Onderstepoort Journal of Veterinary Science and Animal Industry, Volume 16, *Numbers* 1 *and* 2, *January and April*, 1941.

Printed in the Union of South Africa by the
Government Printer, Pretoria.

The Nutritive Value of Animal Proteins.—The Biological Values of Fishmeal, Whale and Fishmeal, Meatmeal, Meat and Bonemeal, Crayfishmeal, and White Fishmeal.

By B. A. DU TOIT and D. B. SMUTS, Section of Nutrition,
Onderstepoort.

THE importance of protein as a dietary essential in human and animal nutrition has become exceptionally prominent in recent years. This constituent and its decomposition products, the amino acids, are not only in various ways intimately connected with the most vital, essential and intricate physiological functions of the system but form in reality an inevitable portion of the actual protoplasmic tissues. Thus the requirements of protein for maintaining the normal metabolic functions such as enzymatic reactions, hormone secretions, etc., as well as supplying nitrogenous material for the replenishment of the endogenous losses from the protoplasm is of vital importance and indispensable to life. However, the second purpose of protein in nutrition namely construction of new tissues is of equal importance. Production, that is the formation of any tissue such as growth, milk, gestation, etc., cannot be accomplished without the correct quality and quantity of protein in the ration.

The involved and complicated nature of protein nutrition has given rise to a wide field of experimentation. From these investigations it has become abundantly clear that the quality and not the quantity of protien is of primary importance. Hence it appears absolutely essential that in practical nutrition the feeder should be conversant with the quality of the proteins. However, the biological value which is the only true measurement of the quality of a protein, is comparatively speaking a fairly new conception and has, mainly due to the scarcity of data, not enjoyed universal application in practice. On the other hand it expresses the true value of a protein feed in such a significant and indisputable manner, that its application in practical nutrition is long overdue. In our programme on the nutritive value of proteins, we have accumulated sufficient data for plant proteins to be applied in practice. With this investigation we are initiating a similar programme on animal proteins.

For some unknown reason it has always been assumed that animal proteins are superior in nutritive value to plant proteins. This assumption is in all probability erroneously based on the protein content and digestibility of the former type of proteins. As has previously been pointed out the protein content of a feed coupled with its digestibility, give no indication of the quality of a protein. This may be especially true in the case of animal proteins which during the different processes of manufacture are subjected to different forms of heat treatment, thus maintaining in all probability their high crude protein value but become impaired as regards their biological quality. However, these differences in quality can only be settled by a systematic investigation of the respective biological values.

Our knowledge on the difference in feeding value of the various animal proteins is largely based on the results of feeding trials in which increase in weight constitutes the sole criterion. Since a difference in gain in weight may be due to other factors than the protein content of the ration it is in many cases difficult to assess the true significance of such results. It is evident from the literature that the quality of animal proteins can be seriously affected by the method of preparation as well as by a difference in the quality of the materials used from which they are manufactured. Thus Houcamp found that the feeding value depends to some extent on the method of preparation since it affects the digestibility of the proteins. Oshuna and Tlaya found the digestibility of steam proteins to be higher than the flame-dried product. Bethke and Wilder reporting on the manufacturing of fishmeals showed that the vacuum dried product is superior in nutritional value. Schneider working on the quality of proteins under different methods of manufacture found that vacuum dried white fishmeal is superior to any form of preparation. That the method of manufacture or more specifically the form of heat application actually destroys or damages the amino acids in the protein molecule is clearly shown by the work of Greaves, Morgan and Loveen. They found that if casein is heated at 140° for 30 minutes, first lysine and then histidine is damaged. This damage is not due to oxidation, but renders the nitrogen nevertheless less unabsorbable. Little direct evidence exists on the qualitative differences between animal proteins. Almquist and co-workers found that when used as supplementary sources of protein in chicks, growing rations containing tankage gave decidedly inferior results, meat scraps and cracklings gave much better but yet unsatisfactory results, while vacuum dried beef and whale meat gave very satisfactory results. Schneider found vacuum dried white fishmeal a superior protein for rats and pigs. Smuts and Marais obtained for white fishmeal the highest biological value so far established. De Wildt found fishmeal to give better growth than meatmeal in young pigs. Wohlbier and Schranum showed that wholemeat manufactured by modern processes is a good feed with a high digestibility. Frohlich reports that lobstermeal is a complete protein for pigs. Monroe, Kraus and Hayden after experimenting with white fishmeal on dairy cows and calves found that the health and vigour of new borne calves were slightly better on white fishmeal. Carbone found fishmeal to be an excellent feed for pigs.

