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The utilization of dietary protein by Nigerian men

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1. The excretion of urinary and faecal nitrogen by young Nigerian men of a low income group was found to vary significantly between subjects, but was not significantly different in the same subject, when they were given a mixed diet composed of rice, vegetables and fish on two separate occasions. At the levels of energy and protein supplied by this diet the men gained or lost small amounts of weight, mean values indicating N equilibrium, the variation around the mean being high.

2. The correlation between the urinary and faecal N of these men was significantly negative at and below the level of N equilibrium, becoming positive 2–3 weeks after they had consumed the above diet supplemented by 400 g of lean beef per day, and had already established considerable rates of gain in body-weight and N retention. The diets were made isoenergetic by adding the beef at the expense of cassava flour and red palm oil.

3. The physiological processes involved in the adaptation, by young Nigerian men of low income, to a highly efficient use of low-protein diets are discussed in relation to the biological value and true digestibility of those diets, and to the 'safe level of protein intake' and protein-energy ratios proposed by FAO/WHO (1973, 1975).

4. It is concluded that the protein requirements of apparently healthy men can only be established in the context of their ecological, socio-economic and nutritional backgrounds.

The idea that all apparently healthy men, irrespective of ethnic and socio-economic differences, have the same protein requirements, whether expressed in terms of body-weight or basal metabolic rate (BMR) has been discussed in a previous paper (Nicol & Phillips, 1976). At minimal levels of protein intake students of the University of California, Massachusetts Institute of Technology and Taiwan University (based on the results of Calloway & Margen (1971), Scrimshaw, Hussein, Murray, Rand & Young (1972) and Huang, Chong & Rand (1972) respectively) and Indian and Nigerian peasant farmers and labourers (based on the results of Gopalan & Narasinga Rao (1968) and Nicol & Phillips (1976) respectively), were found to excrete comparable amounts of urinary and faecal nitrogen per unit body-weight or basal energy. The correlation between urinary and faecal N was positive in North America and Taiwan students at the endogenous level of excretion but was negative in Indian and Nigerian men of low income. The biological value (BV) and net protein utilization (NPU) of whole egg protein were found to be significantly higher when an egg diet was consumed by Nigerian men (Nicol & Phillips, 1976) than when eaten by University of California students (Calloway & Margen, 1971), the true digestibility (TD) of egg protein being the same in each instance.

These findings led us to study the utilization of protein derived from a mixed diet of rice, fish and vegetables (rice diet), which provided the same amount of N as the egg diet (Nicol & Phillips, 1976), by seventeen young Nigerian farmers and labourers; the variability of the subjects' urinary and faecal N excretion by giving the rice diet during

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two feeding trials separated by a period of 4–6 weeks; and the utilization of protein provided by a high-protein diet (HPD), composed of the rice diet supplemented by lean beef, by five Nigerian men. The HPD was given for periods exceeding the 6 d pre-balance and 6 d balance periods used in earlier feeding trials, and supplied protein greater in quantity and better in quality than that customarily consumed by these men (Nicol, 1959*a*, *b*).

METHODS

Subjects

Nineteen Nigerian men participated in the present feeding trials. Their nutritional and ecological backgrounds, the clinical procedures carried out and the methods employed to prepare and supervise the consumption of diets, have been described (Nicol & Phillips, 1976). The men were ambulant throughout and their only exercise was walking in the garden of the 'metabolic' compound attached to the Federal Nigerian Nutritional Unit laboratories.

The endogenous urinary and faecal N excretion of six of the seventeen men who participated in the two rice diet feeding trials, and of the five men who participated in the HPD feeding trial, had been determined previously. The individual values for endogenous urinary and faecal N excretion, and for BMR (subjects O, P, Q, R, S, T, and O, P, Q, U, X respectively) were given in an earlier paper (Nicol & Phillips, 1976).

Diets

The ingredients of the minimal protein diet (MPD) used to determine the subjects' endogenous urinary and faecal N excretion, and those of the rice diet and HPD, with their proximate composition (determined in duplicate by methods described by McCance & Walsham (1948)), are given in Table 1. The daily ration was given as three meals at 08.00, 13.30 and 19.00 hours. The MPD was offered as three equal meals each containing the same amount of individual foodstuffs. The rice diet was served as cassava and sauce at the morning and evening meals, and as rice and sauce at 13.30 hours. The HPD was given as was the rice diet, equal portions of lean beef being added to each of the three meals. Drinking water was freely available and the ranges of intake (ml/d) with the different diets were 800–1200, MPD; 900–1500, rice diet and 1200–1800, HPD.

