Rate of Abomasum Emptying in Kids Fed on Fish Proteins Subjected to Heat Treatment Under Different Conditions

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Seven groups of kids were fed on isonitrogenous diets identical in all respects, except in the nature of the protein. Proteins in all test diets were derived from fish subjected to heat treatment under different conditions. Control group had skim milk as the sole source of protein. 5 test groups had their proteins from muscle of the lean fish whiting, heat processed under different conditions. The seventh group had a spray dried and solvent extracted functional fish protein concentrate prepared from the fatty fish capelin as the sole source of protein. The effect of the mode and extent of thermal denaturation of fish protein on the rate of abomasum emptying in kids was studied using these diets with a view to check the possibility that increased thermal denaturation causes lesser coagulation of the protein in the abomasum resulting in reduced digestibility. Results however, indicate that in kids, the extent of thermal denaturation of the protein in the diet cannot be directly correlated to the rate of abomasal emptying. Results are discussed in the light of earlier reported differences in protein digestibility between these diets in calves.

Heat denaturation of fish muscle proteins during fish meal manufacture is known to decrease the digestibility of proteins in young calves (Opstvedt & Sobstad, 1975). The mode and extent of heating determine the extent of heat damage and consequently the loss in nutritive value. Thus raw lean fish muscle, when homogenised in water is a very good feed, of high nutritional value to young calves. Heating the fish muscle in an aquous medium at 55°C for 30 minutes did not reduce the nutritive value while heating at 95°C for 30 minutes caused a substantial reduction in the digestibility. A comparison of the nutritive value of three different types of fish protein concentrates also revealed interesting differences. An ordinary steam-dried fish protein concentrate had a much lower digestibility compared to a spray dried FFPC prepared from the same lean blue whiting. But spray dried FFPC prepared from a fatty fish had the lowest digestibility (unpublished results).

One possible reason for these differences in protein quality was thought to be differences in the time of retention in the abomasum. Thus more severely heated proteins may be coagulated to a lesser extent in the abomasum, leading to an increased outflow of partially digested protein to the intestines, causing intestinal irritation and diarrhea.

This effect has been reported by several workers. Tagari & Roy (1969) noticed decreased secretion of HCl in the abomasum of calves when the proteins in milk were heat denaturated. This resulted in lesser coagulation and increased outflow of undigested protein from the abomasum. Ternouth *et al.* (1974) observed that in the case of a severely heated skim milk diet, the undigested protein flowing through the duodenum of calves was higher during the first 6 hours after feeding compared to diets heated to a lesser extent. According to the same authors severely preheated skim milk containing 20 g fat/litre took longer time to leave the abomasum compared to a mildly preheated sample. Newport (1979) suggested that total replacement of skim milk powder with fish protein concentrates in diets of piglets may increase the rate of flow of digesta from the stomach reducing the protein digestibility. Differences in the rate of passage through the abomasum, depending on the nature of the protein source in the diet, were reported by Frantzen *et al.* (1979). Gaudreau & Brisson (1980) attributed such differences mainly to differences in the solubility of the proteins. In view of these observations, it was felt desirable to study the influence of heat treatment of fish proteins on their time of retention in the abomasum of young ruminants.

Materials and Methods

Experimental design and diets

The experiment was conducted using kids, in which the rumen was not developed. They were studied in 7 groups, all fed on isonitrogenous diets of similar composition, differing only in the protein source. For the control group (Group I) dried milk was used as the sole protein source. The other six groups had the following fish protein concentrates as the sole source of protein.

Group II: Eviscerated and decapitated raw blue whiting minced and suspended in water and thoroughly homogenised.

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Group III: As II but heated at 55°C for 30 minutes and then homogenised.

Group IV: As II but heated at 95°C for 30 minutes and then homogenised.

These suspensions, were frozen after homogenisation and stored at 20°C until use.

Group V: A spray dried functional fish protein concentrate (FFPC) (Opstvedt & Sobstad, 1975) prepared from blue whiting.

Group VI: FFPC prepared as in V, but usnig the fatty fish capelin. This product was defatted by extraction with hexane after drying.

