Endogenous nitrogen excretion and utilization of dietary protein

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1. The endogenous nitrogen losses of men of different ethnic, ecological and socio-economic backgrounds are similar when calculated per unit body-weight or per unit basal energy consumption. The hypothesis that endogenous N losses, adjusted upwards by a factor of 0·30 to equate them with N equilibrium, can be used to derive man's physiological requirements for proteins of high quality, e.g. those of egg and milk, was studied.

2. Men living in Nigeria, accustomed to eat diets which provided mixtures of protein only slightly higher than the 'safe level of intake' proposed by the Joint FAO/WHO *ad hoc* Expert Committee on Energy and Protein Requirements (FAO/WHO, 1973), were found to use absorbed N more efficiently than University of California students who habitually consume diets which supply a great excess of protein over that 'safe level'.

3. The greater protein-sparing effect of carbohydrates than of fats and oils may play a part in this more efficient use of protein by men living in developing countries. Also, man possesses mechanisms in intermediary metabolism which allow him to adjust to low levels of protein intake.

4. Thus it appears that all apparently healthy men cannot be considered equal in regard to their requirements for protein.

All apparently healthy men have been considered equal by the US National Research Council's Food and Nutrition Board (National Research Council, 1968) and by the Joint FAO/WHO *ad hoc* Expert Committee on Energy and Protein Requirements (FAO/WHO, 1973), when formulating recommendations about their protein requirements, irrespective of their ethnic, ecological or socio-economic backgrounds. In both instances they used the 'factorial method' as the basis on which to formulate protein allowances or requirements. This method assumes that the total urinary and faecal nitrogen losses, determined after adaptation to an essentially N-free diet (endogenous urinary and faecal N), plus integumental and other minor N losses, equate with physiological requirements for dietary protein (calculated as crude protein (N × 6·25)) of high biological value (BV); for example, those of milk or egg. Another approach which has been used to assess minimal protein requirements is the relationship between urinary N excretion and basal metabolic rate (BMR). Smuts (1935) considered this relationship to be 2 mg N/kcal (basal) (0·48 mg N/kJ (basal)). Hegsted (1964) has reviewed this approach to protein requirements.

Martin & Robison (1922) found that milk protein did not replace man's endogenous N losses on a weight-for-weight basis. They estimated that the daily loss of urinary and faecal N, about 3 g in their opinion, could be replaced by a daily intake of 6 g milk N or 10·5 g N from whole wheat. Calloway & Margen (1971) reported that the amount of egg protein required to maintain N equilibrium in adult men is greater than

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endogenous losses. The FAO/WHO Committee (FAO/WHO, 1973) considered studies made in India, Japan and Nigeria, as well as in the USA and Europe, and also noted that the amounts of N provided by mixed diets, or by proteins of high quality, needed to maintain N equilibrium in adult men, was greater than the endogenous losses determined by the 'factorial method'. To quote that Committee's report (FAO/WHO, 1973): 'The estimates of average requirements finally adopted for adults and children (over 6 months of age) are the factorial calculations corrected by a factor of 1·3, which agree with the few directly determined values for milk and egg proteins' (obtained from N balance studies).

Leitch & Duckworth (1937) and Hegsted (1964) have reviewed the efforts made to determine man's protein requirements. Until recently, most of the work was done using European and North American subjects. While accepting the 'factorial method', adjusted by a factor considered to be appropriate, the FAO/WHO Committee (FAO/WHO, 1973) emphasized the need for comparative studies of endogenous N losses in different ethnic groups. Scrimshaw, Hussein, Murray, Rand & Young (1972) considered it pertinent to ask whether the results obtained with Caucasian university students apply equally to population groups of differing racial origins and nutritional backgrounds. Huang, Chong & Rand (1972) suggested that 'Chinese men may be able to maintain N balance at lower levels of N intake, expressed on a body-weight or BMR basis, than similar subjects of Caucasian origin'.

