3. These observations are consistent with the hypothesis of Martland & Robison [1927] that the enzyme possesses the properties of a weak base, whose undissociated molecule combines with the substrate to form a compound which breaks down

into the products of hydrolysis, and with the postulate of Kay [1932] that the rate of hydrolysis continues to increase with increasing alkalinity and that the apparent optimum is set by the increasing rate of enzyme destruction.

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The Nutritive Value of Potato Protein for the Pig

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It has long been known that only about one-half of the nitrogen of the potato is in the form of protein, the remainder being in amino-acids and amides, chiefly asparagine. Neuburger & Sanger [1942] have recently shown that not only the total N of the potato, but also the relative proportions of the above three types of nitrogenous compounds, are widely different in different varieties, and that generally the amount of true protein N is rather less than half the total.

Although it is common convention in agricultural practice to reckon the protein value of the potato N as that obtained by adding together the true protein value and one-half of the value obtained by multiplying the non-protein N by 6.25, in this paper the proportion of the N in the different diets, rather than that of the protein, is considered, and the term crude protein is used to indicate the figure obtained by multiplying the total N by 6.25.

The maintenance of N equilibrium in adult man by potatoes was established by Hindhede [1913], Abderhalden, Ewald, Fodor & Rose [1915], Rose & Cooper [1917], Rubner & Thomas [1918] and by Kon & Klein [1928]. The last-named workers found that N equilibrium and good health could be maintained for several months in an adult man and

woman on a diet of steamed potato, butter fat and fruit. The daily N intakes averaged 5.7 and 3.8 g. respectively.

The value of potato nitrogen for the support of growth. The value of potato N for the support of growth is not so clear, for it is difficult to obtain a sufficiency for young animals with potato alone since the protein is diluted with so much starch. McCollum, Simmonds & Parsons [1918] found that hardly any weight increase occurred in young rats when potatoes provided the only source of N. The diets contained but 7–8% crude protein. However, growth was no better when cereal proteins were fed at the same level but was much improved on addition of 5 or 10% of casein. Growth of rats on diets containing 9% protein from oats, maize, peas or millet was much better and reproduction occurred when a proportion of these was substituted by potato, thus indicating a supplementary action of the N of the latter for that of the above grains [McCollum, Simmonds & Parsons, 1921]. Hartwell [1925; 1927] found that potato providing 7.6% crude protein in the diet supported only very poor growth in rats and was quite insufficient for lactation.

Mitchell [1924*b*] determined the biological value of potato N for growth and maintenance in young rats by his modification [1924*a*] of Thomas's N balance technique. The biological value, when the diet contained 5% crude protein, was 68.5, as compared with 72 for maize, 78.6 for oat, and 86.1 for rice protein. With 10% crude protein in the diet, the biological values were 66.7 for potatoes, 59.6 for maize

and 64.9 for oats. These results are somewhat inconclusive, since potatoes appeared to be inferior to cereal proteins when the diet contained 5% crude protein but as good or better when it contained 10%.

Schifftan [1933] made a series of careful N balance experiments with pigs fed on diets in which respectively potatoes, barley and other foods were the only sources of protein. The tests were made with protein given at maintenance level, and also at a level to support both maintenance and growth. His experiments were carried out on four animals only and the collection periods were of 5 days' duration; his technique was, however, unexceptionable and good agreement was obtained in duplicate tests made on different pigs. For maintenance, the biological value of potato N in a diet containing 2.2% crude protein was 69.6, and that of barley N in a diet containing 2.3% was 58.7. Milk, casein (purified) and fish meal gave figures of 100.6, 69.3 and 66.2 respectively. For growth and maintenance, the biological value of potato N was 73.2 in a diet containing 13% protein. The value for N of fishmeal was of about the same order and the values for that of milk and casein again superior. Potato N was thus slightly superior to that of barley in the tests at both low and high levels of intake. Since biological values of proteins normally fall as protein level is raised, one would expect that the value obtained for barley for growth and maintenance in the above experiment would be relatively too low in comparison with that given for potato. However, Schifftan, contrary to other investigators, found in general that his biological values increased slightly with level of protein fed.

Jones & Nelson [1931] obtained poor growth with rats on diets containing 9% of crude protein from potato. Neither addition of gelatin, nor a supplement of tryptophan or of tyrosine and cystine with or without gelatin, improved matters, but addition of casein or lactalbumin supplemented the potato, and good growth occurred. The potato N was fed as a concentrate, prepared by removal of the starch, and contained 90% of the original N. From this experiment it appeared that the potato lacked some unidentified essential amino-acid. Beadles, Braman & Mitchell [1930], on the other hand, also working with rats, had previously found that cystine itself improved growth when added to a potato diet containing 8.9% crude protein. The potatoes were boiled and dried at low temperature.

The biological value of the true protein of potato appears to be fairly high. Kon [1928], using Mitchell's N balance technique for estimating its value for growth and maintenance of rats, found a biological value of 71 for tuberin compared with 68 for caseinogen; both proteins were fed at a level of 8.5-8.6% in the diet. By the method of Osborne, Mendel & Ferry [1919] with growing rats, he obtained a maximum figure of 2.0 g. weight increase per g. of protein intake, when the diet contained 8% protein.

Mangold & Columbus [1937] used Schifftan's technique to determine the biological value, for maintenance of N balance in pigs, of two dried potato protein concentrates called 'potato protein pulp flakes' (*Kartoffeleiweiss-pulpe-flocken*) and 'potato protein flakes' (*Kartoffeleiweiss-flocken*), respectively. In these preparations nearly all the N was in the form of true protein. The biological value of the 'potato protein pulp flakes' was 86.3 in a diet containing 3.8% protein and 88.5 in one containing 7.1%; that of the 'potato protein flakes' was 83.3 in a diet containing 5.1% protein and 79.0 when it contained 9.7%.

Digestibility of potato nitrogen. In the following paragraphs the coefficient of digestibility refers to 'apparent'

digestibility, the figure for which is calculated from the difference between the N ingested and that eliminated in the faeces, on the assumption that the latter is derived from undigested food. The faeces, however, also contain N of endogenous origin, e.g. that contributed from gastric and intestinal secretions from, and into, the gut. A large proportion of the N of faeces is contained in its bacterial component and it is uncertain whether these bacteria are nourished from endogenous nitrogenous substances or from those of undigested food. The true digestibility of any food will therefore always be greater than the apparent digestibility.