Group VII. A commercial steam dried fish meal prepared from blue whiting by the conventional method used by the fish meal industry. A spray dried lactose-cream mixture (36.16% fat) was used as the source of fat in all cases (Opstvedt *et al.*, 1978). The final diets were in all cases adjusted to have the following composition: protein 23%, fat 21.5% and lactose 40%. Adequate amounts of vitamins and essential minerals were added and the diets were balanced with glucose. Composition of the diets are given in Table 1. In the case of the milk diet, dry skim milk and cream was mixed and spray dried and the dry mixture used to provide the desired level of fat.

Kids and management

Kids less than one week old were procured from the breeders and were airectly placed in metabolism cages. They were fed on the respective milk replacer diets reconstituted in water. The dry matter content of the diets was adjusted to be 8% on the first day and was raised by 1% every day thereafter till the 6th day when the dry matter content of the diets reached 13%. Feeding was done twice a day, once in the morning and once in the evening. Total daily intake of liquid feed was adjusted so as to be 10% of the body weights of the kids. The kids were generally well adapted to the feed within the period of 5 days. They were killed on the sixth day, at definite time intervals after feeding, by intravenous injection of sodium barbital. The abdomen was carefully opened, and both ends of the abomasum were tightly clipped to prevent leakage before it was removed and the contents carefully and quantitatively emptied into weighed plastic trays. The pH of the abomasal contents were measured before freeze drying. The freeze dried material was analysed for dry matter, protein and ash to measure the amount of dry matter and protein retained in the abomasum after each time interval. The kids were slaughtered at time intervals of 1,2,4,6 and 8 h after feeding. In all cases 2 kids were used for each time interval. When the sampling was unsucccessful additional kids were used to ensure reliable results.

Table 1. *Composition (%) of diets*

	Milk	Raw	Fish 55°C	95°C	FFPC** blue whiting	Capelin	Fish meal (blue whiting)
Dried skim milk-cream mixture	72.20	—	—	—	—	—	
Dried skim milk	10.60	—	—	—	—	—	
Lactose	5.50	6.843	6.848	6.850	6.848	6.848	8.848
Vitamins & minerals	10.84	0.860	0.860	0.860	0.860	0.860	0.860
Glucose	0.86	13.432	13.122	13.480	12.992	11.767	11.767
Fish suspension/FFPC		24.270	24.580	24.220	24.710	25.935	25.935
Lactose-cream mixture*		54.590	54.590	54.590	54.590	54.590	54.590
Protein%	23.0	23.02	23.02	23.02	23.02	23.02	23.02
	(23.93)	(24.35)	(26.04)	(25)	(25.93)	(23.51)	(20.77)
Fat (Chloroform—methanol)	20.0	21.56	21.58	21.55	21.58	21.89	21.45
	(19.97)	(20.56)	(18.95)	(21.58)	(22.48)	(22.36)	(22.14)
Ash%	5.4	2.69	2.05	1.67	2.74	2.93	3.99
		(2.90)	(2.30)	(2.0)	(3.2)	(2.8)	(5.5)
Lactose%	40.0	40.0	40.0	40.0	40.0	40.0	40.0

*Provide per kg of dry feed: vtamin A, 10,000 I.U., vitamin D, 1,000 I. U., vitamin E, 100 I.U., nicotinic acid 6 mg; Ca pantothenate 40 mg; riboflavin 15 mg; pyridoxin 15 mg; thiamine 150 mg, folic acid 1 mg; biotin 0.2 mg; vitamin B_{12} 0.15 mg; choline-Cl 3900 mg; MgO 1000 mg and Zn-bactitracin 80 mg

**Functional fish protein concentrate

Values in parenthesis–Analysed values.