Riboflavin and thiamine 2 mg each, nicotinic acid 17 mg, calcium citrate 500 mg and 30 mg capsulated ferrous sulphate (all supplied by British Drug Houses Ltd, Poole, Dorset, UK) were added to the three diets.

The energy value of all diets was maintained as closely as possible at a constant level, providing 188 kJ (45 kcal)/kg body-weight per day when subjects were given the MPD, falling to 180 kJ (43 kcal)/kg body-weight per d when they consumed the rice diet and HPD, the latter value being approximately (mean and SE) $168 \pm 4\%$ of the BMR of the eight subjects whose basal energy had been measured. Results of the proximate analysis indicated that the energy value of the rice diet and HPD varied from one batch to another within the limits of 10·04–10·80 MJ (2400–2410 kcal) and

Table 1. *The composition (g/d) of the minimal protein (MPD), rice and high-protein (HPD) diets given respectively to nine, seventeen and five low-income group Nigerian men to determine their endogenous nitrogen excretion, variability of urinary and faecal nitrogen excretion and their utilization of protein at different levels of dietary intake at constant energy intake.*

Ingredients*	MPD	Rice diet	HPD
Cassava (*Manihot utilissima*) starch	440	436	270
Maize starch	140	—	—
Refined cane-sugar	30	—	—
Peppers, fresh	4	8	8
Peppers, dried	2	3	3
Tomato, fresh	20	22	22
Onions, fresh	10	10	10
Red palm oil	45	21	15
Melon (*Citrullus vulgaris*) seed	—	12	12
Dried fish	—	7	7
Parboiled rice	—	174	174
Lean beef	—	—	400
Common salt (NaCl), iodized	10	10	10
Vitamin and mineral mixture†	0·551	0·551	0·551
Chemical analysis			
Energy	10·04 MJ (2400 kcal)	10·06 MJ (2405 kcal)	10·08 MJ (2410 kcal)
Nitrogen	0·77	3·90	16·90
Protein (N × 6·25)	4·8	24·4	105·6
Fat	50	30	48
Energy (g/kg) from:			
Protein	10	40	180
Fat	190	110	180
Carbohydrate	800	850	640

* Edible portion.

† Contained (mg): riboflavin 2, thiamin 2, nicotinic acid 17, calcium citrate 500, ferrous sulphate (capsulated) 30.

10·07–10·09 MJ (2407–2412 kcal) respectively. The N content of the rice diet and HPD varied from 3·9 to 4·0 g and 16·8 to 17·0 g respectively.

The amino acid composition of the diets was estimated using tables (Orr & Watt (1957) and FAO (1970)), certain supplementary information being supplied by the Government Chemist, London, from direct analysis of Nigerian foods. The chemical score of the egg diet was calculated to be 100, using either the FAO (1957) 'provisional pattern of amino acid requirements' or the FAO/WHO (1973) 'provisional amino acid scoring pattern.' The chemical score of the rice diet was 66 (FAO, 1957), limited by sulphur amino acids and tryptophan (84), or 80 (FAO/WHO, 1973) limited by sulphur amino acids, lysine (82) and threonine (91). The chemical score of the HPD was 68 (FAO, 1957), limited by sulphur amino acids, tryptophan (72) and isoleucine (96), or 83 (FAO/WHO, 1973) limited by sulphur amino acids and threonine (95).

Analytical methods

The methods employed to collect samples of food, urine and faeces for analysis, the analytical procedures used, and the method employed to determine BMR, have been

Table 2. *Body-weight and daily nitrogen metabolism of seventeen young Nigerian men of a low-income group when consuming a rice diet* during a 6 d balance period, after a 6 d pre-balance period, on two occasions separated by 4–6 weeks*

(Daily dietary energy and N intake varied from 10·04 to 10·08 MJ (2400–2410 kcal) and from 3·9 to 40 g respectively)