The figures quoted in the literature for the digestibility of the crude protein of potatoes are very variable and usually low. Table 1 gives a summary of the figures obtained with swine for potatoes and various potato products; it will be seen that the coefficients of apparent digestibility vary from 0 to 84%! There are four possible explanations of this great variation: (1) that the variations are due to differences in the samples or varieties of potatoes before cooking or processing, (2) that the digestibility is affected by processing, (3) that it depends on the bacterial flora inhabiting the gut, (4) that it is affected by other constituents of the ration. There is not sufficient evidence in the literature to permit discussion of the first and third possibilities, but so far as the effect of processing is concerned, it is noticeable that all the lower figures for digestibility with the pig have been obtained with potatoes dried in various ways. With herbivora, on the other hand, comparatively low digestibility coefficients have frequently been obtained for cooked fresh potatoes. For example, Woods [1919] found a coefficient of 43.4% for the sheep, Brügge-mann [1939] 58.3% for the rabbit, and Woodward, Davidson, Watson, Robinson & Muir [1938] 65.0% for the steer. Kellner, Just, Eisenkolbe & Poppe [1908] determined the digestibility of different dried potato products, fed in combination with soya-bean meal, with pigs and sheep; with both there were large differences between the different products, but the order of their merit was different in the two species. For example, potato flakes dried by the Paucksch process gave the highest coefficient (75.5%) with pigs and the lowest (14.4%) with sheep.

It is probable that some of the very low figures may be connected with the method of computation. In many investigations determination was first made of the digestibility of a ration, often of mixed foodstuffs, and then again when a portion had been substituted by potato or potato products. Any lowering in digestibility in the second case compared with the first was then attributed solely to the potato. If the potato was present in relatively small proportion, the result of such a calculation will give an unduly low figure for its digestibility.

Fingerling [1932] obtained the very low digestibility coefficient of 29.2% for the crude protein of potato cossettes when fed to pigs with fishmeal and barley meal. When the basal ration consisted of fishmeal and potato flakes, the digestibility of the nitrogen of additional potato flakes, however, was 70.5%. It is possible that in the first test the digestibility of the fishmeal and barley meal was depressed by addition of the potato cossettes and that, in the second, the addition of extra potato flakes caused no further depression in the digestibility of a ration which already contained them. With steers, the digestibility of the crude protein in both flakes and cossettes was low, but the order was reversed; the coefficient for flakes was negative while that for the cossettes was 30.9%; in these experiments the

Table 1. 'Apparent' digestibility of the crude protein of potatoes for pigs

Type of potato product	Digestibility coefficient of crude protein	Author
Raw	84.5	Snyder [1895].
Cooked	82.0	"
Dried 'Kartoffelscheiben'	53.9	Kellner <i>et al.</i> [1908]
Dried 'Kartoffelschnitzel' (Schütz)	46.2	"
Dried 'Kartoffelschnitzel' (Knauer)	63.5	"
Dried 'Kartoffelschnitzel' (Petry & Kecking)	70.6	"
Dried 'Kartoffelschnitzel' (Venuleth & Ellenberger)	42.9	"
Dried 'Kartoffelflocken' (Paucksch)	75.5	"
Dried 'Presskartoffel' (1)	26.7	Kellner & Neumann [1910]
Dried 'Presskartoffel' (2)	<0.0	"
Dried 'Kartoffelflocken'	70.5	Fingerling [1932]
Dried 'Kartoffelschnitzel'	29.2	"
Cooked	56.5*	Schifftan [1933]
Cooked	67.3*	"
Dried 'Kartoffeltrockensaft-Pülpflocken'	62.3	Nehring & Schramm [1937]
Dried 'Kartoffeleiweissflocken'	73.9	Mangold & Columbus [1937]
Dried 'Kartoffeleiweiss-Pulpe-Flocken'	66.5	"
Cossette meal	39.9	Woodman & Evans [1939]

* True digestibility.

basal ration was composed of wheat straw, 'molasses slices' and cotton-seed meal. Fingerling notes in his paper that in the case of the steers the addition of potato products appeared to depress the digestibility of the N and N-free extract of the basal ration.

Woodman & Evans [1939] found the digestibility of the crude protein of potato cosettes, ground into a meal for pigs and sheep, to be 45.4% for the sheep and 39.9% for the pig. Tests *in vitro* gave a figure of 94%. Here again it is possible that the apparent digestibility of the barley meal, weatings and white fish meal in the basal ration may have been lowered when fed with the potato cossette meal and thus a low estimate made of the digestibility of the latter.

The experiments of Kellner & Neumann [1910], on the

other hand, gave little evidence that depression of the digestibility of the N of the constituents of the ration was caused by the presence of potato. They determined the digestibility of pressed dried potatoes, first when fed alone and later when fed with soya-bean meal. The coefficient of digestibility of the N of the potatoes fed alone was 26.7%. Using this coefficient they calculated from the second experiment a coefficient for soya-bean meal of 94%, a figure which could not have been so high if the pressed dried potatoes had appreciably lowered the digestibility of the soya-bean meal. However, from a further trial with a second sample of dried pressed potatoes, also fed with soya-bean meal, they calculated a negative digestibility for the crude protein of the potatoes when the figure of 94% for the soya bean was used in the computation.

Section 1. GROWTH EXPERIMENTS

METHODS

The object of the experiment was to compare the growth of pigs which received all their protein as barley, or as barley supplemented with certain levels of casein, with that of pigs which received all their protein as potato, or as potato supplemented with identical levels of casein.

Mitchell's paired feeding method was adapted to the conditions of this experimental layout. Twenty-four pigs (17 hogs and 7 gilts) of the Wessex Saddleback breed were obtained from a local farm, and were kept in the same stalls and under the same system of management as those observed by Macrae, El-Sadr & Sellers [1942] in their studies on yeast protein. The animals were from four litters, all of which were farrowed between 6 and 16 January 1941; their individual identity was unknown. During the 3 weeks in which they were housed at the Institute prior to the commencement of the experiment, they were provided with a commercial pig food, with a few potatoes added daily. When they were 15-16 weeks of age, and of 25-36 kg. body

weight, the groups and subgroups were selected. First, 12 pairs of as nearly equal live weights as possible were chosen: one pig from each of these pairs was allotted at random to a potato diet and the other to a barley diet, thus forming two groups (potato and barley), each comprising 12 animals. The four subgroups, each comprising three animals chosen at random from the potato group and a corresponding three animals from the barley group, received, respectively, unsupplemented diets, and diets containing 1, 3 and 6% casein. All the pigs were individually fed in separate pens. Each of the 12 pigs receiving the potato diets consumed the same amounts of N and of dry matter as its corresponding barley-fed partner. The barley-fed pigs obtained slightly less digestible energy than the potato-fed animals because the barley was less digestible (see below), but there are not sufficiently reliable comparative figures to show whether this implied a lower intake of net energy under optimal conditions of protein intake.

