. The NMR images, displayed on a monitor screen, were also photographed and the areas corresponding to subcutaneous fat were likewise estimated by planimetry. Replicated estimates of the area of fat made on the same image with independent interpretation of the interface were highly reproducible (usually within 0·2%). The mean values from each of the three locations are given in the Table.

Area of subcutaneous fat (m^2) in three transaxial sections

	Anatomical section	NMR image
Thoracic	0·0145	0·0141
Lumbar	0·0118	0·0121
Sacral	0·0105	0·0109

The results do not suggest a consistent bias. The observed discrepancies could have been caused by failure to take body sections and NMR images in exactly the same planes, or by movement of the tissues between imaging and freezing. The subjective interpretation of interfaces is also a potential source of error and the possibility of replacing this with computer image analysis is being examined.

Foster, M. A., Hutchison, J. M. S., Mallard, J. R. & Fuller, M. F. (1984). *Magnetic Resonance Imaging* **2**, 187–192.

Preliminary experiments to assess the suitability of whole-body neutron activation for body composition analysis in 70 kg pigs. By T. PRESTON[1], M. F. FULLER[2], B. W. EAST[1] and I. BRUCE[2], [1]*Scottish Universities Research and Reactor Centre, East Kilbride, Glasgow* and [2]*Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB*

In vivo neutron activation analysis (NAA) has proven to be a powerful method of whole-body elemental measurement in the clinical sciences for over 15 years (Chettle & Fremlin, 1984). Methods in routine use at different centres permit measurement of suitable gamma photons produced by neutron irradiation in hydrogen, nitrogen, oxygen, sodium, phosphorus, chlorine and calcium and naturally-radioactive potassium (^{40}K). Although no single NAA facility measures all of these elements at present, the East Kilbride apparatus routinely measures seven elements (the above minus H; Williams *et al.* 1978) with typical repeatabilities of (SD) 2–4%.

The adaptation of this technique to measure large animals of agricultural importance would seem a logical development. Initial calibration experiments used crudely constructed polyethylene bottle 'phantoms' filled with elemental solutions of known composition. NAA results from carcasses of pigs weighing 60–70 kg, calculated using sensitivity factors derived from these phantoms, showed similar repeatabilities compared with human measurements (SD: N 3·5%, O 4·9%, Na 2·4%, P 2·2%, Cl 2·9%, K 1·8%, Ca 2·9%). A large part of the uncertainty in these analyses were predicted by counting statistics. Accuracy, assessed by conventional chemical analysis of tissue homogenates, showed variable discrepancy which could be attributed to poor phantom design. Further experiments to compare NAA measurements (calibrated by chemical analyses) with chemical analyses of carcasses not used for calibration are in progress.

Elemental data can be used to calculate the major body compartments (protein, mineral, water, fat), which are of increasing agricultural importance. Problems associated with whole-body NAA include uneven sensitivity response, radiation dose and equipment costs. However, development of more modest apparatus specifically designed for agricultural use may well be possible. Proposed agricultural applications of in vivo NAA include production experiments, breeding studies and carcass quality prediction.

The authors wish to acknowledge the MRC and the AFRC for financial support.

Chettle, D. R. & Fremlin, J. H. (1984). *Physics in Medicine and Biology* **29**(9), 1011–1043.
Williams, E. D., Boddy, K., Harvey, I. & Haywood, J. K. (1978). *Physics in Medicine and Biology* **23**(3), 405–415.

Effect of zinc supplementation on the composition of newly synthesized tissue in children recovering from malnutrition. By B. E. GOLDEN and M. H. N. GOLDEN, *Tropical Metabolism Research Unit, University of the West Indies, Kingston 7, Jamaica*

We demonstrated previously that children recovering from malnutrition have a high energy cost of tissue deposition, which decreases with zinc supplementation (Golden & Golden, 1981). These results suggested that the low-Zn content/availability from the high-energy diet used to treat severe malnutrition limited lean tissue synthesis but permitted energy-rich adipose tissue synthesis. Lean tissue has over four times the water and Zn concentration of adipose tissue.

