PROCEEDINGS OF THE NUTRITION SOCIETY

ABSTRACTS OF COMMUNICATIONS

A meeting of the Nutrition Society (One Hundred and Eighty-fourth of the Scottish Group) was held in the Colville Building, University of Strathclyde, on Thursday and Friday, 29/30 March 1990, when the following papers were read.

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Protein utilization during energy undernutrition in steers. By S. A. CHOWDHURY, E. R. ØRSKOV and N. A. MACLEOD, *Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB*

The variable degradation in the rumen of protein supplements casts doubt on some of the early experiments of host animal protein–energy requirements. This is because the responses obtained may have reflected protein supply to the rumen, rather than the needs of the animal, and is probably why the models of Balch (1967) and the Agricultural Research Council (1980) show no responses to protein at low energy nutrition, as clearly demonstrated by Fattet *et al.* (1984).

Two Friesian steers (422 and 334 kg) were given, by abomasal infusion, for consecutive 3 d periods, 0, 250, 500, 750, 1000, 1500 and 2000 mg casein nitrogen/kg body-weight $(W)^{0.75}$ per d. Minerals and vitamins were supplied, but no additional energy. N equilibrium was obtained with an infusion of 883 mg/kg $W^{0.75}$ per d (116 kJ metabolizable energy (ME)) and gain of 283 mg N/kg $W^{0.75}$ per d with an N infusion of 2000 mg/kg $W^{0.75}$ per d (Fig. 1). With all ME from casein, maintenance energy would have been 395 kJ ME/kg $W^{0.75}$ per d (Agricultural Research Council, 1980), which indicates a contribution from body fat catabolism of 253, 250, 251, 241, 226, 187 and 146 kJ ME/kg $W^{0.75}$ per d for the seven protein levels respectively.

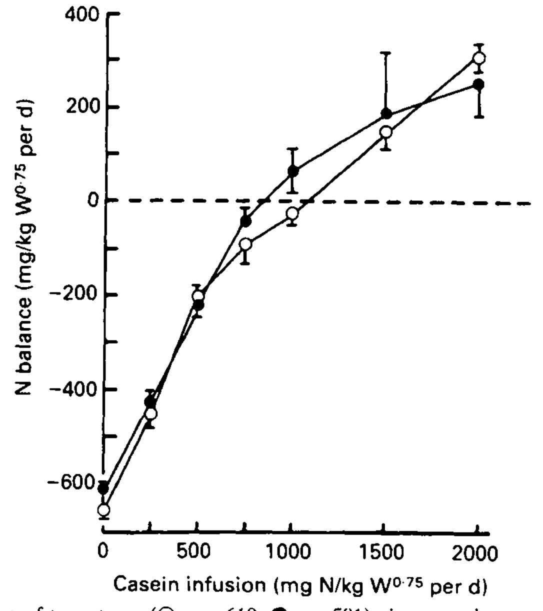

Fig. 1. Nitrogen balance of two steers (○, no. 619; ● no. 501) given varying amounts of casein by abomasal infusion but no additional energy. Values are 3 d means with standard errors represented by vertical bars.

The results indicate that cattle without energy-yielding nutrition can attain substantial positive N balance at the expense of body fat utilization provided sufficient exogenous protein is supplied and with adequate body fat reserves. In fact the tissue gain calculated from N balance was in excess of 1 kg/d.

Agricultural Research Council (1980). *Nutrient Requirements of Ruminant Livestock*, p. 118. Slough: Commonwealth Agricultural Bureaux.

Balch, C. C. (1967). *World Review of Animal Production* **3**, 84–91.

Fattet, I., Hovell, F. D. DeB., Ørskov, E. R., Kyle, D. J., Pennie, K. & Smart, R. I. (1984). *British Journal of Nutrition* **52**, 561–574.

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Effect of nutritional level and body condition on susceptibility of N'Dama cattle to *Trypanosoma congolense* infection in The Gambia. By D. A. LITTLE, R. H. DWINGER, D. J. CLIFFORD, A. S. GRIEVE, S. KORA and M. BOJANG, *International Trypanotolerance Centre, PMB 14, Banjul, The Gambia*

Trypano-tolerant N'Dama cattle normally graze low-quality pastures. Quantitative data are required to show whether poor nutrition impairs their ability to cope with trypanosome infection (Murray *et al.* 1982).

Two groups (low, 174 kg, and medium, 205 kg, body condition) of twenty, 3-year-old N'Dama bulls were used. Half of each group was fed on a low (LP) and half on a high (HP) plane of nutrition. The ration was a milled mixture of native grass, rice bran and groundnut cake (*ca.* 180 g crude protein and 7·4 MJ metabolizable energy/kg dry matter (DM), consumed at 3·5 kg DM/d, and HP animals received extra groundnut cake (1·5 kg DM/head per d). For 9 weeks after intradermal inoculation with 10^4 *T. congolense* organisms, cattle were bled regularly for parasitic examination and packed cell volume (PCV) measurement, and weighed weekly. Ten similar bulls acted as uninfected controls; five were fed on LP and five on HP. Severity of response to infection was assessed from rates of decline in PCV and body-weight, determined by regression of individual animal data on time, then examination by analysis of variance.

Parasitaemia occurred 6–7 d after inoculation, and group mean PCV declined linearly to a minimum 24 d later. PCV then slightly increased to means averaging 1·2 units above their respective minima. The Table shows that PCV declined less rapidly in HP compared with LP animals (0·199 *v.* 0·273 units/d; $P<0·01$), and in low rather than medium initial body condition (0·198 *v.* 0·274; $P<0·01$). From 27 to 56 d after initial parasitaemia, the mean PCV was higher in HP than in LP animals (21·1 *v.* 19·8; $P<0·01$). Degree of parasitaemia was not affected.

Mean decline in PCV over 24 d after detection of parasitaemia. Live-weight gains and body condition scores during 9 weeks following T. congolense *infection of N'Dama bulls in low or medium body condition and fed at low (LP) or high (HP) planes of nutrition*

Initial body condition/score	PCV decline (units/d)		Live-weight gain (g/d)		Body condition score	
	LP	HP	LP	HP	LP	HP
Low (3·5)	0·223	0·173	−155	−66	3·16	3·62
Medium (4·5)	0·322	0·226	−217	−46	3·36	4·58
SEM/LSD	0·0337/0·068		45·5/92		0·161/0·326	

SEM, standard error of the mean; LSD, least significant difference.

Nutritional treatment influenced rate of live-weight gain (HP −56 *v.* LP −186 g/d; $P<0·01$). The uninfected controls gained weight (LP 62 and HP 178 g/d; $P<0·05$) at a rate significantly greater than the infected groups ($P<0·05$), showing a deleterious effect of trypanosome infection on efficiency of nutrient utilization.

The most severe response to infection occurred in medium-condition LP animals (Table). While the higher plane of nutrition clearly was beneficial in reducing the severity of trypanosome infection in trypano-tolerant cattle, the syndrome was more severe in animals in better body condition at the time of infection. Thus, trypanosomiasis resembles another blood protozoal infection, viz: malaria in man (e.g. McGregor, 1988).

McGregor, I. A. (1988). In *Malaria*, vol. 1, pp. 753–767 [W. H. Wernsdorfer and I. A. McGregor, editors]. Edinburgh: Churchill Livingstone.

Murray, M., Morrison, W. I. & Whitelaw, D. D. (1982). *Advances in Parasitology* **21**, 1–68.

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Sodium and phosphorus supplementation of lactating N'Dama cows under village husbandry conditions in The Gambia. By D. A. LITTLE, K. AGYEMANG, J. VAN ROMPAEY, G. VAN ISTERDAEL and B. BADJI, *International Trypanotolerance Centre, PMB 14, Banjul, The Gambia*

Village cattle in The Gambia are almost exclusively the trypano-tolerant N'Dama breed. Lactating cows are milked once or twice daily after a brief sucking period by the calf to stimulate milk letdown. This milk offtake contributes significantly both to human nutrition and to the incomes of herd owners/herdsmen. No supplementary feeding is practised, other than to draught oxen. Other cattle obtain their feed exclusively from native pastures and browse, and from residues of maize, millet, sorghum and groundnut crops which become available for a short period after harvest, early in the dry season (November/December).

Preliminary analyses of available feeds have shown that among the essential mineral nutrients, concentrations of sodium are very frequently deficient, and those of phosphorus low to marginal, in relation to commonly accepted levels for dietary adequacy, a situation typical of tropical materials (e.g. Little *et al.* 1989). While Gambian farmers recognize the need for salt, their attempts to ensure a supply are frequently limited to their cattle occasionally visiting a source of saline water if available. Such visits may occur only once every month or two, which is almost certainly inadequate for lactating animals, those especially at risk of Na deficiency.

An experiment was conducted in Nioro Jattaba village, during the wet and early dry seasons (August–December 1988), in which forty N'Dama cows averaging 50 d post-calving were given supplementary NaCl (50 g/d), and twenty of them also received bonemeal (70 g/d). Body-weights of cows and calves, and rates of milk offtake for human consumption were measured monthly (Agyemang *et al.* 1988). Twenty unsupplemented cows at the same stage of lactation were also monitored: there was no significant difference between groups in initial level of milk offtake. Rates of change in these variables were determined by linear regression of individual animal data on time, and group differences examined by *t* tests.