This paper has two objectives. The first is to reassess values for endogenous N losses in Nigerian men of a low-income group, obtained some years ago, and to compare them with more recent values published by Calloway & Margen (1971) and Scrimshaw *et al.* (1972), derived from studies made on students at the University of California (Berkeley, California, USA) and at the Massachusetts Institute of Technology (MIT) (Cambridge, Massachusetts, USA) respectively, by Huang *et al.* (1972), from studies on Chinese students at Taiwan University, Taipei, Taiwan, and with the results of studies of Gopalan & Narasinga Rao (1968) on Indian men of a low-income group in Hyderabad; the second objective is to report the utilization of egg proteins by Nigerian men and to compare values obtained with those for University of California students (Calloway & Margen, 1971).

In selecting studies for comparison of endogenous N loss and of utilization of dietary proteins it is necessary to ensure a sufficient period of time to allow the excretion of urinary and faecal N to stabilize, either with a diet containing minimum amounts of N (endogenous level) or with diets providing protein at specified levels. This criterion was met in all studies compared here. In all groups the participating subjects were young men, although they were from different ethnic groups and socio-economic backgrounds. The amounts of N provided by the minimal-protein diets (MPD) used to determine endogenous urinary and faecal N excretion were of the same order, as were the MPD energy values, expressed on a kJ/kg body-weight basis, with one exception (Gopalan & Narasinga Rao, 1968). The amount of N derived from egg in the diet used to compare high-quality protein utilization by Nigerian men and by University of California students was similar.

METHODS

Nigerian subjects. The nine men were of the low-income working class, or farmers of smallholdings. They were selected to be between 20 and 30 years of age and between 50 and 60 kg body-weight. Their customary diet was based on sorghum (*Sorghum vulgare*) and bulrush millet (*Pennisetum typhoideum*); secondary foods were rice, sweet potatoes (*Ipomoea batatas*), yams (*Dioscorea* spp.) and cassava (*Manihot utilissima*). A sauce containing fresh or dried peppers (*Capsicum* spp.), green leaves, tomatoes, groundnut oil or red palm oil, imported common salt (NaCl) and small amounts of meat, chicken or fish is eaten with the staple food. This diet provides an adult man with 10·0–12·6 MJ (2400–3000 kcal), 25–45 g fat, 50–90 g protein (of which 5–15 g is of animal origin)/d. Seasonal variations within the above limits are found (Nicol, 1952, 1959*a*, *b*). Riboflavin, nicotinic acid, calcium and iron often are lower than the requirements proposed by FAO/WHO (1962, 1967, 1970).

During feeding trials the subjects lived in a house attached to the Federal Nigerian Nutrition Unit laboratories, where they were supervised by two laboratory technicians. They were paid a daily wage, but, unlike the MIT and Taiwan students, they were completely disinterested in the objectives of the studies. Two nursing sisters (dieticians) prepared all diets and ensured they were completely consumed, including plate washings. The trials were done during the comparatively cool and dry season between August and December.

Clinical examination did not show any sign of disease. Three consecutive daily examinations of blood, urine and faeces, repeated twice during pre-balance and balance periods, did not indicate the presence of any parasites.

Analytical methods. Collections of urine over 24 h were made during pre-balance and balance periods, using toluene as preservative. Urinary creatinine estimations, using an alkaline picrate method (Peters, 1942), indicated that the entire urinary output had been collected. The complete faecal output of each subject during balance periods was collected into wide-mouthed, screw-topped jars containing 0·1 M-sulphuric acid as preservative. Carmine, 1 g in gelatine capsules, was used as the marker at the beginning and end of balance periods, the first marked faeces being included and the last rejected.

N in foods, urine and faeces was determined by a micro-Kjeldahl method using a Markham still, with the collection of the final distillate in a boric acid solution (2·5 g/l) containing a mixed indicator of bromocresol green and methyl red. The proximate nutrient composition of the staple foods and sauce ingredients was determined in duplicate by methods described by McCance & Walsham (1949). The dietary energy (MJ/kg) was calculated using the factors 4, 9 and 4 for protein ($N \times 6{\cdot}25$), fat and carbohydrate respectively.

BMR were measured by the Haldane method, using a Douglas bag (Haldane & Graham, 1935), after pilot studies had been completed, and again at the end of the feeding trial to determine endogenous N levels. BMR was consistent in each of the nine subjects. The individual mean of the two measurements was applied to all calculations involving the basal energy of Nigerian men reported in this paper.

