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PROTEIN VALUE OF HERRING MEAL AND SOME OTHER PROTEIN CONCENTRATES OF MARINE ORIGIN FOR THE YOUNG RAT

BY

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INTRODUCTION

Herring meal is produced in this country by different methods (SOLA, 1954). Previously the whole herring was cooked and pressed, the press cake was dried in a flame drier and ground into meal whereas the press water went to waste. This method is practically obsolete, the press water is now mixed into the press cake by various methods so that a "whole herring meal" is produced. The mixing of the press cake and the press water is done at various stages, all procedures having the objective of preventing the material to stick to the apparatus during the drying process. The press water is often referred to as "stick water" or "glue-water".

It was presumed that the great variety of methods used for production of herring meal would render meals with different protein values as measured by nitrogen balance studies with rats. To test this assumption some herring meals produced by different methods were compared either between themselves or with other protein sources. A total of 33 commercial herring meals were tested in one or more experiments. Some acetone dried samples of herring organs or herring meal were also tested, as well as some other protein concentrates. The results of these experiments are presented in this publication. The effect of the antioxidant BHT (butylated hydroxytoluene) on the protein value of herring meal will bereported on in a following paper.

MATERIALS

The commercial herring meals used in the experiments are listed in Table 1 together with available analytical data. Information regarding the general steps in the production processes is given in Table 2. In some cases the raw material was preserved with sodium nitrite, formalin or a mixture of both substances (ANON., 1953).

In Table 3 are listed the other protein concentrates tested and in Table 4 are listed the acetone dried samples. The foreign fish meals (nos. 24—28) were obtained commercially. The Peruvian meal (no. 24)

Table 1. *Analyses of commercial Norwegian herring meals.*

Meal[1] no., method, type	per cent					p.p.m.[2]							
	Protein	Dry matter	Fat	Ash	Ca	Zn	Cu	Co x100	Mn	Riboflavin	Niacin	Pant acid	B_{12}
1–C–Wm	73.3	91.3											
2–A–Pc ...	74.1	91.5											
3–A– « ...	73.1	91.6	6.8	9.5									
4–D–Wm .	73.3	90.3	6.4	9.5									
5–E– « .	73.2	89.4	5.5	10.0	2.13	69.3	4.8	8.3	5.6	8.5	87.8	33.5	0.36
6–D– « .	72.9	90.7	10.9	9.7	1.83	60.7	3.8	3.1	2.6	9.6	110.6	41.0	0.45
7–A–Pc ...	73.9	90.6	5.8	9.0	2.00	82.6	8.0	3.0	3.6	6.3	59.6	20.5	0.34
8–K–Wm..	75.4	91.3	5.2	10.3	1.76	67.6	6.9	2.6	1.7	10.1	126.7	41.6	0.37
9–H– « ..	75.2	91.7	6.0	10.3	1.63	66.5	4.2	2.8	3.3	9.5	114.9	38.1	0.33
10–K– « ..	73.3	90.0	6.0	10.4	1.66	94.8	5.2	1.9	1.1	10.1	113.3	33.7	0.41
11–K– « ..	75.5	91.0	6.1	9.5	1.71	64.9	3.5	6.4	1.4	7.4	110.0	19.2	0.23
12–K– « ..	74.9	90.8	4.8	9.3	2.35	65.7	4.1	1.8	4.5	6.0	69.0	12.9	0.23
13–C– « ..	72.0	90.3	6.5	9.3	1.44	69.8	5.9	14.7	3.9	9.4	112.0	43.2	0.36
14–L– « ..	72.3	89.8	10.2	8.8	1.65	106.5	5.9	1.5	3.2	7.5	80.5	20.7	0.28
15–L– « ..	75.5		4.2			76.1	5.9	2.9	2.8				
34–G– « ..	76.8			10.0	1.94							42.4	
35–G– « ..	74.9			9.2	1.63							39.2	
36–H– « ..	74.3			10.0	1.89							42.0	
37–K– « ..	76.7			9.2	1.79							18.8	
46–H– « ..	73.1			9.1	1.76							34.1	
47–H– « ..	74.3			10.0	1.81							36.1	
50–C– « ..	73.0			9.9	1.99							47.5	
51–C– « ..	73.3			9.9	1.90							39.0	
52–K– « ..	73.8			9.4	1.89							19.1	
53–H– « ..	78.4			9.5	1.78							35.8	
56–E– « ..	75.0												
57–F– « ..	76.5												
80–H– « ..	76.3												
81–I– « ..	75.8												
82–B–Pc....	73.8												
87–H–Wm..	72.2												
88–H– « ..	72.9												
92–K– « ..	71.8												

[1] Meth.=Production method, see Table 2; Wm=whole meal; Pc=press cake meal.
[2] Note that the values for Co has been multiplied by 100.

was probably made from anchovies, the Danish meal (no. 25) was probably a press cake meal carefully dried in a steam drier. It was of light colour, but contained some lumps which necessitated that it was ground before use. No details were known of the Angola (no. 26) and the Dutch (no. 28) fish meals, the South-African meal (no. 27) was stated to be

Table 2. *Short description of the methods used for production of Norwegian herring meals tested.*

Method	
A	The raw material is cooked and pressed. The press cake is disintegrated and dried in a flame drier. (Meal nos. 2, 3 and 7).
B	The procedure is the same as under A except that a steam tube drier is used instead of a flame drier (Meal no. 82).
C	The raw material is cooked and pressed. The press cake is disintegrated and dried to about 20—30% residual water in a flame drier. The unconcentrated stickwater is added, one portion of the mixture is recirculated in the first drier, for the remainder the drying is finished in a second flame drier. (Meal nos. 1, 13, 35, 50, 51).
D	The raw material is dried by vacuum in a steam-jacketed drier to about 10—15% residual water. The dry material is pressed hydraulically to reduce the fat content to about 10%. The dry press cake is stored or ground into meal. (Meal nos. 4 and 6).
E	The raw material is cooked and pressed. The solubles are concentrated to about 40% dry matter in a two-step vacuum evaporator. The disintegrated press cake is dried to about 20% residual water in a flame drier, the concentrated solubles are added and the drying is finished in a second flame drier (Meal nos. 5 and 56).
F	The procedure is the same as under E except that the second flame drier is substituted by a steam tube drier. (Meal no. 57).
G	The procedure is the same as under E except that two steam tube driers are used instead of two flame driers. (Meal no. 34).
H	The procedure is the same as under E except that the drying is completed in one step in a flame drier. (Meal nos. 9, 36, 46, 47, 53, 80, 87, 88 and 89).
I	The procedure is the same as under H except that a steam tube drier is used instead of a flame drier. (Meal no. 81).
K	The procedure is the same as under H except that the solubles are concentrated in a three-step high pressure evaporator. (Meal nos. 8, 10, 11, 12, 37, 52 and 92).
L	The raw material is cooked and pressed, the solubles are concentrated in a three-step high pressure evaporator and added to the disintegrated press cake. The mixture is dried in two steps, one very rapid with hot flame gases, and one slower in a steam tube drier. (Meal nos. 14 and 15).

made from pilchards. It is not known to what extent the meals tested are typical of their countries of origin. The object of testing them was to get a general impression based on one random sample from each country.