Two calves died in each treatment, and results were calculated only for those animals for which complete data were available. The rate of decline in milk offtake for those cows given NaCl (*n* 26) was 3·4 (SE 0·29) ml/d, significantly less rapid than that of control cows (*n* 12, 5·0 (SE 0·64) ml/d, $P<0·05$). Thus during the supplementation period, mean daily offtake from supplemented cows was 75% (SE 2·9) of their initial level (63% (SE 3·4) for the control cows, $P<0·05$). The calves sucking supplemented-cows (*n* 33) grew at 174 (SE 10·8) g/d and those of control cows (*n* 16) at 143 (SE 13·7) g/d; this difference approached statistical significance ($P<0·1$). No effect of the bonemeal supplement was detected.

Increased milk offtake is rapidly appreciated by farmers, and there is clear potential for such basic and cheap nutritional interventions to have an impact on animal productivity in traditional husbandry situations in developing countries. Strong interest in adopting them is frequently encountered among the farming communities.

J.v-R. and G.v-I. were visiting students from University of Leuven, Belgium.

Agyemang, K., Jeannin, P., Grieve, A. S., Bah, M. L. & Dwinger, R. H. (1988). In *Livestock Production in Tsetse Affected Areas of Africa*, pp. 231–245. Nairobi: ILCA/ILRAD.

Little, D. A., Kompiang, S. & Petheram, R. J. (1989). *Tropical Agriculture, Trinidad* **66**, 33–37.

Differential response in rat gut hypertrophy to inclusion of guar gum and volatile fatty acid salts in the diet. By LAURENTINA M. R. PEDROSO, J. C. MATHERS and HEATHER J. FINLAYSON, *Department of Agricultural Biochemistry and Nutrition, The University, Newcastle upon Tyne NE1 7RU*

Hypertrophy of the large bowel often accompanies complex carbohydrate (dietary fibre, DF) feeding in rats (Wyatt *et al.* 1988; Seal & Mathers, 1989). The mechanism for this effect has yet to be established but may include the trophic effects of volatile fatty acids (VFA), the major end-products of carbohydrate fermentation in the large bowel. In germ-free (GF) rats, DF feeding has no effect on intestinal crypt cell production rate (Goodlad *et al.* 1989) but the latter is stimulated by ileal infusion of VFA in both GF and conventional rats with effects in both the large bowel and proximal small intestine, implying the presence of a systemic mechanism (Sakata, 1987). We have compared the effects on gut hypertrophy of providing similar amounts of VFA either via dietary inclusion of VFA salts or by giving guar gum.

Male Wistar rats (initial weight 82 g; five per diet) were offered 15 g/d for 18 d of semi-purified diets based on maize starch (M) and casein. In three diets, 350 sucrose (S)/kg replaced maize starch. One M and one S diet contained 100 g guar gum/kg whilst another pair contained 100 g VFA salt mix/kg – the latter comprising (g/kg) sodium acetate 550, sodium propionate 200 and sodium butyrate 250.

		Caecum				Colon	
Diet	Stomach tissue (g)	Tissue (g)	Wet contents (g)	pH	Total VFA (mmol/kg contents)	Tissue (g)	Wet contents (g)
M – basal	1·05	0·44	1·56	7·2	95	0·67	0·38
S – basal	1·09	0·50	1·67	7·2	95	0·73	0·44
M – guar gum	0·94	1·11	3·61	6·7	110	0·85	0·40
S – guar gum	0·99	1·10	4·63	6·3	120	0·97	0·85
M – VFA	1·21	0·43	1·28	7·3	92	0·70	0·33
S – VFA	1·13	0·47	1·36	7·1	85	0·77	0·37
SEM	0·053	0·048	0·207	0·11	8·4	0·047	0·089

Compared with the basal diets, guar gum increased caecal and colonic tissue weights by 2·4- and 1·3-fold respectively. In contrast, VFA feeding had no effect on large-bowel tissue weights and the effects on stomach tissue weights were not apparent when the results were expressed on a per unit body-weight basis. These findings suggest that for VFA to exert a generalized trophic effect on the gut, they must be supplied to the distal intestine.

Goodlad, R. A., Ratcliffe, B., Fordham, J. P. & Wright, N. A. (1989). *Gut* **30**, 820–825.
Sakata, T. (1987). *British Journal of Nutrition* **58**, 95–103.
Seal, C. J. & Mathers, J. C. (1989). *British Journal of Nutrition* **62**, 157–163.
Wyatt, G. M., Horn, N., Gee, J. M. & Johnston, I. T. (1988). *British Journal of Nutrition* **60**, 197–207.

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Effects of guar gum or volatile fatty acid salts on activities of key enzymes for lipid synthesis in livers from rats given starch- or sucrose-containing diets. By LAURENTINA M. R. PEDROSO, J. C. MATHERS and HEATHER J. FINLAYSON, *Department of Agricultural Biochemistry and Nutrition, The University, Newcastle upon Tyne NE1 7RU*

Diets rich in complex carbohydrates (dietary fibre) provided by wheat bran (Pedroso *et al.* 1989) or peas (Pedroso *et al.* 1990*a*) at the expense of sucrose and casein reduced the capacity for hepatic lipid synthesis in rats as indicated by reduced activities of glucose-6-phosphate dehydrogenase (*EC* 1.1.1.49; G6PDH), malate dehydrogenase (*EC* 1.1.1.40; ME), ATP-citrate lyase (*EC* 4.1.3.8; CL) and acetyl-CoA carboxylase (*EC* 6.4.1.2; ACC). The present study tested the hypotheses that these effects were due to (i) reduced absorption of fructose (and glucose) or (ii) increased absorption of volatile fatty acids (VFA) from large-bowel fermentation of carbohydrate.

Specific activities of G6PDH, ME, isocitrate dehydrogenase ($NADP^+$) (*EC* 1.1.1.42; IDH), CL and ACC were measured in livers from rats (five per group) given one of six semi-purified diets based on maize starch (M) and casein. In three of the diets, 350 g sucrose (S)/kg replaced M. One M and one S diet each contained 100 g guar gum/kg and a further pair contained 100 g VFA salt mix/kg (see Pedroso *et al.* 1990*b* for details).

Diet	Growth rate (g/d)	Liver wt (g)	Liver enzyme activities (nmol substrate utilized/min per mg protein)				
			G6PDH	ME	IDH	CL	ACC
M – basal	4·9	8·0	21·7	10·5	163	12·6	1·56
M – guar gum	4·0	6·8	24·5	15·8	176	8·4	1·10
M – VFA	4·4	7·9	25·0	8·5	169	8·5	1·46
S – basal	5·0	8·5	41·0	20·2	174	21·2	2·06
S – guar gum	5·3	8·0	28·4	21·0	176	11·0	1·56
S – VFA	5·0	8·5	32·2	13·6	162	14·5	1·53
SEM	0·23	0·20	2·43	1·19	8·9	1·60	0·140

Inclusion of sucrose (S) in the basal diet resulted in large increases in the activities of the two principal NADPH-producing enzymes (G6PDH and ME) of CL and of ACC. For the S diets, inclusion of guar gum or VFA reduced activities of G6PDH, CL and ACC, the latter two enzymes to values close to M–basal values. Effects of guar gum and VFA in M diets were small and diet had no effect on IDH. These results suggest that guar gum or VFA salts may reduce the hepatic lipid synthesis-enhancing effects of high-sucrose diets.

Pedroso, L. M. R., Finlayson, H. J. & Mathers, J. C. (1989). *Proceedings of the Nutrition Society* **48**, 54A.

Pedroso, L. M. R., Mathers, J. C. & Finlayson, H. J. (1990*a*). *Proceedings of the Nutrition Society* **49**, 52A.

Pedroso, L. M. R., Mathers, J. C. & Finlayson, H. J. (1990*b*). *Proceedings of the Nutrition Society* **49**, 211A.

Role of bovine milk lactoperoxidase system in *Escherichia coli* diarrhoea – development of a model using the early-weaned pig. By K. J. McCracken, *Food and Agricultural Chemistry Research Division, Department of Agriculture, Newforge Lane, Belfast BT9 5PX* and J. J. O'Brien, *Veterinary Research Laboratory, Stoney Road, Stormont, Belfast BT4 3SD* and K Anantharaman, *Nestlé Research Centre, Nestec Ltd, 1000 Lausanne 26, Switzerland*

The milk lactoperoxidase (LP) system has been shown to be bactericidal against a range of *Escherichia coli* organisms in the calf (Reiter, 1978). Some studies have indicated beneficial responses to LP in calves under field conditions (Reiter *et al.* 1981; Waterhouse *et al.* 1982). *E. coli* infections are of major clinical importance in weaned infants in developing countries and are also of economic importance in the weaned pig. There is, however, little published information on the role of the LP system either in children or pigs (Reiter, 1985). LP can be produced commercially for addition to milk products, as can lactoferrin which also contains relatively high levels of active LP. The study described is the development phase of a project to examine the prophylactic/therapeutic role of the LP system in the piglet and the implications as a model for the infant.