Table 1. *The composition (g/d) of the minimal-protein diet (MPD) and of MPD supplemented with whole-egg protein (egg diet), used to determine the endogenous nitrogen excretion of Nigerian men and their utilization of egg protein*

Ingredients*	MPD	Egg diet
Cassava flour	440	440
Maize starch	140	36
Refined cane sugar	30	30
Peppers, fresh	4	4
Peppers, dried	2	2
Tomato, fresh	20	20
Onion, fresh	10	10
Red palm oil	45	45
Common salt (NaCl), iodized	10	10
Whole egg (guineafowl)†	—	154
Vitamin and mineral mixture‡	0·551	0·551
Chemical analysis		
Energy	10·04 MJ (2400 kcal)	10·08 MJ (2410 kcal)
Nitrogen	0·77	3·92
Protein (N × 6·25)	4·8	24·5
Fat	50	68
Energy (g/kg) from:		
Protein	10	40
Fat	190	250
Carbohydrate	800	710

* Edible portion.
† Homogenized whole egg, lightly cooked.
‡ Contained (mg): riboflavin 2, thiamin 2, nicotinic acid 17, calcium citrate 500, ferrous sulphate (capsulated) 30.

The Nigerian MPD and MPD supplemented with egg (egg diet). The composition of these diets are given in Table 1. The diets were given in three equal meals, at 08.00, 13.30 and 19.00 hours. Water intake ranged from 800 to 1200 ml/subject per d. The MPD was designed to provide the minimum amount of N from commonly used Nigerian foods which would supply approximately 188 kJ (45 kcal)/kg body-weight per d. The egg diet contained the same ingredients but maize starch was replaced isoenergetically by 154 g homogenized whole guineafowl (*Numida* spp.) egg, lightly cooked, distributed equally between the three meals. Riboflavin 2 mg, thiamin 2 mg, nicotinic acid 17 mg, calcium citrate 500 mg, ferrous sulphate (capsulated) 30 mg, were added to the diets (all were supplied by British Drug Houses Ltd, Poole, Dorset, UK).

Diets with which the Nigerian diets were compared. The MPDs used by Calloway & Margen (1971) at the University of California (California MPD), by Scrimshaw *et al.* (1972) at MIT (MIT MPD), by Huang *et al.* (1972) at Taiwan University (Taiwan MPD) and in India by Gopalan & Narasinga Rao (1968) (Indian MPD) to determine the endogenous N excretion of their subjects are described in detail by these authors. The energy value and N content of the MPDs are given in Table 2. Two points of difference between the five diets should be noted. First, the Californian and MIT MPDs were designed to maintain constant body-weight by varying the amounts of

Table 2. *Physical characteristics and endogenous nitrogen excretion for groups of young men from different ethnic, socio-economic amd nutritional backgrounds when given a minimal-protein diet*

	Age (years)	Body-wt* (BW) (kg)	Basal metabolic rate		Urinary creatinine (mg/kg BW)	Energy intake† (kJ/kg BW)	N intake (g)	Apparent N balance‡ (g)	Urinary N excretion		Faecal N excretion		Urinary + faecal N	
			MJ (kcal)/d	kJ/kg BW					mg/kg BW	mg/kJ (basal)	mg/kg BW	mg/kJ (basal)	mg/kg BW	mg/kJ (basal)
Thirteen students at University of California, Berkeley (Calloway & Margen, 1971)														
Mean	27	70·8	7·85 (1875)	109	22	180§	0·5–0·6	−2·82	38	0·34	14	0·12	52	0·47
Range	21–37	52·3–88·3	6·49–9·56	92–151	18–25	—	—	—	27–53	0·29–0·50	—	—	—	—
SD	4	9	0·92	8	4	—	—	—	7	0·09	3	—	—	—
Eighty-three Caucasian students at MIT, Cambridge, Mass. (Scrimshaw *et al.* 1972)														
Mean	21	73·5	6·43 (1536)	88	23	188§	0·5–1·0	−2·57	37	0·42	9	0·10	46	0·52
Range	18–26	57·9–104·1	4·56–8·69	—	—	—	—	—	—	—	—	—	—	—
SD	2	9	1·03	—	—	—	—	—	6	0·07	2	0·03	6	0·08
Fifty Chinese students at Taiwan University (Huang *et al.* 1972)														
Mean	24	54·9	5·92 (1416)	109	23	201	0·54	−2·50	33	0·30	13	0·12	47	0·43
Range	20–32	42–75	4·84–7·15	—	—	155–234	—	—	—	—	—	—	—	—
SD	2	6	0·62	—	—	17	—	—	4	0·05	3	0·02	5	0·05
Four Indian men, low-income group, from Hyderabad (Gopalan & Narasinga Rao, 1968)														
Mean	27	46·0	5·12 (1223)	113	—	272	0·54	−2·27	38	0·33	23	0·21	61	0·54
Range	25–31	44·8–48·4	4·50–5·41	100–121	—	259–280	—	—	34–43	0·31–0·39	21–27	0·19–0·22	44–65	0·51–0·70
SD	3	2	0·41	8	—	8	—	—	5	0·04	3	0·01	9	0·08
Nine Nigerian men, low-income group, from Kaduna (present work)														
Mean	26	54·0	5·97 (1427)	109	24	188	0·77	−2·30	34	0·31	23	0·21	57	0·52
Range	21–30	50·1–58·0	5·52–6·32	105–117	20–27	172–201	—	−2·03 – −2·65	30–44	0·27–0·40	14–27	0·12–0·24	51–61	0·39–0·64
SD	3	3	0·29	3	2	13	—	−0·22	4	0·04	5	0·04		0·05