The sand-eel (*Ammodytes Spp.*) meals were produced in this country. Meal no. 54 was a press cake meal produced by method B on a factory ship, meal no. 55 was produced by method H in a plant.

The sample of dried herring solubles (no. 58) was spray dried.

The feed grade whale meals were supplied by the producers. No. 70 was dried at 400°C for 20 min., no. 71 was dried in about 3 min. in a flash drier using a great excess of air at 200°C.

The solvent extracted herring meal (no. 89) was made by light petrol extraction of herring meal no. 88 to which had been added 0.03% BHT before the process of grinding.

Meal no. 95 was a commercial rennet casein. The squid meal (no. 97) was a commercial sample produced from the species *Ommatostrephes todarus*. The off-fall meals (nos. 108 and 109) were commercial samples of allegedly good protein quality produced by method D (Table 2). In view of the results obtained, it was later confirmed by the producer that they were meals produced from fish off-fall and shark liver in unstated proportions.

The acetone dried samples were made either from raw or "cooked" fish or fish organs. The "cooked" samples were coagulated for five minutes in boiling water. The material was taken through a meat mincer, 1 kg portions were treated first with 2 l acetone and then two times with 1 l. It was then soaked first with ethyl alcohol and then with ethyl ether. After each treatment the liquid was removed by suction, the material was spread to allow some evaporation, after the treatment with ethyl ether it was air dried either over night or over the week-end. The samples were finally ground before use.

The egg albumin used as reference protein in most of the experiments, was a commercial spray dried product guaranteed free from yolk.

METHODS

The chemical analyses were done by standard methods: Dry matter by drying at 105°C, fat by ethyl ether extraction in Soxhlet apparatus, protein by Kjeldahl digestion and titration (NJAA, 1963), ash by incineration at 800°C, calcium in the ash by titration of the oxalate with potassium-permanganate. The analyses of the microelements were carried out by Mrs. I. OUREN using colorimetric methods (OUREN, 1957). The vitamins were determined by microbiological analyses by standard methods (BRÆKKAN, 1959).

Table 3. *Analyses of commercial protein concentrates other than Norwegian herring meal.*

Meal		per cent				p.p.m.			
No.	Type and origin	Protein	Fat	Ash	Ca	Riboflavin	Niacin	Pant. acid	B_{12}
24	Peru	69.0				4.8	71.4	6.1	0.24
25	Denmark	71.4				5.1	103.0	10.8	0.19
26	Angola	63.3				6.4	71.5	16.6	0.22
27	S. Africa	57.1				4.4	53.3	5.5	0.19
28	Holland	60.8				11.9	85.5	24.0	0.19
54	Pc, sand-eel meal	63.7		18.6	3.4	9.7	60.5	7.3	0.19
55	Wm, sand-eel meal	67.4		11.7	3.1	14.1	120.6	29.1	0.30
58	Spray dried herring solubles	69.6							
70	Whale meal, slow drying	82.5		1.9				5.0	
71	Whale meal, rapid drying.	82.1		2.3				11.1	
89	Solvent extr. herring meal	78.8							
95	Rennet casein	72.9							
97	Squid meal	75.8							
108	Off-fall meal	50.0	33.5	11.0			54.1		0.53
109	Off-fall meal	56.0	26.4	11.0		7.9	54.8	9.7	0.48

Table 4. *Protein content of the acetone dried samples.*

Meal no.	Description	Protein %	Meal no.	Description	Protein %
0	Herring fillets	88.9	91	Cooked Iceland herring preserved during transport with $NaNO_2$	82.1
16	Herring fillets	81.5			
73	Raw herring milt	94.5			
75	Cooked herring roe	77.6	90	Extracted herring meal 92	75.7
76	Raw herring roe	78.0	98	Whole male herring	84.3
77	Whole raw herring	83.5	99	Whole female herring	80.4
78	Whole cooked herring	85.6	106	Cooked squid	85.4
79	As 78 — head and backbone	86.7			

The nitrogen balance experiments were performed by the methods described by NJAA (1959a and b, 1963). In Expts 1—3 metabolic faecal nitrogen and endogenous urinary nitrogen excretion were estimated as described by NJAA (1959a) and NPU was calculated accordingly. In the other experiments these excretions were not determined but NPU was estimated by assuming that the maintenance protein requirement is equivalant to 190 mg N per kg body weight taken to the power of 0.73

(NJAA, 1965). Comparisons between protein sources were made on the basis of apparent digestibilities and percentage nitrogen balances (NJAA, 1963). The diet was mixed with water to reduce spilling and given in restricted daily amounts, usually 10g/rat/day, which were generally eaten completely. The dietary protein level was in most cases about 8%, in Expts 2—5 the protein level was about 10% (N×6.25). The animal room was kept at 22°C.

EXPERIMENTS

The experiments are described under headings indicating the various problems considered. In Tables 5—7 the experiments are presented in chronological order.

COMPARISON BETWEEN WHOLE MEALS

In *Expt 4* ten herring meals (nos. 5—14, Table 1) from factories with known production processes (Table 2) were fed to groups of two rats. It was hoped that meals with extreme protein values could be singled out for further examination. Five of the meals from Expt 4 were tested more thoroughly in *Expt 5*. They were given to groups of four rats and compared with egg albumin as a protein source. The comparisons were replicated two times with new rats so that 12 observations were made with each protein source. Of the meals tested one was a press cake meal (no. 7), the others were whole meals.

Expt 10 involved the comparison of four meals (nos. 34—37, Table 1) produced by different methods (methods G, C, H and K, respectively (Table 2)). Moreover, meal no. 34 was from unpreserved herring, meal no. 35 from herring preserved with nitrite and formalin, meal no. 36 from herring preserved with nitrite and meal no. 37 from herring preserved with formalin. Meal no. 37 was produced in a factory concentrating the solubles under rather hard conditions, a fact which is reflected in the low content of pantothenic acid in this meal (Table 1).

Expt 11 compared two meals from the same factory using method H (Table 2), one produced from unpreserved herring (no. 46) and one from nitrite preserved (no. 47). The same raw materials were dried in the laboratory by infra-red lamps and these meals were included in the experiment (Nos. 48 and 49).