		First trial						Second trial					
					N excretion						N excretion		
Subject	Age (years)	Body-wt† (kg)	Urinary creatinine (mg/kg BW)	N intake (mg/kg BW)	Urinary (mg/kg BW)	Faecal (mg/kg BW)	UN+FN (mg/kg BW)	BW (kg)	Urinary creatinine (mg/kg BW)	N intake (mg/kg BW)	Urinary mg/kg) BW)	Faecal (mg/kg BW)	UN+FN (mg/kg BW)
A	21	57·1	21	69	45	24	69	57·9	19	69	43	22	65
B	30	55·6	19	71	39	28	67	56·3	19	71	40	29	69
C	28	54·2	23	73	40	32	72	54·8	24	73	39	31	70
D	30	54·4	24	72	46	33	78	54·6	24	73	44	32	76
E	30	54·4	24	72	39	33	72	55·1	22	73	38	33	71
F	25	57·3	22	69	32	40	72	58·3	23	69	33	34	67
G	26	58·3	20	67	46	24	70	58·3	21	68	47	21	68
H	25	56·4	21	70	37	28	65	56·7	22	70	37	28	65
I	25	58·4	21	67	46	22	68	58·7	22	68	50	18	68
J	30	59·2	19	66	36	27	63	59·6	20	67	37	26	63
K	28	58·9	21	67	47	27	74	60·0	21	67	50	26	76
O	23	51·5	23	75	42	26	68	52·0	22	77	43	27	70
P	21	60·2	22	64	35	23	58	59·8	22	67	37	23	60
Q	28	55·8	24	69	46	24	70	56·0	24	72	47	25	72
R	26	55·2	26	70	45	35	79	56·1	26	71	43	33	76
S	25	50·3	26	77	37	35	72	51·2	24	78	36	35	71
T	30	52·2	25	74	50	19	69	52·6	25	76	49	21	70
Mean	27	55·8	22	70	42	28	70	56·3	22	71	42	27	69
SE	1	0·7	0·5	1	1	1·5	1	0·7	0·5	1	1	1	1
CV	12	5	10	5	12	20	7	5	9	5	13	19	6

* For details of composition, see Table 1

† BW at the start of the 6 d balance period: mean (±SE) in weight (kg) during the balance period was −0·2±0·1 in both trials: change in BW during the 6 pre-balance period was −0·4±0·1 in the first trial and −0·5±0·1 in the second trial.

Table 3. *Body-weight, change in body-weight and 'observed' and expected* nitrogen loss or retention of five young Nigerian men of a low-income group during the respective feeding periods when they were given minimal-protein (MPD), rice and high-protein (HPD) diets*†

(Mean values with their standard error. Mean age 26 ± 1 years)

		Mean body-wt (kg)		'Observed' change in body-wt (g/d)		'Observed' N loss or retention (g/d)		Expected N loss or retention (g/d)		Change in body-wt per g N loss or retention (g/d)		'Observed' minus expected N loss or retention (g/d)		'Observed' minus expected N loss or retention mg/kg body-wt per d	
Diet	Feeding period	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
MPD	6 d balance period	53·93	1·37	−63	12	−2·24	0·08	−1·89	0·35	28	5	+0·35	0·23	+6	4
Rice	Days 1–6 pre-balance	54·68	1·73	+33	34	—	—	—	—	—	—	—	—	—	—
	Days 7–12 balance	54·86	1·52	+27	4	+0·12	0·16	—	—	—	—	—	—	—	—
HPD	Days 13–18 pre-balance	55·05	1·57	+37	6	—	—	—	—	—	—	—	—	—	—
	Days 19–24 balance	55·47	1·55	+103	6	+4·64	0·33	+3·09	0·19	23	3	+1·55	0·42	+28	8
	Days 25–42	56·69	1·57	+101	9	+4·52‡	0·27	+3·03	0·29	22	4	+1·49	0·58	+26	10
	Days 43–46 balance	57·77	1·58	+85	22	+4·43	0·23	+2·55	0·65	20	5	+1·87	0·72	+32	12
	Day 46 last day of final period	57·94	1·60	—	—	+4·23	0·20	—	—	—	—	—	—	—	—
	Mean values for days 19–46	56·58	1·57	+99	10	+4·53	0·28	+2·97	0·30	22	4	+1·56	0·57	+28	10

* Assuming tissue lost or gained contained 3 % N.
† For details of composition of diets, see Table 1.
‡ Calculated from mean retention of N for days 19–24 and days 43–46, assuming a linear decrease in N retention.

described (Nicol & Phillips, 1976). Haemoglobin was measured using a Medical Research Council grey-wedge photometer which was calibrated regularly against a standard. Serum cholesterol was determined by the method of Abell, Levy, Brodie & Kendall (1952) and plasma proteins by the method described by King & Wootton (1956).

Design of feeding trials

The rice diet was given to seventeen young Nigerian men during two feeding trials separated by a period of 4–6 weeks. Each trial comprised a 6 d pre-balance and a 6 d balance period (Table 2). Five men participated in the HPD feeding trial which comprised a 6 d pre-balance period and a 6 d balance period on the rice diet; a 6 d pre-balance period and a 6 d balance period on the HPD; 18 d consuming the HPD, and a final 4 d balance period on the HPD (Table 3). The feeding trial on the MPD to measure endogenous urinary and faecal N losses was conducted 2–3 months earlier than the rice diet and HPD trials.