To test directly the resultant hypothesis that Zn is limiting for lean tissue synthesis, total body water (TBW) was measured, using ^3H_2O dilution, in eleven oedema-free children three times during recovery from severe malnutrition. The children were given, *ad lib.*, a high-energy (5·9 MJ/l) soya-bean-based formula containing either 52 μmol Zn/l (low-Zn group, *n* 4), 126 μmol Zn/l (moderate-Zn group, *n* 4) or 196 μmol Zn/l (high-Zn group, *n* 3). The formula contained 1·33 mmol phytate/l.

For all children, TBW decreased (mean and SD) from 700 (50) g/kg body-weight during early recovery (64 (6)% weight-for-height) to 600 (60) g/kg body-weight during late recovery (93 (4)% weight-for-height).

There was a positive linear correlation between TBW and body-weight. The slope of the regression line was different for the three Zn groups. For 1 kg increase in body-weight, TBW increased by 312 g in the low-Zn group (*r* 0·97), 421 g in the moderate-Zn group (*r* 0·87) and 641 g in the high-Zn group (*r* 0·98). Similar values were obtained when the ratio, increment in TBW:increment in body-weight was calculated for each child. Thus, the water content of the newly synthesized tissue increased as the dietary Zn content, and intake, increased. As the rates of weight gain of the children were high (11·7 (SD 1·5) g/kg body-weight per d) relative to height gain (9 SD 6 mm/month)—and both were similar among the three Zn groups—it may be assumed that the water content of the new tissue reflects the relative proportion of lean to adipose tissue. Thus, as dietary Zn increased, lean tissue synthesis increased at the expense of adipose tissue synthesis. This supports the original hypothesis that Zn was a limiting nutrient for lean tissue synthesis.

It is concluded that the type of tissue laid down during recovery from severe malnutrition can be determined by the balance of nutrients in the diet.

This work was supported by the MRC (BEG) and the Wellcome Trust (MHNG).

Golden, M. H. N. & Golden B. E. (1981). *American Journal of Clinical Nutrition* **34**, 900–908.

Bile acid excretion in an animal model of colon cancer in rats treated with azoxymethane. By M. S. SIAN, A. P. SAVAGE, J. L. MATTHEWS and T. COOKE, *Professorial Department of Surgery, Charing Cross and Westminster Medical School, London W6 8RF*

Epidemiological, clinical and laboratory results suggest that bile acids are implicated in the pathogenesis of human colonic cancer (Hill, 1977). Several studies have shown that the rat is a good animal to use for the induction of intestinal tumours by chemical carcinogens such as azoxymethane and 1, 2-dimethylhydrazine (Nigro *et al.* 1973) and that small-bowel resection may enhance the susceptibility to neoplasia. In the present study, we have investigated the changes in the faecal bile acid excretion in an animal model of colon cancer in rats following small-bowel resection.

Eighty male Wistar rats were subjected to either jejunal transection or 20, 50 or 80% small-bowel resection. Colonic tumours were induced with azoxymethane (10 mg/kg) for 12 weeks. Faeces (24 h) were collected at 6 and 16 weeks and the bile acids were analysed by gas–liquid chromatography (Sian & Greenhalgh, 1984). The animals were killed at 26 weeks and the numbers and sites of tumours recorded.

Although the tumour yield rose from 0·44 (SEM 0·2)/rat in the transected group to 1·24 (SEM 0·24)/rat in the 50% resected group ($P<0·01$), bile acid excretion (mg/d, mean with SEM) fell from 10·4 (2) in the transected group to 6·2 (0·5 in both the 20 and 50% resected groups) and 4·2 (0·2) ($P<0·001$) in the 80% resected group at 6 weeks. The main bile acid, hyodeoxycholic acid, expressed as a percentage of total faecal bile acids, was 16·5 in the transected group compared with 42·0, 45·1 and 51·5 in the 20, 50 and 80% resected groups respectively.

The results of the present study suggest that enhanced neoplasia following small-bowel resection may not be associated with increased bile acid excretion and that the reduction in excretion may be due to functional adaptation of the colon.