In vitro studies were conducted using tryptacase soya broth or reconstituted milk as substrate to determine the optimum concentration of the LP system and the effective pH range. A system containing 15 μg LP/ml, 0·1 IU glucose oxidase (*EC* 1.1.3.4, GO)/ml and 1 mM-potassium thiocyanate was bactericidal in the pH range 4–6·5 within 2–3 h of inoculation. At pH >6·8 the system was ineffective.

The pH of stomach contents withdrawn at intervals after a meal of reconstituted milk remained between 5 and 6 for several hours, indicating that conditions in the stomach would be satisfactory for the LP system to be effective. The supernatant fraction of stomach contents, recovered 1 h after a milk feed, was satisfactory as a substrate for *E. coli* growth and inhibition with the LP system.

Pigs given a milk diet were weaned (20±2 d of age) and challenged orally at weaning (*n* 6) or on days 4 and 5 (*n* 12) or on days 6, 7 and 8 (*n* 10) with approximately 10^7 organisms of *E. coli* (0149: K91(b), K88 a.c. (L)). Twenty-seven of the twenty-eight pigs excreted high levels of the challenge strain for 2–8 d (mean 5·6 d) and had corresponding diarrhoea. To test the effectiveness of the LP system, piglets were given milk with (*n* 6) or without (*n* 6) the LP system (0·1 IU GO/l mM-potassium thiocyanate) and challenged on days 4 and 5 with 10^7 organisms of *E. coli*. All pigs excreted the K88 strain. The mean periods were 5·5 and 3·5 d for control and LP pigs respectively, but the LP value was confounded by the death of two pigs from dehydration.

It is concluded that (1) this challenge model is of potential value for the study of *E. coli*-induced diarrhoea, (2) the bactericidal effects of the LP system are likely to be restricted to the stomach since, in vitro, the LP system does not appear to be effective above pH 6·8, (3) the levels of the LP system which were effective in vitro are not effective in the piglet against a high-dose oral challenge. Further studies on lower levels of challenge and higher levels of the LP system are indicated.

Reiter, B. (1978). *Journal of Dairy Research* **45**, 131–147.

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Reiter, B., Fulford, R. J., Marshall, V. M., Yarrow, W., Ducker, M. J. & Knutsson, M. (1981). *Animal Production* **32**, 297–306.

Waterhouse, A., Mullan, W. M. A. & Ekstrand, B. (1982). *Animal Production* **34**, 378.

The 'anabolic' effect of subcutaneous testosterone implants in rats. By C. J. H. WOODWARD[1], G. R. HERVEY[1], R. E. OAKEY[2] and E. M. WHITAKER[1], [1]*Department of Physiology* and [2]*Division of Steroid Endocrinology, Department of Chemical Pathology, University of Leeds, Leeds LS2 9NQ*

Although it is commonly assumed that injected testosterone increases body-weight and lean body mass, it has not been possible to demonstrate this consistently in the adult rat (Hervey & Hervey, 1981). In the present experiment, therefore, we have studied the effects on intact and gonadectomized Wistar rats of subcutaneous implants of testosterone (Sigma) in Silastic tubes (i.d. 2 mm; length 10 mm). The initial weights of the rats were approximately 250 g and 170 g for males and females respectively. Six weeks after implantation the rats were killed and the carcasses analysed. Fat-free mass was calculated as the sum of carcass water and defatted dry matter. Plasma testosterone was determined by radioimmunoassay with a commercial antiserum (ICN Immunobiologicals).

Castration significantly reduced body-weight in males (−9·0%; $P<0·02$). The implant, however, restored body-weight to that of the controls. In females, ovariectomy caused a weight gain of 20% ($P<0·001$) The implant caused a further significant increase in body-weight, in both intact and ovariectomized rats. All these changes were mainly attributable to alterations in fat-free mass.

	Body-weight (g)		Fat-free mass (g)		Fat (g)		Plasma testosterone concentration (ng/ml)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Males:								
Intact	355	10	300	6·4	55	5·7	1·4	0·2
GDX	321	10	278	8·8	43	2·5	nd	
GDX/implanted	352	5	301	4·4	51	2·7	1·0	0·1
Females:								
Intact	200	8	172	5·3	29	2·5	nd	
GDX	240	6	206	5·1	33	1·6	nd	
Intact/implanted	262	7	224	5·0	38	2·6	1·6	0·1
GDX/implanted	261	8	226	6·1	35	2·9	1·4	0·1

GDX, gonadectomized; nd, not detectable; *n* 6 per group.

Thus the implant produces a detectable anabolic effect in castrated male rats. The results for females are consistent with the hypothesis that testosterone suppresses endogenous oestrogen production in intact rats, resulting in a form of chemical ovariectomy, as well as having a separate anabolic effect in both intact and ovariectomized animals which may be analogous to that found in males.

This work was carried out under a contract with MAFF.

Hervey, E. & Hervey, G. R. (1981). In *The Body Weight Regulatory System: Normal and Disturbed Mechanisms*, pp. 345–352 [L. A. Cioffi, W. P. T. James and T. B. van Itallie, editors]. New York: Raven Press.

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Effect of energy restriction on the relationship between body fat and food intake in broilers. By A. Y. YALDA and J. M. FORBES, *Department of Animal Physiology and Nutrition, University of Leeds, Leeds LS2 9JT*

Reduction of body fat in female broiler-type chickens by under-feeding is followed by hyperphagia when the food becomes freely available until the fat is restored to the previous levels. This suggests that food intake is controlled by body-fat content (March *et al.* 1982). However, broiler chickens appear not to regulate intake following manipulation of body fatness by the removal of abdominal fat pads (Taylor & Forbes, 1988).

In order to determine whether reduction of fatness would affect feeding in broiler chickens, thirty-six male broilers were caged individually at 4 weeks of age and assigned to two groups. One group was fed *ad lib.* until 11 weeks of age and the other restricted to 85% of *ad lib.* intake (with the addition of extra protein to prevent deficiency) from 4 to 7 weeks of age and fed *ad lib.* until 11 weeks of age. Body-weight, food intake and tibia length were recorded weekly. Birds were killed at 7, 9 and 11 weeks for carcass analysis and abdominal fat weight.

Effect of energy restriction on body-weight, food intake, tibia length, abdominal fat weight and total lipid content of the carcass

Feeding . . .		*Ad lib.*			Restricted		
Age (weeks) . . .		7	9	11	7	9	11
Body-weight (g)	Mean	1910^{a}	2793^{a}	3593^{a}	1526^{b}	2278^{b}	3542^{a}
	SE	60·9	91·6	160·4	97·8	65·0	63·0
Carcass weight (g)	Mean	1232^{a}	1869^{a}	2494^{a}	1021^{b}	1424^{b}	2524^{a}
	SE	113·2	99·0	95·0	85·6	26·0	75·4
Food intake (g/bird per d)	Mean	151^{a}	175^{a}	200^{a}	119^{b}	148^{b}	215^{a}
	SE	5·9	5·8	8·9	0·0	6·3	5·2
Abdominal fat (g)	Mean	22^{a}	72^{a}	94^{a}	6^{b}	17^{b}	70^{a}
	SE	2·9	5·0	10·4	2·2	1·2	2·3
Total lipid content (g/bird)	Mean	162·0^{a}	294^{a}	472^{a}	109·0^{b}	182·0^{b}	359·0^{b}
	SE	14·2	22·8	33·6	5·5	11·4	24·8
Tibia length (mm)	Mean	126^{a}	144^{a}	164^{a}	122^{a}	152^{a}	170^{a}
	SE	1·6	1·5	2·4	2·3	1·3	2·0

^{a,b} Means in the same horizontal row for the same age with different superscript letters were significantly different: $P<0·05$.

Restricting the male broilers to 85% of *ad lib.* energy intake decreased body-weight by 25% by reducing body-fat without affecting body protein, ash and tibia length. During the first 2 weeks of recovery the restricted birds still had significantly lower body-weights but tended to recover by week 11. Food intake increased slowly on return to *ad lib.* feeding and was still significantly lower than the control birds 2 weeks after the end of restricted feeding. Abdominal fat pad weight and total lipid content of the carcass were significantly decreased by restriction, and by the 4th week of recovery had not returned to normal.

Thus, after the end of a period of restricted feeding, during which body fat content was greatly reduced, food intake increased slowly towards control values. This suggests that body fat content does not exert a major influence on the control of voluntary food intake in broiler chickens.

March, B. E., Chu, S. & Macmillan, C. (1982). *Poultry Science* **61**, 1137–1146.
Taylor, C. G. & Forbes, J. M. (1988). *Proceedings of the Nutrition Society* **47**, 90A.

Photoperiodic changes in food intake and rumen function in Soay rams. By C. EBONG* and R. N. B. KAY, *Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB*

Soay sheep come from the St Kilda Islands where for long they have been subject to the strongly seasonal climate of the North Atlantic. During summer, in response to long day length, the mature rams gain fat and have a large appetite and a high metabolic rate; converse changes occur during winter (Argo & Smith, 1983). We have studied the extent to which the rams may meet their seasonally changing energy requirements from diets of good or poor quality (Ebong, 1985).