Expt 12. Two meals from a factory using method C (Table 2), one from unpreserved herring (no. 51) and one from formalin preserved (no. 50) were compared.

Expt 13. Two meals, one from a factory using method H (Table 2) reputed to concentrate the presswater carefully (no. 53) and one from a factory using method K (Table 2) reputed to concentrate it under hard conditions (no. 52) were compared. This difference is evidenced by the contents of pantothenic acid in the meals (Table 1). In this experiment were also included two sand-eal meals (nos. 54 and 55).

Expt 14. Two meals from the same factory were produced from the same raw material on the same day. Meal no. 56 was produced by method E, meal no. 57 by method F (Table 2). Included in this experiment was also a spray dried herring solubles meal (no. 58) and spray dried egg albumin.

Expt 19. Two meals from a factory using method H (Table 2), one with 0.03% BHT added before grinding (no. 88) and one without this addition (no. 87) as well as meal no. 88 extracted with light petrol (no. 89) were compared with spray dried egg albumin.

Expt 20. Meal no. 92 produced by method K (Table 2) was compared with meal made from the same raw material by acetone drying (no. 91), with acetone extracted whole meal made from no. 92 (no. 90) and with spray dried egg albumin.

COMPARISONS BETWEEN WHOLE MEALS AND PRESS CAKE MEALS

Expts 2a and b. Press cake meal no. 2 produced by method A (Table 2) was compared with whole meal no. 1 produced by method C by the Mitchell method and by a modification of this method as described by NJAA (1959a). The experimental results were presented in that publication; in connexion with the present work NPU was calculated as previously described and by applying the procedure mentioned above (p. 7).

Expt 3. Press cake meal no. 3 produced by method A (Table 2) was compared with whole meal no. 4 produced by method D by the Mitchell method as described by NJAA (1959b Expt 1). In the first egg protein period and in the first experimental period 8 g of food was given, in the second experimental period and in the second egg protein period 10 g of food was given.

Expts 4 and 5. As mentioned above one press cake meal produced by method A (Table 2) (no. 7) was included among the whole meals in these experiments.

Expt 6. Press cake meal no. 7 produced by method A (Table 2) was compared with whole meal no. 15 produced by method L as well as with acetone dried herring fillets (no. 16) and spray dried egg albumin.

Expts 7a and b. Press cake meal no. 7 produced by method A (Table 2) was compared with whole meal no. 11 produced by method K, the latter being produced by a factory concentrating the press water under rather hard conditions as is seen by the low content of pantothenic acid (Table 1). The meals were compared with and without addition of methionine, 1.25% of the protein in Exp 7a and 2.50% in Expt 7b.

Expt 16. Two whole meals (nos. 80 and 81) produced by methods H and I (Table 2) were compared with a press cake meal (no. 82) produced by method B and with spray dried egg albumin. The three herring meals were produced in the same factory from the same batch of raw material. Meals nos. 80 and 82 were produced on the same day, no. 81 was produced the following day.

COMPARISON BETWEEN OTHER PROTEIN CONCENTRATES THAN NORWEGIAN HERRING MEAL

Expt 8. Fish meals from Peru (no. 24) and Denmark (no. 25) were compared with Norwegian herring meal no. 13 produced by method C (Table 2) and with spray dried egg albumin. The same rats were used in two consecutive collection periods each of 5-days duration.

Expt 9. Fish meals from Angola (no. 26), South Africa (no. 27) and Holland (no. 28) were compared with spray dried egg albumin.

Expt 13. As mentioned above (p. 9) two sand-eel meals (nos. 54 and 55) were compared with two herring meals.

Expt 14. As mentioned above (p. 9) a spray dried sample of herring solubles (no. 58) was compared with two herring meals (nos. 56 and 57) and with spray dried egg albumin.

Expt 17. Two whale meat meals (nos. 70 and 71) were compared with herring meal no. 81 and with spray dried egg albumin.

Expt 21. A commercial squid meal (no. 97) was compared with meal no. 81, casein (no. 95) and spray dried egg albumin.

Expt 24. Two fish off-fall meals (nos. 108 and 109) were compared. The rats were given 9 g food daily, but they did not eat this amount completely. The mean daily food intake of the rats on meal no. 108 was 8.1 and of those on meal no. 109 8.6 g.

EXPERIMENTS WITH ACETONE-DRIED SAMPLES

Expt 1. Acetone dried herring fillets (no. 0) was tested by the method of MITCHELL & CARMAN (1926) as modified by NJAA (1959a). Net protein utilization was estimated by both the methods mentioned on p. 7. The diet contained 8.6% protein.

Expt 6. As mentioned above (p. 00) a sample of acetone dried herring fillets (no. 16) was compared with a press cake meal (no. 7) and whole meal (no. 15), as well as with spray dried egg albumin.

Expt 15. Acetone dried meals of raw (no. 75) and cooked (no. 76) herring roe and of raw herring milt (no. 73) were compared with spray dried egg albumin.

Expt 18. Acetone dried meals from whole raw herring (no. 77) and cooked herring (no. 78) and from whole cooked herring from which the head and the backbone had been removed (no. 79) were compared with spray dried egg albumin.

Expt 20. Acetone dried whole cooked herring (no. 91) was compared with herring meal made from the same raw material (no. 92) and with an acetone extracted sample of this meal (no. 90).

Expt 22. Acetone dried meals from cooked male (no. 98) and female (no. 99) herring and a 1:1 mixture of these meals were compared with spray dried egg albumin.

Expt 23. Acetone dried meal from frozen squid (no. 106) was compared with commercial squid meal (no. 97) and with two samples of spray dried egg albumin.