Hill, M. J. (1977). *The Bile Acids*, vol. 3, pp. 190–192. New York: Plenum Press.
Nigro, N. D., Bhadrachari, N. & Chomchai, C. (1973). *Diseases of the Colon and Rectum* **16**(6), 438–443.
Sian, M. S. & Greenhalgh, R. M. (1984). *Proceedings of the Nutrition Society* **43**, 126A.

The effect of feeding cholesterol with polyunsaturated or saturated fats on cholesterol homeostasis in the rat. By J. J. STRAIN and KATHY SHERRY, *Department of Biology, University of Ulster at Jordanstown, Shore Road, Newtownabbey, Co. Antrim BT37 0QB*

Recent studies in the rat have demonstrated the importance of changes in tissue cholesterol content during the measurement of whole body cholesterol synthesis by sterol balance methods (McNamara *et al.* 1982). In the present study the rate of whole body cholesterol synthesis was measured in male albino Wistar rats (n 5) given the following synthetic diets which varied in their lipid contents (g/kg diet): diet A, 70 maize oil; diet B, 220 maize oil; diet C, 210 maize oil and 10 cholesterol; diet D, 210 coconut oil and 10 cholesterol. The individually caged weanling rats were given the diets for 4 weeks. During the final 10 d, faeces were collected for analysis of neutral and acid sterols (enzymic and gas chromatography–mass spectrometry methods). Cholesterol levels of carcass, liver, blood and contents-free digestive tract of each rat were obtained by enzymic analysis.

Sterol balance (mg/kg body-weight per d)

Diet . . .	A		B		C		D	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Faecal neutral sterols	38·8	9·82	47·7	9·83	339·6	18·28	375·2	11·35
Faecal acidic sterols	18·1	6·98	35·8	9·49	216·8	23·93	431·0	45·95
Net tissue cholesterol accumulation*	27·8	1·33	35·2	1·82	45·1	1·98	42·6	1·67
Dietary cholesterol intake					600·9	14·43	637·5	14·02
Cholesterol synthesis†	84·7	10·92	118·7	12·95	0·6	34·56	211·2	40·78

*Change in body-weight × carcass cholesterol concentration.
†Total sterol excretion + net tissue cholesterol accumulation − dietary cholesterol intake.

Dietary cholesterol supplementation gave significant ($P<0·001$) increases in faecal neutral and acid sterol excretions and significant ($P<0·01$) increases in net tissue cholesterol accumulation. There was a marked decrease in daily synthesis of cholesterol by the rats consuming the polyunsaturated fat (diet C) but not by the rats consuming the saturated fat (diet D). The latter group also had significantly ($P<0·01$) higher acid sterol excretion rates than rats given diet C. These differences in response to feeding cholesterol along with saturated fat or polyunsaturated fat were reflected in differences in plasma lipoprotein profiles (Strain *et al.* 1984).

The higher concentrations of cholesterol and triglycerides in specific plasma lipoprotein fractions of the rats given the saturated fat suggest that there are changes in lipid transport from the intestine and lipoprotein metabolism when this fat is consumed with cholesterol. These changes may affect tissue cholesterol biosynthesis and accumulation.

McNamara, D. J., Proia, A. & Edwards, K. O. G. (1982). *Biochimica et Biophysica Acta* **711**, 252–260.
Strain J. J., Sherry, K., Toner, D. P. & Owens, J. J. (1984). *16th Meeting of the Federation of European Biochemical Societies* (Moscow), p. 204.

Effects of isoenergetic concentrate and roughage diets on lipogenic enzyme activities in sheep adipose tissue. By M. E. BARKER, *Department of Agricultural and Food Chemistry, The Queen's University of Belfast, Newforge Lane, Belfast BT9 5PX* and J. PEARCE, *Department of Agriculture for Northern Ireland*

It is known that the plane of nutrition can modify the metabolism of ruminant adipose tissue (see Vernon, 1981) with lipogenesis being positively correlated with energy intake. It has also been shown that feeding concentrate rations, as compared with roughage diets, results in increases in lipogenesis in sheep adipose tissue and liver (Ballard *et al.* 1972). Vernon (1981) commented that in some experiments these effects could be due to differences in energy intake. The present study was undertaken to examine the effects of feeding isoenergetic, high-concentrate and roughage diets on lipogenic enzyme activities in subcutaneous (S/C), mesenteric (M) and perirenal (P) adipose tissue in sheep.