Table 2. *Abomasal retention (% of intake) of dry matter, at various time intervals after feeding, in kids fed different fish samples, in comparison with milk*

			Fish*			FFPC**		
Hours after feeding	Replicates	Milk	Raw	55°C	95°C	Blue whiting	Capelin	Fish meal (blue whiting)
1	1	81.3	93.8	100.8	83.0	92.3	92.7	76.2
	2	73.4	85.1	89.9	84.6	98.2		95.7
	Average	77.3	89.4	95.3	83.8	95.8		86.0
2	1	76.1	69.4	64.1	77.1	86.1	91.7	86.5
	2	73.1	71.0	68.2	79.0	67.3	72.0	67.2
	Average	74.6	70.3	66.2	78.0	76.7	81.9	76.8
4	1	45.1	32.8	75.9	83.9	83.8	53.3	49.9
	2	48.9	53.2	36.7	49.0	67.9	56.2	41.2
	Average	47.0	43.0			60.6	53.0	
6	1	29.8	30.9	39.3	44.2	21.6	31.4	18.8
	2	32.3	60.4	40.5	50.7	27.0	23.7	39.6
	Average	31.1		39.9	47.5	24.3	27.5	
8	1	11.9	13.7	22.7	50.7	29.6	11.0	46.9
	2	18.6		27.8	33.0	7.8	57.5	17.5
	Average	15.3		25.2	41.8			

*Heated in an aquous medium
**Functional fish protein concentrate (Opstvedt & Sobstad, 1975)

Table 3. *Abomasal retention (% of intake) of nitrogen at various time intervals after feeding in kids fed different fish samples, in comparison with milk*

			Fish			FFPC*		
Hours after feeding	Replicates	Milk	Raw	55°C	95°C	Blue whiting	Capelin	Fish meal (blue whiting)
1	1	97.5	(107.0)	(110.6)	91.7	89.9	(106.4)	83.4
	2	86.9	91.2	95.2	89.9			(114.3)
	Average	92.2			90.8			
2	1	92.9	69.8	61.4	82.5	91.3	(107.4)	(104.4)
	2	86.9	73.2	73.5	79.5	68.9	88.9	93.6
	Average	89.9	71.5	67.5	81.0			
4	1	66.7	33.7	88.4	91.7	54.2	56.9	92.7
	2	71.6	60.1	38.7	51.0	69.3	66.3	57.7
	Average	69.2				61.8	61.6	
6	1	48.8	35.7	38.9	45.1	21.8	34.2	27.2
	2	48.0	67.7	50.1	86.7	28.6	33.3	85.9
	Average	48.4		44.5		25.2	33.8	
8	1	21.6	18.2	34.0	41.4	30.7	18.1	80.2
	2	27.4		31.7	7.1	6.7	83.5	24.4
	Average	24.5		32.8				

*Functional fish protein concentrate (Opstvedt & Sobstad, 1975)

Analytical methods

Total nitrogen and dry matter (DM) were determined by the method of A. O. A. C. (1960). The nonprotein nitrogen of the freeze dried stomach contents, was determined quantitatively in a 1 g sample as the nitrogen not precipitated by 10% TCA. This measurement was supposed to give an idea of the extent of protein digestoin in the abomasum.

Results and Discussion

The retention of DM (as per cent of intake) in the abomasum at different time intervals after feeding, in the kids fed the different diets, are shown in Table 2. Figs. 1A, 2A, 3A, 4A, 5A, 6A and 7A show abomasal DM retention graphically. The regressions between abomasal DM retention and time are shown in Table 7. The replicate determinations in the kids fed milk were fairly consistant showing a straight line relationship between DM retention and time. Thus ingested DM in the milk diet left the abomasum at a rate of 9.3% per hour. The replicate determinat-ions of abomasal DM retention were much more variable and less consistant in the kids fed the different fish diets than in those fed the milk diet. Due to this variability it is not possible to draw firm conclusions, but the indications are that there were no differences between the milk diet and the different fish-based diets with regard to abomasal DM retention. This conclusion is supported by the fact that despite the numerical differences in the regression coefficients for abomosal DM retention vs. time for the different diets (Table 7), these difference were insignificant.