The quantity of food given was regulated by the appetite of that pig of each pair which consumed the smaller amount: this was in every case the potato-fed pig. By this procedure, the results of the experiment could not be vitiated by

inability of the potato-fed pigs to consume as much of their more bulky ration as the barley-fed animals. It was not practicable to equalize the food intakes of animals receiving different levels of casein, since this would have meant reducing the food intake of all pigs to that of the one which ate least food. Except in so far as the food intake of the barley-fed animals was restricted by paired feeding, the diets were so constituted that the protein supply was the factor limiting growth. Only those pigs which received diets containing the highest proportion of N, viz. 2.4%, chiefly from casein, showed a growth rate approaching that obtained with Wessex Saddlebacks under good commercial conditions (H. A. Parsons, private communication; see Fig. 1).

The composition of the foodstuffs and of the experimental rations are set out in Tables 2, 3 and 4. In order to reduce the bulk of the potato diets, half the potatoes (on a dry matter basis) were given as boiled fresh potatoes and half as commercial potato flakes which were ground into a meal before mixing. Corresponding barley and potato rations were arranged to contain the same quantity of N (see Table 3).

The *cod-liver oil* was of the type used in veterinary practice, and was of guaranteed vitamin potency.

The *salt mixture*, made from commercial materials, contained bone ash 2, CaCO_3 1, NaCl 1 and Fe_2O_3 0.1 parts.

The *yeast extract* was made by the method of Macrae *et al.* [1942], from brewer's yeast kindly supplied by Messrs Greene, King and Sons. The extract, which was protein-free, contained 1.607 mg. N/ml., and the daily dose, given separately with the ration of each pig, contained the equivalent of 30 g. dry yeast.

The *boiled potatoes* were from two batches of 'Majestic' potatoes, obtained locally and stored under straw in a tin hut; there was a good deal of sprouting during the experiment, but the sprouts were rubbed off, and the potatoes were washed before cooking. They were cooked in a cage lowered into a large copper of boiling water. The N content of the first batch was 1.58, and of the second, 1.85%, on a dry matter basis.

The *potato flakes* were obtained from the Farmers' Marketing and Supply Co., Ltd., and were processed at the beginning of March 1941. The processing was as follows: raw potatoes were thoroughly washed and cooked in a

Table 2. *Composition of foodstuffs incorporated in the diets*

	Dry matter (%)	Total N content of dry matter (%)	Gross energy (kg. cal./100 g. of dry matter)	True protein N (% of total N)	Non-protein N (% of total N)
Potatoes (Majestic): Batch 1	29.90*	1.570*	406.0	41.1	58.9
Batch 2	28.07†	1.848†	402.7	39.8	60.2
Casein	89.53	15.26	567.9	—	—
Potato flake meal	87.47	1.507	403.0	—	—
Barley meal (1)	84.31‡	1.826‡	418.9	—	—
(2)	85.30§	1.869§	418.9	—	—
Yeast extract	—	1.607 mg./ml.	—	—	—
Starch	87.00	—	422.0	—	—
Cod-liver oil	—	—	945.0	—	—

* Mean of 29 duplicate determinations.

† Mean of 27 duplicate determinations.

‡ Mean of 6 duplicate determinations.

§ Mean of 3 duplicate determinations.

Table 3. *Percentage composition of the diets, calculated on dry weights*

Subgroup	Boiled potatoes	Potato flake meal	Barley meal	Casein	Starch	Salt mixture	Cod-liver oil	N content of dry matter (%)
No casein: Barley	—	—	79.90	—	16.60	2.00	1.50	1.49
Potato	45.25	45.25	—	—	6.00	2.00	1.50	1.49
1% casein: Barley	—	—	79.90	1.00	15.60	2.00	1.50	1.64
Potato	45.25	45.25	—	1.00	5.00	2.00	1.50	1.64
3% casein: Barley	—	—	79.90	3.00	13.60	2.00	1.50	1.95
Potato	45.25	45.25	—	3.00	3.00	2.00	1.50	1.95
6% casein: Barley	—	—	79.90	6.00	10.60	2.00	1.50	2.40
Potato	45.25	45.25	—	6.00	—	2.00	1.50	2.40

In addition pigs received yeast extract equivalent to 30 g. dry yeast daily.

The following materials were utilized in the construction of the rations:

The *barley meal* was ground whole barley from a single batch.

The *casein* was 'Ashless G.L.', described by the manufacturers (Glaxo Laboratories, Ltd.) as a 'self-soured' type, well washed with dilute acetic acid. It contained 15.27% N on a dry matter basis.

The *starch* was purest maize starch, obtained from Messrs Mackean of Paisley; it contained about 0.04% N.

pressure steamer for approximately 20 min. The cooked potatoes were then passed through a mashing screw and spread over rollers heated by steam at a pressure of 80 lb./sq. in. The flakes contained 1.507% N on a dry matter basis.

The cooked potatoes were carefully mixed with the dry potato meal, starch, salts, cod-liver oil and water before feeding. It was necessary to feed the rations in a very sloppy state and to titivate the appetites of the animals with additions of water towards the end of each meal. The

Table 4. *Analysis of diets*

Sub-group	Ration	% casein in diet	g. N/100 g. dry diet contributed by				% of total N contributed by				Total quantities/100 g.			
			Boiled potatoes	Flake potatoes	Barley meal	Casein	Boiled potatoes	Flake potatoes	Barley meal	Casein	N (g.)	Digestible N (g.)	Gross energy (kg. cal.)	Digestible energy (kg. cal.)
1	Barley	0	—	—	1.494	—	—	—	100.0	—	1.494	1.212	418.93	366.61
	Potato	0	0.813	0.681	—	—	54.4	45.6	—	—	1.494	1.242	404.08	382.25
2	Barley	1	—	—	1.494	0.151	—	—	90.8	9.2	1.645	1.341	420.39	358.59
	Potato	1	0.813	0.681	—	0.151	49.4	41.4	—	9.2	1.645	1.348	405.54	382.02
3	Barley	3	—	—	1.494	0.455	—	—	76.7	23.3	1.949	1.651	423.31	366.59
	Potato	3	0.813	0.681	—	0.455	41.8	34.9	—	23.3	1.949	1.671	408.46	385.18
4	Barley	6	—	—	1.494	0.909	—	—	62.2	37.8	2.403	2.048	427.68	360.53
	Potato	6	0.813	0.681	—	0.909	33.9	28.3	—	37.8	2.403	2.142	412.83	389.30

amounts of food left unconsumed by the potato-fed animals were often considerable, and it was then necessary to weigh the residues and to determine their water content.