Two experiments were conducted using, in each, six wether sheep divided into two groups of three animals. In Expt 1 the sheep (mean body-weight 61 kg, age 29 months) received either flaked maize + pelleted ground dried grass or pelleted ground dried grass alone, to provide 11·96 MJ/d, and in Expt 2 the sheep (mean body-weight 61·5 kg, age 33 months) received flaked maize + hay or hay alone to provide 11·9 MJ/d. After 3 weeks on these diets the animals were killed, tissue cell-free extracts were prepared and assayed for the fatty acid synthetase [FAS] system, glucose-6-phosphate dehydrogenase [G6PDH], phosphogluconate dehydrogenase [PGDH], malate dehydrogenase (decarboxylating) ($NADP^+$) [MD] and isocitrate dehydrogenase ($NADP^+$) [ICDH].

In both experiments the specific activities (nmol/mg protein per min) of all the enzymes except ICDH were substantially greater in extracts from the concentrate-fed animals. For FAS and G6PDH in Expt 1 and G6PDH and MD in Expt 2 the differences were statistically significant ($P<0.05$). There were no apparent differences in the enzymic responses of the three different adipose tissue depots to concentrate feeding.

Diet . . .		High concentrate			Roughage			
Tissue . . .		S/C	P	M	S/C	P	M	SEM
FAS	Expt 1	23·7	21·5	19·9	15·0	14·4	9·3	2·33
	Expt 2	10·8	7·9	7·8	1·7	0·3	0·3	2·22
G6PDH	Expt 1	63·3	60·3	52·0	34·6	40·4	22·3	4·88
	Expt 2	47·5	50·2	53·9	13·9	14·0	17·6	8·80

The differences in enzyme activity between Expts 1 and 2 were probably due to season. Expt 1 was done in October and Expt 2 in February. The results indicate that the provision of dietary cereal leads to an increase in lipogenic enzyme activities in the adipose tissue of animals receiving isoenergetic concentrate or roughage rations; this could be due to the increased availability of α-linked glucose polymer in the duodenum of concentrate-fed sheep.

Ballard, F. J., Filsell, O. H. & Jarrett, I. G. (1972). *Biochemical Journal* **126**, 193–200.
Vernon, R. G. (1981). In *Lipid Metabolism in Ruminant Animals*, pp. 279–362 [W. W. Christie, editor]. Oxford: Pergamon Press.

Hepatic denervation alters insulin secretory response to propionate in sheep. By M. H. ANIL, J. M. FORBES and J. FOX, *Department of Animal Physiology and Nutrition, University of Leeds, Leeds LS2 9JT*

Endocrine pancreatic function is controlled by the autonomic nerves with stimulatory and inhibitory signals transmitted by the splanchnic and vagus nerves. As well as glucose, propionate has also been shown to be an insulin secretagogue in ruminants (Manns & Boda, 1967) and we have demonstrated this in preliminary experiments. While we were investigating the effects of selective denervation on food intake we also looked at the changes in insulin secretion and the response to propionate administration.

Sheep, fed *ad lib.*, received 1·2 mmol sodium propionate/min for 3 h into the hepatic portal vein after bilateral splanchnotomy and later following total hepatic denervation which included hepatic vagotomy. Blood samples were taken from the jugular vein at 30-min intervals and analysed for immunoreactive insulin.

Plasma insulin levels were not affected by propionate following splanchnotomy but increased at 60 and 90 min after the start of propionate infusion following total hepatic denervations (Table). There was no effect on food intake by propionate which depresses feeding in the intact animal (Anil & Forbes, 1984).

