Nutrition of Domestic Rabbits

2. The Efficiency of Rabbit-meat Production from Weeds, Fed Alone and with Cooked Potatoes

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It is often stated that rabbits may be reared exclusively or very largely on weeds and attempts have been made to increase in this way rabbit production for meat in various countries in times of food scarcity, on the ground that such waste feeding-stuffs may be used in feeding the animals without calling to an appreciable extent on food suitable for human consumption. Up to the present time no exact trials appear to have been carried out to find out how far this is true, and the experiments described in this paper are an attempt to obtain some information on the problem.

EXPERIMENTAL

General plan of the experiment

Litters of weaned rabbits were put on experiment at intervals from the last week of May to the middle of July so as to cover the season when weeds are plentiful in England. The litters were divided into three groups. Group 1 was given a ration of weeds only *ad lib.* Group 2 received weeds *ad lib.* and cooked potatoes fed at three levels, 100 g./day, 150 g./day and *ad lib.* (about 200 g./day). Group 3 received a pelleted stock concentrate ration, fresh cabbage and hay *ad lib.*, with the exception of one animal which did not receive hay. The experimental feeding period continued for 7 weeks, after which the animals were slaughtered, and the increase in edible meat was estimated as described in the preceding paper (Hutchinson, 1947). Throughout the feeding trial the time expended in collecting weeds and carrying them to the Small Animal Breeding Station where the rabbits were housed was noted. Finally, the energy cost to man of collecting the weeds was experimentally determined at the Department of Human Anatomy, Oxford University.

Genetic history of the animals

The rabbits were the offspring of the same five does of mixed Flemish-Giant and Belgian-Hare breeds and of the same buck as those considered in the preceding paper (Hutchinson, 1947). The numbers of the mothers are included in Table 3.

Rations

Weed ration

The species of weeds used depended partly on the preference of the rabbits and partly on their availability at any particular time. Sow thistles were by far the most palatable of the kinds fed, and were, therefore, given in preference to othér weeds so far as the quantity obtainable allowed. The following species were fed.

Fed in large quantities. Sow thistles (*Sonchus oleraceus palustris*, *asper* and other species of *Sonchus*), about 70% of total; shepherd's purse (*Capsella Bursa-pastoris*), about 20% of total.

Fed in small quantities. Chervil (*Chaerophyllum sylvestre*), only fed for 1 week to rabbits nos. 78–92, dandelion (*Taraxacum Dens-leonis*), groundsel (*Senecio vulgaris*), plantain (*Plantago major*), bindweed (*Convolvulus arvensis* and *sepium**), veronica (*Veronica spicata*), dock (*Rumex obtusifolius*), chickweed (*Stellaria media*), mallow (*Malva sylvestris*), great willow herb (*Epilobium hirsutum*), white goosefoot (*Chenopodium album*). The last four were not very palatable.

All the weeds were fed as far as possible in a young condition before flowering. Occasionally, if gathered after rain, they were spread out to dry off, but they were not fed wilted. The weeds were given to the animals in excess of requirements. Rabbits feed selectively on the tender leaves and reject the fibrous stalks, provided that they are offered a sufficient quantity of food. Samples of the weeds and of the weed residues in the hutches were collected daily for estimation of dry matter. These samples were bulked for the determination of crude protein and fibre at about monthly intervals. The composition varied with rainfall and season of the year (Table 1).

Table 1. *Percentage composition of bulked weeds and weed residues on the dry-matter basis*

	June–July	August	September
Crude protein (N × 6·25)	15·5*	17·2*	24·5*
	—	13·6†	16·5†
Ether extract	6·6*	—	—
Ash (incl. silica)	22·7*	—	—
Crude fibre	19·6*	18·1*	15·4*
	—	24·4†	25·8†
Nitrogen-free extract	35·6*	—	—

* Weeds. † Weed residues.

The dry matter content of the weeds as fed varied from 11 to 20% and was normally around 15%. Water and blocks of common salt were available in the hutches. The animals were fed twice a day. The digestibility of September-fed sow thistles determined on two rabbits was 74·6% for dry matter, 83·8% for crude protein and 23·4% for crude fibre. These figures would have been lower for the weeds gathered earlier in the season because the latter were less succulent.

* *Convolvulus sepium* fed to rabbit no. 92 only.

