FISH SOLUBLES AS A PARTIAL SUBSTITUTE FOR MILK AND MILK BY-PRODUCTS IN LIQUID RATIONS FOR NEONATAL ANIMALS

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ABSTRACT

This paper presents (1) a literature review of the use of fish protein in milk replacers for neonatal animals, (2) a list of criteria for proteins used in milk replacers, and (3) reports on three experiments in which menhaden fish solubles were partially substituted for milk protein in milk replacer rations.

Initial experiments reported here indicated that low levels (5%) of fish solubles produced equal calf growth when they replaced a similar amount of milk products in veal calf rations. However, the addition of 15% freeze-dried solubles at the expense of dried skim milk (DSM) did not produce satisfactory growth in young lambs. This was true even when lecithinated soy flour or delactosed whey powder supplemented part of the protein in the ration. Therefore, it is concluded that if significant quantities of fish protein are to be incorporated into milk replacer rations, protein of higher quality than that present in fish solubles must be used.

Attempts to develop a product suitable for replacing fresh whole milk for feeding calves occurred in the early 1900's. However, due to the lack of knowledge regarding calf nutrition, these products were not very satisfactory. By the end of the 1940's knowledge of the nutritional needs of calves had developed to a point that made it possible for satisfactory substitutes for whole milk to be marketed. Today, milk replacers have been refined to such an extent that many dairymen are reporting faster weight gains by feeding milk replacers instead of fresh whole milk. Several important developments contributed to this improved performance. They include: (1) the use of antibiotics, (2) the use of stabilized vitamins, and (3) the increased use of dried milk proteins. Recently the use of milk replacers has increased because of automation of feeding techniques, their ease of handling and storing, improved formulations, and the increased emphasis on salvaging orphan and runt animals which would have previously have been lost by the producer.

Manufacturers of milk replacers depend largely upon dried skim milk (DSM) and dried whey as the major ingredients. Because of the continued high market price of DSM throughout the world, feed manufacturers are looking for lower priced substitutes to be used in their milk replacer formulations. The superior value of feeding milk solids as compared to vegetable feedstuffs in milk replacers has been well demonstrated (Huber, 1965). Therefore, it is the purpose of this paper (1) to briefly review work reported in the literature, (2) to list the criteria necessary for proteins used in milk replacers, and (3) to report the results of our work to determine if fish solubles can be partially substituted for milk and milk products in liquid rations for neonatal animals.

REVIEW OF RECENT LITERATURE

Harshbarger and Gelwicks (1965) reported that calves fed a milk replacer containing 20% low-fat fish meal performed as well as calves that were receiving a 50% DSM replacer. Average daily gains and feed intakes at 12 weeks of age were similar for all calves studied that received either DSM or fish meal.

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Huber and Slade (1967) substituted varying levels of fish protein (defatted fish meal) for skim milk protein in calf milk replacers in growth and balance studies. They also investigated the effect of varying levels of dietary fat in combination with fish protein on growth response. Their data showed that average daily gains and feed efficiencies were not significantly different when fish protein replaced up to 40% of the dietary protein. However, when fish protein replaced from 60 to 67% of the dietary protein, significant decreases ($P<0.01$) occurred. Increasing fat in the rations from a 10 to 20% level caused a linear increase ($P<0.05$) in gains. However, no interaction between protein source and fat level was detected. Furthermore, as the amount of fish protein in the milk replacer increased, digestibilities of dry matter, crude protein, fat, and ash decreased. Only when fish protein furnished 100% of the dietary protein was there a significant depression ($P<0.05$) in the percent of digested nitrogen retained. Crude protein in the fish concentrate was reported to be 80% digestible compared to 90% for skim milk protein.

Williams and Rust (1968) reported a study with four different formulations of experimental milk replacers, and their results supported the findings of Huber and Slade (1967). Defatted fish flour provided from 14 to 42% of the total protein in these experimental rations. Total protein, fat, and digestible nutrients were equal in all experimental rations and were similar to those of the standard milk replacer ration. At the termination of the 42-day experiment, they reported that calves fed the various experimental milk replacers gained similar amounts of weight and they were comparable to calves on the conventional milk replacer. These results indicated that fish protein could be effectively utilized and provide up to 42% of the protein in the ration.

Gorrill (1970) conducted similar studies on the use of fish protein in milk replacers. Fish protein concentrate (FPC), which was in this case isopropanol extracted fresh whole herring, accounted for 50% of the protein in the fish containing milk replacer. He also fed a dry starter on a restricted basis and hay ad lib. with the liquid diet and found that at least 50% of the milk replacer protein could be supplied by FPC with no significant difference in weight gains from those of whole milk or an all-milk product replacer ration.