Immunoreactive insulin (ng/ml) following selective denervations

(Mean values with their standard errors for six to ten observations)

Time relative to start of infusion (min)	Splanchnotomy				Total hepatic denervation			
	Saline		Propionate		Saline		Propionate	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
−30	2·0	0·5	1·6	0·3	1·5	0·3	1·9	0·3
+30	1·9	0·3	2·3	0·6	1·5	0·2	2·6	0·8
+60	2·4	0·4	2·3	0·4	1·7	0·2	2·7*	0·3
+90	2·2	0·4	2·0	0·3	1·5	0·1	2·5*	0·3
+120	1·9	0·3	1·8	0·3	1·9	0·2	2·3	0·2
+150	2·5	0·4	2·0	0·4	2·3	0·2	1·8	0·1
+180	2·2	0·4	2·0	0·5	1·7	0·1	1·7	0·2
+210	2·2	0·4	1·6	0·3	1·7	0·2	1·6	0·3
+240	2·0	0·4	1·4	0·2	1·7	0·3	2·2	0·4

Significance of difference (Student's *t* test): *$P<0·05$.

The results indicate that there may be an increased sensitivity to propionate after hepatic vagotomy, as has been shown in other species with glucose (Campfield *et al.* 1983), because of the diminished stimulatory signal from the vagus.

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The effect of oestradiol implantation on the response to fishmeal in calves offered silage. By M. GILL[1], D. E. BEEVER[1], P. J. BUTTERY[2] and R. D. BAKER[1], [1]*The Grassland Research Institute, Hurley, Maidenhead, Berkshire* and [2]*Department of Applied Biochemistry and Food Science, School of Agriculture, University of Nottingham, Sutton Bonington, Loughborough LE12 5RD*

Supplementing silage with fishmeal has shown increased intake and live-weight gain in young growing calves (England & Gill, 1985). However, the magnitude of the response is variable and the mechanisms involved not clearly understood. The aim of the present experiment was to determine how the response to increasing levels of fishmeal is modified in hormone-implanted animals.

Thirty-six Friesian steers (initially 3 months of age and weighing 119 kg) were offered grass silage *ad lib.* alone (C) or supplemented with 50, 100 or 150 g fishmeal (Provimi; high undegraded dietary protein)/kg silage dry matter (DM) (diets FM1, FM2 and FM3 respectively). Twelve calves were allocated to treatments C and FM3 respectively and six calves to diets FM1 and FM2 respectively. Within each dietary group, half of the calves were ear-implanted with oestradiol-17β (Compudose 365, Elanco Products Ltd) at the start of the experiment.

The silage (primary growth perennial ryegrass, harvested 24th May, 1984, with 4 litres formic acid/tonne) had total nitrogen and lactic acid contents of 2·28 and 8·78 g/kg DM and a pH of 3·7. Intakes were recorded daily and live weights weekly for 75 d (control and FM3) or 63 d (FM1 and FM2).

	Without Compudose				With Compudose				SE of mean	
	C	FM1	FM2	FM3	C	FM1	FM2	FM3	C *v.* FM3	FM1 *v.* FM2
DM intake: kg/d	3·35	3·66	3·65	3·49	3·45	3·52	3·98	3·59	0·131	0·185
g/kg LW	24·2	24·2	24·0	24·0	24·5	24·3	24·6	23·8	0·42	0·59
LW gain (kg/d)	0·77	0·94	1·03	1·02	0·79	0·90	1·19	1·17	0·049	0·069
Final LW (kg)	172	—	—	188	171	—	—	200	2·9	—
Carcass wt (kg)	83·6	—	—	94·5	82·1	—	—	99·2	1·5	—

DM intake was not significantly ($P<0·05$) affected by treatments and was high on all diets. A curvilinear response in LW gain to fishmeal supplementation was obtained in both implanted and non-implanted calves, but the magnitude of the response to oestradiol was greatest and led to a significant ($P<0·05$) interaction in LW gain, LW at slaughter and carcass weight between fishmeal and oestradiol. Studies to determine nutrient supply and utilization on some of these diets are currently in progress.

This work is part of an AFRC-linked research project. The provision of the implant by Elanco Products Ltd is gratefully acknowledged.