In order to find out whether the opportunity to take exercise would enable the animals to eat more weeds and so to make better gains, six of the rabbits, nos. 94–99, were kept out of doors in a couple of pens (three animals in each pen). The pens, measuring about 10 × 2 ft., were placed in a paddock of rough grass and were moved every few days. The animals had hutches to retire to at night.

Weed and potato ration

The weeds were fed *ad lib.* as to the group which received weeds only. The potatoes were of the Majestic variety. They were cooked whole in a steamer till tender, left to cool and dry off, and were then mashed up before feeding. Sodium chloride (0·5 % on the dry-matter basis) was fed with the potatoes. Samples were taken for analysis for dry-matter determination daily and the crude protein was determined on bulked samples. The moisture content of the potatoes fed was between 71 and 79 %. The crude protein content on a dry-matter basis was 10·7 %. Digestibility coefficients for the potatoes fed were 89·9 % for dry matter and 77·8 % for crude protein.

Stock ration

The pelleted concentrate ration was the same as that used in the preceding paper (Hutchinson, 1947). It contained 21·1 % crude protein on a dry-matter basis. Cabbage and hay were fed *ad lib.*, except to rabbit no. 117 which received no hay. The cabbage consisted usually of the outer leaves but sometimes of whole heads. The hay was rough meadow-hay of poor quality. The cabbage was sampled daily and the hay at frequent intervals for dry-matter determinations. The cabbage contained 8–11 % dry matter and the hay 84–89 %. The crude protein content of the cabbage was 22·9 % on the dry-matter basis and that of the hay varied from 8 to 9 % in different samples. Digestibility coefficients for the concentrate ration were 70·7 % for dry matter and 76·1 % for protein, and for the hay, 39·2 and 48·4 %, respectively. Voris, Marcy, Thacker & Wainio (1940) found the digestibility of cabbage for rabbits to be 101·3 % for dry matter and 98·6 % for crude protein.

Carcass analysis

Analyses of the carcasses were made, and the increase in edible matter determined, in the same manner as in the preceding paper (Hutchinson, 1947). Carcasses of four of the animals kept in outside pens were not analysed. Protein and fat of edible offal which was not considered in the preceding paper were determined by analyses of the dried edible offal of some of the animals. For other animals average analyses thus obtained were used to compute protein and fat from the weight of dry matter. Edible offals are early developing parts of the animal so that the increase in these was very small during the feeding experiment. Small errors in estimating the gains in these parts would not, therefore, have an appreciable influence on the result of the experiment. The glycogen of the liver was neglected.

RESULTS

Performance of the rabbits

Condition of animals

The animals maintained excellent condition on all three rations. The feeding of such a large quantity of weeds produced no digestive troubles. There was no diarrhoea; in fact the faeces appeared to be somewhat harder than usual. The coats of the two weed-fed groups appeared better than those of the control group, though all were in good condition. Two animals of the control group and two of the group fed weeds and potatoes died of coccidiosis. Owing to the fact that wooden hutches were used it was not possible to keep the stock entirely free from this disease. No illness occurred in the other animals.

Growth

Food intakes of those animals of the weed-fed group which were housed in hutches are given in Table 1 of the preceding paper (Hutchinson, 1947), and of the remaining animals of all groups in Table 2 of this paper. The level of potatoes in the ration of the

Table 2. *Food intake of rabbits during the feeding trial*

Weed-fed group (outside runs)

Rabbit no.		Total dry matter (g.)	Protein (g.)	Protein in dry matter (%)
94, 95, 99	Pen 1	17,414	3605	20·7
96, 97, 98	Pen 2	19,870	3995	20·1

Group fed weeds and potatoes

Rabbit no.	Potato dry matter (g.)	Weed dry matter (g.)	Total dry matter (g.)	Potato dry matter as percentage of total	Protein (g.)	Protein in dry matter (%)
101	1283	3975	5258	24·4	992	18·9
103	1282	3456	4738	27·0	908	19·2
106	1286	3455	4741	27·1	908	19·1
87	1188	2895	4083	29·1	687	16·8
111	1918	3979	5897	32·5	1180	20·0
110	1878	3235	5113	36·7	1040	20·3
78	2490	3670	6160	40·4	953	15·5
83	2828	2917	5745	49·2	878	15·3
Mean	1769	3448	5217	33·3	943	18·1