MIT, Massachusetts Institute of Technology.
* Initial BW.
† Calculated value.
‡ N balance, excluding cutaneous and other minor N losses.
§ Energy intake adjusted to maintain essentially constant BW

non-protein-containing foods, whereas the Taiwan, Indian and Nigerian MPDs were fed at constant levels of energy and N intake, so subjects lost weight during the feeding trials. Secondly, the Californian, MIT and Taiwan MPDs consisted mainly of purified and industrially processed foodstuffs. The Indian and Nigerian MPDs were composed of low-protein, vegetable foods of local origin which were domestically processed and may have contained more crude fibre than the other three diets.

The egg diet used by Calloway & Margen (1971) to determine the utilization of high-quality protein consisted of their MPD to which egg white or whole egg was added to provide a N intake of 4 g/d, 0·5 g N from the MPD and 3·5 g N from egg; carbohydrate and fat were replaced to obtain a diet isoenergetic with the MPD.

Duration of N balance determinations. Endogenous urinary and faecal N were found to stabilize after 6 d in all groups of subjects except the Indian men, whose N excretion was found to stabilize within 2–3 d. The pre-balance periods with the MPD were 6–7 d and balance periods 5–6 d, with the exception of the Indian subjects, for whom the pre-balance period was 4 d and the balance period 3 d.

RESULTS

Comparison of the endogenous N excretion of different ethnic and socio-economic groups

Certain physical characteristics of young men from the University of California, MIT, Taiwan University, India and Nigeria are given, together with their endogenous urinary and faecal N excretion, in Table 2. Energy provided by the MPD was of the same order on a body-weight basis (180–201 kJ (43–48 kcal)/kg per d), except that for the Indian men (272 kJ (65 kcal)/kg per d). The amount of N derived from the MPD varied from 0·5 to 1·0 g/d. The groups of subjects varied considerably in weight but BMR, in terms of kJ/kg body-weight, was approximately the same, except for a low value recorded for the MIT students. The similarity of urinary creatinine excretion, on a body-weight basis, is surprising in view of expected differences in lean body mass.

Endogenous urinary N excretion, on a body-weight basis, was comparable in all groups. The endogenous faecal N excretion of the Indian and Nigerian men was higher than that of the three student groups. This difference may have been associated with the composition of the Indian and Nigerian MPDs. The endogenous urinary + faecal N excretion for all five groups ranged from 46 ± 6 (SD) to 61 ± 9 mg/kg body-weight per d. The relationship between endogenous urinary N excretion and basal energy intake was similar for four of the five groups, the exception being the MIT group whose BMR were low. Endogenous faecal N excretion, in terms of basal energy intake, was higher in the Indian and Nigerian men than in the other three groups. The endogenous urinary + faecal N excretion for all five groups ranged from 0·43 ± 0·05 to 0·54 ± 0·08 mg/kJ (basal) per d.