METHODS OF PREPARATION OF MATERIALS USED IN THIS INVESTIGATION.

1. *White fishmeal* is manufactured from fresh white fish, heads, cuttings and bones of white fish, i.e., non-oily fish. These products are sterilized in vacuo at a temperature of 230° F. for 20 minutes and dried at 140° for 2¾ hours. This product has a crude protein content of 65·1 per cent.

2. *Cray fishmeal* is manufactured from fresh cray-fish bodies, which are sterilized in vacuo at 230° F. for 20 minutes and dried at 140° F. for 2¾ hours. This product has a crude protein content of 40·1 per cent.

3. *Fishmeal* is prepared from fish refuse principally fish heads, sharks, skate and inedible fish. The material is dried in a steam jacketed concentrator. The direct heating is applied for 5 to 8 hours according to the quality of material in the concentrator. This product has a crude protein content of 65·1 per cent.

4. *Meatmeal* is manufactured from whalemeat after oil extraction. The flesh is cooked in digestors for a period of 12 hours by means of direct live steam at 40 to 50 lbs. pressure. The wet meal is then dried in a jacketted drier, the jacket of which is heated by steam, kept at about 60 lbs. The material is in this drier from 1 to 1½ hours. This material is again extracted by hot solvent in an extractor. The solvent is removed by means of live steam which is blown through the material while it is continuously agitated. This recovery takes 1½ hours and the steam pressure is 70-80 lbs. This product has a crude protein content of 80 per cent.

5. *Meat and Bonemeal* is prepared by mixing bones which have been subjected to the action of petroleum ether vapour at 100° C. for 8-10 hours, with whalemeat. The bones are freed from the solvent by live steam treatment for 2½ hours. The pressure at which the steam is kept is from 70-80 lbs. A mixture of whalemeat and bones prepared in the above manner gives the commercial product bone and meatmeal. This product has a crude protein content of 53·0 per cent.

EXPERIMENTAL.

Male rats of not less than 90 grams were used in these metabolism experiments. For each biological value determination a series of six rats were utilized. The rats were first placed on a nitrogen free diet, the composition of which is given in Table 1, for a period of 6 days, and thereafter on a collection period of 7 days on the same ration. They were then transferred to the experimental protein rations. These rations were compounded in such a manner, that the total protein of the ration, was derived from the commercial protein feed under investigation. The protein feeds investigated were of commercial quality manufactured by the processes described above. The preperiod on the protein ration lasted 7 days followed by a collection period of the same duration. Urine was collected in acid medium and the day's collection stored in the ice chest. The daily collection of faeces was digested in the usual manner and stored. At the end of the collection period,

suitable aliquots of the week's collection of urine were taken, digested and the nitrogen determined therein. Similarly aliquots of the week's digestion of the faeces were taken for nitrogen analysis. The composition of the experimental rations is given in Table 1.

Experimental Results.

It is evident from the results that there are distinct nutritional differences between the different commerical proteins investigated. These differences are not restricted to a difference in digestibility but definitely point to a qualitative difference in the construction of their respective amino acid complexes. These variations in the amino acid constitution of individual feed proteins make it therefore impossible to calculate the protein requirements of an animal from its digestible protein. To illustrate the utter impossibility of utilizing digestible protein in such calculations it is only necessary to refer to fishmeal and white fishmeal. From a digestible protein point of view, these two proteins would be fed in almost similar amounts since their crude protein content and digestibilities are almost the same. In reality however, fishmeal is a poorer protein, due mainly to its lack in certain amino acids essential for growth. This lack of indispensable amino acids is reflected in its lower biological value of 71 compared with 94 of white fishmeal. When this difference is taken into account as it should be in practical nutrition then for every 15 lbs. of fishmeal fed only 11 lbs. of white fishmeal is necessary to give the same amount of utilizable protein.

In a comparison of the nutritive value of the various animal proteins, it is clear from the data that white fishmeal is by far superior in quality. The biological value of 94 represents almost a complete assortment of indispensable amino acids in the protein complex of this product. Third in quality ranks fishmeal with a biological value of 71. These figures clearly illustrate that even in a product generally assumed in practice to be of the same nature there is a distinct and significant difference in nutritive value. There appears to be two possibilities why such a difference may actually exist. Firstly there is a distinct difference in the type of material used and secondly the length and type of heat treatment is different. White fishmeal as described previously, is manufactured from non-oily fresh white fish, heads, cuttings and bones, while fishmeal is manufactured from fish refuse, sharks, skate and inedible fish. The former product is subjected to heat treatment for approximately 3 hours, while the latter remains in the presence of heat for 5-8 hours. While there may exist a qualitative difference in the amino acid constitution of the various fish residues, it appears, however, from the literature that the second point, namely, method of manufacture is more likely to have a detrimental effect on the protein quality of the final product. Fairbanks and Mitchell found that the biological value of milk is decreased by cooking. Schneider found by a study on the manufacturing processes on the quality of fishmeal proteins, that difference in heat treatment definitely effects the biological value. Greaves and Loveen showed clearly that in heating casein to 140°, first lysine and then histidine are damaged. Thus it appears that the most likely explanation for the difference in biological values of white fishmeal and fishmeal may be due to a difference in the