The analyses of the materials are given in Table 2 and details of the composition of the different diets in Tables 3 and 4.

RESULTS

The experimental rations were fed for a preliminary period of a week before live weight increases were recorded. About three days after this feeding was commenced, scouring was noted in the potato-fed animals of each subgroup. This scouring reappeared at intervals throughout the experiment, but was never severe. Otherwise the pigs remained in good health. The condition of the coat remained good in all animals, and no skin lesions developed. Carriage and behaviour were in most cases normal throughout. Coprophagy was never observed. During the 7th week of the test there was an exceptional heat wave, and all the potato-fed animals went off their feed. Pigs 8, 10 and 12 were once observed to vomit and scoured at this time. In addition, pig 21, a barley-fed animal, went off its feed and vomited once. No stiffness of the legs was noticed until the last fortnight of the experiment, when a few of the heavier pigs were a little stiff. This was probably because bedding material was not provided. The joints of the animals did not show any macroscopic lesions on slaughter.

Fig. 1 gives the composite growth curves of the various subgroups; Table 5 gives details of their food intake and weight increases. In 11 of the 12 pairs of pigs, the barley-fed pig grew better. The total weight increase of the barley-fed pigs during the 12 weeks averaged 29.5 kg., while that of the potato-fed animals was 23.6 kg.; the weight increase per unit N intake and per unit digestible N intake was higher, and food intake and digestibility energy per unit weight increase were lower, in the barley-fed animals (Table 5).

The results of our experiment are not, therefore, in accordance with those of Schiffan, who found the N of fresh potatoes of higher biological value than that of barley. It is possible that the value of the N of the potato flakes used in our experiments was somewhat reduced by heat treatment during processing. The pigs in subgroup 1 which received the potato N without casein supplement, made better gains than those fed on maize without supplement in the experiment of Macrae *et al.* [1942]. The initial weights of the pigs in our experiment were, however, initially greater than those used by Macrae *et al.*, which averaged about 20 kg. They would therefore not require so large a proportion of N in their ration, since, as age and live weight increase, relatively more fat and less muscle are laid down.

A comparison of the figures obtained from the four subgroups, summarized in Table 5, shows that:

Table 5. *Experimental data for individual pigs during whole experimental period*

Sub-group	Casein in diet (%)	Pig		Body weight				Total dry food intake (kg.)	Total N intake (kg.)	Wt. increase/ unit intake of N	Wt. increase/ unit intake of digestible N	Food intake/ unit wt. gained	Digestible energy consumed/ unit wt. gain (kg. cal./kg.)	
		No.	Sex	Ration	At beginning (kg.)	At end (kg.)	Increase (kg.)							Average weekly increase (kg.)
1	0	1	♂	Barley	34.6	69.9	35.3	2.94	128.25	1.893	18.7	22.9	3.63	13,300
		2	♂	Potato	34.5	66.4	31.9	2.66	129.83	1.931	16.5	19.9	4.07	15,600
		3	♂	Barley	35.8	58.6	22.8	1.90	94.21	1.399	16.3	20.0	4.13	15,100
		4	♂	Potato	35.2	51.6	16.4	1.37	87.44	1.416	11.6	13.9	5.33	22,300
		5	♀	Barley	32.0	49.0	17.0	1.42	77.83	1.158	14.7	18.1	4.58	16,800
		6	♂	Potato	31.5	42.0	10.5	0.88	79.13	1.174	8.9	10.7	7.54	28,900
Average barley fed				—	—	25.0	2.1	—	—	16.6	20.3	4.11	15,100	
Average potato fed				—	—	19.6	1.6	—	—	12.3	14.8	5.65	22,300	
2	1	13	♂	Barley	36.6	63.4	26.8	2.23	102.22	1.670	16.1	19.7	3.81	13,700
		14	♀	Potato	34.5	55.8	21.3	1.78	103.87	1.693	12.6	15.4	4.88	18,700
		15	♀	Barley	26.6	43.0	16.4	1.37	74.30	1.223	13.4	16.4	4.53	16,200
		16	♂	Potato	27.2	39.8	12.6	1.05	74.38	1.220	10.3	12.6	5.90	22,600
		17	♂	Barley	32.0	64.8	32.8	2.73	118.66	1.931	17.0	20.8	3.62	13,000
		18	♂	Potato	33.0	61.1	28.1	2.34	120.55	1.963	14.3	17.5	4.29	16,500
Average barley fed				—	—	25.3	2.1	—	—	15.5	19.0	3.99	14,300	
Average potato fed				—	—	20.7	1.7	—	—	12.4	15.2	5.02	19,300	
3	3	7	♀	Barley	33.8	65.2	31.4	2.62	93.14	1.808	17.4	20.5	2.97	10,900
		8	♂	Potato	34.6	54.7	20.1	1.68	95.10	1.835	11.0	12.8	4.73	18,300
		9	♂	Barley	32.4	60.6	28.2	2.35	95.73	1.859	15.2	17.9	3.39	12,400
		10	♀	Potato	32.7	54.2	21.5	1.79	92.54	1.781	12.1	14.1	4.30	16,600
		11	♂	Barley	34.6	70.8	36.2	3.02	114.81	2.219	16.3	19.3	3.17	11,600
		12	♂	Potato	33.6	59.7	26.1	2.18	116.22	2.231	11.7	13.7	4.45	17,200
Average barley fed				—	—	31.9	2.7	—	—	16.3	19.2	3.18	11,600	
Average potato fed				—	—	22.6	1.9	—	—	11.6	13.5	4.49	17,400	
4	6	19	♂	Barley	29.8	62.0	32.2	2.68	90.30	2.164	14.9	17.4	2.80	10,100
		20	♀	Potato	30.2	52.8	22.6	1.88	92.56	2.189	10.3	11.6	4.10	15,800
		21	♂	Barley	30.9	70.9	40.0	3.33	119.08	2.835	14.1	16.5	2.98	10,700
		22	♂	Potato	31.4	67.6	36.2	3.02	123.32	2.911	12.4	14.0	3.41	13,400
		23	♂	Barley	33.7	68.7	35.0	2.92	110.89	2.648	13.2	15.5	3.17	11,400
		24	♀	Potato	33.3	68.6	35.3	2.94	109.89	2.599	13.6	15.2	3.11	12,100
Average barley fed				—	—	35.7	3.0	—	—	14.1	16.5	2.98	10,700	
Average potato fed				—	—	31.4	2.6	—	—	12.1	13.6	3.54	13,800	
Average of all barley fed				—	—	29.5	2.5	—	—	15.6	18.7	3.56	12,900	
Average of all potato fed				—	—	23.6	2.0	—	—	12.1	14.3	4.67	18,200	