Control group

Rabbit no.	Pellets dry matter (g.)	Cabbage dry matter (g.)	Hay dry matter (g.)	Total dry matter (g.)	Protein (g.)	Protein in dry matter (%)
79	3708	1111	976	5795	1148	19·8
88	3162	1313	1066	5541	1085	19·6
89	2650	1531	1264	5445	1040	19·1
102	2709	1390	681	4780	978	20·4
105	2674	1284	601	4559	938	20·6
107	2687	1808	659	5154	1074	20·8
117	2275	2237	0	4512	1042	23·1
Mean	2838	1525	749	5112	1044	20·5

group fed weeds and potatoes ranged from 24 to 49% on a dry-matter basis. Growth, estimated initial carcass weight and final carcass weight of the weed-fed animals which were housed in hutches are given in Table 2 of the preceding paper, and of the remaining animals of all groups in Table 3 of this paper. The rate of growth of the

Table 3. *Live weights, dressed-carcass weights and killing out percentages of rabbits which received the weed ration, the weed and potato ration and the control ration*

		Live weight			Dressed-carcass weight*			
Rabbit no.	Mother no.	Initial (g.)	Final (g.)	Gain in 7 weeks (g.)	Estimated initial (g.)	Final (g.)	Gain in 7 weeks (g.)	Killing out percentage†
			Weed-fed group (outside runs)					
94	B2	810	1596	786	—	—	—	—
95	B7	642	1578	936	—	—	—	—
96	B7	833	1860	1027	429	1147	718	61·7
97	B2	982	1958	976	—	—	—	—
98	B7	869	1982	1113	—	—	—	—
99	B7	966	2135	1169	497	1228	731	57·5
Mean		850	1851	1001	—	—	—	—
			Group fed weeds and potatoes					
101	B7	877	2172	1295	451	1259	808	58·0
103	B7	936	2032	1096	483	1246	764	61·3
106	B2	1081	2160	1079	556	1269	713	58·7
87	B3	896	1586	690	461	908	447	57·2
111	B4	1150	2418	1268	592	1464	872	60·5
110	B4	921	1948	1027	474	1234	760	63·3
78	B1	1202	2412	1210	619	1512	893	62·6
83	B1	1180	2411	1231	608	1444	836	59·9
Mean		1030	2142	1112	530	1292	762	60·2
			Control group					
79	B3	1086	2290	1204	559	1437	878	62·7
88	B3	1255	2560	1305	646	1570	924	61·3
89	B3	1222	2345	1123	629	1312	683	55·9
102	B7	710	2088	1378	365	1221	856	58·5
105	B2	814	1800	1086	419	1094	675	60·7
107	B7	970	2120	1150	499	1311	812	61·8
117	B4	991	2270	1279	510	1384	874	60·9
Mean		1007	2210	1218	518	1333	815	60·2

* Weight of carcass after removal of the pelt, inedible offal, edible offal and feet.
† Dressed-carcass weight expressed as a percentage of live weight.

weed-fed group in individual hutches was about 75% of that of the control group. This is a quite satisfactory rate of growth on a substitute ration. The growth of the animals kept in outdoor pens was not significantly greater than that of the animals kept in hutches. Apparently any increase in appetite caused by access to grass and exercise was balanced by greater energy expenditure. The growth of the group fed on weeds and potatoes was 91% of that of the control group and was therefore nearly at the maximum rate at which animals of this breed can grow. It is reasonable to suppose that if all the animals in the group had received potatoes *ad lib.* the rate of growth would have equalled that of the control group. It appears, therefore, that, as far as increase in live weight is concerned, a substitute ration of weeds will give reasonably satisfactory growth, and one of weeds and potatoes excellent growth, provided the weeds are mainly sow thistles and are fed in excess as described above.

Killing out percentage

The killing out percentage is the dressed-carcass weight expressed as a percentage of the live weight of the animal. Table 3 of the preceding paper gives the killing out percentage of the animals of the weed-fed group which were housed in hutches; that of the remaining animals of all groups is given in Table 3 of this paper. It averaged 60·2 % for the group fed weeds and potatoes and for the control group. For the weed-fed group it was slightly lower (57·0 %) but the difference was not significant.