RESULTS

The results are presented chronologically in Tables 5—7. Table 5 contains results obtained by NJAA (1959a, b) using modifications of the MITCHELL method (Expts 1—3), Table 6 contains results obtained in two experiments with meals produced from winter herring within about a

Table 5. *Apparent protein digestibility (D_a), percentage nitrogen balance (Bal%), net protein utilization (NPU) and calculated net protein utilization (NPU_c) of acetone dried herring fillets, whole herring meal and press cake meal.*

Expt. no.	Meal no., method,[1] type	Nitrogen intake (mg/day)	D_a	Bal%	NPU	NPU_c	Body weight (g)	Weight gain g/6days
1	0–acetone dried herring fillets	137.3	84.6	44.3	72.5	76.1	84.4	6.8
2a	1–C–Wm[3]	163.6	81.7	39.9	63.2	58.1	79.3	10.8
	2–A–Pc[2]	158.9	82.6	42.1	66.2	61.1	80.3	11.8
2b Period 1	1–C–Wm	160.5	80.8	43.9	67.9	65.3	96.2	15.7
Period 2	1–C–Wm	157.6	81.8	32.2	59.2	57.6	119.3	10.3
Period 1	2–A–Pc	156.0	81.4	46.9	73.0	68.9	97.0	16.0
Period 2	2–A–Pc	155.3	83.1	38.5	64.8	63.9	120.4	10.5
3	3–A–Pc	132.3	82.5	44.2	69.2	68.1	85.1	8.2
	3–A–Pc	160.3	80.6	41.8	66.8	62.1	104.5	13.8
	4–D–Wm	129.5	84.9	44.6	68.9	68.7	84.3	8.6
	4–D–Wm	161.5	85.8	36.6	65.1	63.9	104.1	13.6

[1] Production method, see Table 2. [2] Press cake meal. [3] Whole meal.

week during the season of 1956 (Expts 4 and 5). Table 7 contains results obtained with various protein sources, including herring meals, between 1956 and 1961 (Expts 6—24). The mean body weight of the rats used in Expts 6—24 varied between 65 and 85 g. There was a tendency, although insignificant, for the mean nitrogen balance values for the herring meals to be negatively correlated with the mean body weight ($r = -0.36$, $n = 27$, $p \approx 0.1$, excluding meal no. 81 in Expt 17).

COMPARISON BETWEEN WHOLE MEALS

Expt 4 was a screening test with nine whole meals and one press cake meal. The whole meals were produced by six different methods (C, D, E, H, K and L, Table 2). The four meals produced by method K were from different factories. The apparent protein digestibilities decreased in the order meal nos. 6, 14, 5, 9 and 13 or when considering methods in the order D, L, E, H and C. The meals produced by method K (nos. 8, 10, 11 and 12), were all at the lower end of the scale. The sequence for the nitrogen balance values of the former group was similar, whereas the meals produced by method K showed about the same range as the other meals. The low values for pantothenic acid in meals 11 and 12

Table 6. *Apparent protein digestibility (D_a), percentage nitrogen balance (Bal%) and calculated net protein utilization (NPU_c) of herring meals produced by various methods during one week of the winter herring season 1956—1957.*

Expt no.	Meal[1] no., method, type	Nitrogen intake (mg/day)	D_a	Bal%	NPU_c	Body weight (g)	Weight gain g/6days
	5–E–Wm	160.6	82.2	34.8	56.9	100.5	11.0
	6–D–Wm	159.0	84.1	38.1	60.3	99.8	9.5
	7–A–Pc	159.6	81.0	34.7	57.1	101.0	12.0
	8–K–Wm	158.3	80.5	34.2	56.2	98.0	10.0
4	9–H–Wm	162.2	81.9	33.0	54.2	96.0	11.0
	10–K–Wm	159.0	80.3	31.9	54.1	99.8	9.5
	11–K–Wm	157.2	78.0	35.0	57.1	97.5	9.0
	12–K–Wm	155.8	78.5	39.0	61.9	101.0	13.0
	13–C–Wm	155.7	76.1	30.4	52.8	97.5	8.0
	14–L–Wm	160.4	83.4	40.0	62.3	101.0	10.0
							g/5days
	6–D–Wm	149.3	81.7	33.0	56.9	101.6	5.6
	7–A–Pc	152.8	79.1	33.4	56.8	101.4	5.7
5	11–K–Wm	151.8	77.8	30.1	53.6	101.3	5.6
	13–C–Wm	155.3	78.1	29.1	52.1	101.7	4.7
	14–L–Wm	153.3	82.7	32.4	55.7	101.5	5.6
	Egg-alb.	151.4	82.6	44.2	68.0	101.9	7.1

[1] Production method, see Table 2. Pc = press cake meal. Wm = whole meal.

indicated that the solubles had been overheated during the concentration process (BOGE, 1957). However, the high Ca-content in meal no. 12 cast some doubt as to this being a proper "whole" meal (Table 1). The two apparently best meals (nos. 6 and 14) as well as the apparently poorest meal (no. 13) were chosen together with meal no. 11 and the press cake meal no. 7 for testing in Expt 5. The mean apparent digestibility of meal nos. 6, 14 and egg albumin was significantly higher than the mean apparent digestibility of meal nos. 7, 11 and 13, the differences within the groups were non-significant. The percentage nitrogen balance was significantly higher for egg albumin than for the mean of the herring meals which showed no significant differences. The results obtained in Expts 4 and 5 were in general agreement in indicating that meal nos. 6 and 14 were better digested than meal nos. 11 and 13. This indicated that the production method may influence on the protein digestibility. In this case vacuum drying of the raw material (meal no. 6) or the rapid drying of the press cake mixed with concentrated solubles involved in method L (meal no. 14) gave better digestibilities than slower drying (meal nos. 11 and 13). The differences found between nitrogen balances seemed to be practically entirely due to the differences in digestibility.

In Expt 10 were tested meal nos. 34—37 produced at different factories by the methods G, C, H and K, respectively. The mean digestibility of meal nos. 35 and 37 was significantly less than that of meal nos. 34 and 36, whereas the difference within each group was nonsignificant. Meal nos. 35 and 37 were produced by the same methods as meal nos. 13 and 11, respectively, which gave low digestibilities in Expts 4 and 5. Meal no. 36 was produced by the same method as meal no. 9 (Expt 4, Table 6) and showed a digestibility value of the same high order. There were no significant differences between the nitrogen balance values. Meal no. 35 showed the lowest value, the weight gain of the rats on this meal was significantly less than the mean gain for the other meals. Interpretation of these results is complicated by the fact that the production procedures differed also with respect to whether or not nitrite and/or formalin had been used as preservatives for the raw material. The two meals with the lowest digestibilities derived from raw material preserved with formalin and nitrite (no. 35) or with formalin (no. 37). Meal no. 35 also showed the lowest balance value and weight gain. The two meals with the highest digestibilities derived from unpreserved herring (no. 34) or from nitrite preserved herring (no. 36).

In Expt 11 were compared meals from a factory using production method H, one from unpreserved herring (no. 46) and one from nitrite preserved herring (no. 47) and corresponding meals dried in the laboratory. In Expt 12 were compared meals from a factory using production method C, one meal from unpreserved herring (no. 51) and one meal from formalin preserved herring (no. 50). In these experiments the difference between the meals from unpreserved and preserved raw material was insignificant as measured by the apparent digestibility as well as by the percentage nitrogen balance. The differences observed in Expt 10 thus seem to be due to the differences in the production process and not related to the preservatives.