manufacturing process. Since no difference is actually obtained in the digestibility of the two proteins it seems reasonable, if there is no difference in the amino acid constitution of the raw products, that the difference in the actual biological values is due to an impairing effect on the amino acids contained in the respective protein molecules. This assumption is indirectly strengthened by the fact that even crayfish with a lower digestibility than fishmeal, has a biological value of 81 which is 10 per cent. higher than fishmeal. Crayfish like white fishmeal is subjected to heat for a much shorter interval than fishmeal. Furthermore both white fishmeal and crayfishmeal is vacuum dried, while with fishmeal direct heating is applied. Although the available evidence at present strongly suggests an impairment of the protein quality by type and length of heating, it cannot at present be regarded as conclusive until a possible difference in the protein quality is entirely eliminated. This aspect it is hoped will be settled experimentally in the near future.

As regards digestibility, crayfishmeal protein is the least digestible, while no statistical difference exists between the values of fishmeal and white fishmeal. The values for the apparent and true digestibilities are 64 and 80 for crayfishmeal, 78 and 94 for fishmeal and 78 and 96 for white fishmeal. These values, especially that of fishmeal and white fishmeal, show that the difference in nutritive value is due to a better constituted amino acid complex in the case of white fishmeal. Whether this superiority as regards amino acid constitution is due to a difference in the manufacturing process, is still to be investigated.

With reference to the meatmeals, it will be seen that no difference in biological value as well as digestibility exists between meatmeal and bonemeal. Probably the quantity of bonemeal included in the meatmeal ration at an 8 per cent. level is too small to alter the biological value of meatmeal at the same level of intake. Coming to the values obtained for whale and fishmeal, it will be noticed that the biological value is lower than either meatmeal or fishmeal. Unfortunately this product was from a different manufacturer and could therefore not be compared with our values on meat and fishmeal. The biological value of 63 is the lowest value recorded. The apparent digestibility of 52 and the true digestibility of 70 contribute to the low nutritive value of this product. As will be noticed all the meatmeal products are subjected for long periods to heat treatment.

From these results it is clear that the animal proteins investigated rank in the following order in respect of their utilizable protein content, white fishmeal; meatmeal; crayfishmeal; meat and bonemeal; whale and fishmeal. Thus a 100 lbs. of white fishmeal will give 47·7, 100 lbs. of fishmeal 32·7, 100 lbs. meatmeal 30·6, 100 lbs. crayfishmeal 20·8, 100 lbs. meat and bonemeal 20·6 and 100 lbs. whale and fishmeal 17·4 lbs. of utilizable protein.

Summary and Conclusions.

By means of nitrogen metabolism experiments, the biological values of 94 for white fishmeal, 81 for crayfishmeal, 71 for fishmeal, 67 for meatmeal, 67 for meat and bonemeal and 63 for whale and

fishmeal were determined. From these figures and the digestibility coefficients it was shown that white fishmeal is superior in its utilizable protein content, and that whale and fishmeal is the poorest in this respect.

REFERENCES.

ALMQUIST, H., STOKSTAD, E., AND HALBROOK, E. (1925). Supplementray values of animal protein concentrates in chickrations. *J. Nutr.*, Vol. 10, No. 2, p. 193.

BETHKE, R. M., AND WILDER, O. (1934). Effect of Method and manufacture on the nutritive value of fishmeals as determined by growth studies on chickens. *J. Agric. Res.*, Vol. 49, pp. 715-722.

CARBONE, E. (1937). La farina di pesce vele alimentazoine del bestiane. *Riv. Zootec.*, Vol. 14, pp. 429-435.

DE WILDT, R. (1933). Vischmeel en Diermeel by het mesten van Varkens. *Verslag Rykslandbouw Proefstataion te Hoorn*, No. 39 C.

FROLICH, G. (1932). Lobstermeal as complete protein rich supplement for pigs. *Zeitsch. fur Schweinz.*, Vol. 39, p. 402.