Abomasal nitrogen retention is shown in Table 3 and Figs. 1B, 2B, 3B, 4B, 5B, 6B and 7B and the regressions between abomasal nitrogen retention and time in Table 8. The results parallelled those for DM. The

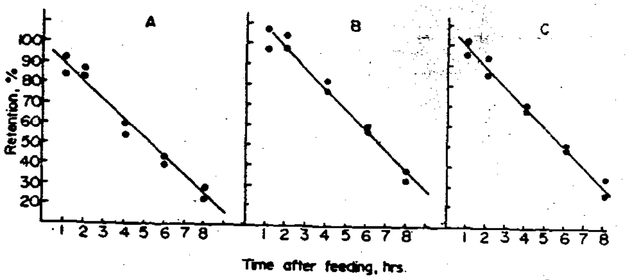

Fig. 1. Abomasal retention (% of intake) of D M (A), nitrogen (B) and TCA precipitable nitrogen (C) in kids fed with protein.

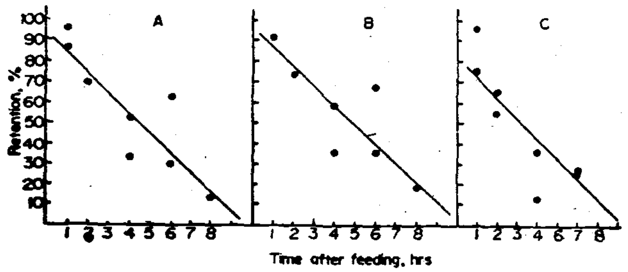

Fig. 2. Abomasal retention (% of intake) of DM (A), nitrogen (B) and TCA precipitable nitrogen (C) in kids fed raw fish.

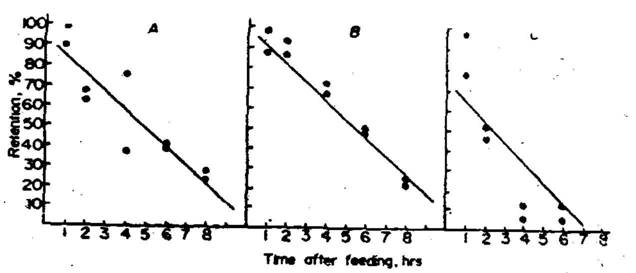

Fig. 3. Abomasal retention (% of intake) of DM (A), nitrogen (B) and TCA precipitable nitrogen (C) in kids fed fish protein heated to 55°C.

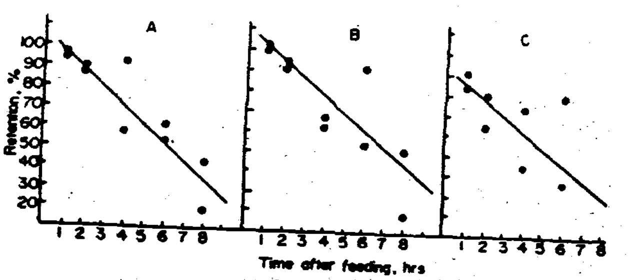

Fig. 4. Abomasal retention (% of intake) of DM (A), nitrogen (B) and TCA precipitable nitrogen (C) in kids fed with protein heated to 95°C.

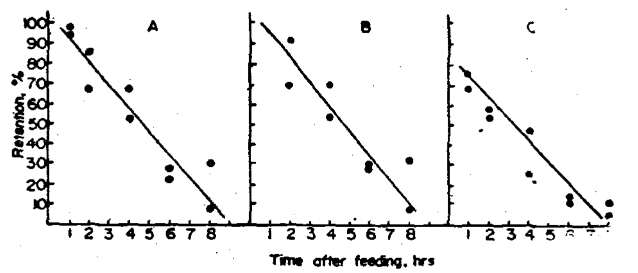

Fig. 5. Abomasal retention (% of intake) of DM (A), nitrogen (B) and TCA precipitable nitrogen (C) in kids fed FFPC (product 305) from blue whiting.