(1) the average weight increase of both barley-fed and potato-fed animals was greater as the level of the casein supplement was raised, although there was little difference in food intake between the subgroups; (2) animals receiving the larger casein supplements made better use of the food energy;

though the animals which received the higher levels of casein were less deficient in protein than those which received less casein, their average food intake was not significantly greater. It would therefore seem as if the food consumption of the potato-fed pigs was limited not by the lack of protein but rather

Fig. 1. Average growth curves of pigs in eight subgroups on diets containing barley and potato respectively as staple, with varying proportions of casein. — signifies barley; ---- signifies potato. Curves A, B, C, D: pigs on barley ration +6, 3, 1% and no casein respectively. Curves a, b, c, d: pigs on potato ration +6, 3, 1% and no casein respectively. Curve x = average growth curve for Wessex Saddleback pigs on ordinary commercial pig feed.

(3) the differences in weight increase between barley-fed and potato-fed pigs were roughly similar at all levels of casein intake; (4) the casein therefore supplemented barley N and potato N about equally.

If the food intake of the barley-fed pigs had not been limited to that of the potato-fed pigs, the differences in weight increase between the two groups would have been considerably greater. Al-

by their inability to consume more of their very bulky ration. In other words, this is one of those cases to which Mitchell has frequently drawn attention, in which appetite does not run parallel with the protein efficiency of the ration; and fallacious results would have been obtained had not the food intake of the barley-fed animals been controlled. Since, on the average, the level of casein in the diet

had little effect on food intake, it was not found necessary, as had been anticipated, to equalize the food intakes of the different subgroups.

From Table 5 and Fig. 1 it appears that a supplement of 1 or 3 % of casein to the barley ration gave approximately the same rate of growth increase, and utilization of digestible energy, as a supplement of 6 % casein to the potato ration. In commercial feeding practice, therefore, it would be necessary to

feed more than twice as much protein concentrate when potato is substituted for a barley ration of equal N content. Under conditions in which there might be a depression of the digestibility of N consequent on the substitution of potato for barley, it would be necessary to give still more protein concentrate. In practice the growth of the potato-fed pig would be limited by the bulkiness of the ration as well as by its deficiency of N of good biological value.

Section 2. DIGESTIBILITY EXPERIMENTS

METHODS

Six crates were made by placing the individual feeding pens upon wooden tables covered with galvanized iron. Holes were bored through the tables to drain off the urine. The pigs were prevented from moving backwards and forwards by horizontal bars fixed across the back of the pens, and adjusted to fit each pig. The animals soon learnt that the forward end of the crate, where the food appeared, was the more interesting, and there was no trouble from their turning movements in the cage during the collection periods.

After the experiments on growth were concluded, the animals continued to receive the same experimental rations until they were required for the digestibility trials. In all these trials there was a 4-day preliminary period, followed by a 10-day collection period. Food intake was adjusted to the amount which the animals were expected to finish, and was maintained at this level throughout the experiment. There were no refusals of food. The faeces were collected at intervals during the day into buckets placed behind the crates, and the animals conveniently refrained from excreting faeces during the night. The faeces were preserved by moistening with about 2 l. of $N H_2SO_4$ and analyzed for total N by the Kjeldahl method, and for gross energy in the bomb-calorimeter. Samples of the boiled potatoes were analyzed daily for dry matter and N; the gross energy was determined on a bulk dried sample.

Hogs only were utilized for these experiments, two potato-fed animals and one barley-fed animal being selected from each subgroup. It was necessary to use pig 12, a potato-fed animal, for tests with both 3 and 6 % casein diets, as two of the potato-fed pigs in the subgroup receiving 6 % of casein were gilts; pig 12 had its ration changed between the two tests.

In addition, pigs 11, 12, 17 and 18 were utilized in a further trial (see below) in which approximately half of the ration consisted of boiled potatoes and potato flakes, and approximately half of barley meal. Pigs 11 and 12 also received 6 % casein, while pigs 17 and 18 did not receive any.

RESULTS

Tables 6 and 7 give details of food intakes and faecal excretions, and (apparent) digestibility coefficients. The digestibilities of the N and energy of potato and barley are computed on the assumption that the casein, yeast extract, cod-liver oil, and starch were entirely digested. The digestibility coefficients obtained from tests with different pigs

were in close agreement. Fig 8, on the potato ration with 3 % casein, scoured during the experiment, but this did not apparently influence the digestibility coefficients, which were the same as those of its fellow pig 12 on the same ration. In contradistinction to the results of Fingerling [1932], and of Woodman & Evans [1939], the presence of the casein in some of the potato rations did not depress the digestibility either of the N or of the gross energy. The digestibility of the latter was, in fact, high and independent of casein level. The coefficients averaged 93.7 % for energy, and 81.5 % for N, of the potato, and 82.3 % for energy, and 79.1 % for the N, of the barley.

When this experiment was completed, it occurred to us that, although the digestibility of the potato rations had not been lowered by feeding casein in combination with the potato, it might have been depressed if barley had been fed in combination with the potato, either with or without casein; Woodman & Evans [1939] and Fingerling [1932], in the majority of their trials, used barley meal in the basal ration. We therefore undertook a further digestibility trial on pigs 11, 12, 17 and 18. The first batch of fresh 'Majestic' potatoes had by this time deteriorated and, when cooked, usually blackened badly. These potatoes were, however, still palatable, and were given to pigs 11 and 17, while those of the second batch were fed to pigs 12 and 18.