FAIRBANKS, B. W., AND MITCHELL, H. H. (1935). The nutritive value of skim milk powders, with special reference to the sensitivity of milk proteins to heat. *Jl. Agric. Res.*, Vol. 51, p. 1107.

GREAVES, E., MORGAN, A., AND LOVEEN, M. (1938). The Effect of amino acids supplements and of variations in temperature and duration of heating upon the biological value of heated casein. *J. Nut.*, Vol, 16 No. 2, p. 115.

MONROE, C., KRAUSS, W., AND HAYDEN, C. (1937). White fishmeal for growth and milk production. *Br. M. Bull.* Ohio Agric Exp. St., No. 22, pp. 46-52.

OSHUNA, K., AND TLAYA, S. (1938). The relation of the qualities and the manufacturing method of fishmeal and scrap. *J. Agric. Chem. Soc. Japan.*, Vol. 14, pp. 512-517.

SCHNEIDER, B. (1932). Nitrogen balance studies with various fishmeals. *J. Agric. Res.* Vol. 44, pp. 723-732.

TABLE 1.

Constituents.	N. Low Ration.	White Fish Meal Ration.	Fish Meal Ration.	Crayfish Meal Ration.	Meat Meal Ration.	Meat and Bone Meal Ration.	Whale and Fish Meal Ration.
White Fish Meal.....	—	12·3	—	—	—	—	—
Fish Meal.....	—	—	12·3	—	—	—	—
Crayfish Meal.....	—	—	—	20·0	—	—	—
Meat Meal.....	—	—	—	—	10·0	—	—
Meat and Bone Meal..	—	—	—	—	—	15·0	—
Whale and Fish Meal..	—	—	—	—	—	—	15·0
Dext Starch.....	70	59·7	59·7	52·0	62·0	57·0	57·0
Sugar.....	10	10	10	10	10	10	10
Butter Fat.....	8	8	8	8	8	8	8
Yeast Harris.....	2	2	2	2	2	2	2
Cod Liver Oil.....	2	2	2	2	2	2	2
Agar.....	2	2	2	2	2	2	2
Minerals.....	3	3	3	3	3	3	3
NaCl.....	1	1	1	1	1	1	1
Ext Egg White.....	2	—	—	—	—	—	—
TOTAL.....	100	100	100	100	100	100	100
Percentage N.....	·46	1·53	1·62	1·62	1·54	1·60	1·47

FISH MEAL PERIOD, 1·62 PE

Rat No.	Initial Weight.	Final Weight.	Average Weight.	Daily Food Intake.	Daily N Intake.	Daily N Faeces.	Body N Faeces.	
							Per Gram Food.	Per Day.
7	135	137	136	9·4	152·3	30·7	2·23	21·0
8	132	139	136	9·4	152·3	32·1	2·59	24·3
9	123	129	126	9·4	152·3	31·4	2·45	23·0
10	123	130	127	9·4	152·3	32·9	2·39	22·5
11	126	132	129	9·4	152·3	33·6	2·42	22·8
12	107	115	111	9·4	152·3	35·7	2·58	24·3

CRAYFISH MEAL PERIOD, 1·62

13	116	118	117	9·3	150·7	54·6	2·59	24·1
14	131	131	131	9·3	150·7	52·1	2·66	24·7
15	108	117	113	9·3	150·7	55·7	2·68	24·9
16	124	131	128	9·3	150·7	61·1	2·76	25·7
17	107	114	111	9·3	150·7	51·1	2·27	21·1
18	107	114	111	9·3	150·7	54·3	2·52	23·4

WHALE AND FISH MEAL PERIOD, 1

19	71	71	71	4·9	72·0	33·2	2·67	13·1
20	66	63	65	4·3	63·2	29·6	2·66	11·4
21	68	69	69	4·9	72·0	34·3	2·86	14·0
22	69	68	69	5·1	75·0	37·5	2·70	13·8
23	67	66	67	4·6	67·6	33·2	2·50	11·5
24	76	77	77	5·3	77·9	38·6	2·74	14·5

MEAT MEAL PERIOD, 1·54 PE

1	94	99	97	7·5	116	48·9	2·61	19·6
2	89	97	93	7·5	116	49·0	2·57	19·3
3	87	86	87	5·2	80·1	36·8	3·03	15·8
4	92	95	94	6·5	100	43·2	2·71	17·6
5	90	97	94	7·0	108	45·7	2·51	17·6
6	80	86	83	7·0	108	44·6	2·53	17·8