In Expts 14 and 16 flame drying and steam drying were compared. Within each experiment the two meals tested were produced on the same day from the same batch of raw material. In Expt 14 methods E and F (meal nos. 56 and 57) and in Expt 16 methods H and I (meal nos. 80 and 81) were compared. The meals were not significantly different neither with respect to digestibility nor percentage nitrogen balance. Thus flame drying and steam drying under conditions which in other respects were as similar as possible, resulted in meals of about equal protein quality.

In Expt 19 two meals produced by method H in the same factory were compared. The meals were as far as possible identical except that 0.03% BHT was added to meal no. 88 before grinding whereas no addition was made to meal no. 87. Also included in the comparison was meal

Table 7. *Apparent digestibility (D_a), percentage nitrogen balance (Bal%) and calculated net protein utilization (NPU_c) in Expts 6—24.*

Expt no.	Meal[1] no., method, type	Nitrogen intake (mg)	D_a	Bal%	NPU_c	Body weight (g)	Weight gain g/5days
	7–A–Pc	126.6	77.2	37.4	60.8	78.3	6.2
6	15–L–Wm	126.8	78.6	37.9	61.2	77.7	6.0
	16–X–Fillets	126.6	84.0	49.0	73.0	80.7	8.0
	Egg-alb	127.1	81.4	62.2	86.6	83.7	9.8
	7–A–Pc	127.0	77.0	41.2	62.6	69.3	4.5
7a	"+1.25%methionine	127.2	77.4	54.7	76.5	71.3	6.8
	11–K–Wm	127.3	77.3	40.4	61.8	69.3	3.8
	"+1.25%methionine	127.0	76.5	51.7	73.4	70.7	6.3
	7–A–Pc	127.4	78.0	30.6	54.8	82.7	5.0
7b	"+2.5% methionine	127.5	76.5	45.4	70.1	85.8	8.0
	11–K–Wm	127.8	75.0	30.1	54.2	82.4	4.2
	"+2.5% methionine	127.1	75.7	45.9	70.3	83.7	7.7
	13–C–Wm	126.2	76.7	43.5	64.1	65.8	7.0
8a	24–Peru	128.7	68.7	46.9	67.6	67.6	6.5
	25–Denmark	134.2	80.6	60.7	80.8	78.8	8.5
	Egg-alb	119.7	81.5	64.8	87.9	71.5	10.0
	13–C–Wm	128.5	77.8	40.5	62.7	74.8	5.2
8b	24–Peru	123.6	71.3	41.1	64.6	76.2	7.6
	25–Denmark	128.2	80.8	53.8	76.9	78.5	7.8
	Egg-alb	127.4	82.0	61.1	85.1	81.8	6.9
	26–Angola	125.8	73.7	41.1	64.5	77.4	4.5
9	27–S.Afr.	125.6	71.7	35.5	58.8	76.7	2.7
	28–Holland	126.3	73.0	39.3	62.9	79.1	5.2
	Egg-alb	124.2	83.6	65.4	90.6	84.3	7.3
	34–G–Wm	125.0	81.6	38.9	61.4	73.3	6.0
10	35–C–Wm	125.1	78.8	33.6	55.9	72.6	3.5
	36–H–Wm	126.9	82.1	36.8	59.6	75.6	5.8
	37–K–Wm	125.4	78.6	35.6	58.5	75.0	5.7
	46–H–Wm	124.1	75.9	43.2	66.6	76.5	6.7
11	47–H–Wm	125.5	76.5	41.1	64.0	74.8	5.2
	48–Lab. Wm	127.0	78.1	44.2	67.0	76.0	6.3
	49–Lab. Wm	125.9	77.2	45.2	68.4	76.1	7.2
12	50–C–Wm	125.0	78.7	42.3	65.8	77.7	6.3
	51–C–Wm	123.8	78.4	38.9	62.8	78.7	7.7

[1] Meth. = Production method, see Table 2; Wm = whole meal; Pc = press cake meal; X = acetone dried.

Table 7. (*cont.*)

Expt no.	Meal[1] no., method, type	Nitrogen intake (mg)	D_a	Bal%	NPU_c	Body weight (g)	Weight gain g/5days
	52–K–Wm	127.4	75.7	39.0	60.7	71.7	6.2
13	53–H–Wm	125.4	77.7	37.3	59.5	72.5	5.0
	54–Sand-eel	124.0	77.1	46.5	69.5	74.2	6.0
	55–Sand-eel	126.6	72.0	37.8	59.0	68.2	6.4
	56–E–Wm	125.4	79.2	37.7	62.3	82.7	4.7
14	57–F–Wm	124.8	78.0	36.8	61.5	82.7	5.0
	58 Dry solubles ...	85.4	69.9	–11.2	20.7	69.9	–3.5
	Egg-alb.	122.3	81.9	60.4	87.5	90.8	7.7
	73–X–Raw milt ...	132.2	82.5*	6.7	28.3	74.3	–0.4
15	75–X–Cooked roe..	131.9	85.6	45.4	68.4	80.9	5.9
	76–X–Raw roe ...	131.9	83.2	42.8	66.0	81.7	5.8
	Egg-alb.	128.7	84.5	57.1	82.2	88.0	7.2
	80–H–Wm	126.4	84.3*	33.5	57.1	79.0	5.2
16	81–I–Wm	130.8	82.6	36.3	59.4	80.5	5.2
	82–B–Pc	124.4	83.6	39.8	63.9	79.5	4.8
	Egg-alb.	113.3	81.6	57.4	84.8	83.2	7.0
	70–Whale	119.8	61.8*	16.0	41.9	82.0	3.1
17	71–Whale	130.7	84.3	39.6	65.1	92.1	6.6
	81–I–Wm	127.8	80.9	41.6	67.2	89.6	7.3
	Egg-alb.	126.0	81.3	56.1	83.6	97.3	9.6
	77–X–Raw herring	122.4	82.4*	40.0	66.1	86.8	6.5
18	78–X–Cooked herring	124.8	80.5	40.7	66.4	87.6	6.3
	79–X–as 78–head & bone	126.0	82.4	43.4	69.4	89.5	7.4
	Egg-alb.	126.8	81.1	58.9	86.0	96.4	10.3
	87–H–Wm	125.0	79.5	39.3	62.9	77.5	8.1
19	88–H–Wm	127.8	80.0	42.3	64.9	76.0	7.9
	89–H–Wm	125.0	80.0	43.9	66.9	75.5	8.5
	Egg-alb.	124.2	83.8	66.5	91.3	82.6	10.5
	90–X–92	128.1	77.4	48.1	69.5	70.6	6.5
20	91–X–Cooked herring	124.6	83.6	51.9	74.1	71.0	6.6
	92–K–Wm	129.4	75.3	40.4	60.8	67.1	4.9
	Egg-alb.	119.4	84.8	63.6	87.6	74.7	10.1

[1] Meth. = Production method, see Table 2; Wm = whole meal; Pc = press cake meal; X = acetone dried.