Correlations between selected variables of N metabolism for the five groups of young men consuming the respective MPDs are given in Table 3. Some discrepancies are apparent, but certain intergroup correlations are of a similar order, e.g. body-weight *v.* (a) urinary creatinine excretion, (*b*) endogenous urinary N excretion, (*c*) endogenous urinary + faecal N excretion. One noteworthy difference is the positive

Table 3. *Correlations between age, basal metabolic rate* (BMR), *body-weight and nitrogen metabolism for groups of young men from different ethnic, socio-economic and nutritional backgrounds when given a minimal-protein diet*

Source of results	Variable	BMR	Body-wt	Urinary creatinine	Urinary N	Faecal N	Urinary + faecal N
Calloway & Margen (1971)	Age	—	—	—	0·40	—	0·39
Scrimshaw *et al.* (1972)		—	—	—	—	—	—
Huang *et al.* (1972)		—	—	—	—	—	—
Gopalan & Narasinga Rao (1968)		0·30	0·11	—	−0·36	−0·12	−0·97**
Present results		0·24	0·06	0·17	0·24	0·37	0·68**
Calloway & Margen (1971)	BMR	—	—	—	0·40	−0·55**	—
Scrimshaw *et al.* (1972)		—	0·64*	0·62*	0·49*	0·26**	0·52*
Huang *et al.* (1972)		—	0·67*	0·57*	0·62*	0·29**	0·65*
Gopalan & Narasinga Rao (1968)		—	0·11	—	−0·84	0·74	−0·19
Present results		—	0·90*	0·40	0·42	0·21	0·72**
Calloway & Margen (1971)	Body-wt	—	—	0·92*	0·45	0·23	—
Scrimshaw *et al.* (1972)		—	—	0·75*	0·56*	0·35*	0·60*
Huang *et al.* (1972)		—	—	0·62*	0·56*	0·06	0·51*
Gopalan & Narasinga Rao (1968)		—	—	—	0·36	−0·01	0·67
Present results		—	—	0·68**	0·54	0·06	0·69**
Calloway & Margen (1971)	Urinary creatinine	—	—	—	—	—	—
Scrimshaw *et al.* (1972)		—	—	—	0·61*	0·36*	0·65*
Huang *et al.* (1972)		—	—	—	0·64*	0·17	0·63*
Gopalan & Narasinga Rao (1968)		—	—	—	—	—	—
Present results		—	—	—	0·22	0·10	0·33
Calloway & Margen (1971)	Urinary N	—	—	—	—	0·80*	—
Scrimshaw *et al.* (1972)		—	—	—	—	0·21**	0·56*
Huang *et al.* (1972)		—	—	—	—	0·11	0·91*
Gopalan & Narasinga Rao (1968)		—	—	—	—	−0·47	0·49
Present results		—	—	—	—	−0·61	0·47
Calloway & Margen (1971)	Faecal N	—	—	—	—	—	—
Scrimshaw *et al.* (1972)		—	—	—	—	—	0·47*
Huang *et al.* (1972)		—	—	—	—	—	0·50*
Gopalan & Narasinga Rao (1968)		—	—	—	—	—	0·31
Present results		—	—	—	—	—	0·41

* $P < 0·01$; ** $P < 0·05$; all other correlations were not significant ($P > 0·05$).

Table 4. *Apparent daily nitrogen balance of nine Nigerian men when given a minimal-protein diet (MPD) composed of Nigerian foodstuffs (energy intake* 10·04 *MJ* (2400 *kcal)/d, N intake* 0·77 *g/d), and when given MPD supplemented with whole-egg protein (egg diet) (energy intake* 10·08 *MJ* (2410 *kcal)/d, N intake* 3·29 *g/d)**