Statistical analysis

Analysis of variance was used to separate and evaluate the variability of N intake and urinary and faecal N losses (Table 2). Significance of differences between mean values was determined using paired 't' tests. $P \leqslant 0{\cdot}05$ was considered significant.

Body-weight and nitrogen loss or retention

In all calculations it was assumed that body tissue lost or gained by Nigerian men during the feeding trials contained 3 % N. This assumption was based on the following observations. Davidson, Passmore & Brock (1972) reported the N content (protein ÷ 6·25) of a 'normal' (presumably Caucasian) man's body to be 2·7 %, and the fat content 13·8 %. The body-fat of Nigerian men of the same age group, and possibly of the same socio-economic background as our subjects, was 11·3 % of body-weight (Watson & Etta, 1975). The composition of body-tissues gained by healthy men as a result of over-eating was found to be independent, in respect of extra-cellular fluid, fat and cytoplasm, of weight gain over a wide range, but was lower in cytoplasm and higher in fat than the composition of tissue gained by men re-fed after prolonged, severe undernutrition (Keys, Anderson & Brozek, 1955).

The values given in Table 3 for 'observed' N loss or retention are equivalent to apparent N balance, i.e. N intake minus the sum of urinary and faecal N excretion, excluding dermal and other N losses. The values for expected N loss or retention were calculated from 'observed' change in body-weight during each period of the HPD feeding trial, assuming the tissue lost or gained contained 3 % N. Thus the values for 'observed' minus expected N loss or retention were expected to give a measure of all N lost from the body through the integument or other sources, and of N diverted within the body to purposes other than change in body-weight.

Throughout the rest of this paper 'N balance' and 'N equilibrium' indicate 'apparent N balance' or 'apparent N equilibrium' as defined above. Average values are expressed in terms of mean and standard error.

RESULTS

Utilization of the rice diet protein by Nigerian men

Changes in body-weight during the pre-balance periods were not significantly different when seventeen young Nigerian men were given the rice diet on two separate occasions (Table 2). The mean loss of weight (g/d) found during both 6 d blance periods was the same (-33 ± 50). Mean values indicated N equilibrium in both trials, individual variance being high ($+0.02 \pm 2.24$ g/d first trial, $+0.10 \pm 1.99$ g/d second trial). N balance was not correlated with dietary energy or protein intake.

The variations, per unit body-weight, between N intake and urinary N, faecal N, and urinary+faecal N excretion were not significant either between subjects (inter-individual variance), or in the same subject from the first to the second trial (intra-individual variance). The inter-individual variances of urinary, faecal and urinary+faecal N excretion were all significant ($P < 0.001$), but the intra-individual variances from the first to the second trial were not significant. Intra-individual variation between urinary and faecal N excretion was not significant. Combining the results from both trials, the coefficient of correlation between urinary and faecal N excretion was -0.73 ($P < 0.01$). The coefficients of variation of urinary, faecal and urinary+faecal N excretion were 13, 20 and 7 respectively.

The sum of the endogenous urinary and faecal N excretion of subjects O, P, Q, R, S, T was 57 ± 1 mg/kg body-weight per d (Nicol & Phillips, 1976). The rice diet supplied 58 mg N/kg body-weight per d in excess of the N in the MPD used to measure endogenous levels of N excretion, indicating that an amount of N from the rice diet, approximately equal to the sum of endogenous urinary and faecal losses, was sufficient to establish N equilibrium in apparently healthy young Nigerian men.

The BV, TD and NPU of the rice diet, calculated by using the individual values for endogenous urinary and faecal N excretion of the six subjects, were 0.83 ± 0.06, 0.88 ± 0.01 and 0.73 ± 0.04 respectively. When the same six men were given an egg diet (Nicol & Phillips, 1976), which supplied approximately the same amount of energy and protein as the rice diet, BV, TD and NPU were calculated to be 0.90 ± 0.08, 0.93 ± 0.06 and 0.84 ± 0.12 respectively, the values obtained for the rice and egg diets not being significantly different. The 'net dietary protein energy per cent' (NDp:E%) of the egg and rice diets were 3.65 ± 0.20 and 3.13 ± 0.21 respectively.

When five Nigerian men (subjects O, P, Q, U, X) consumed the rice diet during the HPD feeding trial (Table 3), they gained 27 ± 4 g body-weight per d, N balance being $+0.12 \pm 0.16$ g/d. N balance was not correlated with energy or protein intake. The BV, TD and NPU were 0.88 ± 0.02, 0.88 ± 0.02 and 0.77 ± 0.03 respectively, values which were not significantly different to those obtained for the egg diet. NDp:E% was calculated to be 3.50 ± 0.23 for the egg diet when given to these five men (Nicol & Phillips, 1976) and 3.25 ± 0.09 for the rice diet (present results).