Table 7. (*cont.*)

Expt no.	Meal[1] no., method, type	Nitrogen intake (mg)	D_a	Bal%	NPU_c	Body weight (g)	Weight gain g/5days
	81–I–Wm	125.7	83.3	48.6	70.6	71.7	8.0
21	95–Casein	124.0	83.5	47.8	69.7	69.9	6.0
	97–Squid	125.2	70.7	35.7	57.1	68.6	5.3
	Egg-alb.	120.3	85.8	67.0	91.6	78.2	11.3
	98–X–♂ herring ...	129.3	85.8	39.6	60.6	69.6	5.6
22	99–X–♀ herring....	129.0	83.8	50.0	71.2	70.2	7.3
	98+99 Mix	131.7	84.5	44.3	65.0	69.9	5.7
	Egg-alb.	121.5	82.8	63.6	86.9	73.7	10.1
	97–Squid	120.5	68.6	30.1	51.8	66.5	1.7
23	106–X–Squid	125.9	83.2	51.9	74.7	75.1	6.5
	Egg–alb.–1	125.2	84.9	68.0	91.6	78.3	8.3
	Egg–alb.–2	126.1	86.0	67.6	90.8	77.3	9.7
24	108 Off-fall meal ..	88.6	63.8	2.7	32.7	68.0	1.9
	109 —«— ..	96.2	70.3	12.0	40.3	69.6	3.7

[1] Meth. = Production method, see Table 2; Wm = whole meal; Pc = press cake meal; X = acetone dried.

no. 89 which was obtained by extraction of meal no. 88 with light petrol. There were no significant differences between the meals as measured by the apparent protein digestibility and by the percentage balance, although the tendency was that meal no. 89 was slightly better than meal no. 88 and the latter slightly better than meal no. 87. All the meals showed significantly lower values than spray dried egg albumin. Thus, the effect of added BHT and of removing most of the fat contained in the meal had but a small effect on the protein value.

In Expt 20 a meal produced by method K from nitrite preserved Iceland herring (no. 92) was compared with the same meal but extracted successively with ethyl-ether, ethyl-alcohol and acetone in the laboratory (no. 90), as well as with an acetone dried sample of the raw material (no. 91). Meal no. 90 was slightly, but significantly better digested than meal no. 92, meal no. 91 was significantly better digested than the mean of meal nos. 90 and 92, and meal no. 91 was equally well digested as spray dried egg albumin. Similar relations were found for the percentage protein balance. The fact that the acetone dried sample (no. 91) was of a high protein value suggested that there was no effect of nitrite on the protein value before production took place.

COMPARISON BETWEEN WHOLE MEAL AND PRESS CAKE MEAL

In Expts 2a and b the press cake meal (no. 2) showed a higher nitrogen balance that the whole meal (no. 1), whereas the digestibilities were approximately equal. In Expt 3 the press cake meal (no. 3) showed a higher nitrogen balance than the whole meal in the second experimental period when the daily food intake was kept at 10 g/rat but not in the first period when it was kept at 8 g/rat. The digestibility was significantly higher for the whole meal. In Expt 4 press cake meal no. 7 showed values for digestibility and nitrogen balance approximately equal to the mean value for the whole meals. In Expt 5 the digestibilities were again equal whereas for meal no. 7 the nitrogen balance was the highest observed among the five herring meals tested, although the range was very narrow. In Expt 6 there were no significant differences between the press cake meal (no. 7) and a whole meal (no. 15), and in Expts 7a and b the utilization of meal no. 7 was about equal to that of another whole meal (no. 11) without and with added methionine. In Expt 16 the press cake meal (no. 82) showed a higher percentage nitrogen balance than the mean of two whole meals (nos. 80 and 81), between which the difference was non-significant. The digestibilities, however, were not significantly different.

Thus, there was a tendency for press cake meals to show a higher percentage nitrogen balance than whole meals which was not due to a better digestibility of the former. The tendency was not consistent, but whole meals showing significantly better utilizations than press cake meals have not been encountered. The essential amino acid composition of whole meal is slightly inferior to that of press cake meal (BOGE, 1960) and this probably accounts for the tendency for the latter type to be better utilized.

COMPARISON BETWEEN OTHER COMMERCIAL CONCENTRATES

The other commercial protein concentrates tested were five foreign fish meals, two Norwegian sand-eel meals, two whale meals, one squid meal, casein and spray dried egg albumin (see p. 7). Spray dried egg albumin was included as a standard of reference in some of the experiments. (Expts 5, 6, 8a, 8b, 9, 14—23). It was better utilized than all the other protein sources tested as measured by the percentage nitrogen balance.

Four foreign fish meals (nos. 24, 26—28) showed digestibility values lower than those usually found for Norwegian herring meals (Expts 8a, 8b and 9), whereas no corresponding differences between the nitrogen balance values were observed. Thus, the protein utilization of the digest-

ible portion of the foreign meals was probably slightly better than for the herring meals. Meal no. 25 showed in repeated tests digestibility values as high as those observed for egg albumin and for the more digestible herring meals. The nitrogen balance values approached those observed for egg albumin and were significantly higher than the corresponding values for herring meal (Expts 8a and b). In fact, the Danish meal was apparently better utilized than acetone dried samples of herring (Expts 18, 20 and 22). Possible explanations for these observations may be the type of raw material used, the drying procedure or the meal being a press cake meal. These factors, alone or in combination, may have resulted in a meal with a good amino acid composition or with a better availability of the sulphur containing amino acids than generally found (MILLER, 1956; NJAA, 1961).

The two sand-eel meals tested in Expt 13 were significantly different both with respect to digestibility and nitrogen balance. The digestibility of meal no. 55 was also lower than that of the two herring meals (nos. 52 and 53) whereas the nitrogen balances were about equal. The digestibility of meal no. 54 was about equal to that of the herring-meals, but in this case the sand-eel meal showed higher nitrogen balance. Thus, the difference between the sand-eel meals seems to be both in the digestibility and in the utilization of the digestible portion. The better utilization of meal no. 54 than of no. 55 may be explained by the former being a press cake meal (p. 18).