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Estimation of true nitrogen digestibility in cattle by a modified nylon bag technique. By R. C. RAE and R. R. SMITHARD, *Department of Agricultural Biochemistry and Nutrition, University of Newcastle upon Tyne, Newcastle upon Tyne NE1 7RU*

True nitrogen digestibility in ruminants is difficult to measure because of the close association of dietary components with microbial biomass and endogenous secretions. Sauer *et al.* (1983) have described a procedure which, if applied to ruminants, could overcome this problem. These authors inserted small nylon bags containing feed samples into the duodena of pigs. The bags were recovered from the faeces and N disappearance determined. In the present experiment, the procedure was modified to give an estimate of true N digestibility in cows.

Three Jersey cows were equipped with rumen cannulas and re-entrant intestinal cannulas at the proximal duodenum. Samples (5·0 g) of rapeseed meal (RSM), soya-bean meal (SBM), formaldehyde-treated SBM (FSBM), Danish herring meal (DHM) and micronized flaked barley (MFB) were placed in nylon bags (160×100 mm; pore size 45 μm) and suspended in the rumen. After incubation, the bags were washed thoroughly and the residue remaining was oven-dried at 60°. Small samples (0·5 g) of the residues were transferred to smaller nylon bags measuring 50×30 mm (pore size 45 μm) and incubated with 1 g pepsin (*EC* 3.4.23.1)/l 0·01 M-hydrochloric acid for 1 h at 39° to simulate abomasal conditions. Two bags per feedstuff were then inserted into the proximal duodena of three cows; the bags were recovered from the faeces approximately 15–20 h later and washed. The disappearance of N from rumen bags and intestinal bags was determined and the values combined to give an estimate of N disappearance in the whole gastrointestinal tract. Results are shown in the Table.

(Mean values with their standard errors for three cows per group)

		Mean N disappearance from:					
		Ruminal bags (g/g feed N)		Intestinal bags (g/g rumen undegraded N)		Overall N disappearance (g/g feed N)	
Feed sample	Rumen incubation time (h)	Mean	SE	Mean	SE	Mean	SE
	8	0·561	0·107	0·791	0·020	0·908	0·042
RSM	12	0·651	0·003	0·745	0·002	0·911	0·002
	24	0·876	0·034	0·569	0·024	0·947	0·021
SBM	8	0·454	0·103	0·905	0·005	0·948	0·007
	12	0·544	0·052	0·885	0·023	0·948	0·021
FSBM	12	0·301	0·025	0·883	0·018	0·918	0·023
DHM	12	0·406	0·017	0·785	0·048	0·872	0·050
MFB	12	0·279	0·118	0·906	0·014	0·932	0·027

The technique offers a means of rapidly estimating true digestibility of N and other nutrients from large numbers of feed samples.

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Binding of rare earths to specific feed particles. By D. E. BEEVER and W. C. ELLIS, *Department of Animal Science, Texas A&M University, College Station, Texas* 77843

Use of rare earths (M) bound to particles to examine passage rates within the alimentary tract has been limited by the reported dissociation of weakly-bound M from particles following introduction into the animal (Combs *et al.* 1985).

The present study was undertaken to examine ways of producing more tenaciously bound M on feed particles. Rare-earth and soluble ligands (ML and SL respectively) with contrasting association constants (K_a) were applied to cell wall constituents (CWC) by three methods: (1) transfer binding (T), M transferred to binding sites ($K_a > x$) with ML of differing K_a (x); (2) competitive binding (C), M as M acetate (MAc) prevented from binding to sites of low K_a ($K_a > x$) using SL ($K_a = x$) at time of binding, and (3) selective removal binding (R), all sites saturated with MAc and subsequent removal of M from weak binding sites ($K_a < x$) with SL ($K_a = x$).

Initial bindings (overnight soaking with 60 mg M (as ytterbium)/g CWC at pH 6) were followed by exposure to pH 1·5 for 6 h and the extent of binding and removal was estimated from the amount of M recovered in the washings.