Carcass composition

Table 4 gives the increase in edible matter of the three groups comprising dry matter, protein, fat, gross energy and available energy for human nutrition. Available energy means calorific value calculated from Rubner's (1885) factors, namely, 9·3 Cal./g. for fat and 4·1 Cal./g. for protein ($N \times 6 \cdot 25$). These factors are used to make the figures correspond to those in the tables for the calorific value of foods used in Great Britain (McCance & Widdowson, 1946). Rubner intended these factors to be used for mixed rations and not for single feeding-stuffs. The factor for protein is the heat of combustion less the heat of combustion of the urine, with a further subtraction of about 3 % for the nitrogen of the faeces. The factor for fat is the average heat of combustion of the fat in a mixed ration uncorrected for any fat in the faeces. The mean of the gains in edible matter for the weed-fed group is calculated for the animals housed in hutches only.

The most striking observation from Table 4 is that the gains in fat and energy do not run parallel with the growth rates. The weed-fed group laid down but little depot fat and, therefore, energy, whereas the other two groups laid down considerable quantities of fat. The fat laid down by the weed-fed group was 8·8 %, the gross energy 37·4 %, and the available energy 32·5 %, of that of the control group. The fat laid down by the group fed weeds and potatoes was 76·2 %, the gross energy 81·0 %, and the available energy 80·0 %, of that of the control group. The animals which received potatoes ***ad lib.*** laid down considerably more fat than those which had less potatoes. The amount of protein laid down corresponded fairly well to the growth of the animals. The weed-fed group produced 73·2 %, and the group fed weeds and potatoes 87·4 %, of that laid down by the control group.

Conversion of animal feed to meat

Table 5 gives the efficiency of conversion of food into live weight and dry matter, protein, fat, gross energy and available energy of meat; it also includes conversion of protein of food into edible protein. The weed and potato group and the control group converted both the dry matter of the feed and the protein of the feed into live-weight increase and edible protein rather more efficiently than the weed-fed group. The differences between the groups in the conversion of the dry matter of the food into edible dry matter, fat, gross energy and available energy were much greater. For example, the efficiency of conversion of the dry matter of feed into fat by the weed-fed group was 11·6%, and by the group fed weeds and potatoes 71·5%, of that of the

Table 4. *Estimated gains in edible matter of rabbits during the feeding trial*

Rabbit no.	Dry matter (g.)	Protein (g.)	Dissected fat* (g.)	Total fat (g.)	Gross energy (Cal.)	Available energy† (Cal.)
			Weed-fed group			
80	121·8	108·0	− 5·6‡	7·9	689	515
84	62·9	72·6	−10·7‡	−12·6‡	300	182
85	50·7	78·1	−11·8‡	−28·4‡	177	56
92	171·8	142·4	4·0	19·2	993	762
100	133·1	112·5	− 4·0‡	10·1	737	553
104	114·7	94·8	− 2·6‡	8·5	621	468
108	137·7	124·5	− 5·0‡	6·9	775	574
114	183·7	144·3	1·0	38·3	1181	947
116	97·2	97·6	− 7·4‡	1·8	573	414
118	191·6	138·1	7·6	49·0	1247	1020
99	116·1	114·1	− 7·4‡	1·1	662	477
96	145·6	134·7	− 7·7‡	1·8	786	570
Mean§	126·5	111·3	− 3·5‡	10·1	729	549
			Group fed weeds and potatoes			
101	184·9	128·3	15·0	50·1	1204	992
103	190·6	127·3	20·0	50·0	1198	985
106	186·7	107·2	27·1	70·4	1276	1092
87	120·0	77·7	14·1	39·5	815	685
111	264·5	167·6	31·6	90·8	1811	1529
110	223·0	139·0	31·2	78·4	1531	1297
78	312·2	153·2	64·7	160·3	2390	2116
83	319·9	161·2	71·8	159·3	2423	2117
Mean	225·2	132·7	34·4	87·4	1581	1352
			Control group			
79	276·3	168·7	39·5	101·3	1916	1633
88	366·9	197·7	69·9	146·7	2515	2175
89	236·4	120·1	45·2	114·6	1766	1555
102	248·0	156·7	28·1	90·4	1747	1480
105	224·7	108·7	44·0	117·5	1731	1534
107	288·7	147·6	58·6	127·4	2046	1788
117	274·1	163·7	45·7	105·8	1932	1653
Mean	273·5	151·9	47·3	114·8	1950	1688

* Dissected fat is the sum of fat round the kidney and that over the shoulders and pubic region (see Hutchinson, 1947).

† Available energy = energy available for human nutrition.