The two whale meals tested in Expt 17 were of very different biological quality. Meal no. 70 showed a low percentage nitrogen balance as compared with the flash dried meal (no. 71). This difference was almost entirely due to a low digestibility of the former, thus indicating that the utilization of the digestible portions of the meals were about equal. The better meal (no. 71) showed about the same nitrogen balance as Norwegian herring meal (no. 81), but the digestibility of the whale meal was better than that of the herring meal. Thus, the utilization of the digestible portion was probably slightly better in the latter. The results in Expt 21 show that commercial rennet casein was about equally digested and utilized as herring meal no. 81, whereas a commercial squid meal tested in the same experiment was of inferior quality as compared with both. This was entirely due to a poorer digestibility. The low digestibility was confirmed in Expt 23 in which it was shown that acetone dried squid gave utilization values at least as high as those usually found for commercial herring meals.

The two commercial off-fall meals tested in Expt 24 showed low utilization values. This may be a result of the raw material used or it may be a consequence of the high content of residual fat (Table 3).

EXPERIMENTS WITH ACETONE DRIED SAMPLES

Acetone dried whole herring both raw (no. 77) and cooked (no. 78) gave results for digestibilities and percentage nitrogen balances of about the same magnitude as commercial herring meals tested at about the same time (compare Expt 18 with Expts 16, 17 and 19). When the head and backbone were removed from cooked herring (no. 79) the nitrogen balance was slightly higher. Similar results as those obtained in Expt 18 was obtained with acetone dried whole herrings in Expt 22. The sample made from female herrings (no. 99) showed a slightly poorer digestibility and a decidedly better percentage nitrogen balance than the sample made from male herrings (no. 98). A 1:1 mixture of these samples gave intermediate values for both digestibility and nitrogen balance. These results indicated no supplementary effect between the two protein sources. The winter herring used contained about 19 and 17% by weight of roe or milt respectively. The acetone dried samples of herring roe showed high values both for digestibility and nitrogen balance (nos. 75 and 76) whereas acetone dried herring milt showed good digestibility but very low nitrogen balance (Expt 15). This may be explained by the known differences in the amino acid composition of roe and milt (DEAS & TARR, 1949).

Acetone dried whole herring (no. 91) was also compared with a commercial meal (no. 92) and with the latter extracted with acetone (no. 90), all three samples were from the same batch of sodium nitrite preserved herring which had been transported from Iceland to a Norwegian factory (Expt 20). The acetone dried whole herring showed a better digestibility than the two other meals. Acetone extraction seemed to improve the digestibility and the nitrogen balance value of the commercial meal. The main effect was due to the differences in digestibilities. Thus, in contrast to Expt 18 where extraction with light petrol was without effect on the protein quality of a commercial meal, acetone extraction of meal 92 in Expt 20 markedly improved the protein utilization.

Acetone dried herring fillets were tested in Expt 0 and 6. In the first of these experiments no comparison was made, whereas in Expt 6 the acetone dried sample of herring fillets (no. 16) was compared with two commercial herring meals. The better nitrogen balance of the acetone dried sample seemed to be due partly to a better utilization of the absorbed portion.

THE RELATIONSHIP BETWEEN THE CALCIUM AND PANTOTHENIC ACID CONTENTS OF HERRING MEALS

By a scrutiny of the analyses available for the herring meals tested in these experiments and those described in the following publication, the only obvious interrelationship seemed to be between the contents

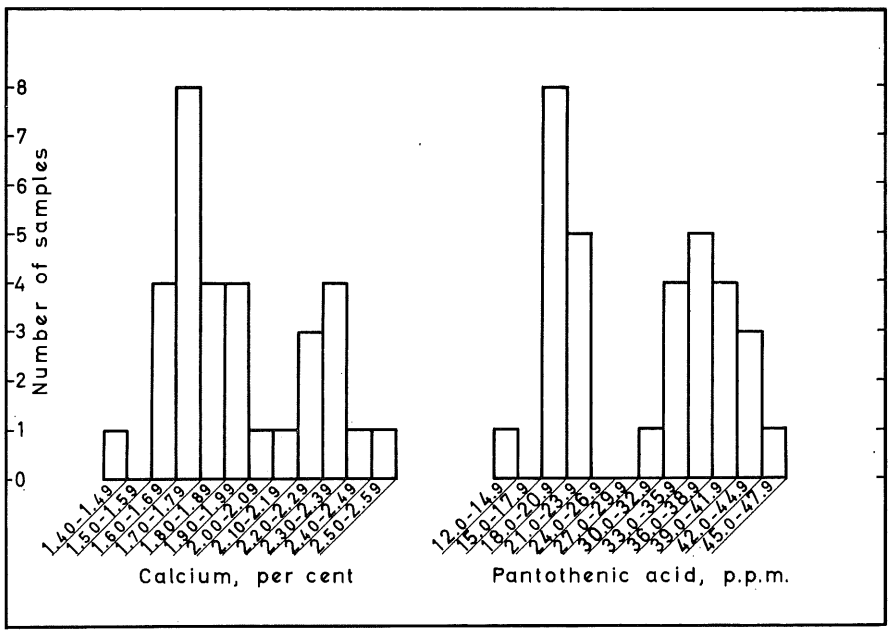

Fig. 1. Frequency distribution of calcium and pantothenic acid values in 32 herring meals.

of Ca and pantothenic acid. For 32 corresponding values a correlation coefficient of —0.62 was found. When the meals 11, 37 and 52 were omitted a correlation coefficient of —0.72 was obtained. These meals were produced in factories where the concentration of the solubles was known to cause destruction of pantothenic acid.

The reason for this relationship was thought to be that the calcium values would be a measure of the press cake contents of the meals and the pantothenic acid values a measure of the solubles contents. The latter relationship would be true if there was no great loss of pantothenic acid during the production process.

A closer scrutiny of the results, however, showed the distribution of both Ca and pantothenic acid to be bimodal. No values were found for pantothenic acid in the range 24—30 p.p.m, and for Ca only two values were found between 2.0 and 2.2% (Fig. 1). No explanation is suggested for this observation. However, it renders a judgement of the "wholeness" of the herring meal by these analytical criteria rather doubtful.