Ligand ...	Acetate (Ac)	Aspartate (Asp)	Citrate (Cit)	Nitrilotri-acetate (NTA)	Ethylene-diamine-tetra-acetate (EDTA)
K_a (0·1 M-Yb)	1·8	6·2	8·1	12·2	19·5
Method	Initially bound (mg Yb/g CWC)				
T	50·2	49·7	36·2	35·7	21·8
C	44·9	41·0	48·1	49·8	17·9
R	37·8	32·8	27·3	14·2	16·1
	Bound after exposure to pH 1·5 (% initial bound)				
T	62·8	68·8	71·9	46·6	86·7
C	67·7	50·1	76·7	78·8	86·6
R	62·6	71·8	94·3	62·4	92·7

The amount initially bound was higher for methods T and C, whilst the amount of Yb initially bound decreased in response to increased K_a. After exposure to pH 1·5, 50–70% of original bound Yb remained from Ac and Asp, whilst values for Cit and especially EDTA were higher. In contrast, NTA showed major, as yet unresolved, deviations from theoretical expectations.

This preliminary study confirms that feedstuffs possess a relative high density of high affinity binding sites, and suggests that use of ligands of high K_a may limit dissociation of M at pH 1·5.

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The effect of energy restriction on the carcass composition of laying hens.

By N. JACKSON and M. H. STEVENSON, *Department of Agricultural and Food Chemistry, The Queen's University of Belfast, Newforge Lane, Belfast BT9 5PX* and *Department of Agriculture for Northern Ireland*

There are many reports of the effects of energy restriction on egg production but the changes in carcass composition which accompany restriction have received less attention.

504 Warren Studler SSL hens were caged individually and given one of five diets formulated to contain the same apparent metabolizable energy but with increased crude protein (nitrogen × 6·25) concentrations so that as energy intake was restricted, crude protein intake remained constant.

The birds were given the diet at the following levels (g/d): (1) *ad lib.*, (2) 123, (3) 113, (4) 102, (5) 92. The experiment lasted for ten × 28-d periods.

At the end of each period, nine birds from each treatment were slaughtered and, after plucking, carcass composition was determined.

Overall, restriction of food intake significantly reduced body-weight. Also, the two most severe levels of energy restriction had the greatest effect on body-weight. However, during period 10, there was no significant difference between treatments in the body-weights of birds killed for carcass analysis. Egg number was significantly reduced by energy restriction but egg weight was unaffected.

From the end of period 1, carcass dry matter significantly declined with increasing energy restriction. Total carcass crude protein was significantly reduced ($P<0·05$) by energy restriction during periods 3, 5, 6 and 7 but unaffected throughout the remainder of the experiment. Energy restriction had its greatest effect on carcass total lipid. By the end of period 2, the birds which had been most severely energy-restricted contained only 65% of the lipid of those fed *ad lib.* This declined further until by the end of period 7 it was only 46% of that of the *ad lib.*-fed group. However, by the end of period 10, the percentage of carcass total lipid in the most severely energy-restricted group had increased to 69% of the *ad lib.*-fed birds. Total ash content was unaffected by dietary treatment.

The reductions in body-weight following energy restriction were almost entirely accounted for by reductions to total lipid.

The growth of goslings up to 9 weeks of age. By MARY H. STEVENSON[1,2] and W. D. GRAHAM[2], [1]*Department of Agricultural and Food Chemistry, The Queen's University of Belfast, Newforge Lane, Belfast BT9 5PX* and [2]*Department of Agriculture for Northern Ireland*

The growth of goslings and their various component parts has been studied to only a limited extent. This experiment was carried out to provide information on the growth of goslings reared intensively to 9 weeks of age.

Forty-eight male and forty-eight female, 1 d old goslings were used. Four of each sex were killed immediately after hatching and the remaining eighty-eight offered standard diets for 9 weeks. A starter diet with 210 g crude protein (CP, nitrogen × 6·25)/kg and 12·0 MJ metabolizable energy/kg was given from 0 to 4 weeks. From 5 to 9 weeks, a grower diet with 155 g CP/kg and the same energy concentration was given.