‡ Negative sign denotes an estimated loss of fat.

§ Not including animals nos. 96 and 99.

control group. For the efficiency of conversion of the dry matter of the feed into available energy for human nutrition the values were 32·6 and 76·1%, respectively. The average total intake of dry matter was nearly the same for the three groups so that these differences in conversion must have been due to differences in digestible energy and possibly also to difficulty in synthesis of fat from the products of digestion of the

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weeds. No attempt was made to get a valid estimate of the digestibility of the weeds because their composition varied from day to day, and it would have been necessary to keep animals on digestibility trials throughout the season.

Table 5. *Efficiency of conversion of feed into live weight and meat*

	Increase/100 g. feed dry matter						Increase/100 g. feed protein	
Rabbit no.	Live weight (g.)	Meat dry matter (g.)	Meat protein (g.)	Meat fat (g.)	Meat gross energy (Cal.)	Meat available energy* (Cal.)	Live weight (g.)	Meat protein (g.)
				Weed-fed group				
80	17·2	2·34	2·07	0·15	13·2	9·9	92	11·10
84	14·2	1·60	1·84	0·0	7·6	4·6	73	9·56
85	14·7	1·14	1·75	0·0	4·0	1·3	78	9·36
92	15·5	2·45	2·03	0·27	14·2	10·9	83	10·95
100	21·5	2·79	2·36	0·21	15·5	11·6	104	11·35
104	20·4	2·61	2·16	0·19	14·1	10·7	96	10·16
108	20·6	2·66	2·41	0·13	15·0	11·1	96	11·30
114	19·1	3·45	2·71	0·72	22·2	17·8	82	11·66
116	24·4	2·51	2·52	0·05	14·8	10·7	95	9·88
118	20·3	3·61	2·60	0·92	23·5	19·2	84	10·80
Mean	18·8	2·51	2·24	0·26	14·4	10·8	88	10·61
				Group fed weeds and potatoes				
101	24·6	3·52	2·44	0·95	22·9	18·9	131	12·93
103	23·1	4·02	2·69	1·05	25·3	20·8	121	14·01
106	22·7	3·94	2·26	1·48	26·9	23·0	119	11·80
87	16·9	2·94	1·90	0·97	19·9	16·7	100	11·31
111	21·5	4·48	2·84	1·54	30·7	25·9	107	14·20
110	20·1	4·36	2·72	1·53	29·9	25·3	99	13·36
78	19·6	5·07	2·49	2·60	38·8	34·4	127	16·06
83	21·4	5·57	2·80	2·77	42·2	36·8	140	18·34
Mean	21·2	4·24	2·52	1·61	29·6	25·2	118	14·00
				Control group				
79	20·8	4·77	2·91	1·75	33·1	28·2	120	14·69
88	23·5	6·62	3·57	2·65	45·4	39·3	120	18·22
89	20·6	4·34	2·21	2·10	32·4	28·5	108	11·55
102	28·8	5·19	3·28	1·89	36·5	30·9	141	16·02
105	23·8	4·93	2·38	2·58	38·0	33·6	116	11·59
107	22·3	5·60	2·86	2·47	39·7	34·7	107	13·74
117	28·3	6·07	3·63	2·35	42·8	36·6	122	15·71
Mean	24·0	5·36	2·98	2·25	38·2	33·1	119	14·50

* Available energy = energy available for human nutrition.

If, for the moment, the time and energy cost to man of collecting weeds be neglected, it is possible to make an estimate of the efficiency of conversion into rabbit meat of potatoes when fed with weeds. The values are set out in Table 6. The conversion of the dry matter of potatoes into edible protein varied from 5·7 to 10% according to the quantity of potatoes fed. The yield of edible protein was over 90% of the potato protein fed at low levels of intake, and did not fall below 50% when potatoes were fed *ad lib.* This was because weeds are a very good source of protein and provided the greater part of the protein of the ration. For the calculation of the increase in gross energy of meat/100 Cal. gross energy in the potatoes fed, the gross energy of potatoes was taken as 4·06 Cal./g. on a dry-matter basis (Hutchinson, Bacon, Macrae & Worden, 1943). The average energy conversion on this basis was 22 %.