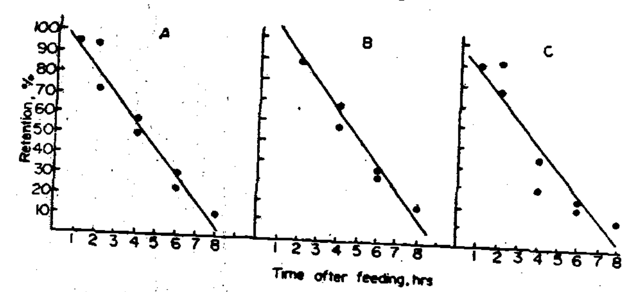

Fig. 6. Abomasal retention (% of intake) of DM (A), nitrogen (B) and TCA precipitable nitrogen (C) in kids fed FFPC (product 305) from capelin.

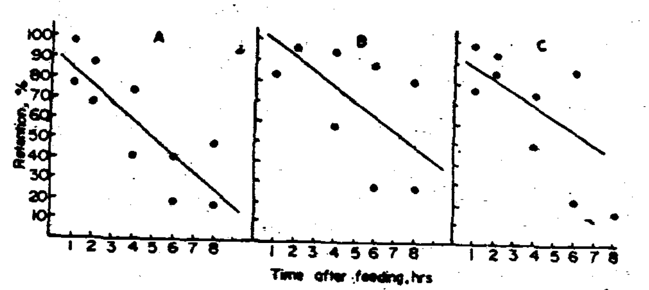

Fig. 7. Abomasal retention (% of intake) of DM (A), nitrogen (B) and TCA precipitable nitrogen (C) in kids fed conventional fish feed from blue whiting.

Table 4. *TCA precipitable nitrogen (% of intake) in the abomasum at different time intervals after feeding in kids fed different fish samples in comparison with milk*

Hours after feeding	Repli-cates	Milk	Fish: Raw	Fish: 55°C	Fish: 95°C	FFPC: Blue whiting	FFPC: Capelin	FFPC: Fish meal (bluew hiting)
1	1	91.4	93.6	96.4	81.9	68.3	89.1	76.9
	2	85.0	74.9	77.9	75.1			100.3
	Average	88.2	84.3	87.2	78.5			
2	1	75.7	54.0	46.0	70.5	64.0	92.0	94.7
	2	84.1	65.4	50.7	55.0	57.1	77.5	84.6
	Average	79.9	59.7	48.4	62.8	55.6	84.8	88.7
4	1	59.9	13.8	11.9	65.2	25.7	29.8	74.2
	2	58.3	35.8	6.4	34.9	46.7	45.0	49.6
	Average	59.1		9.7			37.4	
6	1	41.6	24.4	7.3	25.8	10.9	20.9	22.2
	2	39.7	25.9	12.8	71.1	13.7	23.1	88.7
	Average	40.7	25.2	10.1		12.3	22.0	
8	1	16.9	14.7	9.5	23.0	10.9	15.5	77.2
	2	25.6		8.9	6.5	6.5	50.8	16.3
	Average	21.3		9.2	14.8	8.7		

Table 5. *TCA non-precipitable nitrogen (% of total nitrogen) in the abomasum at different time intervals after feeding in calves fed different fish samples in comparison with milk*

Hours after feedng	Repli-cates	Milk	Fish: Raw	Fish: 55°C	Fish: 95°C	FFPC: Blue whiting	FFPC: Capelin	FFPC: Fish meal (blue whiting)
1	Diet	10.6	12.5	21.8	12.1	20.2	13.9	18.1
	1	16.7	22.4	26.7	21.5	36.5	27.9	24.4
	2	13.3	28.2	33.7	26.6	26.8		28.0
	Average	15.0	25.3	30.2	24.1	31.6		28.2
2	1	27.2	33.8	41.5	24.9	50.7	26.2	27.3
	2	18.3	23.0	46.1	37.7	34.0	24.3	25.9
	Average	22.8	28.4	43.8	31.3	42.3	25.3	26.6
4	1	20.0	63.4	44.2	37.5	60.4	54.9	34.4
	2	18.2	47.9	53.9	40.0	46.2	41.5	29.5
	Average	19.1	55.7	49.1	38.7	53.3	48.2	31.5
6	1	24.1	41.3	63.1	49.6	58.2	47.6	33.1
	2	23.7	66.5	58.0	27.8	59.9	40.2	15.3
	Average	23.9	53.9	60.6	38.7	59.1	43.9	24.2
8	1	30.0	48.4	45.3	50.9	70.3	26.0	21.6
	2	16.4		52.3	20.5	22.5	47.6	45.3
	Average	23.2		48.0				

nitrogen in the milk diet left the abomasum at a rate of 9.9% per hour. No significant differences were found between the milk diet and the different fish diets with regard to the regression coefficients for abomasal nitrogen retention vs. time (Table 8), but the vaiiabilities in the fish diets were large.