Subject	Age (years)	Body-wt (kg) Initial†	Final†	Change in wt†	Basal metabolic rate (MJ(kcal)/d)	Urinary creatinine (g/d)	N excretion (g/d) Urinary	Faecal	Urinary + faecal	Apparent N balance‡ (g/d)
				MPD (pre-balance period 10–15 August, balance period 16–21 August)						
O	23	50·2	49·8	−0·4	5·52 (1320)	1·16	1·83	0·98	2·81	−2·04
P	21	57·9	57·8	−0·1	6·32 (1510)	1·39	1·90	1·02	2·92	−2·15
Q	28	54·9	54·4	−0·5	5·98 (1430)	1·33	2·39	0·75	3·14	−2·37
R	26	55·7	55·2	−0·5	6·07 (1450)	1·49	1·77	1·49	3·26	−2·49
S	25	50·1	49·0	−1·1	5·52 (1320)	1·30	1·55	1·25	2·80	−2·03
T	30	51·5	51·2	−0·3	5·98 (1430)	1·40	1·73	1·37	3·10	−2·33
U	30	55·6	55·1	−0·4	6·19 (1480)	1·29	1·89	1·39	3·28	−2·51
X	25	52·0	51·6	−0·4	5·86 (1400)	1·56	1·05	1·35	2·91	−2·14
Y	28	58·0	57·4	−0·6	6·28 (1500)	1·25	2·03	1·39	3·42	−2·65
Mean	26·22	53·99	53·51	−0·48	5·97 (1427)	1·296	1·850	1·221	3·071	−2·301
SD	3·08	3·11	3·00	0·28	0·29	0·13	0·26	0·25	0·22	0·22
CV	12	6	6	58	5	10	14	20	7	10
				Egg diet (pre-balance period 11–16 September, balance period 17–22 September)						
O	23	50·3	50·8	+0·5	5·52 (1320)	1·17	2·82	0·77	3·59	+0·33
P	21	58·0	58·4	+0·4	6·32 (1510)	1·38	2·04	1·13	3·17	+0·75
Q	28	54·5	54·7	+0·2	5·98 (1430)	1·35	2·53	0·89	3·42	+0·50
R	26	55·4	56·0	+0·6	6·07 (1450)	1·42	1·90	1·52	3·42	+0·50
S	25	49·9	50·1	+0·2	5·52 (1320)	1·23	1·57	1·68	3·25	+0·67
T	30	51·1	51·6	+0·5	5·98 (1430)	1·31	2·04	1·30	3·34	+0·58
U	30	56·0	56·5	+0·5	6·19 (1480)	1·33	2·13	1·18	3·31	+0·61
X	25	52·6	53·0	+0·4	5·86 (1400)	1·14	1·63	1·58	3·21	+0·71
Y	28	58·3	58·7	+0·4	6·28 (1500)	1·25	1·75	1·46	3·21	+0·71
Mean	26·22	54·01	54·42	+0·41	5·97 (1427)	1·287	2·046	1·279	3·324	+0·596
SD	3·08	3·20	3·24	0·15	0·29	0·10	0·41	0·31	0·14	0·14
CV	12	6	6	37	5	8	20	24	4	23

CV, coefficient of variation.
* For details of composition of diets, see Table 1; for details of subjects, see Table 2.
† Days 7–12 of trial (balance period).
‡ Excluding cutaneous and other minor N losses.

Table 5. *Biological value* (BV)* *and true digestibility* (*TD*)† *of whole-egg protein determined in a study using six University of California male students* (*Calloway & Margen*, 1971) *and one using nine Nigerian men of low-income group* (*present study*) *given a minimal-protein diet* (*MPD*) *supplemented with whole-egg protein* (*egg diet*)‡

	Californian men	Nigerian men
Dietary energy (kJ(kcal)/kg body-wt per d) ...	180±17 (43±4)	188±13 (45±3)
Nitrogen intake from MPD (g/d) ...	0·50	0·77
N intake from whole egg (g/d)	3·50	3·15
Total N intake	4·00	3·92
Apparent N balance (g/d)§	−0·23	+0·60±0·13
N intake (mg/kg body-wt per d)	—	73±4
TD	0·96±0·03 (CV 3)	0·97±0·04 (CV 4)
BV	0·78±0·08 (CV 10)	0·93±0·09 (CV 10)
Net protein utilization (BV × TD)	0·75	0·90

CV, coefficient of variation.
* Absorbed N −(urinary N_{egg} −urinary N_{MPD}) ÷absorbed N.
† Dietary N −(faecal N_{egg} −faecal N_{MPD}) ÷dietary N.
‡ For details of composition of diets, see Table 1; for details of subjects, see Table 2.
§ N balance excluding cutaneous and other minor N losses.

correlation of 0·80 and the negative correlation of 0·61 for endogenous urinary N excretion *v.* endogenous faecal N excretion recorded for the Californian group of students and the Nigerian men respectively. This subject will be considered again in relation to the utilization of egg protein by these two groups.