Finally, the available energy of rabbit meat for human nutrition was assessed in terms of the available energy for human nutrition which could have been obtained had the potatoes been allocated for human consumption. Rubner & Thomas (1918)

Table 6. *Efficiency of conversion to meat of potatoes when fed with weeds*

		Increase in meat					
		Increase/100 g. potato dry matter					
Rabbit no.	Potato dry matter as percentage of total	Dry matter (g.)	Protein (g.)	Fat (g.)	Gross energy/ 100 Cal. potato gross energy (Cal.)	Available* energy/100 Cal. potato available energy (Cal.)	Protein/ 100 g. potato protein (g.)
101	24·4	14·4	10·00	3·90	23·2	21·0	93·6
103	27·0	14·9	9·93	3·90	23·1	20·8	92·9
106	27·1	14·5	8·33	5·47	24·5	23·0	78·2
87	29·1	10·1	6·54	3·32	16·9	15·6	61·1
111	32·5	13·8	8·73	4·73	23·3	21·6	81·7
110	36·7	11·9	7·40	4·17	20·1	18·7	69·5
78	40·4	12·5	6·15	6·44	23·7	23·0	57·6
83	49·2	11·3	5·70	5·63	21·2	20·3	53·3
Mean	—	—	—	—	22·0	20·5	—

* Available energy = energy available for human nutrition.

found in an experiment with a man who lived on potatoes for 6 days that the digestibility of the energy of boiled potatoes was 93·3 % and that of nitrogen 72·1 %. The potatoes were cooked in their skins and peeled before being eaten. The results of this experiment were in close agreement with other experiments carried out by Rubner (1901) on mixtures of new and old potatoes and with experiments of Constantinidi (1887) and Hindhede (1912) in which potatoes were eaten with other food, but were higher than those obtained in an earlier experiment by Rubner (1879) in which he gave baked as well as boiled potatoes. The figure of 93·3 % is therefore taken as the digestibility of the energy of potatoes for man; the error introduced by neglecting the skins is small. The digestible energy for man of potatoes is thus 3·79 Cal./g. dry matter. After subtraction of 1·3 Cal./g. digestible crude protein of potato (Sherman, 1941) to represent the energy lost in the urine, the available energy for human nutrition becomes 3·69 Cal./g. potato dry matter. The available energy of potatoes thus reckoned takes into account loss in digestion and, therefore, corresponds to Rubner's (1901) *Reinkalorie*. That of the rabbit meat with which it is compared does not allow for loss in digestion of fat as explained above and corresponds to Rubner's (1901) *Bruttowärme*. The difference between *Bruttowärme* and *Reinkalorie* of meat is not quantitatively important in an approximate calculation of this nature.

The conversion of available energy of potatoes to rabbit meat averaged 20·5 %. If it is considered that the potatoes would have been peeled before feeding to man, the conversion would be 23–25 %.

It is important to emphasize that the efficiency of conversion of food to meat discussed above relates to the productive phase of the rabbit's life, and cannot therefore be used in comparisons of the overall efficiency of the domestic rabbit with that of other animals.

At this point in the assessment of the value of weeds it may be concluded that weeds, when fed alone, give reasonably good growth and protein deposition but a poor conversion of food to edible fat, while weeds fed with potatoes give a satisfactory conversion of total food or of potatoes into edible protein and fat. It is now necessary to consider the labour expended and the energy cost to man of collecting the weeds.

Table 7. *Assessment of labour expended in collecting weeds for rabbits, in terms of human food produced*

	Weed-fed group		Group fed weeds and potatoes	
	hr.	min.	hr.	min.
Time required to gather weeds:				
1. To fatten one rabbit	6	51	5	20
2. To produce 100 Cal. available energy as rabbit meat	1	15	0	24
3. To produce 100 g. meat protein	6	9	4	1
4. To produce enough available energy to feed one adult human being for 1 day (2400 Cal.)*	30	0	9	36
5. To produce enough animal protein to feed 1 adult human being for 1 day (32·5 g.)†	2	0	1	19

* League of Nations standard for sedentary worker (Technical Commission of the Health Committee, 1936).

† One-half of League of Nations standard for total protein of 1 g./kg. body-weight calculated for a body-weight of 65 kg.