The retention of TCA precpitable nitrogen in the abomasum is shown in Table 4 and Figs. 1C, 2C, 3C, 4C, 5C, 6C and 7C and the regression between abomasal TCA precipitable nitrogen and time in Table 9. The results were similar to those for total nitrogen. Despite the fact that the differences in the numerical values

Table 6. *pH of abomasal contents at different time intervals after feeding in calves fed different fish samples in comparison with milk*

Hours after feeding	Replicates	Milk	Fish Raw	Fish 55°C	Fish 95°C	FFPC Blue whiting	FFPC Capelin	Fish meal (blue whiting)
1	Diet	6.8	7.6	7.6	7.8	7.0	7.3	7.2
	1	6.8	7.6	6.5	6.1	6.4	6.0	6.1
	2	5.7	6.4	6.2	5.6	6.6		4.9
	Average	6.3	7.0	6.3	5.9	6.5		5.5
2	1	5.5	5.0	6.0	5.1	5.1	6.1	5.2
	2	6.4	5.9	5.0	5.4	6.1	5.3	5.1
	Average	6.0	5.5	5.5	5.3	5.6	5.7	5.2
4	1	4.1	4.2	5.3	5.8	5.0	5.0	5.1
	2	5.1	4.7	4.5	3.8	5.0	3.8	5.6
	Average	4.6	4.5	4.9	4.8	5.0	4.4	5.4
6	1	5.3	6.3	6.2	5.8	6.1	5.5	5.9
	2	6.6	4.1	4.1	5.4	4.3	3.9	5.7
	Average	6.0	5.2	5.2	5.2	5.6	4.7	5.8
8	1	5.2	6.4	6.1	6.1	5.1	5.9	5.2
	2	6.7		5.1	6.8	7.1	3.6	6.3
	Average	6.0		5.6	6.5	6.1	4.8	5.8

Table 7. *Regression between abomasal content of DM (% of intake) and time after feeding in kids fed different fish samples in comparison with milk*

Sample	Regression equation	sb*	r**
Milk	Y = 88.106 − 9.311x	0.540	−0.987
Fish raw	Y = 92.224 − 9.141x	2.011	−0.871
55°C	Y = 93.939 − 8.890x	1.549	−0.897
95°C	Y = 96.104 − 8.787x	1.429	−0.908
FFPC (blue whiting)	Y = 102.235 − 11.223x	1.339	−0.948
FFPC (capelin)	Y = 104.759 − 12.396x	1.135	−0.976
Fish meal	Y = 92.192 − 8.546x	1.955	−0.840

* Standard error of regression coefficient

** Coefficient of correlation

of the regression coefficients for the retention of abomasal precipitable nitrogen vs. time were large, they were not significantly different due to the large variation between the parallel determinations in the kids fed the various fish diets.

The content of TCA non precipitable nitrogen as a percentage of total nitrogen in the abomasal content is shown in Table 5. On the milk diet the content of non precipitable nitrogen increased from about 15% one hour after feeding to about 20% at two hours after feeding and remained thereafter relatively constant. The contents of non precipitable nitrogen was generally higher in the abomasum of fish-fed compared with milk-fed kids. There were no consistant differences between the different fish-fed groups.

The pH of the abomasal contents is shown in Table 6. pH decreased till 4 h after feeding and increased somewhat thereafter till 8 h after feeding. There were no conistant differences between the various diets with regard to abomasal pH.