WHITE FISH MEAT PERIOD, 1·53

7	95	108	102	7·5	115	23·6	2·69	20·2
8	100	110	105	7·5	115	23·9	2·65	17·4
9	87	95	91	7·1	109	25·7	2·72	19·3
10	86	99	93	7·4	113	23·9	2·61	19·3
11	88	99	94	7·5	115	24·3	2·60	19·5
12	88	103	96	7·5	115	21·8	2·71	20·3

MEAT AND BONE MEAL PERIOD, 1·

7	109	113	111	9·3	148·9	59·8	2·45	22·8
8	103	110	107	9·3	148·9	63·5	2·80	26·0
9	103	107	105	9·3	148·9	65·2	3·03	28·2
10	112	115	114	9·3	148·9	64·5	2·90	27·0
11	110	115	113	9·3	148·9	60·8	2·85	26·5
12	94	97	96	6·9	110·5	46·9	2·53	17·5

PERIOD, 1·62 PER CENT. N.

Food N Faeces.	Absorbed N.	Daily N Urine.	Body N Urine. Per 100 Gram Weight.	Body N Urine. Per Day.	Food N Urine.	Retained N.	Biological Value.	App. Digest.	True Digest.
9·7	142·6	74·6	21·0	28·6	47·8	94·8	66	80	94
7·8	144·5	56·4	13·6	18·5	37·9	106·6	74	79	95
8·4	143·9	58·6	15·3	19·3	39·3	104·6	73	79	95
10·4	141·9	63·2	15·4	19·6	43·6	98·3	69	78	93
10·8	141·5	75·3	25·5	32·9	42·4	99·1	70	78	93
11·4	141·9	65·7	22·8	25·3	40·4	101·5	72	76	93
						Average.....	71	78	94

L PERIOD, 1·62 PER CENT. N.

30·5	120·2	49·6	24·3	28·4	21·2	99·0	82	64	80
27·4	123·3	50·7	19·9	26·0	24·7	98·6	80	65	82
30·8	119·9	47·5	22·9	25·9	21·6	98·3	82	63	80
35·4	115·3	53·2	20·4	26·1	27·1	88·2	76	59	76
30·0	120·7	48·2	26·8	29·8	18·4	102·3	85	66	80
30·9	119·8	41·8	19·4	21·5	20·3	99·5	83	64	80
						Average.....	81	64	80

MEAL PERIOD, 1·47 PER CENT. N.

20·1	51·9	35·7	22·5	16·0	19·7	32·2	62	54	72
18·2	45·0	33·6	26·3	17·1	16·5	28·5	63	53	71
20·3	51·7	37·1	22·6	15·6	21·5	30·2	58	52	72
23·7	51·3	35·0	24·6	17·0	18·0	33·3	65	50	68
21·7	45·9	34·3	26·5	17·8	16·5	29·4	64	51	68
24·1	53·8	38·6	25·4	19·6	19·0	34·8	65	50	69
						Average.....	63	52	70

PERIOD, 1·54 PER CENT. N.

29·3	86·7	47·1	23·2	22·5	24·6	62·1	72	58	75
29·7	86·3	49·3	21·2	19·7	29·6	56·7	66	58	74
21·0	59·1	41·4	24·6	21·4	20·0	39·1	66	54	74
25·6	74·4	47·8	21·0	19·7	28·1	46·3	62	57	74
28·1	79·9	50·0	24·2	22·8	27·2	52·7	66	58	74
26·8	81·2	46·4	25·9	21·5	24·9	56·3	69	59	75
						Average.....	67	57	74

AT PERIOD, 1·53 PER CENT. N.

3·4	111·6	32·1	21·9	22·3	9·8	101·8	91	79	97
6·5	108·5	26·4	20·0	21·0	5·4	103·1	95	79	94
6·4	102·6	30·0	25·4	23·1	6·9	95·7	93	76	94
4·6	108·4	29·3	26·1	24·3	5·0	103·4	95	79	96
4·8	110·2	27·9	26·1	24·5	3·4	106·8	97	79	96
1·5	113·5	27·9	23·8	22·9	5·0	108·5	96	76	99
						Average.	94	78	96

MEAL PERIOD, 1·60 PER CENT. N.

37·0	111·9	66·1	23·3	25·9	40·2	71·7	64	60	75
37·5	111·4	42·1	16·9	18·1	24·0	87·4	78	57	75
37·0	111·9	58·9	23·0	24·2	34·7	77·2	69	56	75
37·5	111·4	60·3	22·0	25·1	35·2	76·2	68	57	75
34·3	114·6	66·1	26·1	29·5	36·8	78·0	68	59	77
29·4	81·1	54·3	20·2	19·4	34·9	46·2	57	57	73
						Average.....	67	58	75