Six mature Soay rams were fitted with rumen cannulas. They were housed in pens where the illumination was changed abruptly at 8-week intervals, from 6 to 18 h light daily and back, giving a cycle of 16-week period. The rams were divided into two equal groups, matched for weight, and offered a pelleted diet to appetite. The diet contained concentrates and barley straw, either in the ratio 80:20 (300 g neutral-detergent fibre (NDF)/kg, 'low roughage', LR) or 50:50 (460 g NDF/kg, 'high roughage', HR). The concentrates included ground barley, soya-bean meal, molasses, urea, etc. During weeks 4–6 and 12–14, when appetite reached its highest and lowest points respectively in response to the photoperiodic stimulus occurring some 12 weeks earlier, the rumen content, turnover and outflow of fluid and particulate matter were determined by dilution methods using polyethylene glycol and chromium-mordanted fibre as markers.

		High appetite				Low appetite			
	n	HR	SE	LR	SE	HR	SE	LR	SE
DMI (g/kg body-wt$^{0.75}$ per d)	3	90	8·1	113	7·7	47	13·7	32	5·6
MEI (kJ/kg body-wt$^{0.75}$ per d)	3	759	68·0	1185	81·0	397	11·5	339	58·0

When appetite was high, dry matter intake (DMI) was slightly less and estimated metabolizable energy (ME) intake (MEI) was significantly less ($P<0·01$) on the HR diet. When appetite was low, DMI for the HR diet was substantially but not significantly greater and MEI was only slightly greater than that for the LR diet. When appetite was high, rumen fluid and particulate contents and outflow rates and rumination time were similar for both diets. When appetite was low these values declined, especially in rams receiving the LR diet.

It seems that when appetite was lowest during the 4-month photoperiodic cycle the rams on the HR diet were able to maintain a sufficient MEI to meet the low ME requirement shown by the rams on the LR diet, whereas at the peak of the appetite cycle the HR rams were unable to process this poor diet in their rumens fast enough to equal the high MEI of the LR rams. However, this restriction might not apply to rams on a natural 12-month photoperiod, as there would be more time for rumen capacity and function to adapt to changing nutritional requirements.

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Growth and food intake responses of broiler and layer chickens to diets of different protein contents, and a choice of protein contents. By F. SHARIATMADARI and J. M. FORBES, *Department of Animal Physiology and Nutrition, University of Leeds, Leeds LS2 9JT*

Although many studies have been carried out on chickens given a choice of food, they have not normally included treatments in which single feeds were offered in order to assess the optimum concentration of the constituent being studied, nor have birds with different growth potentials been compared.

In order to assess the ability of both broiler and layer chickens to select a diet that meets their requirement, five groups of five male birds of each strain were offered access *ad lib.* to isoenergetic diets with protein contents of 70, 125, 170, 230 and 300 g/kg (A, B, C, D and E respectively) with a sixth group having a choice of diets A and E (thus called F) from 4 to 9 weeks of age. The diets B to E were prepared by replacing glucose in diet A with a mixture of fish meal and soya bean. Results given in the Table are the means for weeks 4–9.

	Strain		Treatments					
			A	B	C	D	E	F
Food intake (g/bird per d):	Broiler	Mean	65^{c}	120^{ab}	124^{a}	124^{a}	131^{a}	112^{b}
		SE	4·0	5·2	5·3	5·3	9·8	3·6
	Layer	Mean	35^{b}	84^{a}	83^{a}	80^{a}	70^{a}	78^{a}
		SE	1·6	1·5	0·9	3·2	3·9	1·5
Live-wt gain (g):	Broiler	Mean	103^{c}	1432^{b}	1912^{a}	1759^{ab}	2078^{a}	1764^{ab}
		SE	40·2	65·3	170·1	144·2	146·6	160·1
	Layer	Mean	18^{c}	758^{b}	937^{a}	887^{a}	836^{ab}	887^{a}
		SE	15·6	26·9	44·7	39·1	61·2	23·0
Protein content of carcass at week 9 (g):	Broiler	Mean	$88{\cdot}4^{d}$	$123{\cdot}1^{c}$	$230{\cdot}4^{b}$	$346{\cdot}2^{ab}$	$380{\cdot}9^{a}$	$330{\cdot}5^{ab}$
		SE	6·6	5·6	15·6	19·2	18·8	17·5
	Layer	Mean	$65{\cdot}1^{c}$	$152{\cdot}5^{b}$	$187{\cdot}9^{a}$	$205{\cdot}7^{a}$	$185{\cdot}6^{a}$	$182{\cdot}1^{a}$
		SE	6·1	9·9	6·7	5·5	5·9	7·6

a,b,c,d Mean values in the same horizontal row with different superscript letters were significantly different: $P<0{\cdot}05$.

Average protein intakes for broilers and layers on treatment F were 275 (SE 35·1) and 136 (SE 12·0) g/kg food per bird respectively. The ratio of E:total A+E intake taken by birds on treatment F was significantly reduced from 0·94 (SE 0·03) and 0·62 (SE 0·1) at 5 weeks of age to 0·81 (SE 0·2) and 0·38 (SE 0·06) at 9 weeks of age for broilers and layers respectively.

There was an approximately linear increase in protein deposition with dietary protein content up to diet E with broilers, and diet D with layers. When a choice of low- and high-protein feeds were offered, birds of both strains grew at a rate not significantly different from that of birds given the optimum diets singly by making an apparently appropriate choice from the two feeds.

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The ability of broiler chickens to regulate protein intake when offered a choice of diets containing different levels of protein. By F. SHARIATMADARI and J. M. FORBES, *Department of Animal Physiology and Nutrition, University of Leeds, Leeds LS2 9JT*

The work of Holcomb *et al.* (1976) showed that when chickens of a layer strain were offered a choice of diets with low and adequate protein contents, they chose a higher proportion of the latter, whereas when the choice was between adequate and higher protein diets, birds chose more of the former. It is not known how broilers would behave in similar circumstances.

To test the proposition that growing broilers, when given a choice of two feeds, are able to select a diet that meets their requirement, five isoenergetic feeds (A, B, C, D and E) with different levels of crude protein (CP, nitrogen × 6·25) (70, 125, 180, 300 and 350 g CP/kg fresh feed respectively) were formulated and offered as two-way choices of AB, AC, BC, CD and DE from 4 to 9 weeks of age. Broilers were first familiarized with both diets on offer for 1 week before the experiment began. Results given in the Table are the means for weeks 4–9.

		Treatment				
		AB	BC	CD	AC	DE
Food intake (g/bird per d):	Mean	123·8[a]	130·5[a]	133·5[a]	126·5[a]	127·8[a]
	SE	4·9	12·0	3·8	5·4	8·4
High-protein food intake: total food protein intake ratio	Mean	0·95[a]	0·75[b]	0·09[c]	0·97[a]	0·08[c]
	SE	0·012	0·053	0·013	0·014	0·034
Live-wt gain (g)	Mean	1500·0[b]	1892·0[a]	2024·0[a]	1984·0[a]	1475·0[b]
	SE	54·7	82·4	99·6	184·0	137·0

[a,b,c] Mean values in the same row with different superscript letters were significantly different: $P<0·05$.

When broilers had to select between two diets of lower protein content than requirement (A and B) or two diets of higher protein content than required (D and E) for normal growth, they preferred the one closer to the optimum but also took a very small amount from A (in the case of AB) or E (in the case of DE). The food and protein intakes of broilers on AB increased gradually from 101·4 (SE 4·0) g/bird per d and 122·2 (SE 4·6) g/kg at week 5, to 134·1 (SE 12·7) g/bird per d and 166·0 (SE 16·0) g/kg at week 9 respectively. Broilers on DE at first increased food intake from 103·3 (SE 9·0) g/bird per d at week 5 to 152·4 (SE 9·8) g/bird per d at week 8, but then their food intake was reduced to 124·0 (SE 7·1) g/bird per d at week 9.

BC, AC and CD were a choice between a feed close to requirement (C) and a very-low-protein (A), low-protein (B) or a high-protein (D) feed. Food intake of broilers offered AC or CD was almost entirely from C. So, those on AC and CD had similar amounts of food intake, i.e. 82·6 (SE 10·5) and 89·2 (SE 2·4) g/bird per d at week 5 to 172·9 (SE 4·6) and 160·2 (SE 3·8) g/bird per d at week 9 respectively. Those on BC selected a proportion of both feeds. The ratio of food intake of C:total AC decreased from 0·76 (SE 0·07) at week 5 to 0·63 (SE 0·05) at week 9. There was a positive growth rate for all groups except those on DE, which started to lose weight from week 8.

Clearly broilers are able to choose a balanced diet and reject any feed that is a great distance away from their requirement. Thus, they do not tend to prefer a very-high-protein diet, nor to overconsume protein as has generally been thought.

Holcomb, D. J., Roland, D. A. & Harms, R. H. (1976). *Poultry Science* **55**, 1731–1736.

