nitrogen used in the experiments had a purity of 99% or better. With these gases it is believed that the permeability constants that were determined were well within 5% of their true values.

Permeability constants reported in the literature for various organic films have been recalculated to the same units used with the acetostearin products and have been recorded in Table VI. It is evident that ethylcellulose, polystyrene, and the ethylene polymer are more permeable to both oxygen and nitrogen than are the films of acetostearin. Polyethylene has approximately the same permeability to these gases, while cellulose acetate, regenerated cellulose, and nylon have a lower permeability.

The permeability of the acetostearins to carbon dioxide was found to be less than that reported by other investigators for ethylcellulose and approximately the same as that of polystyrene and polyethylene. Nylon and regenerated cellulose have lower permeabilities to carbon dioxide.

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Received for review January 22, 1955. Accepted February 27, 1956. Division of Agricultural and Food Chemistry 126th Meeting, ACS, New York, N. Y., September 1954. Trade names are given as part of the exact experimental conditions and not as an endorsement of the products over those of other manufacturers.

FISH MEAL STABILITY

Changes in Fat Extractability and Protein Digestibility in Fish Meal during Storage

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Fish meals prepared by conventional methods from whole California sardines were analyzed periodically up to 331 days' storage for solvent-extractable fat, protein, and pepsin-indigestible proteins. The extractability of the fat progressively decreased, while the pepsin-indigestible protein slowly increased. The latter also increased in samples from which the fat had been extracted initially. Little or no change was observed in sealed-in-glass samples. Oxidation appeared to be responsible for the changes noted. Some arginine was lost during 24 hours' holding of the raw fish.

Changes in extractable fat of fish meals were studied, because of the report that fish meals several months old might fail to meet the guarantee of fat content. The possibility of alterations in enzyme digestibility of protein was also considered.

Investigation

On the same day as caught, California sardines were processed into press cake and fish meal by conventional equipment, including steam cookers, presses, and a steam tube dryer. No press water was returned to the meals. Some press cake was dried in a laboratory tray-type dehydrator using hot air entering at 160° F. and discharging at not over 140° F. A part of the same catch was held in a large bin for 24 hours until soft, and processed as before. All preparations were made from whole fish.

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The commercial meals and laboratory-dried press cakes were passed through a Wiley mill and reduced to the same maximum particle size, not over $^1/_{16}$ inch. Portions of each lot were extracted with ethyl ether in a large Soxhlet-type extractor. All meals were placed in cloth bags and stored at room temperature with free circulation of air around each bag. Each lot was periodically sampled by repeated mixing and quartering. Samples were analyzed for moisture, petroleum and ethyl ether–extractable fat, total protein, and pepsin-indigestible protein. The latter was determined as described by Almquist, Stokstad, and Halbrook (*1*). Fat was determined by continuous extraction for approximately 7 hours and weighing of the dry solvent-free residue. The results were calculated to dry basis and are given in Table I.

Samples of the factory meals were sealed in glass tubes with and without evacuation of air to 10-mm. pressure, and kept for the duration of the study. Results from the sealed samples are given in Table II.

Conclusions

The pepsin-indigestible protein increased slowly with aging. The amount started at a lower value and remained lower throughout in samples that had been extracted with ether. While the presence of fat caused a definite increase in indigestible protein, the majority of the indigestible protein must have arisen from other causes, and the gradual increase of indigestible protein on storage may be attributed to progressive changes in the protein, rather than any increased interference with digestion caused by changes in the fat. This implies that little enhancement in protein value would be caused by removing the normal amount of fat from fish meal.

Progressive alteration of fat was shown by a steady decrease in petroleum ether and ethyl ether–extractable fat.

Samples A, AX, B, and BX, made from "hard" (very fresh) fish, showed a consistent loss of crude protein on storage. Samples C, CX, D, and DX, made from "soft" (24 hours older) fish, showed comparatively little drop in crude protein on storage. It may be that the apparently volatile nitrogen compounds were more completely removed from soft fish in the press water.

Samples of the commercially dried meals (B and D), which were sealed in glass tubes with and without air and kept at the same temperatures as the other samples, showed at the end of the experiment little change as compared to the probable condition of the samples at the time of sealing. This indicates that oxidation was primarily responsible for the changes noted in fat and protein. The small amount of air sealed in with the sample had no appreciable effect on the analyses, as compared to sealing in vacuum.

Comparison of the two methods of drying showed no appreciable differences in any respect. The commercial drying, therefore, was equivalent to the drying at low temperature in the laboratory dehydrator, so far as effect on any measured property of the meals is concerned.