Utilization of protein in the high-protein diet by Nigerian men

N balance was 4.53 ± 0.28 g/d during days 19–46 when five Nigerian men were given the HPD (Table 3). Although the correlations between N balance and energy and protein intake were not significant, they were positive at this level, being +0·45 and +0·49 respectively.

The NPU of the HPD (Table 4) was, as expected, significantly lower than that of the rice and egg diets, TD being the same as the value obtained for the egg diet. The NDp:E% of the HPD calculated from the values for NPU obtained during days 19 to 24 and 43 to 46 was 7·84 ± 0·26.

Differences between the following mean values given in Table 4 were significant: urinary N excretion; MPD *v.* rice diet days 7–12 ($P < 0·05$): faecal N excretion; MPD *v.* rice diet days 7–12 ($P < 0·01$).

Body-weight and nitrogen loss or retention

The relationship between change in body-weight and N loss or retention can be followed (Table 3) through physiological states varying from loss of weight and negative N balance (MPD), small gains in weight and wide inter-individual variation of N loss or retention near to the level of N equilibrium on the rice diet, to positive increases in body-weight and N retention continuing for 34 d when five Nigerian men consumed the HPD. The variation of N balance around mean values was less when those values differed significantly from N equilibrium, either positively (HPD) or negatively (MPD). N balance was not correlated to change in body-weight around the level of N equilibrium, inter-individual variance of N balance being so large that values calculated for expected N loss or retention, and 'observed' minus expected N loss or retention, during the balance period on the rice diet (days 7–12) were meaningless and have not been included in Table 3.

Differences between the following mean values given in Table 3 were significant: 'observed' change in body-weight; MPD *v.* rice diet days 1–6 ($P < 0·001$); HPD days 13–18 *v.* HPD days 19–24 ($P < 0·001$); HPD days 25–42 *v.* HPD days 43–46 ($P < 0·01$). The difference between change in body-weight per g N loss or retention MPD *v.* HPD days 19–46 was not significant.

Urinary creatinine excretion (mg/kg body-weight per d) varied between 22 ± 0·67 and 24 ± 0·04 when Nigerian men were given a MPD, egg, rice or high-protein diet (Table 4 and Nicol & Phillips, 1976).

Correlation between urinary and faecal nitrogen excretion

When seventeen young Nigerian men consumed the rice diet (Table 2) the correlation between urinary and faecal N excretion was −0·73 ($P < 0·01$). When six young Nigerian men ate an egg diet (Nicol & Phillips, 1976) the correlation was −0·97 ($P < 0·001$). The values for the same correlation, obtained when five young Nigerian men were given a MPD, rice diet and HPD are given in Table 4. The correlation only became positive when they had consumed the HPD for 18–24 d, significantly positive gains in body-weight and N retention having been established after 12–18 d of high-protein feeding.

Haematological measurements

The level of haemoglobin increased from 131 ± 8 to 139 ± 7 g/l during the period the subjects were given a HPD (days 13–46, Table 3). Over the same period total

Table 4. *Urinary creatinine, nitrogen intake and apparent N balance, expressed on a body-weight basis, of five young Nigerian men of a low income group, during the respective feeding periods when they were given minimal-protein (MPD), rice and high-protein (HPD) diets,* and values for biological value* (BV)†, *true digestibility (TD)*‡ *and net protein utilization* (NPU)§ *of the rice and high-protein diets*

Diet and feeding period	Mean body-wt (BW) (kg)		Urinary creatinine (mg/kg BW per d)		N intake (mg/kg BW per d)		N excretion: Urinary (UN) (mg/kg BW per d)		N excretion: Faecal (FN) (mg/kg BW per d)		Correlation coefficient UN *v.* FN		Apparent N balance (mg/kg BW per d)		BV‖		TD‖		NPU‖	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
MPD																				
6 d balance	53·93	1·37	23	0·7	14	0·4	36	2·4	21	2·2	−0·81	0·50	−42	3·6	—	—	—	—	—	—
Rice¶																				
Days 7–12 balance	54·86	1·52	23	0·7	72	2·0	41	2·5	29	2·2	−0·28	0·50	+2	2·5	0·88	0·02	0·90	0·02	0·79	0·03
HPD¶																				
Days 19–24 balance	55·47	1·55	22	0·8	306	8·5	193	5·4	29	4·0	+0·20	0·50	+84	6·8	0·43	0·01	0·97	0·01	0·42	0·01
Days 43–46 balance	57·77	1·58	23	0·7	292	7·5	189	5·4	26	1·7	+0·77	0·50	+77	4·5	0·42	0·01	0·98	0·01	0·41	0·01
Day 46 last day of final period	57·94	1·60	22	0·4	290	7·7	191	5·2	26	1·9	+0·76	0·50	+73	3·9	0·41	0·01	0·98	0·01	0·40	0·01
Mean values for days 19–46	56·58	1·57	23	0·7	299	8·2	191	5·4	27	2·2	—	—	+80	6·4	0·42	0·01	0·98	0·01	0·41	0·01