The influences of meal composition on subsequent food selection in broiler and layer chickens. By F. SHARIATMADARI and J. M. FORBES, *Department of Animal Physiology and Nutrition, University of Leeds, Leeds LS2 9JT*

Most of the information currently available describing macronutrient-intake regulation is based on studies in which food intake is measured for several days or weeks. In order to explore possible mechanisms involved it is important to characterize this regulation on a short-term basis.

Nine male broiler and nine male layer chickens were first familiarized with two isoenergetic feeds varying in crude protein (CP, nitrogen × 6·25) content (70 g and 300 g CP/kg fresh feed, diets LP and HP respectively). They were then fasted overnight and were allowed access to one of the above feeds for 10 min. In the first experiment they were presented with both feeds immediately and intakes measured over 1 h. In the second experiment they were starved 45 min after the initial feed to allow time for postdigestive effects to appear and were then allowed access to both diets. In a third experiment the birds were tube-fed on the same amount as that taken by chickens during their 10 min access to the initial feed, and they were then starved for 45 min after the initial feed. Food intakes were recorded over the following 1 h.

Effect of protein content of initial meal on subsequent intake of high- and low-protein feeds (g/1 h)

(Mean values with their standard errors for nine determinations)

Crude protein content (g/kg): Initial meal . . .		70				300			
1 h subsequently . . .		70		300		70		300	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
Expt 1:	Broiler	8.4^{ab}	5·0	15.5^{a}	3·5	16.8^{a}	3·2	6.1^{b}	2·5
	Layer	4.9^{b}	1·1	8.6^{a}	1·9	9.0^{a}	1·6	5.9^{b}	1·1
Expt 2:	Broiler	9.2^{b}	3·0	18.3^{a}	3·2	12.8^{ab}	2·5	6.1^{b}	0·9
	Layer	4.2^{b}	0·8	11.6^{a}	0·9	5.3^{b}	1·0	5.9^{b}	1·1
Expt 3:	Broiler	15.9^{a}	3·4	18.9^{a}	3·9	20.0^{a}	3·2	15.7^{a}	1·8
	Layer	11.0^{a}	3·6	13.6^{a}	2·0	13.5^{a}	3·4	10.0^{a}	2·5

[a,b] Mean values in a horizontal row with different superscript letters were significantly different: $P<0.05$.

There were no significant differences due to protein content in the weight of food eaten during the 10 min initial meal, broilers eating 11·3 (SE 0·9) g of LP and 11·0 (SE 0·8) g of HP diets while layers took 5·3 (SE 0·3) g of LP and 5·9 (SE 0·4) g of HP diets. When subsequently given a choice of both feeds, there was preference for the one which had not recently been eaten.

The results show that the composition of recently ingested and digested food may be a factor determining the short-term regulation of macronutrients in both strains of chicken. However, in the experiment in which the initial meal was given by tube into the crop, there was no significant effect of the composition of the premeal on subsequent choice of high- and low-protein diets.

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Associations of breed and nematodiasis with intake of a free-access mineral mixture by grazing lambs. By N. SUTTLE and J. BREBNER, *Moredun Research Institute, 408 Gilmerton Road, Edinburgh EH17 7JH*

In a study of the effects of free-access mineral intake on efficacy of an oral copper supplement in two different breeds, mineral intake was found to vary with breed. The 2×2 factorial experiment involved four groups of ten Finnish Landrace (FL) or Suffolk × Blackface (S × B) lambs, recently weaned and weighing about 21 kg initially; they were either allowed or denied access to a proprietary, iron- and magnesium-rich mineral mixture (Stockmin, FSL Bells Ltd) presented in plastic containers, under cover, in lamb creeps from 24 July. Each group grazed a separate plot of approximately 0·4 ha and was moved in rotation (with any mineral dispenser) around the plots at weekly intervals to minimize plot bias. Weekly intakes of mineral were measured for each group for 11 weeks beginning on 5 September, when seven lambs from each group received 1·3 g cupric oxide needles (CuO, Copacaps, RMB Ltd). Samples of plasma and faeces were occasionally taken for multi-element analysis. Nematode egg counts in faeces were increasing prior to dosing and many lambs had diarrhoea at CuO dosing. All received anthelmintic 2 d and 32 d later.

Period of experiment	Group mineral consumption (g/head per d)										
(weeks) . . .	1	2	3	4	5	6	7	8	9	10	11
Breed											
FL	36	18	17	50	20	14	17	18	20	15	21
S × B	7	6	12	16	NM	12	10	7	11	6	5
Rainfall (mm)*	4·4	11·6	18·1	0	6·9	14·9	20·3	24·8	3·6	12·3	0·2

NM, not measurable. * Recorded at Penicuik, approximately 10 km southwest of experimental site.

The Table shows that FL lambs consumed more mineral than S × B lambs every week ($P<0·01$) and 243% more on average. There was considerable variation from week to week in mineral consumption, particularly in FL lambs (mean 22·4 (SD 10·9) compared with 9·2 (SD 3·6) g/head per d for S × B) but no correlation between intakes of the two breed groups. The manufacturer's recommended maximum intake is 12·5 g minerals/25 kg live weight. Peak consumption of minerals in FL lambs coincided with anthelmintic administration. Faecal Fe and Mg concentrations in FL lambs were correlated and indicated wide individual differences in mineral consumption. Allowing access to minerals for 14 weeks did not improve weight gain in FL lambs (3·9 (SE 35) *v.* 3·6 (SE 0·41) kg) but did so in S × B lambs (7·8 (SE 1·91) *v.* 4·8 (SE 0·60) kg for groups given and denied access respectively; $P<0·05$). Faecal dry matter (FDM, g/kg fresh weight) showed transient evidence of a breed × treatment interaction. At dosing with CuO, access to mineral reduced FDM in S × B lambs from 264 (SE 24) to 145 (SE 14) ($P<0·01$) but not in FL lambs in which values were uniformly low (142 (SE 9)).

The variation in consumption of minerals may reflect the need for and success of self-treatment of a salt deficit induced by the nematode infection. That need would be reduced by anthelmintic treatment but ill met by a mineral mixture rich in the laxative cation, magnesium, in the breed with greater need (FL).

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Effect of hepatic portal infusion of propionate or equivalent saline loads on food intake in sheep. By D. A. H. FARNINGHAM, *Rowett Research Institute, Greenburn Road, Bucksburn, Aberdeen AB2 9SB*

Volatile fatty acids are putative mediators of food intake in ruminants and hepatic portal propionate infusions have been shown to suppress food intake (Anil & Forbes, 1980). It is, however, uncertain whether there is a graded response to portal propionate and whether effects are due to the osmotic load.

Female sheep (50–85 kg) were fed *ad lib.* on a pelleted diet (g/kg: 500 hay, 300 barley, 100 molasses, 90 white fish meal, and minerals). Catheters were inserted via a mesenteric vein into the portal vein. After recovery animals were infused with molar solutions of sodium propionate or sodium chloride for 3 h (see Table). Control intakes were calculated as the mean of days preceding and following infusion days. Statistical significance was calculated using paired or unpaired t tests.

Effects of sodium propionate and sodium chloride on food intake (g) in four sheep

Infusion solution and rate (mmol/min for 3 h)	0–3 h Intake (g)		0–24 h Intake (g)		Number of infusions
	Mean	SE	Mean	SE	
Expt. 1 (four animals)					
Propionate control	408	43	1810	91	13
Propionate 1·2	258	57	1769	92	13
NaCl control	380	34	1778	89	14
NaCl 1·2	316	46	1739	106	14
Expt. 2 (five animals)					
Pooled control	299	16	1389	28	57
Propionate 0·6	283	39	1338	145	11
Propionate 0·9	248	30	1293	127	11
Propionate 1·2	173	23	1327	70	12
Propionate 1·8	141	23	1220	116	12
Propionate 2·5	103	15	1177	57	12

Propionate inhibited food intake significantly more than an equivalent osmotic load of sodium chloride ($P<0·05$). In Expt. 2 intake was significantly depressed by propionate over the 3 h of the infusion ($P<0·05$) and, at the highest level of propionate, also over 24 h ($P<0·05$). Theoretical propionate absorption from the diet would have been about 4 mmol/min over 24 h and therefore the infusions were at physiological rates. It is concluded that propionate inhibits intake independently of its osmotic effect, and that short-term satiety induced by propionate may be involved in longer term control mechanisms.

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Cholecystokinin effects on wet and dry meals in pigs. By D. V. RAYNER and S. MILLER, *Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB*

The decrease in food intake with peripheral administration of cholecystokinin has been attributed to its effects on the rate of gastric emptying (McHugh & Moran, 1986). In pigs cholecystokinin octapeptide (CCK-8) reduced meal size (Gregory *et al.* 1989), but did not inhibit emptying during the feeding period (Rayner & Gregory, 1989).