THE NET PROTEIN UTILIZATION OF MARINE PROTEIN CONCENTRATES

In a few cases net protein utilization was estimated conventionally (NJAA 1959a and b) but in most cases it was calculated from the percentage nitrogen balances on the assumption that the daily maintenance

requirement of protein is equivalent to 190 mg N per kg body weight taken to the power of 0.73 (NJAA 1965). The estimated NPU values for press cake meals and whole meals given in Table 5 were within the ranges 65—73 and 58—69, respectively. The corresponding calculated ranges were 61—69 and 58—69. Most of the calculated NPU values for whole meal in Table 7 were also within the latter range. The net protein utilization (NPU) calculated for spray dried egg albumin ranged from 82—92 (Table 7). The differences found within the same experiment between NPU for egg albumin and whole meal ranged from 17.4 to 28.4 with a mean value of 24.5. Thus, if the net protein utilization of egg albumin protein is arbitrarily put at 100, the value of whole herring meal relative to this standard would be about 75, which is in good agreement with literature data (SURE & EASTERLING 1952). Judging the acetone dried samples on the same relative basis, the NPU would be: Herring fillets (no. 16) about 86 (Expt 6). Whole herring raw, cooked and cooked without head and backbone about 80, 80 and 83, respectively (Expt 18). Herring males, females and a 1:1 mixture of these, about 74, 84 and 78, respectively (Expt 22). Raw herring milt, raw and cooked herring roe about 46, 84 and 86, respectively (Expt 15). Similarly, the value for the foreign fish meals would score: Peru 80 and 80, Denmark 93 and 92 (Expts 8a and b) Angola 74, S. Africa 68 and Holland 72 (Expt 9), and the whale meals about 58 and 82 (Expt 17).

GENERAL DISCUSSION

The results obtained with commercial herring meals showed that the various reduction processes rendered products of uniform protein value. Similar findings were reported by HOMB (1962) and by French workers studying Norwegian herring meal (RERAT & LOUGNON, 1963). This is in agreement with the conclusion of MILLER, CARPENTER & MILNER (1965) that "ordinary commercial drying causes very little damage to the protein in fish meal". Our findings were also in agreement with the conclusion that severe drying conditions may rather cause decreased digestibility than destruction of essential amino acids (ANON. 1953a). Literature data indicate, however, that the biological availability of fish meal protein may vary considerable even when the meals are from the same type of raw material (BENDER & HAIZELDEN, 1957; BOYNE, CARPENTER & WOODHAM, 1961; BUNYAN & WOODHAM, 1964; BARBER, BRAUDE, CHAMBERLAIN, HOSKING & MITCHELL, 1964). If comparison between our results and those of BENDER & HAIZELDEN (1957) and BOYNE *et. al* (1961) is permissible, the Norwegian herring meals tested all fall in the upper part of the ranges given. There are indications that

Table 8. *Comparison of protein digestibilities determined with pepsin-hydrochloric acid*[1] *and in rat tests.*

Meal no.	Pepsin	Rat	Expt no.	Meal no.	Pepsin	Rat	Expt no.
5	95	82	4	70	92	62	17
6	98	84	«	71	99	84	«
7	94	81	«				
8	95	81	«	80	97	84	16
9	92	82	«	81	96	83	«
10	93	80	«	82	96	84	«
11	93	78	«				
12	92	79	«	90	97	77	20
13	97	76	«	91	99	83	«
14	94	83	«	92	96	75	«
46	96	76	11	97	94	68	23
48	98	78	«	106	98	83	«

[1] The values for pepsin-hydrochloric acid digestibility were obtained through the courtesy of J. Jebsen (unpublished data).

the small differences observed between herring meals may be due to different production methods, but it has not been possible to point out which method is preferable. Under the conditions employed, the addition of sodium nitrite, formaline or both preservatives to the raw material did not have had any significant effect on the protein value of the meals. In agreement with the finding of HOMB (1962) working with pigs, press cake meal was slightly better utilized than whole meal. Of the other commercial protein concentrates, one of the whale meals, a squid meal, spray dried herring solubles and two off-fall meals were of decidedly poorer quality than the herring meals. One whale meal, four foreign fish meals and casein were of about the same quality as the herring meals, whereas a Danish fish meal and spray dried egg albumin were of decidedly better quality than the herring meals. The outstanding high quality of the Danish meal is difficult to explain, because it is better than the most carefully produced acetone dried samples. Likewise, no commercial sample of outstanding protein quality was reported by BENDER & HAIZELDEN (1957), who tested fish meals from several countries. One possible explanation could be that the meal had been fortified with methionine, but nothing is known on this point.

It was mentioned that in most cases differences in protein quality were mainly due to differences in protein digestibility. It is of interest whether such differences may by detected by data on pepsin digestibility. Some of the meals tested in these experiments were analyzed for pepsin digestibility (JEBSEN, unpublished data). The results are presented in

Table 8. It may be noted that the pepsin digestibility test failed to detect pronounced differences observed between some of the meals in the rat test. (Expts 17, 20 and 23).

Several studies report poor quality for some fish meals, but so far the factors responsible for this impaired utilization have not been detected. LAKSESVELA & AGA (1965) pointed out that the age of the meals may be of importance, but it may be assumed that extremely old meals will not be commercially available. Poor quality fish meals have been produced in the laboratory by heating them for many hours (MILLER, 1956; MILLER *et al.* 1965). The reduction in protein quality was greater then could be expected from the amino acid analyses of heated and unheated meal (MILLER, HARTLEY & THOMAS, 1965). Similar observations were made on two commercial anchovy meals of different biological value (BUNYAN & WOODHAM 1964). Further studies on the effect of the production method on the nutritive value of herring meal and other marine protein concentrates should aim at measurement of the biological availability of the amino acids. Methods for such measurement require a great capacity for amino acid determinations independent of whether the method is based on chemical criteria or on analyses of amino acids in blood plasma or in intestinal contents above the cæcum.

SUMMARY

Protein concentrates, mainly of marine origin, were tested in nitrogen balance experiments with young rats.

Commercial herring meals produced by several methods showed only small differences in protein utilization values. In most cases when differences in nitrogen balance values were found they were mainly due to corresponding differences in the protein digestibility.

Press cake meals were slightly better utilized than whole meals, this difference was not accounted for by a corresponding difference in digestibility.

Steam drying did not produce meals of better protein value than flame drying.

No effect on the protein quality of herring meals was found of the preservatives sodium nitrite or formalin used during the storage of the raw material.

Extraction of a whole meal with light petrol did not improve the protein quality wheras extraction of another whole meal with ethyl alcohol, ethyl ether and acetone improved the quality.

Four foreign fish meals were of about the same protein value as Norwegian herring meal, whereas one was decidedly better.

A sand-eel press cake meal was better than a whole meal produced from this raw material. The whole meal was of about the same protein quality as the herring meals.

A flash dried whale meat meal was of about equal protein value as herring meals, but decidedly better than a slowly dried whale meal.

A squid meal, a spray dried herring solubles meal and two fish off-fall meals were of decidedly poorer protein quality than the herring meals.

Rennet casein was of about the same protein value as the herring meals, whereas the reference protein source, spray dried egg albumin, was better than all the other protein sources tested.

Acetone dried samples of herring fillets and whole herring were of moderately better protein value than commercial herring meals.

Acetone dried male herring was of poorer protein value than a corresponding sample of female herring.

Acetone dried herring roe was of good protein value whereas the corresponding sample of herring milt was of poor protein value.

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