Table 8 gives the results obtained. In computing the digestibility of the potatoes, the casein, yeast extract, cod-liver oil and starch were again assumed to be entirely digested. The mean coefficients obtained for the barley meal in the first series of experiments, viz. 82.3 % for the gross energy and 79.1 % for the N, were taken as the digestibility of the barley meal in the mixed rations. Any associative effect would thus be debited or credited to the boiled potatoes and potato flakes. The average digestibility for the potato energy in the mixed rations was calculated to be 91.0 % with no casein and 92.5 % with 6 % of casein, while that of the N averaged 75.5 and 80.7 % respectively. Thus, addition of casein to the potato ration when barley meal also was present had not depressed the digestibility

Table 6. 'Apparent' digestibility of the nitrogen and energy of potato ration

Group	Casein in ration (%)	Pig no.	Nitrogen intake (g.) from				Gross energy intake (kg. cal.) from			Nitrogen (g.) in			Gross energy (kg. cal.) in			Digestibility coefficients of			
			Total dry matter (kg.)	Casein	Yeast extract	Potatoes	Total ration	Potatoes	Total	Faeces	Digested total ration	Digested potato	Faeces	Digested total ration	Digested potato	N in total ration	N in potato ration	Energy in total ration	Energy in potato ration
1	0	2	11-982	—	4.4	239.0	243.4	57,261	63,363	44.9	198.5	194.1	355.0	59,813	53,711	81.6	81.2	94.4	93.8
1	0	4	15-055	—	4.4	182.0	186.4	43,625	48,305	28.5	157.9	153.5	249.4	45,811	41,141	84.7	84.3	94.8	94.3
2	1	16	9-631	14.2	4.4	147.6	166.2	35,046	39,501	35.3	187.3	161.0	266.2	36,389	32,384	79.7	77.1	93.2	92.4
2	1	18	14-740	21.9	4.4	196.3	222.6	53,825	59,771	39.7	241.3	174.8	291.6	56,855	50,909	84.1	82.0	95.1	94.6
3	3	8	13-994	62.1	4.4	214.5	281.0	50,917	57,140	38.9	227.7	157.4	329.0	53,860	47,637	85.9	81.5	94.3	93.6
3	3	12	14-740	65.9	4.4	196.3	266.6	53,825	60,192	41.8	343.5	199.5	345.4	56,738	50,371	85.4	80.2	94.3	93.6
4	6	12	15-749	139.6	4.4	241.3	385.3	57,330	64,976	39.7	324.5	188.3	386.0	61,116	53,470	89.2	82.7	94.1	93.3
6	6	22	14-874	131.8	4.4	228.0	364.2	54,126	61,366	39.7	324.5	188.3	344.7	57,919	50,679	89.1	82.6	94.4	93.6
															Average	85.0	81.5	94.3	93.7

Table 7. 'Apparent' digestibility of the nitrogen and energy of barley-meal ration

Casein in diet (%)	Pig no.	Food intake (kg. dry matter)	Nitrogen intake (g.) in					Gross energy intake				Nitrogen (g.) in				Gross energy (kg. cal.) in				Digestibility coefficients of			
			Barley meal	Casein	Yeast	Total ration	Total ration (kg. cal.)	As barley (kg. cal.)	Total ration (kg. cal.)	Faeces	Digested total ration	Digested barley	Faeces	Digested total ration	Digested barley	N in total ration	N in barley	Energy in total ration	Energy in barley				
0	3	12.374	184.9	—	4.4	189.3	41,453	51,835	35.4	153.9	149.5	6,471	45,364	34,982	81.3	80.9	87.5	84.4					
1	17	15.947	238.2	24.1	4.4	266.7	53,422	67,041	49.2	217.5	189.0	9,822	57,219	43,600	81.6	79.3	85.3	81.6					
3	11	15.947	238.2	72.7	4.4	315.2	53,422	67,504	48.2	267.0	190.0	9,029	56,475	44,393	84.7	79.8	86.6	83.1					
6	21	15.085	225.4	137.1	4.4	366.9	50,535	64,519	53.6	313.3	171.8	10,138	54,381	40,397	85.4	76.2	84.3	79.9					
															Average	83.2	79.1	85.9	82.3				

Table 8. 'Apparent' digestibility of the nitrogen and energy of potatoes when fed in a mixed diet consisting of potatoes, barley meal and casein*

Group	Pig no.	Food intake (kg. dry matter)				Nitrogen intake (g.) in				Gross energy intake (kg. cal.) in				Nitrogen (g.) in				Gross energy (kg. cal.) in				Digestibility coefficients of			
		Pota- toes	Barley	Total ration	Barley	Casein	Yeast	Pota- toes	Total ration	Pota- toes	Barley	Total ration	Faeces	Di- gested total	Faeces due to total ration	Di- gested potato	Faeces due to potato	Total faeces	N in total ration	N in potato ration	Energy in total ration	Energy in potato ration			
0% casein	17	8.338	7.974	16.312	119.1	—	4.4	123.9	247.4	30,657	26,713	67,224	56.9	190.5	31.9	92.0	314.3	81.41	77.0	74.3	87.9	89.8			
	18	7.792	7.974	15.766	119.1	—	4.4	120.0	243.5	26,322	26,713	64,868	49.6	193.9	24.6	95.4	224.6	69.74	79.6	76.7	86.3	92.1			
6% casein	11	8.338	7.974	16.312	119.1	142.3	4.4	123.9	389.7	30,657	26,713	68,593	51.5	338.2	26.5	97.4	248.2	72.10	86.7	78.6	89.6	91.9			
	12	7.792	7.974	15.766	119.1	142.3	4.4	120.0	385.0	26,322	26,713	66,257	46.2	339.6	20.7	99.3	197.7	67.25	88.0	82.8	89.9	93.0			

* The digestibility of potato is calculated by assuming both energy and N of casein and yeast to be 100 % digestible, energy of barley meal to be 82.3 % digestible and N of barley meal to be 79.1 % digestible. The potatoes fed to pigs 11 and 17 were from batch 1 and those fed to pigs 12 and 18 from batch 2.

of either energy or N. We had not expected that there would be any effect on the digestibility of the energy, but had anticipated from the results obtained by Fingerling and by Woodman & Evans that the digestibility of the N might be lowered. The average digestibility coefficients of the potato in the rations containing the second batch of 'Majestic' potatoes (pigs 12 and 18) were 92.6 % for energy and 80.1 % for N, compared with average values of 93.7 and 81.5 % obtained with the same potatoes in the first series of trials (Table 6). The presence of the barley with the potatoes, therefore, caused no lowering of the digestibility of the ration. In short, these three feeding stuffs, potatoes, barley, and casein, gave the same digestibility coefficients when fed in a mixture as they gave, or in the case of casein, were assumed to give, when fed separately.