Four pigs were fitted with gastric cannulae and catheters in the abdominal aorta via the saphenous vein. They were given pig meal either dry (DF), but with access to water, or mixed with twice its weight of water (WF), twice daily to appetite. On experimental days, the stomach contents were evacuated before the morning meal and at satiety. CCK-8 (0·25 or 4 μg/kg per h, 0·25 CCK and 4 CCK respectively) or saline (9 g sodium chloride/l) were infused via the blood catheter from 35 min (WF) or 5 min (DF) before feeding so that approximately the same total amount of CCK-8 was infused. (Pigs ate WF more rapidly than DF.) On DF, CCK-8 decreased dry matter (DM) intake and significantly reduced the amount emptied at satiety by reducing the period of feeding at both rates of infusion: with 4 CCK only, the rate of DM emptying and stomach volume at satiety was significantly decreased. On WF, only 4 CCK significantly decreased DM intake but neither rate of infusion significantly decreased the amount emptied, the period of feeding, the rate of gastric emptying or stomach volume.

		Wet feed				Dry feed			
		Saline control	0·25 CCK	Saline control	4 CCK	Saline control	0·25 CCK	Saline control	4 CCK
DM intake (g):	Mean	1010	952	1048	831*	964	832*	1130	783***
	SE	61	72	66	77	62	88	55	98
DM emptied (g):	Mean	197	165	190	136	222	172*	218	94***
	SE	18	45	35	32	20	32	30	30
Period of feeding (min):	Mean	21·1	18·0	21·8	16·2	45·9	36·5*	48·5	28·8***
	SE	2·7	1·6	3·2	3·3	2·8	3·3	3·0	2·0
DM emptied (g/min):	Mean	8·4	7·8	7·5	6·8	4·3	3·9	3·9	2·7**
	SE	0·8	0·6	0·6	1·2	0·3	0·6	0·5	0·8
Stomach volume (ml):	Mean	2785	2803	2886	2371	2264	2036	2492	1890**
	SE	179	253	170	192	153	174	155	190

Significantly different from controls: * $P \leq 0·05$, ** $P \leq 0·01$, *** $P \leq 0·001$.

CCK-8 only inhibited fluid intake at physiological concentrations (0·25 CCK) on DF but not by changing gastric emptying and stretch. Control DM intakes and DM emptied were the same with DF and WF, although on DF the rates of eating and stomach emptying were significantly slower. Intake appeared to be defined by the amount of DM entering the duodenum rather than by stomach stretch.

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The effect of the oestrous cycle in rats on carbohydrate consumption. By H. GILLIAN ANANTHARAMAN-BARR, J. DECOMBAZ, B. DECARLI and K. ANANTHARAMAN, *Nestec Ltd, Nestlé Research Centre, Vers-chez-les-Blanc, CH-1000 Lausanne, Switzerland*

During the oestrous cycle, food intake is reduced at pro-oestrus when levels of oestrogen are high. The mechanism of action of oestrogens on appetite is unclear. Wurtmann & Baum (1980) offered rats a choice of high- and low-protein diets and observed that over the cycle, protein intake remained stable but that the consumption of the low-protein diet, and therefore carbohydrate, was reduced at pro-oestrus. They therefore proposed that serotonergic pathways, which influence carbohydrate selection, may be involved. In the present study, using a continuous food intake monitoring system, we examined the food selection of Wistar rats (*n* 8, initial weight 200 g) offered milled chow (250 mg protein/g, metabolizable energy (ME) 13·4 kJ/g) for three consecutive cycles (control) and subsequently a choice of milled chow and granulated sucrose (ME 16·3 kJ/g) (choice) for four consecutive cycles. The minimum quantity defined as constituting a meal was 0·30 g, and the minimum time between bouts of feeding needed to categorize the bouts as independent meals were 30 min. Meal size and number and energy intake at pro-oestrus were compared with those at all other phases of the cycle (2-way ANOVA with repeated measures).

		ME intake (kJ/d)									
		Di-oestrus		Pro-oestrus		Oestrus		Metoestrus		Cycle mean	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Control period	Chow	236	7·7	204	7·4	234	5·1	242	14·0	230	5·1
Period of choice:	Chow	112	8·0	79	7·3	109	5·7	111	9·3	103	4·4
	Sucrose	149	7·9	159	6·3	147	7·8	157	9·1	153	3·9

During the control period ME intake fell by 14% at pro-oestrus ($P<0·002$). This was the result of a reduction in meal size ($P<0·01$) from 1·9 to 1·3 g/meal on the night of pro-oestrus. This was partly compensated for by an increase in meal frequency from 7·0 to 8·4 meals/night. During the period of choice there was an overall reduction of 55% in mean chow intake ($P<0·001$) but owing to high-sucrose consumption an 11% increase in ME intake occurred. Sucrose selection did not differ over the cycle but chow intake was markedly reduced at pro-oestrus ($P<0·001$) as a result of reduced night-time meal size.

These results demonstrate that the oestrous cycle has little effect on carbohydrate intake and does not support the hypothesis that serotonergic mechanisms play a role in the effect of oestrogens on appetite.

Wurtmann, J. J. & Baum, M. J. (1980). *Physiology and Behavior* **24**(5), 823–827.

Energy intake and basal metabolic rate in lean and overweight women during the menstrual cycle. By H. GILLIAN ANANTHARAMAN-BARR, PATRICIA E. POLLET and ISABELLE BARTHOLDI, *Nestec Ltd, Nestlé Research Centre, Vers-chez-les-Blanc, CH-1000 Lausanne 26, Switzerland*

A number of authors have reported that food intake (Dalvitt-McPhillips, 1983) and basal metabolic rate (BMR) (Solomon *et al.* 1982) increase during the luteal phase of the menstrual cycle whereas others have observed no significant trend (Blunt & Dye, 1921; Sophos *et al.* 1987). In all these studies the subjects were of normal weight.

In the present study we compared energy intake and BMR of nine lean (mean body mass index (BMI, weight/height^2) 21·1, body fat 257 g/kg, age 28 years) and six overweight (mean BMI 25·4, body fat 329 g/kg, age 39 years) women during the follicular (F) and luteal (L) phases of the menstrual cycle. Body fat was calculated using measurement of skin-fold thickness at four sites.

For 3 months subjects weighed and recorded their food intakes on days 6–12 (F) and days 19–25 (L) of the cycle. BMR was measured on the 7th, 8th or 9th day (F) and the 21st, 22nd or 23rd day (L) of the cycle using a ventilated hood. Subjects reported to the Metabolic Unit at 20.30 hours and fasted thereafter. They retired at 22.30 hours, were awakened at 07.30 hours and BMR was measured between 08.15 and 09.15 hours. The phase of the cycle was verified by plasma hormonal status.

		Food intake (kJ/d)				BMR (kJ/d)			
		F		L		F		L	
	n	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Lean	9	8213	342·1	8431	337·6	5151	67·7	5402**	105·0
Overweight	6	7883	325·1	8656	603·8	5674	179·9	5816	141·0
Overweight†	5	8128	262·8	9144*	440·6	5724	210·9	5786	168·2

Mean value significantly greater than F value: * $P<0·05$, ** $P<0·01$.
† Excluding those with intakes less than 1·3 × BMR.

In lean subjects energy intake was not influenced by the phase of the cycle (a small (4·9%) but significant ($P<0·01$ paired *t* test) increase in BMR occurred post-ovulation). BMR of the overweight group was 9% greater than that of the lean but did not vary within the cycle. One overweight subject reported energy intake less than 1·3 × BMR. Including this subject an average increase in energy intake of 10% occurred post-ovulation ($P<0·05$). With their exclusion the difference between F and L rose to 13%.

These results suggest that the menstrual cycle had little effect on energy balance in the lean women, whereas in the overweight (or slightly older women) a tendency towards positive energy balance occurred post-ovulation. A further study to clarify the importance of age on the cyclic changes in energy intake and expenditure over the menstrual cycle is requisite.

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Food knowledge and 'healthy' diets in people with and without coronary heart disease. By
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Poor diet is now thought to contribute to increased risk of coronary heart disease (CHD). Post-myocardial infarction patients and those diagnosed with symptoms of ischaemia are generally advised to lose weight if obese and to eat a healthier diet.

The Scottish Heart Health Study (Smith *et al.* 1989) was a cross-sectional study of 10 359 men and women aged 40–59 years. Subjects completed a questionnaire which included health knowledge, the Rose chest pain questions and a food frequency questionnaire (Yarnell *et al.* 1983). They attended a clinic where the questionnaires were checked and the examination included a 12 lead electrocardiogram (ECG).

The proportion of people with medically diagnosed CHD (diagnosed group, D) who possessed good nutritional knowledge and were actually trying to improve their diet, were compared with those who had symptoms of ischaemia (ECG criteria or a positive Rose angina response, or both) but were undiagnosed (undiagnosed group, UD) and with those who were asymptomatic and apparently healthy with regard to CHD (control group, C).

	Men				Women			
Group . . .	C	UD	D	Significance of difference	C	UD	D	Significance of difference
n . . .	3806	681	378	P*	3744	798	232	P*
% on medically prescribed diets	2·4	5·1	13	<0·001	4·3	7·5	16	<0·001
% believing eating less fat would reduce CHD risk	78	80	83	>0·05	77	79	84	0·028
% trying to eat less fat	45	50	68	<0·001	62	64	70	0·017
% believing losing weight would reduce CHD risk	63	68	72	<0·001	70	75	81	<0·001
% trying to lose weight	28	33	48	<0·001	53	59	60	0·005
% believing fried food is better than grilled food	2·7	4·4	3·4	0·039	1·7	1·5	3·8	0·047
% believing bread and potatoes are fattening	47	53	51	0·006	42	46	57	<0·001

* Significance by the Chi square test.