Utilization of egg protein by Nigerian men and by the Californian group of students

Details of the individual N balances recorded for nine Nigerian men of a low-income group consuming the MPD are given in detail in Table 4, to support the calculations for the true digestibility and BV of the egg diet. All men lost weight during the balance period. The coefficient of variation for endogenous urinary + faecal N excretion (7) was less than that for endogenous urinary N excretion (14) or endogenous faecal excretion N (20), indicating the negative correlation (r −0·61; P < 0·01) between these two measurements of N metabolism in Nigerian men when consuming the MPD (Table 2).

The N balance results obtained for the same nine Nigerian men, while eating the egg diet, are given in Table 4. The addition of 3·15 g egg-protein-N to the MPD produced a gain in body-weight approximating to the loss of weight found with the MPD, conversion of a negative N balance of 2·3 g/d to a positive N balance of 0·6 g/d, a non-significant change in faecal N excretion, an increase in urinary N excretion of 0·2 g/d, and an increase in the negative correlation between urinary and faecal N excretion (r −0·97; P < 0·001).

Table 5 gives a comparison between the utilization of egg-protein-N by the nine Nigerian men and by six University of California students (Calloway & Margen, 1971). At comparable levels of energy, total N and egg-protein-N intakes, apparent N balance (g/d) was −0·23 for the California group and +0·60±0·13 for the Nigerian men. The addition of 3·15 g egg-protein-N to the Nigerian MPD increased urinary and faecal N excretion by 0·20±0·91 and 0·06±0·56 g/d respectively (Table 4), whereas the addition of 3·50 g egg-protein-N to the California MPD produced a daily increase in urinary N excretion of 0·81 g and in faecal N excretion of 0·13 g (Calloway & Margen, 1971).

It is apparent from the results given in Table 5 that egg-protein-N was used more efficiently by the Nigerian men than by the Californian group of students. The respective values for net protein utilization (NPU) were 0·90 and 0·75 at the levels of N balance recorded. Calloway & Margen (1971) gave certain of their subjects the MPD supplemented with egg protein at different levels and, by extrapolation, found that 74 mg N/kg body-weight per d was needed to maintain N equilibrium. They calculated that the NPU of egg protein, at the level of N equilibrium, was 0·65 in their subjects. When the Nigerian men consumed the MPD supplemented with egg protein at a similar level of N intake (73 ± 4 mg/kg body-wt per d), N balance was +0·60 ± 0·13 g/d and the NPU of egg protein was calculated to be 0·90 (Table 5), as Thomas (1909, quoted by Rippon (1959)) and Block & Mitchell (1946) considered it to be.

DISCUSSION

Endogenous N excretion of men of different ethnic, socio-economic and nutritional backgrounds

The values for endogenous urinary and faecal N excretion of male students at the University of California, MIT and Taiwan University, and for young men of low-income groups from India and Nigeria (Table 2), expressed in terms of body-weight or basal energy intake, were generally similar; mean values for daily endogenous urinary N excretion for all five groups were 36 mg/kg body-weight and 0·34 (1·44) mg/kJ (kcal) (basal) respectively. The latter value is somewhat lower than the value of 0·48 (2) mg/kJ (kcal) (basal) reported by Smuts (1935) and by Brody (quoted by Hegsted, 1964), but it is in good agreement with the findings of Murlin, Edwards, Hawley & Clark (1946) and Hawley, Murlin, Nassett & Szymanski (1948) for North American subjects. The value for endogenous urinary + faecal N excretion did not vary significantly between the five groups of different ethnic origin and socio-economic background compared here, and is in good agreement with the levels for adult men accepted by the FAO/WHO Committee (FAO/WHO, 1973). From the evidence available to it, that Committee considered the coefficient of variation for the total endogenous N loss in urine and faeces in adult men to be approximately 15, the main part of the variation being attributable to biological variability. 'A value 30% larger should encompass the losses (of endogenous N, including integumental and other minor losses) of nearly all healthy persons in a normal population' (FAO/WHO, 1973). The FAO/WHO Committee did not assess the correlation between endogenous urinary and faecal N excretion.