Our experiments, therefore, do not shed any light on the perplexingly low digestibility coefficients of potato N encountered by other workers. Both Fingerling and Woodman & Evans included fish meal in their basal rations and had we also used this concentrate in place of casein our results might possibly have been different. It is more probable, however, that differences between different samples of potatoes or methods of processing were responsible for the discrepancy. The digestibility of potatoes in the rations containing boiled potatoes from first batch of 'Majestics' averaged 90.9 % for energy and 76.9 % for N (pigs 11 and 17, Table 8); that of the 'Majestic' potatoes of the second batch averaged 93.7 % for energy and 81.5 % for nitrogen (see Table 6). There was, therefore, little difference in digestibility between the two samples of 'Majestic' potatoes which we used. Since the figures for potato digestibility given in Table 6 were obtained from experiments in which there were more animals, and in which there was no admixture with barley meal, they are considered to be the more accurate, and these figures only have been employed in the computation of the digestible nutrients in the growth experiments described above.

SUMMARY

1. The value of the nitrogen of the potato was compared with that of barley for supporting growth of 'fattening pigs'. The observations were made upon 12 pairs of similar animals, one of each pair receiving a potato, and the other a barley, diet.

2. The rations compared contained equal amounts of nitrogen derived from potato or barley, with and without supplementary nitrogen from casein. Half of the potato ration was composed of fresh boiled (Majestic) potatoes and half of commercial dried potato flakes. The total nitrogen of the diets varied from 1.5 % when no casein was given, to 2.4 % when

6 % casein was included, the figures being calculated on the dry weight.

3. The food intake, on dry weight basis, of each barley-fed pig was limited to the amount consumed by its potato-fed partner.

4. The value of the potato nitrogen, whether fed alone or supplemented with that of casein, was consistently inferior to that of the barley nitrogen. The kg. weight increase per kg. digestible nitrogen intake varied from 16.5 to 20.3 for barley rations and from 13.5 to 15.2 for corresponding potato rations. The kg. (dry) food ingested, per kg. weight increase, varied from 3.0 to 4.1 for the barley, and from 3.5 to 5.6 for the potato, rations. The conversion of food into live weight was thus more economical in the case of barley.

5. Addition of casein increased the economy in the conversion of food into live weight to about the same slight extent when either potatoes or barley were fed. The conclusion drawn is that casein nitrogen supplements equally that of potatoes and barley.

6. Some evidence was obtained that the potato-fed pigs were fatter for their carcass weight than the barley-fed pigs. Those which received no casein or only 1 % in their diet were also relatively fatter for their body weight than those receiving 3 or 6 % (see Appendix 1).

7. The average values for the coefficient of (apparent) digestibility of a mixture in equal parts of potato flakes and fresh boiled potatoes was 93.7 % for energy and 81.5 % for total nitrogen. Corresponding figures for barley were 82.3 and 79.1 %.

8. The digestibility of potatoes was unaffected by admixture with casein up to 6 % of the diet, assuming the latter to be entirely digested. It was also unaffected by admixture with barley to about 50 % of the diet, assuming that the coefficient of digestibility of the barley was the same as that ascertained when the barley was fed alone or with casein.

9. The rate of increase of weight when 3 % casein was added to the barley ration (the total nitrogen being 1.95 %) was about the same as when 6 % was added to the potato ration (the total nitrogen being 2.4 %). The intake of food was not very different in the two groups.

In conclusion we wish to thank Sir Charles Martin not only for his hospitality at Roebuck House, Chesterton, but also for constant help and advice throughout the work, Professor Dalling for the facilities given at the Institute of Animal Pathology where the pigs were kept, and Dr Harriette Chick for her help in preparation of this paper. Dr E. H. Callow, of the Low Temperature Research Station, Cambridge, gave us valuable assistance in the interpretation of the carcass data.

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Appendix 1. Examination of Carcasses. (By J. C. D. HUTCHINSON and A. N. WORDEN)

As described in the main portion of the text, not all the pigs were killed at the termination of the growth experiments, the majority being required for the subsequent digestibility trials. During the first of the two digestibility trials, pig 12 received a diet containing 6% casein instead of 3% as previously, while during the second trials pigs 11, 12, 17 and 18 received mixed rations of barley and potato with or

without casein. The food intake (on dry matter basis) of the pigs fed, respectively, on potato and barley rations continued to be paired, however, and the animals were killed off in pairs as soon as each digestibility trial was concluded.

The carcass measurements are recorded in Table 9. The carcass included the head, feet, flare fat and kidneys, and was weighed within 30 min.

Table 9. Carcass measurements

Pig no.	% casein in diet	Warm carcass weight (lb.)	Length of body cavity (mm.)	Back-fat (mm.)					Calculated value of T (mm.)	$B - T$ (mm.)
				A	B	C ₃	C ₂	C ₁		
1 ♂ B	0	138	822	54	27	42	39	43	21.5	5.5
2 ♂ P		129	849	51	26	31	30	37	20.2	5.8
3 ♂ B		109	800	49	20	35	29	34	17.2	2.8
4 ♂ P		96	760	43	20	32	31	33	15.3	4.7
5 ♀ B		87	646	38	13	22	15	18	14.0	(-1.0)
6 ♂ P		75	612	43	19	29	27	25	12.2	6.8
Average:		Barley-fed	756	—	20.0	—	—	—	17.6	2.4
		Potato-fed	740	—	21.6	—	—	—	15.8	5.8
13 ♂ B	1	113	713	44	18	25	21	26	17.8	0.2
14 ♀ P		99	652	45	18	24	20	23	15.8	2.2
15 ♀ B		86	760	34	15	24	21	23	13.8	1.2
16 ♂ P		81	746	45	17	28	24	31	13.1	3.9
17 ♂ B		154	874	63	29	41	41	47	23.8	4.2
18 ♂ P		147	837	54	29	40	43	39	22.7	6.3
Average:		Barley-fed	782	—	20.6	—	—	—	18.4	2.2
		Potato-fed	745	—	21.3	—	—	—	17.2	4.1
7 ♀ B	3	139	845	45	19	27	21	28	21.7	(-2.7)
8 ♂ P		112	790	42	23	34	26	39	17.5	5.5
9 ♂ B		108	732	40	16	26	19	30	17.1	(-1.1)
10 ♀ P		96	666	37	18	26	20	26	15.3	2.7
11 ♂ B		159	886	59	26	41	30	36	24.5	1.5
12 ♂ P		148	873	51	25	35	33	38	23.0	2.0
Average:		Barley-fed	821	—	20.3	—	—	—	21.1	(-0.8)
		Potato-fed	776	—	22.0	—	—	—	18.6	3.4
19 ♂ B	6	115	806	41	17	26	25	31	18.1	(-1.1)
20 ♀ P		105	791	40	20	32	27	35	16.7	3.3
21 ♂ B		146	845	44	23	33	32	39	22.6	0.4
22 ♂ P		144	852	52	21	33	27	39	22.3	(-1.3)
23 ♂ B		123	711	41	21	26	20	27	19.3	1.7
24 ♀ P		120	734	41	19	27	22	29	18.9	0.1
Average:		Barley-fed	787	—	20.3	—	—	—	20.0	0.3
		Potato-fed	792	—	20.0	—	—	—	19.3	0.7