It was suspected that during the softening and autolysis processes some amino acid might be lost, although noticeable spoilage had not taken place. Arginine was determined in the two factory meals. Arginine was chosen because it might be labile under such conditions, and it is a fully essential amino acid for poultry (*2*). The meal made from very fresh fish contained 7.4% arginine, expressed as a percentage of the crude protein, while that made from soft fish contained 6.4%. This appreciable loss of arginine is evidence of the action of some destructive process, probably enzymatic, on the arginine.

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Received for review November 14, 1955. Accepted February 27, 1956.

Table I. Analyses of Stored Fish Meals

	Sample Age, Days						
	4	42	64	120	164	241	331
	Percentage Composition, Dry Basis						
Lot A Press Cake, Hard Fish							
Protein	72.3	72.0	71.0	71.0	70.9	70.9	70.9
Petroleum ether extract	5.6	4.2	3.8	2.5	2.5	2.5	2.0
Ethyl ether extract	6.8	5.2	4.4	3.5	3.5	3.2	2.8
Pepsin-indigestible protein	...	5.6	5.8	6.6	6.7	6.7	6.8
Indigestible protein as % of total protein	...	7.7	8.1	9.3	9.4	9.4	9.6
Lot AX[a]							
Protein	...	78.2	77.3	77.2	77.1	77.0	77.0
Pepsin-indigestible protein	...	5.0	5.6	5.7	5.8	5.9	6.2
Indigestible protein as % of total protein	...	6.4	7.2	7.4	7.5	7.7	8.0
Lot B Meal, Hard Fish							
Protein	70.7	69.5	69.3	69.3	69.6	69.4	69.4
Petroleum ether extract	6.8	4.7	3.3	2.4	2.3	2.2	2.3
Ethyl ether extract	7.1	6.1	4.1	2.7	2.7	2.7	2.7
Pepsin-indigestible protein	...	4.7	5.3	5.3	6.7	6.8	6.9
Indigestible protein as % of total protein	...	6.8	7.7	7.6	9.7	9.8	10.0
Lot BX[a]							
Protein	...	76.0	74.5	74.5	74.5	74.0	73.5
Pepsin-indigestible protein	...	4.1	4.3	4.3	4.4	4.5	5.4
Indigestible protein as % of total protein	...	5.4	5.8	5.8	5.9	6.0	7.3
Lot C Press Cake, Soft Fish							
Protein	77.0	77.5	77.2	77.0	77.0	76.5	76.5
Petroleum ether extract	...	3.3	3.0	2.3	2.3	2.2	2.2
Ethyl ether extract	6.4	4.5	3.8	3.5	3.2	2.9	2.7
Pepsin-indigestible protein	...	6.7	6.7	6.5	7.0	7.4	8.0
Indigestible protein as % of total protein	...	8.6	8.6	8.5	9.1	9.7	10.5
Lot CX[a]							
Protein	...	82.5	83.0	83.0	83.0	83.0	83.0
Pepsin-indigestible protein	...	4.3	5.6	5.8	6.2	6.3	6.2
Indigestible protein as % of total protein	...	5.2	6.8	7.0	7.5	7.6	7.5
Lot D Meal, Soft Fish							
Protein	75.5	75.9	75.9	76.0	76.0	76.0	76.0
Petroleum ether extract	...	2.6	2.5	1.9	1.8	1.8	1.7
Ethyl ether extract	6.5	4.9	3.6	3.0	3.0	3.0	2.9
Pepsin-indigestible protein	...	6.5	7.4	7.4	8.0	8.0	8.0
Indigestible protein as % of total protein	...	8.6	9.5	9.5	10.5	10.5	10.5
Lot DX[a]							
Protein	...	83.9	83.6	83.4	83.4	83.4	83.4
Pepsin-indigestible protein	...	5.4	5.5	6.0	6.7	6.8	6.8
Indigestible protein as % of total protein	...	6.4	6.6	7.2	8.0	8.2	8.2

[a] Lots designated X are ether-extracted preparations from lots listed directly above.

Table II. Percentage Composition of Sealed-in-Glass Samples after 11 Months' Storage

(Dry basis)

Lot	B	B	D	D
Sealed in	Air	Vacuum	Air	Vacuum
Petroleum ether extract	5.7	5.9	4.4	4.5
Ethyl ether extract	6.7	7.1	6.5	6.4
Protein	69.0	68.0	75.5	77.0
Pepsin-indigestible protein	5.4	5.4	6.3	6.9
Indigestible protein as % of total protein	7.9	7.9	8.4	9.0