* For details of composition of diets, see Table 1.

† BV = absorbed N − (urinary $N_{rice\ or\ HPD}$ − urinary N_{MPD}) ÷ absorbed N.

‡ TD = dietary N − (faecal $N_{rice\ or\ HPD}$ − faecal N_{MPD}) ÷ dietary N.

§ NPU = BV × TD.

‖ BV, TD and NPU calculated by applying individual values for urinary and faecal endogenous N excretion recorded when subjects O, P, Q, U, X (Nicol & Phillips, 1976) were given a MPD.

¶ See Table 3.

plasma proteins increased from 70 ± 2 to 72 ± 2 g/l, the albumin : globulin ratio decreasing from 0·94 ± 0·08 to 0·74 ± 0·07. The amount of N needed for the formation of 8 g Hb/l during the 34 days of high-protein feeding was calculated to be 3 mg/kg body-weight per d, assuming 80 ml blood-volume per kg body-weight. The amount of N required for the formation of 2 g total plasma proteins was calculated to be 1 mg/kg body-weight per d over the same period.

Serum cholesterol remained unchanged, at a level of 3·21 ± 0·48 mmol/l throughout the 46 days of the HPD feeding trial. This level of serum cholesterol was lower than that found by Watson & Etta (1975) for Nigerian men of the same age group, and possibly similar socio-economic background as our subjects, but is approximately the same as that reported by Mann, Nicol & Stare (1955) for low-income group Nigerian farmers and labourers.

DISCUSSION

The significant inter-individual variation of urinary and faecal N excretion recorded when young Nigerian men of a low income group consumed a MPD, rice or egg diet was accompanied by a significantly negative correlation between urinary and faecal N when they were losing weight and N balance was negative (MPD), gaining or losing small amounts of weight when mean values indicated N equilibrium but variation around the mean was high (rice diet), or when they gained weight and N balance was positive (egg diet). Urinary and faecal N did not increase significantly when egg protein was added to the MPD, but were higher on the rice diet than on the MPD, the differences being small but significant.

In contrast to the present results, and those reported in an earlier paper (Nicol & Phillips, 1976), Calloway & Margen (1971) and Calloway (1975*a*) found a positive correlation between urinary and faecal N when University of California students were given a MPD, and a significantly positive increase in urinary N when egg protein was added to the MPD, faecal N remaining unchanged. When their students were given an egg diet these authors calculated that the NPU of egg protein was 0·75, energy and N requirements for maintenance of constant body-weight and N equilibrium varying from 167 to 180 kJ (40–43 kcal) and 68 ± 15 to 89 ± 18 mg N/kg body-weight per d in different feeding trials. If we have interpreted the results correctly Scrimshaw, Taylor & Young (1973) found that 200 kJ (48 kcal) and 117 mg N/kg body-weight per d were needed to maintain constant weight and N equilibrium (−0·09 ± 0·24 g/d) when Massachusetts Institute of Technology students were given a diet in which the protein was derived from wheat gluten supplemented by 2·25 % of lysine. Calloway (1975*a*) reported that ‘energy intake appears to have a much greater effect on N balance than does protein intake in the marginally adequate ranges of intake’. Examination of this author’s findings, and those of Scrimshaw *et al.* (1973) suggests that inter-individual variation in the utilization of absorbed N played an important part in determining N balance at ‘marginal’ levels of energy intake, a conclusion which agrees with the present results.