The diagnosed group appeared to be better informed with regard to the value of reducing fat intake and losing weight, and a greater proportion reported trying to do so than the control and undiagnosed groups. However, their reported knowledge of some foods which would assist them in this was poorer (see Table), while for others (high-fat nature of dairy products; soft margarine better than butter) there was no significant difference in reported knowledge between the groups. For men, significant differences (Chi square test) occurred between the groups in the proportion of people at the extremes of saturated fat (% of energy) and fibre (g/day) intakes (P=0·014 and P=0·004 respectively).

The need for clearer advice to patients about foods rather than nutrients is indicated.

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Dietary organic anions can make a significant contribution to the total fermentable material in the human large intestine. By T. H. J. FLORIN, G. NEALE and J. H. CUMMINGS, *MRC Dunn Clinical Nutrition Centre, 100 Tennis Court Road, Cambridge CB2 1QL*

The organic anions, oxalate and tartrate, are not metabolized by human cells. Dietary oxalate has been reported to vary between 0·7 and 23 mmol/d (Hodgkinson, 1977). The tartrate content of diets has not been reported, although it is used as a food additive and is known to be a constituent of grapes and grape-products. We report experiments which define the potential for these anions to be fermented by colonic bacteria.

Five healthy human ileostomists were given up to five diets, comprising normal foods, and with energy, protein, fat and carbohydrate contents broadly in keeping with a typical British diet. The diets were given in random order for 48 h and complete ileal collections made during the second 24 h of each dietary period and refrigerated. Oxalate and tartrate were measured in food and ileal effluent by anion exchange chromatography, which for oxalate included preliminary treatment with acid to dissolve calcium oxalate. (Losses of oxalate and tartrate in ileostomy fluid were not significant in recovery experiments.) The Table shows that less than 40% of dietary oxalate was absorbed by the upper gastrointestinal tract, and that less than 36% of dietary tartrate was absorbed (except for the lowest intake).

Oxalate and tartrate in diets and ileal effluent (mmol/d)

Diet ...		A	B	C	D	E
n ...		5	5	3	3	3
Oxalate:						
Intake		2·0	1·8	4·0	3·9	4·8
Ileal output:	Mean	1·3	1·9	2·4	2·7	3·4
	SE	0·3	0·3	0·9	0·9	0·3
% Excretion		65	105	60	69	71
Tartrate:						
Intake		0·06	0·7	18·2	33·4	51·4
Ileal output:	Mean	0·01	0·5	13·5	25·7	46·3
	SE	0·02	0·1	1·8	6·0	4·3
% Excretion		16	80	74	77	90

In another experiment, faeces from six healthy volunteers were incubated anaerobically at 37° for 48 h with either 5 mM-oxalic acid or 5 mM-L(+)-tartaric acid buffered at pH 7 (six slurries each). There was no tartrate detected at the end of the incubation in five of the six tartrate slurries. Oxalate metabolism in the slurries was more varied. The mean degradation rates were (μmol/g faeces per h), oxalate: 7·38 (SE 3·91), and tartrate: >16·39 (SE 1·61).

It can be concluded that oxalate and tartrate are poorly absorbed by the upper gastrointestinal tract in man; both anions are fermented by faecal bacteria; although organic anions have not previously been considered a significant substrate for colonic bacteria (Cummings & Englyst, 1987), the contribution of oxalate and tartrate to total fermentable material in the large intestine may be as much as 10 g/d with some diets; derangement of bacterial metabolism of oxalate in the colon may be important in some enteric diseases characterized by hyperoxaluria and renal-stone formation.

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Role of the sympathetic nervous system in the regulation by insulin of the level of uncoupling protein in brown adipose tissue. By A. GÉLOËN[1,2] and P. TRAYHURN[1], [1]*Division of Biochemical Sciences, Rowett Research Institute, Bucksburn, Aberdeen AB2 9SB* and [2]*Laboratoire de Thermoregulation et Energetique de l'Exercice, URA 1341, Lyon, France*

Brown adipose tissue (BAT) is specialized for heat production, both for thermoregulation and in relation to the regulation of energy balance. The thermogenic capacity of BAT is dependent on the amount of the mitochondrial uncoupling protein (UCP) in the tissue (see Trayhurn, 1989; Trayhurn & Milner, 1989). We have recently shown that insulin plays an important role in the regulation of the level of UCP (Géloën & Trayhurn, 1990), and have now examined whether this occurs through a modulation of the activity of the sympathetic innervation to BAT.

Lister Hooded rats, housed singly at 21°, were made diabetic with a single intraperitoneal injection of streptozotocin (75 mg/kg). After 12 d of diabetes, interscapular BAT was surgically denervated on one side only, the other side retaining its innervation. The rats were then infused with 8 or 70 units of insulin/kg body-weight per d (based on initial body-weight), via osmotic minipumps implanted subcutaneously. The two interscapular BAT pads were removed after 12 d of insulin infusion, or following 24 d of diabetes. The innervated and denervated halves of the tissue were separated, and mitochondria prepared from each. The mitochondrial protein content of BAT, and the specific mitochondrial concentration of UCP, were measured as previously (Géloën & Trayhurn, 1990), to give the total tissue protein concentration. Results (see Table) are for six to ten animals in each group.

	Uncoupling protein content (μg/interscapular pad)				
	Innervated		Denervated		Statistical significance
	Mean	SE	Mean	SE	*P* (*t* test)
Control	788[d]	65	182[b]	37	<0·001
Diabetic	41[a]	9	28[a]	9	NS
Diabetic+insulin (8 units)	162[b]	29	51[a]	6	<0·001
Diabetic+insulin (70 units)	461[c]	45	255[b]	61	<0·001

NS, not significant.
[a–d] Values with different superscript letters are significantly different (Fisher PLSD): $P<0{\cdot}05$.

Denervation led to a marked fall in the tissue content of UCP. The amount of the protein was also substantially reduced in streptozotocin-induced diabetes, in agreement with our previous results in mice (Géloën & Trayhurn, 1990). There was, however, no significant effect of denervation in the diabetic animal. Low doses of insulin replacement induced a partial restoration of UCP, and the level was further increased by high replacement doses. Although insulin replacement increased the amount of UCP in denervated, as well as in innervated tissue, the effects were inhibited by denervation.

These results indicate that both insulin and an intact sympathetic innervation are required for the maintenance of normal levels of UCP in BAT. It is concluded that insulin regulates the amount of the protein, at least in part, through an interaction with the sympathetic nervous system.

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The influence of meal composition and frequency of intake on the thermic effect of food.
By JOYCE KINABO and J. V. G. A. DURNIN, *Institute of Physiology, University of Glasgow, Glasgow G12 8QQ*

The effect of meal composition and frequency of intake on the thermic effect of food (TEF) was investigated in eighteen non-obese female subjects. Their metabolic rate before and after consuming a test meal was measured by open circuit indirect calorimetry using the Douglas bag technique, while the subjects were in the resting state (lying down). Eight subjects consumed a high carbohydrate–low fat (HCLF) meal containing 70, 19 and 11% of the energy content from carbohydrate, fat and protein respectively. Ten other subjects consumed a low carbohydrate–high fat (LCHF) meal containing 24, 65 and 11% of the energy from carbohydrate, fat and protein respectively. On two separate occasions, each subject consumed the appropriate diet either as one large meal containing 5040 kJ (1200 kcal) or as two smaller meals each containing 2520 kJ (600 kcal). TEF values were calculated for 6 h after the test meal and the mean values after consuming the HCLF meal were 377·0 (SE 30·0) kJ (90·0 (SE 7·2) kcal) and 381·0 (SE 26·5) kJ (91·0 (SE 6·3) kcal) for the one large and two small meals respectively. The corresponding values for the subjects who consumed the LCHF meal were 356·0 (SE 23·0) kJ (85·0 (SE 5·5) kcal) and 340·0 (SE 15·9) kJ (81·0 (SE 3·8) kcal). No significant differences were found between the two feeding regimens (HCLF, P=0·94; LCHF, P=0·64) as well as between the two meal compositions (P=0·57) (Fig.). Thus, meal frequency and meal composition did not seem to have a significant influence on TEF.