of the death of the animal. The cold carcass weight was obtained by suitable subtraction from the warm carcass weight, i.e. 3 lb. from weights up to 143 lb., and 4 lb. from weights of 144–189 lb. The subcutaneous fat was measured at (A) the shoulder, (B) the last rib, and (C₃, C₂, C₁) the front, middle and back, respectively, of the rump muscle. The length of the body cavity was measured (on the warm carcass suspended from a gambrel) from the pubic symphysis to the junction of the sternum with the first rib [Davidson, Hammond, Swain & Wright, 1937]. The value T was calculated from the equation, $T = 1.4 + 0.149W$, where W is the cold carcass weight [Callow, 1942]; T represents the expected thickness of the back fat at the thinnest portion, i.e. over the last rib. The difference between the observed and calculated values ($B - T$) for this measurement are given in the last column of Table 9, and are discussed in Appendix 2.

In most cases our animals were fatter than expected, i.e. than average pigs of the same carcass weight. Callow's formula, derived from a large number of pigs of various breeds, may possibly not fit our particular Wessex Saddlebacks. Nevertheless, it is clear that the potato-fed pigs were

relatively fatter, in relation to their carcass weight, than their barley-fed partners, and that the pigs which received no casein or 1% were relatively fatter than those which received 3 or 6% casein.

While it is not possible to draw definite conclusions, in view of the possible inapplicability of Callow's formula, the figures suggest that deficiency of nitrogen may affect the composition of the carcass. Those animals which received the most nitrogen of high biological value were relatively the leanest in relation to their carcass weight, thus indicating extra muscle deposition.

McMeekan [1940] could not detect any influence of the level of dietary protein on the body composition of the growing pig. The low protein diet which he used, however, supported optimal growth, and the food intakes of his animals were not limited as in our experiment. Forbes, Swift, Black & Kahlenberg [1935] and Forbes, Voris, Bratzler & Wainio [1938], working with rats whose food intake was paired, found that the nitrogen/fat ratio of the body gains increased as the dietary protein level was raised, and Hamilton [1939] arrived at the same conclusions from a similar experiment.

Appendix 2. Statistical Analysis. (By J. O. IRWIN, Medical Research Council's Statistical Staff, and J. C. D. HUTCHINSON)

Table 10 gives the analysis of variance of (a) body weight increase in kg./kg. of nitrogen intake, (b) body weight increase in kg./kg. of digestible nitrogen intake, (c) dry food intake in kg., (d) digestible energy in kg. cal./kg. increase in body weight, and (e) the difference between the thickness of back fat at the last rib and the average figure for a carcass of the same weight ($B - T$ in Table 9).

In each casein subgroup every pig on a barley ration was paired with another, on a potato ration, of live weight as nearly as possible the same, and their food intakes were similarly paired. Thus the direct effect of casein level is evaluated by an analysis of variance within and between casein groups of the *sums* for two pigs. The difference between the effects of the potato and barley rations, on the other hand, and the effect of addition of casein on this difference—that is, the interaction between the main and subsidiary comparisons—

were evaluated by an analysis of variance of the *differences* between the pairs of pigs. In consequence of the pairing, the error for the direct casein comparison is larger than that for the other two comparisons.

In every case there is a significant difference between the two main groups fed respectively on potatoes and barley. The direct effect of the casein additions is not significant in any of the groups but approaches significance for food intake and for digestible energy intake per kg. weight increase and for thickness of back fat. All three values are on the average less at the higher levels of casein. This fact, which agrees with the result of the previous experiment of Macrae *et al.* [1942], suggests that this non-significance is due to the relatively large error of experiment and that the effect could be shown to be real in an experiment conducted with a larger number of animals.

Table 10. *Analyses of variance*

Variation due to	Degrees of freedom	Weight increase				Food intake (kg./kg. wt. increase)				Intake of digestible energy (kg. cal./kg. wt. increase)				Back fat. Difference between thickness of back fat at last rib and that calculated from warm carcass wt.†			
		(kg./kg. N intake)		(kg./kg. digestible N intake)		(kg./kg. wt. increase)		(kg. cal./kg. wt. increase)		(kg. cal./kg. wt. increase)		(kg. cal./kg. wt. increase)		(kg. cal./kg. wt. increase)		(kg. cal./kg. wt. increase)	
		Sum of squares	Mean sq.	Variance ratio	Mean sq.	Variance ratio	Sum of squares	Mean sq.	Variance ratio	Sum of squares	Mean sq.	Variance ratio	Sum of squares	Mean sq.	Variance ratio	Sum of squares	Variance ratio
Casein level	3	5.81	1.94	0.31	21.95	7.32	0.79	0.263	3.088	3.67	46.45	3.92	49.18	16.39	3.87	49.18	16.39
Error for casein	8	50.34	6.29	—	73.85	9.23	—	6.727	0.841	—	94.81	11.85	33.85	4.23	—	33.85	4.23
Potato compared with barley	1	73.50	73.50	46.52*	119.71	119.71	57.00	7.404	7.404	24.17	104.33	64.33	37.52	36.75	6.92	36.75	6.92
Interaction	3	6.73	2.24	1.42	8.39	2.80	1.33	0.800	0.267	0.87	13.54	4.51	12.78	4.26	0.80	12.78	4.26
Error	8	12.60	1.58	—	16.83	2.10	—	2.450	0.306	—	35.02	4.38	42.50	5.31	—	42.50	5.31
Total	23	148.98			240.73			26.644			447.06		175.06				

* Values of the variance ratios in italics denote a significant effect.

† (B - T) in Table 9.

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