Labour expended in collecting weeds

The number of rabbits for which weeds had to be collected at any given time varied between four and twenty-one, and was on an average about twelve. The weeds were taken from an area of up to about 10 acres of horticultural land in different parts of Cambridge. In any one day only a very small proportion of this land had to be covered, but it was necessary to cycle up to $1\frac{1}{2}$ miles with supplies from the more distant parts. The average rate of collection was 7·45 kg./hr. Each rabbit of the weed-fed group was offered an average of 51·1 kg. weeds during the course of the experiment and each animal of the group fed weeds and potatoes, 39·8 kg. With this information and the data supplied by Table 4, the labour expended in collection can be assessed in terms of the human food produced (Table 7).

These estimates of labour expenditure deal only with the collection of weeds and do not include activities such as care of the animals, cleaning of hutches and cooking of potatoes. It is clear that, so far as expenditure of labour is concerned, rabbits fed on the two dietary regimes investigated are exceedingly unprofitable as producers of available energy for human beings. This would be true even if it were found that under more favourable conditions of collection of weeds the labour might be halved. Moreover, for the purpose of the above calculations it was assumed that available energy obtained from the rabbit meat is net and without appreciable energetic cost to the human collector of weeds. It will be shown in the next section of the paper that this is not true. The production of animal protein is, on the other hand, a much more economic proposition.

Determination of the energy cost to man of collecting weeds

The ordinary Douglas bag method was used for these experiments. One subject (the author) was used in the investigation. He was accustomed to serve from time to time as a subject in experiments in human physiology and had carried out tests involving the use of the Douglas bag equipment on many former occasions. Moreover, he was also practised at collecting weeds for rabbits, having collected about half of the weeds used in the feeding trial. The tests were carried out on cultivated allotment land round the Department of Human Anatomy, Oxford University. Each consisted of a 10 min. preliminary period followed by a 20 min. collection period. Two tests were carried out with the subject sitting reading a book to measure the resting metabolism. In three tests the subject collected weeds of the same varieties as those used in the feeding experiment, and put them in a sack which he carried with him. The sack was empty at the beginning of the preliminary period, and the weeds collected in the preliminary and collection periods were weighed together at the end. In a further test the subject walked at a rate of 1·97 miles/hr. carrying a sack containing 15 lb. weeds over moderately rough ground. Every 100 ft. he put down the sack and lifted it again on to his shoulder. This trial was intended to simulate the energy cost of moving from one patch of cultivated land to another in search of weeds. The energy cost of collecting weeds or of carrying a sack was calculated as the rate of metabolism found less the resting metabolic rate. The results are given in Table 8.

Table 8. *The energy cost to man of collecting weeds for feeding rabbits*

Nature of activity	Density of weed population	Metabolism Cal./hr.
1. Sitting reading a book	—	94·8
2. Sitting reading a book	—	85·5
3. Collecting weeds at the rate of 15·1 kg./hr.	Sparse	432·9
4. Collecting weeds at the rate of 13·1 kg./hr.	Abundant	357·2
5. Collecting weeds at the rate of 25·1 kg./hr.	Very abundant	348·1
6. Walking at 1·97 miles/hr. carrying a 15 lb. sack of weeds	—	353·7

In experiments of this nature the recorded metabolism is liable to be too high owing to the fact that the subject carries out his set activity more actively than he would do in ordinary life. Throughout these tests the subject took care not to exert himself too much, but to make sure that this error is avoided the results of the first collection trial, in which he exerted himself rather more strenuously than in tests 4 and 5, are rejected in the calculations which follow. It will be noticed that the average rate of collection of weeds in tests 4 and 5, 19·1 kg./hr., was considerably greater than the average found during the feeding experiments at Cambridge (7·45 kg./hr., see p. 240). This was due to the fact that the collections were made in an exceptionally wet autumn, a time of year when sow thistles are naturally most abundant, rather than to any difference in the state of the cultivated land at the two universities. Moreover, no allowance is made for the time spent in searching for weeds and carting them. In the calculations which follow the energy cost/kg. weeds gathered at Oxford is reckoned. In addition, one-third of the time, a low estimate, is considered to be spent in searching and carting at the metabolic rate observed in test 6, Table 8. On this basis

the energy cost of collecting 19·1 kg. weeds	=262 Cal.
the energy cost of searching for, and carting, the weeds	= 88 Cal.
total	=350 Cal.
the total energy cost/kg. weeds	= 18 Cal.

This figure is reckoned in terms of net, not of available, energy of human food. If 10% is added for heat increment of food in man, the energy cost becomes 20 Cal. available energy/kg. weeds. The balance sheet in Table 9 can now be set up.