Utilization of absorbed N by men of different ethnic, socio-economic and nutritional backgrounds

The published results of studies made in both developed and developing countries led the FAO/WHO Committee (FAO/WHO, 1973) to the conclusion that 'the lowest estimates of N requirement to obtain equilibrium in adults . . . are consistently higher than the predictions of N requirement based on obligatory losses . . . by a factor of about one-third. It is important to realise that this difference exists even when high-quality proteins such as those of milk or eggs, are fed.' The few published results available to the Committee concerning adult men's needs for N, derived from high-quality proteins (egg, milk, casein), to maintain N equilibrium, were all obtained using subjects of university background, living in developed countries. It is justifiable to assume that the customary consumption of mixed dietary proteins by these subjects was considerably higher than the 'safe level of protein intake' proposed by the FAO/WHO Committee (FAO/WHO, 1973). The NPU of egg, milk and casein, determined under these conditions, varied from 0·63 to 0·70.

The present results obtained for the utilization of egg protein by Nigerian men, accustomed to eat diets which provide levels of protein nearer to, but still somewhat higher than, the 'safe level of protein intake' suggested by the FAO/WHO Committee (FAO/WHO, 1973), indicated that they utilized egg-protein-N very efficiently (NPU 0·90). The addition of an amount of whole-egg-protein-N to the MPD, equal to the total endogenous urinary and faecal N loss with the MPD (Table 4), resulted in a positive N balance and produced a gain in body-weight. These findings are not in accord with those of Calloway & Margen (1971), who reported a negative N balance when they supplemented their MPD with amounts of egg-protein-N equivalent to the endogenous N losses (urinary, faecal and integumental) of their student subjects. Nor are our findings for Nigerian men in accord with the conclusion of the FAO/WHO Committee (FAO/WHO, 1973) that endogenous N losses are 30% lower than the amount of dietary N required for the maintenance of N equilibrium in adult men, whether that amount is derived from high-quality protein sources or from mixed diets.

The quality of dietary protein, in terms of its amino acid composition, undoubtedly influences the amount required to meet man's needs, provided the food available is sufficient to meet his energy requirements (Payne, 1975). However, our finding of a more efficient utilization of egg protein by Nigerian men of a low-income group, compared to that reported for University of California students (Calloway & Margen, 1971), is not affected by these factors. It is suggested that man's requirements for protein are determined, to a considerable extent, by his ecological and socio-economic backgrounds. Waterlow (1968) found that man can adapt to low protein intakes through mechanisms in intermediary metabolism which conserve amino acids. The significantly negative relationship between endogenous urinary and faecal N excretion found by us, and Gopalan & Narasinga Rao (1968) in low-income groups of Nigerian and Indian men respectively, and the significantly positive relationship of these measurements of N metabolism, at endogenous level, obtained by Calloway & Margen (1971) for University of California students, is of interest in this context. It is also important to note that the inverse relationship between urinary and faecal N excretion was greater when Nigerian men consumed the MPD supplemented with whole egg than it was at endogenous level.

Another factor which may influence the utilization of dietary protein by individuals of different ethnic and socio-economic backgrounds is the proximate composition of the diets they customarily consume. Cuthbertson & Munro (1939) found that carbohydrates have a greater sparing effect than fats on man's use of protein 'provided the carbohydrate and fat are ingested together', as they are in developing countries. In certain of these countries protein provides less than 100% dietary energy per person. The contribution of carbohydrates to the energy of these traditional diets is often 800 or more % dietary energy, only 100–150% dietary energy being derived from fats and oils. In more developed countries, and among the more privileged classes in developing countries, 300–400% dietary energy may be supplied by fats and oils, and 120–150% dietary energy by protein (Périssé, Sizaret & François, 1969; Nicol, 1970).

From the results obtained, and the comparisons made in this paper, we do not consider it is possible to establish a single 'safe level of protein intake', based on body-weight and assuming an adequate energy intake, which would apply to all men of different ethnic, socio-economic and nutritional backgrounds.

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