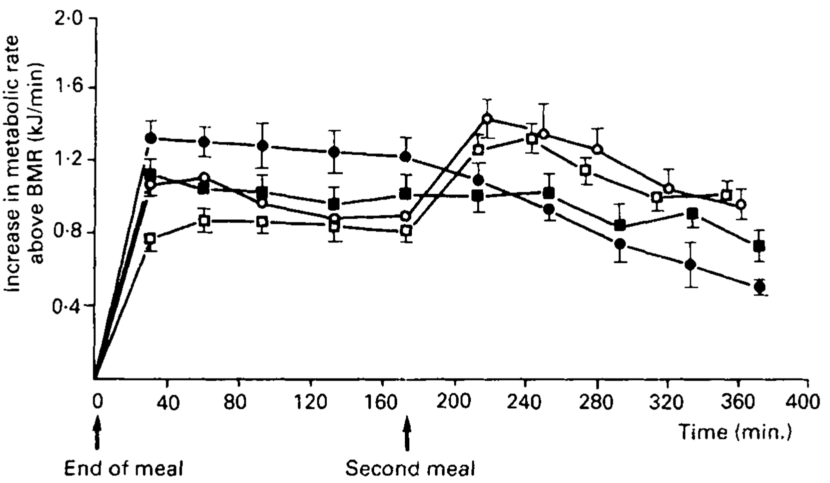

Fig. Increase in metabolic rate above basal metabolic rate (BMR) in non-obese subjects after ingestion of a high carbohydrate–low fat (n 8) meal administered either as a single large meal (5040 kJ (1200 kcal)) (●) or as two smaller meals (2520 kJ (600 kcal)) each (○) and a low carbohydrate–high fat (n 10) meal either as a large single meal (5040 kJ (1200 kcal)) (■) or as two smaller meals (2520 kJ (600 kcal) each (□). Values are means, with their standard errors represented by verical bars.

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Adaptation to a low-protein intake in normal adults: increased production and hydrolysis of urea. By M. LANGRAN[1,2], B. J. MORAN[2] and A. A. JACKSON[1], *Departments of* [1]*Human Nutrition* and [2]*Surgery, University of Southampton, Bassett Crescent East, Southampton SO9 3TU*

On a low-protein intake, nitrogen balance is maintained by a reduction in the urinary excretion of N, mainly due to a fall in the excretion of urea N. It has been accepted that the decreased excretion of urea reflects a decrease in urea production, with an alteration in the fate of urea in the body. On a normal protein intake, 70% of the urea produced is excreted in the urine, with 30% of the N being salvaged after bacterial hydrolysis in the bowel. The N thus becomes available to the body's metabolic pool. The efficiency of the salvaging increases when the metabolic demand for N exceeds that available from the diet (Richards, 1972). No studies have previously assessed normal adults on an adequate and a marginal intake of protein, using [$^{15}N^{15}N$]urea.

Five normal adult males (age 22–43 years) were studied on two occasions whilst receiving one of two liquid feed diets: adequate protein providing 165 mg N and 115 kJ/kg per d, and low-protein providing 78 mg N and 124 kJ/kg per d. Each study was carried out over a 5 d period and 24 h urines were collected throughout. During the final 18 h, urea kinetics were measured using oral [$^{15}N^{15}N$]urea and three-hourly collections of urine (Jackson *et al.* 1984).

On the low-protein diet, urea excretion (Eu) fell as expected and reached a plateau by day 5. Surprisingly, there was no significant change in urea production (P) compared with the adequate-protein intake, with the result that urea hydrolysis (T) and the urea available to other synthetic processess (S) were increased. The values for urea production from recycled urea N (Pr) are also given. There was large inter-individual variation and so these differences only became significant when expressed in relative terms: P/intake and T/P were significantly increased on the low-protein diet, with Eu/P being significantly reduced.

Dietary protein		mg N/kg per d								
		P	Eu	T	S	Pr	Eu/P	T/P	S/P	P/intake
Adequate:	Mean	175	98	77	65	12	0·57	0·43	0·35	1·10
(*n* 4)	SE	27	12	16	18	2	0·02	0·02	0·05	0·23
Low:	Mean	198	66	132	108	24	0·35*	0·65*	0·53	2·56*
(*n* 5)	SE	19	10	21	17	7	0·06	0·06	0·04	0·25

Significantly different from adequate-protein diet (Willcoxon Rank Sum): $*P<0{\cdot}05$.

Although urinary urea excretion decreased, reflecting changes in N balance, there were also substantial changes in urea kinetics. There was a relative increase in production and a significant increase in the salvaging of urea N through gastrointestinal hydrolysis. The demonstration of increased urea production on a low-protein diet is a novel observation which carries important implications for our appreciation of the mechanisms of adaptation to low-protein intakes in man.

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Urinary 5-oxoproline in term and preterm neonates as an index of glycine status. By C. PERSAUD[1], N. EVANS[3], M. HALL[2], N. RUTTER[3], S. SMITH[2] and A. A. JACKSON[1] *Departments of [1]Human Nutrition* and *[2]Child Health, University of Southampton, Bassett Crescent East, Southampton SO9 3TU* and *[3]Department of Child Health, Queen's Medical Centre, University of Nottingham, Clifton Boulevard, Nottingham NG7 2UH*

Glycine is required in substantial amounts for normal growth and development. Large quantities of glycine are consumed by creatinine, haem, collagen, bile salts, glutathione and nucleic acid synthesis. Glycine functions as a conditionally essential amino acid in states where the metabolic demand exceeds that available from intake and endogenous synthesis. The excretion of 5-oxoproline (5OP) in urine may be used as an index of glycine status (Jackson *et al.* 1987). The demands for glycine are very high during infancy and may be increased in preterm infants. In the present study the urinary excretion of 5OP has been measured in term and preterm neonates.

Single samples of urine were collected longitudinally from nineteen term infants from 2 d to 12 weeks of age, and from a group of forty-nine infants born before 36 weeks, in a mixed cross-sectional/longitudinal fashion. Forty infants were receiving exclusively breast milk and twenty-eight exclusively a milk formula (glycine content of formula, 360 mg/l). For comparison, specimens of urine were collected from twenty-six normal adults. 5OP was isolated from urine by column chromatography, hydrolysed to glutamic acid and the glutamic acid measured enzymically. Creatinine in urine was measured using Jaffe's reaction. The excretion of 5OP was expressed as a ratio to creatinine (μmol/mmol).

In term infants on day 2 the excretion of 5OP was 65 (range 11–177) μmol/mmol creatinine, significantly less than the value at day 7 (155, range 22–413 μmol/mmol). There was little change from 1 to 12 weeks of age. In preterm infants on day 2 the excretion of 5OP (152, range 49–419 μmol/mmol) was significantly greater than in term infants on day 2 (Student's t test). In preterm infants the excretion of 5OP between 1 and 12 weeks (240, range 22–777 μmol/mmol) was not different to that in term infants. For both term and preterm infants there was a wide range of intra-individual variation in the excretion of 5OP, from 15 to 72%. In some preterm infants the excretion reached very high levels. For all neonates over 1000 g, there was a significant inverse relationship between birth weight and 5OP excretion (r −0·33, P<0·02).

On day 2, the excretion of 5OP in 44% of term and none of the preterm infants was within the adult range (mean + 2SD). From 1 week onwards only 9% of term and 3·7% of preterm infants had an excretion of 5OP which fell within the adult range.

It is concluded that high rates of 5OP excretion are a normal feature of infancy, possibly in relation to the metabolic demands for glycine for growth. There is a need to identify whether excessively high levels of excretion are a consequence of exceptional demands for glycine.

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The effect of interactions of soluble (pectin) and insoluble (wheat bran) dietary fibres on caecal short-chain fatty acids and caecal tissue weight in the rat. By E. F. ARMSTRONG, M. A. EASTWOOD and W. G. BRYDON, *Wolfson Gastrointestinal Laboratories, Department of Medicine, Western General Hospital, Edinburgh EH4 2XU*

Ingestion of complex carbohydrates often increases caecal tissue weight and this is thought to be due in part to the short-chain fatty acids (SCFA) produced when the carbohydrates are fermented (Sakata, 1987). Pectin, which is readily fermented, increases caecal tissue weight in contrast to bran which is minimally fermented. The present study examines the influence of supplementing a low-fibre diet (25 g/kg dry weight) in rats (five per group) for 28 d with pectin (50 g/kg) alone or with a pectin (50 g/kg)–wheat bran (50 g/kg) mixture. The dry and wet weights of caecal contents, caecal SCFAs, and caecal sac weight were measured. The animals had been reared on a standard laboratory diet (Walters *et al.* 1986), and mean weight at the end of the experiment was 325 g.

	Caecal contents (g/kg body-wt)				Total SCFAs (µmol/g dry wt)		Propionate (mmol/mol)		Caecal sac wt (g/kg body-wt)	
	Wet		Dry							
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Low-fibre diet (LFD)	9·0	0·7	1·9	0·2	769	55	158	10	1·9	0·1
LFD + pectin (50 g/kg)	14·7*	0·5	2·3	0·1	738	26	229*	16	3·0*	0·1
LFD + 5% pectin (50 g/kg) + wheatbran (50 g/kg)	14·7*	1·5	2·2	0·3	678	47	125	8	1·6	0·1

Significantly different from LFD (one-way analysis of variance): * $P<0·05$.

Although the pectin diet increased caecal tissue weight, this effect was abolished when wheat bran was included with the pectin. The weight of caecal contents and the total SCFAs were not different in the two groups, however. The only difference was a higher molar proportion of propionate in the pectin group. These results suggest that caecal tissue weight is not dependent on total caecal SCFAs or contents weight, but propionate may be important.

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