The inconsistant nature of the data obtained from the kids fed the fish diets limits the possibility of drawing conclusions with regard to the abomasal digestion of the different proteins. Since the same degree of variability was not seen in the milk-fed kids, and since parallel kids giving different results apparently were normal and healthy in both cases it is possible that this variability is an inherent characteristic of fish proteins in young ruminants. Also for protein digestibility fish has higher variability than milk, in young calves (unpublished results). It is possible that the variability was

Table 8. *Regression between abomasal content of nitrogen (% of intake) and time after feeding in kids fed different fish samples in comparison with milk*

Sample	Regression equation	Sb*	r**
Milk	Y = 106.937 – 9.850x	0.605	–0.986
Fish raw	Y = 98.185 – 9.607x	2.348	–0.840
55°C	Y = 100.113 – 9.003x	1.892	–0.860
95°C	Y = 101.988 – 8.378x	5.745	–0.777
FFPC (blue whiting)	Y = 111.343 – 12.415x	1.785	–0.926
FFPC (capelin)	Y = 121.050 – 13.892x	1.245	–0.977
Fish meal	Y = 106.876 – 7.280x	3.073	–0.642

* Standard error of regression coefficient

** Coefficient of correlation

Table 9. *Regression between abomasal content of TCA precipitable nitrogen (% of intake) and time after feeding in kids fed different fish samples in comparison with milk*

Sample	Regression equation	sb*	r**
Milk	Y= 98.094 – 9.570x	0.434	–0.992
Fish raw	Y= 82.519 – 9.997x	2.129	–0.872
55°C	Y= 75.669 – 10.207x	2.390	–0.834
95°C	Y= 83.862 – 7.848x	2.047	–0.805
FFPC (Blue whiting)	Y= 87.395 – 11.213x	1.713	–0.918
FFPC (capelin)	Y=100.073 – 12.381x	1.980	–0.931
Fish meal	Y= 95.806 – 6.549x	1.058	–0.604

* Standard error of coefficient of regression

** Coefficient of correlation

due to different degrees of physiological development of the kids.

There is no indication in the data that the passage rate of the digesta through the abomasum was significantly different for milk-based and fish-based diets, some fish-fed kids having higher and some lower passage rates than the milk-fed kids. These results do not agree with some previous studies using duodenal cannulated calves (Ternouth *et al.*, 1974) in which fish meal-based diets had higher passage rate than milk-based diets.

Although variable, there was a tendency that the content of TCA-precipitable nitrogen decreased faster in the fish-fed compared with the milk-fed kids. This would indicate that the pepsin digestion of the fish protein was rather effective. However, no clear differences were observed in pepsin digestibilities of the different fish samples. The only consistant difference between the milk-based and the fish-based diets was in the abomasal contents of TCA non precipitable nitrogen which generally was higher in the fish-based than in the milk-based diets. It, there fore, appears that degraded fish protein brought into solution in the abomasum is not despatched from the abomasum as qiuckly as solubilized milk protein.

Altogether the data on the abomasal protein digestion do not indicate that the differences in protein digestibility in the different fish samples are due to differences in their abomasal digestion. Evidently it is the intestinal digestion that differs for the different classes of protein.

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References

AOAC (1960) *Official methods of analyses.* Association of Official Agricultural Chemists, Washington

Frantzen, J. R., Talec, P., Iheverid, A. & Mathieu, C. M. (1979) *Ann. Biocl. Anim. Biochem. Biophys.* **13,** 718

Gaudreau, J. M. & Brisson, G. J. (1980) *J. Dairy Sci.* **63,** 426

Opstvedt, J. & Sobstad, G. (1975) *Norsk Patent no.* 74468 (53 g-4/02), 72274 (531-4)

Opstvedt, J., Sobstad, G. & Hansen, P. (1978) *J. Dairy Sci.* **61,** 72

Newport, M. J. (1979) *Br. J. Nutr.* **41,** 103

Tagari, H. & Roy, J. H. B. (1969) *Br J. Nutr.* **23,** 763

Ternouth, H., Ray, J H. B & Siddons, (1974) *Br. J. Nutr.* **31,** 13