In European countries there has been increasing interest in developing fish products which could be utilized in milk replacer rations. France is currently producing 550,000 to 600,000 tons of milk replacer per year which includes the use of fish protein in veal diets. In particular, two French feed manufacturers began marketing milk replacers containing fish protein in the form of FPC or autolyzed fish concentrate in an effort to use a lower priced animal protein.

CRITERIA FOR PROTEINS IN MILK REPLACERS

Generally, there are eight criteria that will have to be met by the producers of fish protein before feed manufacturers will consider using such protein in milk replacer formulas.

First, the fish protein must be highly available to the animal. At present, a wide range of values has been reported on fish protein in milk replacer rations. Reports of from 50 to 80% digestible protein can be found in the literature. Since skim milk has a digestible protein value of about 90%, it is imperative that fish products have a protein digestibility as close to this as possible.

Second, the product must be of uniform quality and be available throughout the year in quantities large enough to meet demands.

Third, fish protein must be lower in cost than milk protein or equal if DSM is scarce. Manufacturers will be willing to use fish protein only if its substitution for milk products gives a reduction in price of the milk replacer. There is always risk involved when changing formulas, and the manufacturers must be shown an economic advantage before they will take that risk.

Fourth, the fish protein must be suspendable in water when used in the formulation. With the increased application of automatic feeding devices in the rearing of neonatal animals, a completely suspendable milk replacer is important. The functional properties of current FPC and fish meals must be improved to develop a product that will remain in suspension.

Fifth, fish proteins must be odorless, relatively free from a fishy taste, have a light color, and be stable. Many manufacturers of milk replacers feel that the fat content of the fish product must be kept as low as possible (less than 1%) to maintain the stability of fish protein. Some manufacturers suggest additions of antioxidant since they have experienced a deterioration of autolysates after storage. However, it has been reported by Ronning (1970) that hydrogenated fish oils with an iodine number of 80 are of value in high-energy milk replacers. Through the addition of higher levels of α-tocopherol (Vitamin E) and by reducing the levels of unsaturated fatty acids by hydrogenation, he was able to feed calves up to 26.2% fish oil with no detrimental effects.

Sixth, the bone content of the fish protein product must be relatively low. Producers of milk replacers indicate they want a final product with less than a 10% mineral content. More importantly, they want this concentration of minerals to remain constant from one batch of milk replacers to another. Therefore, the major individual ingredients in the milk replacer must have a constant mineral composition. In addition, if a milk replacer containing fish protein is to be fed for the production of veal calves, it must be low in iron (less than 50 ppm). The preferred paleness of veal muscle tissue results from a state of anemia due to the low iron content of the rations fed to veal calves. At present, the iron content of FPC made by isopropyl alcohol extraction may vary between 147 and 770 ppm (Finch, 1970). However, a large part of this iron comes from mechanical contamination (i.e., grinding) and may be of a type that is poorly available to animals. If the iron content can be made unavailable by adding an iron-chelating agent, as suggested by Saheb and Charpentier (1970), a high-quality veal meat may be produced. Inasmuch as the major market in the United States is for replacement animals, iron should not be a problem.

Seventh, the moisture content of the fish protein must be kept low to prevent lumping of the milk replacer and other texture changes during storage. Most milk replacers contain 5% moisture or less.

Eighth, fish protein to be used in milk replacers would have to have a reasonably low bacterial plate count because neonatal animals are quite susceptible to digestive upsets. A low moisture content would help to keep bacterial growth to a minimum.

EXPERIMENTAL RESULTS

Our research at the National Marine Fisheries Service, College Park Laboratory was conducted to determine the feasibility of using fish solubles in milk replacer rations.

EXPERIMENT I

The objective of the first study was to determine the effect of partially substituting condensed menhaden fish solubles in a commercial ration for veal calves. Four Holstein bull calves were placed individually in stalls at 3 days of age. Two of the calves were fed a commercial veal ration, containing 24% protein and 20% fat. The remaining two calves received the same commercial ration with low-fat (3%) menhaden fish solubles replacing 5% of the ration on an equal weight basis. The calves were full-fed twice daily. Table 1 shows the results of this experiment. At 75 days of age, the milk replacer plus fish solubles group had average daily weight gains (0.93 kg) and feed conversions (1.41) comparable to those of the all-milk products replacer. However, due to the small number of

TABLE 1.—Experiment I. Weight gains and feed consumptions of calves fed either control milk replacers or milk replacers containing 5% fish solubles.

	Control	Fish solubles
Average body weight, kg		
Initial	39.09	36.82
75 days	105.00	106.36
Average daily weight gain, kg		
36 days	0.82	0.72
75 days	0.88	0.93
Average feed (dry)/gain		
36 days	1.09	1.20
75 days	1.53	1.41

animals used in this study it cannot be interpreted clearly that supplementation with fish solubles produced a superior product, but it is apparent that when fish solubles replaced 5% of an all-milk replacer commercial ration, growth rates and feed conversions were at least equal to the control that contained all-milk protein.