Table 9. *Balance sheet of available energy gained and expended in the production of rabbit meat on weeds*

	Weed-fed group (Cal.)	Group fed weeds and potatoes (Cal.)
Available energy obtained from fattening one rabbit	549	1352
Available energy expended in collecting weeds to feed it	1022	796
Balance of available energy	− 473	+ 556

The energy cost as reckoned in the above balance sheet does not include such items as the energy cost of care of the animals, preparation of food and cultivation of potatoes.

DISCUSSION

When the energy cost of collecting weeds is taken into account it is clear that what appears to be a net gain in energy when only the calorific value of the rabbit meat is considered becomes a net loss if weeds alone are fed, or a much reduced gain when weeds are fed in conjunction with potatoes. If a man were dependent for his energy needs on the rabbit meat produced by collecting weeds, he would inevitably starve, since the energy expended in collecting the weeds is more than the return obtained in the carcasses produced. As is shown above, a net gain is obtained by including potatoes in the ration, but if the time of collection for this net gain is taken into consideration (5 hr. 20 min. collection for 556 Cal.) it is apparent that to supply the energy requirement for 24 hr. (2400 Cal.) 23 hr. would be needed for the collection of weeds. In this case the rabbit keeper is faced with a choice of starvation or sleeplessness. Although this conclusion appears somewhat frivolous it is important to remember that governments in times of food scarcity have in the past sponsored programmes of production of rabbit meat from waste feeding-stuffs, such as weeds, without examining the efficiency of the operation; these programmes may well have led to undernutrition in man instead of preventing it as was intended. Production of energy can be efficient only if the weeds form a quite small proportion of the ration and are, therefore, collected much more easily and quickly, or alternatively, if the time and energy expended would otherwise have been used for some unproductive activity. Animal protein with its associated vitamins is produced more efficiently than available energy but at a considerable energy cost to man, especially if weeds alone are fed. The efficiency as a whole of the operation of producing rabbit meat from weeds depends on the relative value to man of available energy and animal protein in times of food scarcity, but discussion of this point is outside the scope of this paper.

SUMMARY

1. The efficiency of fattening weaned domestic rabbits on weeds only (mainly sow thistles) and on weeds with a limited amount of cooked potatoes has been investigated.

2. With rabbits increases in live weight, edible protein, fat, gross energy, energy available for human nutrition, and conversion of food into rabbit meat were measured; for man the cost in time and energy of collecting weeds was determined.

3. Growth and the production of animal protein were for the weed-fed group of rabbits 75 and 73·2%, and for the group fed weeds and potatoes 91 and 87·4%, of the values for a control group of rabbits on a stock ration.

4. The production by the group fed on weeds alone of fat, gross energy and available energy was 8·8, 37·4 and 32·5%, respectively, of the production by the control group. The figures for the group fed weeds and potatoes were 76·2, 81·0 and 80·0%.

5. The weed-fed group converted 100 g. of dry matter of food into 2·24 g. edible protein, 0·26 g. fat, 14·4 Cal. gross energy and 10·8 Cal. available energy. The conversion figures for the group fed weeds and potatoes were 2·52 g., 1·61 g., 29·6 Cal. and 25·2 Cal. and for the control group 2·98 g., 2·25 g., 38·2 Cal. and 33·1 Cal. respectively.

6. From 100 Cal. available energy fed as potato to the group on weeds and potatoes 20·5 Cal. available energy were obtained as rabbit meat.

7. It took 30 man-hours labour to collect weeds to provide available energy (2400 Cal.) for one man for 1 day by converting weeds alone into rabbit meat. The corresponding figure for the group fed weeds and potatoes was 9 hr. 36 min. The provision of 1 day's supply of animal protein (32·5 g.) took 2 hr. by feeding weeds alone and 1 hr. 19 min. by feeding weeds and potatoes.

8. If, in addition, the energy cost to man of collecting weeds was taken into account, there was a net loss of energy in feeding with weeds alone, and the net gain, though positive, was much reduced when potatoes were included in the ration.

9. It is concluded that rabbits fed on weeds or weeds and potatoes are very inefficient producers of available energy for human nutrition but that animal protein is produced more efficiently than available energy.

10. The value of the operation of producing rabbit meat from weeds depends on the relative value to man of available energy and of animal protein with its associated vitamins in times of food scarcity.

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