The differences observed between the utilization of dietary protein by Nigerian men on the one hand, and University of California or Massachusetts Institute of

Technology students on the other hand, at approximately the same level of dietary energy per unit body-weight, suggest that Nigerian men of low income are adapted to low protein intakes, an indicator of such adaptation being an inverse correlation of urinary and faecal N at levels around N equilibrium or negative N balance. The physiological process involved in determining the sign of the correlation between urinary and faecal N in such Nigerian men is concerned with conservation of absorbed N, and possibly also of ingested N, at low levels of dietary protein. The lag periods which occurred between the start of high-protein feeding and gain in weight, positive N retention, increased urinary N excretion, and conversion of a negative to a positive correlation between urinary and faecal N excretion, could be explained by the time taken for the adaptive mechanisms to customarily low protein intakes, involving amino acid activating enzymes and argininosuccinase, to be counterbalanced by high protein intakes (Stephen & Waterlow, 1968; Waterlow 1968). Conservation of absorbed N through this adaptive process could be responsible for the higher BV of egg protein recorded in Nigerian men than in University of California students, and also for the high BV found when Nigerian men consumed the rice diet.

The adaptation of Nigerian men to low protein intakes can be expressed in terms of energy-protein ratios. The rice and egg diets given to Nigerian men provided 180–188 kJ (43–45 kcal)/kg body-weight per d, or 1·68–1·70 × BMR, the energy derived from protein being 4% in each instance. These amounts of energy and protein were sufficient to maintain body-weight and N equilibrium or slightly positive N balance. The men were ambulant but not performing any physical work beyond handicrafts such as mat-weaving, or playing cards. Beaton & Swiss (1974) predicted that the needs for energy and protein of all but 2·5% of a 'moderately active' adult male population would be met by a diet providing 5·4% energy from egg protein, energy intake being 192 kJ (46 kcal)/kg body-weight per d. Calloway (1975*a*) calculated, from the results obtained from feeding trials carried out on University of California students, that approximately 6% of dietary energy derived from egg protein was necessary to maintain constant body-weight and N equilibrium, at a level of 167 kJ (40 kcal)/kg body-weight per d, equivalent to 1·68 × BMR.

Positive N balances associated with gain in body-weight continuing for weeks or months, as found in Nigerian men of low-income (present results), were obtained also by Holmes, Jones & Stanier (1954) who gave East African men of low-income a mixed diet providing 10·04 – 11·55 MJ (2400–2750 kcal) and 100–150 g protein per d, mean values for N balance being +4·96 g/d, continuing for 100 d or more. The 'observed' gain in body-weight in both the Nigerian and East African instances was less than that expected from the amount of N apparently retained. Positive N balances continuing for up to 220 d, but not associated with gain in body-weight or lean body mass, have been reported frequently when North American students were given diets providing from 80 to 225 g protein per d. Mitchell (1949) gave a diet supplying 84 g protein to young men for 156–220 d and obtained an average daily N balance of 1·38 g, body-weight being essentially constant. He attributed 1 g N to the renewal of integumental losses and 0·38 g N to sweat, the feeding trial being conducted under minimal sweating conditions. Mitchell & Ednam (1962) concluded that 'the inclusion of integumental losses of N in estimating the requirements of adult men and women for protein will lead to a considerable increase in these values, of the order of 20 to 30%. Calloway, Odell & Margen (1971) found that dermal nitrogen output varied systematically with N intake, being 112±42 mg with a protein-free diet, 149±51 mg with normal (75 g protein) intake and 514±161 mg with 600 g protein in the daily diet, amounts of N considerably less than those considered by Mitchell (1949) and Mitchell & Ednam (1962) to be lost from the integument. Margen (1975) obtained continuous N balances of 1·7 g (22 mg/kg body-weight)/d for 40–60 d when six young North American men were given a diet providing 225 g protein, body-weight and lean body mass being essentially constant. He concluded that the persistent positive N balances could not result from underestimation of dermal, sweat or other miscellaneous N losses, and must be a phenomenon which could result from N losses which have not yet been considered, such as in flatus or as ammonia in skin or breath. He also questioned the Kjeldahl method of N analysis, which may fail to detect certain nitrogenous compounds. Ashworth & Harrower (1967) found that Jamaican male subjects lost 0·49 g N in sweat during working hours, a figure which Calloway (1975*b*) considered might amount to 0·55 g N during 24 h. Weiner & Wheeler (1971) found N loss from the skin in Africans consuming a 'normal' diet and doing light work to be 10 mg per kg body-weight per d.