Each week, four birds of each sex were killed by cervical dislocation, hand plucked, placed in a chill-room overnight and on the following day the organs and carcass components were dissected out.

No. of weeks . . .	1	3	5	7	9	SEM
Live wt (LW; g): ♂	569	2046	4045	5170	6580	153·8**
♀	476	1917	3523	4885	5788	
Component (g/kg LW)						
Eviscerated carcass	448·1	513·0	568·3	610·4	629·3	6·39***
Thighs	186·1	193·5	192·6	174·4	146·3	4·49***
Wings	27·2	47·9	78·4	93·2	88·4	1·91***
Breast meat	6·8	14·6	34·7	73·6	97·6	2·08***
Abdominal fat	12·7	23·0	40·9	54·5	74·8	3·14***
Gizzard	94·0	67·7	46·3	39·5	32·3	3·26***
Liver	54·6	29·4	20·8	18·1	16·7	1·11***

**$P<0.01$, ***$P<0.001$.

The sex of the birds significantly affected live weight and there was an interaction between weight and date of killing ($P<0.01$). The weights of the organs and carcass components/kg live weight were unaffected by the sex of the goslings. The weight of eviscerated carcass, wings, breast meat and abdominal fat (expressed as g/kg live weight) increased significantly ($P<0.001$) with age. Gizzard, liver and thigh weights/kg live weight declined with age ($P<0.001$).

Goslings grow rapidly during the first few weeks of life and then more slowly from about week 5. There was virtually no breast meat until the birds exceed 5 weeks of age but the amount of abdominal fat progressively increased as the birds aged.

Sex difference in the minimal metabolic rate of the pre-migratory barnacle goose (*Branta leucopsis*). By J. F. ANDREWS[1], D. CABOT[2] and A. B. WEST[3], *Departments of* [1]*Physiology and* [3]*Pathology, Trinity College, Dublin 2, Irish Republic* and [2]*An Foras Forbartha, St Martin's House, Waterloo Road, Dublin 2, Irish Republic*

The population dynamics of the sub-population of Greenland breeding barnacle geese which overwinter on the Inishkea Islands, Co. Mayo in the Irish Republic, have been extensively studied (Cabot & West, 1973, 1983). Unpublished results collected in these studies confirm an increase in body-weight in the few weeks before breeding migration, as observed in other species. These results further show that females gain relatively more weight than males. Here we report the results of a study made on the thermal and metabolic physiology of these geese caught in the pre-migratory period, during the time of rapid weight gain.

Birds were placed in a transportable climatic chamber (Andrews & Mercer, 1974) at a warm ambient temperature and subjected to a cooling–heating cycle, falling to −5°, the reheating continuing sufficiently to achieve minimal metabolic rate (MMR). An opaque ventilated hood placed over the head enabled continuous determination of metabolic rate (MR), indirectly as oxygen consumption. Deep-body temperature was determined by cloacal thermocouple probe.

		Body-wt (kg)		MR (ml O_2/kg body-wt per min)						Lower critical temperature (°) (individual values)
				−5°		+5°		MMR		
Sex	*n*	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Male	3	2·08	0·16	20·7	1·4	17·8	2·2	16·9	0·8	+1, 3, >14
Female	5	1·85•••	0·14	21·4	2·2	16·9	1·6	13·6•••	1·7	8, 11, 14, >17, >18

Significantly different from value for males: •••$P<0.001$.

At both −5° and +5°, MR of the two sexes was indistinguishable. However, in the female the mean MMR was significantly lower and their lower critical temperature tended to be higher. Cloacal temperature showed no change during the cooling cycle, nor was there any sex difference (mean (SD): male 41·5 (0·1)°, female 41·5 (0·2)°).

In the pre-migratory period, female barnacle geese need to store energy, not only for the migration ahead as in the males, but also for egg production and prolonged fast during incubation. We suggest, tentatively, that the suppressed MMR of the females, combined with the favourable ambient temperatures of the pre-migratory period would allow greater efficiency of food energy conversion to stored energy.

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