The difference between 'observed' minus expected N loss (Table 3), when Nigerian men were given a MPD was 6±4 mg N/kg body-weight per d (0·06 mg N/basal kJ (0·24 mg N/basal kcal)/d), a value only slightly higher than those accepted by FAO/WHO (1973) for the obligatory skin and miscellaneous N losses of adult men. This finding agrees with the concept (Nicol & Phillips, 1976) that endogenous N losses of men, whatever their nutritional, ecological or socio-economic background, are approximately equal when expressed per unit of body-weight. The continuing positive N balances and gains in body-weight obtained when Nigerian men were given a HPD, which are of the same order as the findings of Holmes *et al.* (1954) with East African men, can be explained only in part. The mean values given in Table 3 for days 19–46 of the HPD feeding trial show that 67% of the N apparently retained can be attributed to increase in body-weight (resulting from the assumption that the body-tissue laid down contains 3% N). The remaining 33% amounts to 28±10 mg N/kg body-weight per d. Taking into account the findings of Calloway *et al.* (1971) and of Weiner & Wheeler (1971), a generous allowance of 15 mg N/kg body-weight per d was made for loss of N through the integument and other miscellaneous N losses. It was calculated that 3 mg N and 1 mg N/kg body-weight per d would be required respectively for the increases in Hb and plasma proteins recorded during the 34 d period of high-protein feeding. This total of 19 mg N/kg body-weight per day, composed of losses from the body and of diversion of N to physiological processes within the body not concerned with increases in weight, still leaves an unaccounted balance of 9 mg N/kg body-weight per d, or approximately 0·5 g N/d.

The present results indicate that young Nigerian men of low income, when given diets composed of foodstuffs commonly used in Africa, which supply amounts of energy only a little less than their customary intakes (Nicol, 1959*a*), adapt to low protein intakes by conserving urinary N when N balance is at, or below, the level of N equilibrium. The indicator of this aspect of N conservation is an inverse correlation between urinary and faecal N. Conservation of absorbed N at low levels of protein intake is further augmented by reduction of dermal and other miscellaneous N losses. When young Nigerian men are given a diet which provides approximately the same amount of energy, and many times their customary protein intake (Nicol, 1959*b*), they gain weight and retain N in amounts which exceed those predicted from 'observed' gains in body-weight, increases in Hb and plasma proteins and from dermal and other miscellaneous N losses.

The Nigerian men were not 'anaemic', judged by Hb levels (WHO, 1968), and their level of total plasma proteins was above the normal level given by Davidson *et al.* (1972). Yet both these measures of nutritional status increased when the Nigerian men were given a HPD. The low albumin:globulin ratio initially obtained, which decreased when Nigerian men were given a HPD, may indicate a selective priority for the production of γ-globulins in the African environment, where the prevalence of infectious and parasitic diseases is high.

The present findings suggest that the 'provisional amino acid scoring pattern' proposed by FAO/WHO (1973) is a better reflexion of the nutritional value of dietary protein than the 'provisional pattern of amino acid requirements' put forward by FAO (1957). They also indicate that the amino acid score of a diet, calculated from tables of amino acid contents of foodstuffs, is in reasonably good agreement with dietary NPU determined by direct experiment on man, provided the score is adjusted by a factor for digestibility, as recommended by FAO/WHO (1975).

The conclusion of the FAO/WHO Committee (FAO/WHO, 1973) that obligatory N losses, determined by the factorial method, are 30% lower than the amount of dietary N required for the maintenance of N equilibrium in adult men, whether the N is derived from high-quality protein sources or from mixed diets, must be questioned again, as we did in an earlier paper (Nicol & Phillips, 1976). Our previous and present results indicate that the addition to a MPD of an amount of N approximately equal to the sum of endogenous urinary and faecal N, is sufficient to establish positive N balance or N equilibrium when the additional N is derived from egg protein or a mixed diet composed of rice, fish and vegetables, in men who are adapted to low protein intakes. The Committee's conclusion (FAO/WHO, 1973) is possibly correct if applied to the utilization of dietary protein by North American students or other young men who have never had the need to adapt to low dietary protein intakes and to the effects on protein requirements imposed by a high prevalence of infectious and parasitic diseases.

The present results indicate that apparently healthy young Nigerian men of low-income can reverse the processes of adaptation to low protein intakes (protein:energy ratio 4%, NPU 0·8–0·9) within two or three weeks when they consume a HPD (protein:energy ratio 17%, NPU 0·4). Their capacity to adapt to the prevalence of infectious and parasitic diseases, evidenced by albumin:globulin ratios, appears to be enhanced by high-protein feeding. There is no reason to believe that healthy young men, of any ethnic or socio-economic group, accustomed to consume diets providing

17% energy from protein and utilize it at a low level of efficiency, would not adapt to the consumption of low protein diets through the physiological processes described above, and use what protein is available more efficiently, if environmental circumstances made it necessary. Therefore the final conclusion of our earlier paper (Nicol & Phillips, 1976) 'that all apparently healthy men cannot be considered equal in regard to their requirements for protein' should be modified to read as follows: 'the protein requirements of all apparently healthy men can only be established in the context of their ecological, socio-economic and nutritional backgrounds.'

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