A triangular organoleptic test for flavor with 12 panelists was performed on 1.91-cm slices from the liver, loin ends (chops), and rounds (cutlets) of all test animals. Table 2 shows the results of the organoleptic evaluations. When the data from this test were statistically analyzed by the Student's *t*-test, a significant flavor difference ($P<0.05$) was found between the two groups. Meat from the experimental animals appeared to have more beef flavor rather than the desirable bland flavor associated with veal. Likewise, the meat from the experimental animals had a noticeably darker color than that of the control animals. This difference was probably due to the high level of minerals present in the fish solubles, especially iron.

TABLE 2.—Experiment I. Flavor test of meat from veal calves fed either control milk replacers or milk replacers containing 5% fish solubles.

	Control	Fish solubles
Cutlet		
Replication I	[1]7.67 ± 1.07	6.00 ± 1.71
Replication II	6.50 ± 1.88	6.00 ± 1.41
Average	[2]7.08 ± 1.61	6.00 ± 1.53
Chops		
Replication I	7.92 ± 1.00	6.50 ± 2.20
Replication II	7.42 ± 1.56	6.25 ± 1.86
Average	[2]7.67 ± 1.31	6.38 ± 2.00
Liver		
Replication I	6.25 ± 1.91	6.67 ± 1.83
Replication II	5.92 ± 2.19	6.33 ± 1.83
Average	6.08 ± 2.02	6.50 ± 1.79

[1] All values represent a scale of from one (unacceptable flavor) to eight (highly acceptable flavor).
[2] Significant at $P<0.05$.

EXPERIMENT II

The objective of this experiment was to study the feasibility of supplementing dried whey product, DSM, and/or soy flour with dry, lowfat menhaden solubles in lamb rations. Fifteen crossbred lambs, 2 to 7 days old, were placed on a commercial liquid, all-milk replacer ration for a preliminary period of 1 week. At the end of this period, lambs were allotted by weight, sex, and age to one of three experimental rations. The composition of the rations is shown in Table 3. All rations contained 24% protein, 20% fat, vitamins, minerals, antibiotic, and antioxidant. All lambs were given as much liquid feed as they could consume twice daily. Every 7 days body weights were measured, and feed consumption data were recorded daily. The experiment was terminated after 28 days. The average weight gains are shown in Table 4. Ration II (soy, whey product, and fish solubles) produced a growth response equal to 28.6% of that of Ration I (DSM and whey product), and Ration III produced an 82.9% response compared with Ration I.

TABLE 3.—Lamb ration formulations used in Experiments II and III.

Ingredients	Ration I	Ration II	Ration III
	%	%	%
Dried skim milk	65.00	--	30.00
Whey product	3.80	29.74	19.90
Menhaden fish solubles (freeze-dried)	--	15.00	15.00
Lecithinated soy flour	--	20.00	--
Glucose[1]	8.32	16.47	13.02
Emulsified lard	19.63	15.54	18.83
Vitamin premix[2]	1.00	1.00	1.00
Mineral premix[3]	1.00	1.00	1.00
Antibiotic premix[4]	1.00	1.00	1.00
Antioxidant premix[5]	0.25	0.25	0.25
	100.00	100.00	100.00

[1] Cerelose, Corn Products Co., New York. (Reference to trade names in the publication does not imply endorsement of commercial products by the National Marine Fisheries Service.)
[2] Vitamin premix provides per kilogram ration: A, 3,300 IU; E, 22 IU; D_3, 66 IU; B_{12}, 2 mg; niacin, 1,400 mg.
[3] Mineral premix provides per kilogram ration: iron, 42 mg; manganese, 19 mg; zinc, 50 mg.
[4] Antibiotic premix provides 55 mg terramycin per kilogram of ration.
[5] Nine parts glucose to one part Ethoxyquin.

EXPERIMENT III

A third experiment was conducted using Rations I and III, to confirm the previous observations. Ten lambs were placed on each treatment at 2 days of age. The ration formulations were the same as those in the previous experiment and contained 24% protein, 20% fat, vitamins, minerals, antibiotic, and antioxidant. A mixture of the dry ration with water (1:5) was fed

TABLE 4.—Experiments II and III. Weight gains of lambs fed either control milk replacer rations or those containing fish solubles and soy flour.

	Experiment II			Experiment III	
	Control	Fish solubles	Fish solubles + soy flour	Control	Fish solubles
Average weight gain, kg					
Initial	5.64	6.59	5.77	4.88	5.20
14 days	1.72	1.00	0.36	3.13	1.04
28 days	4.50	3.59	1.27	5.75	3.01
Average daily weight gain, g					
14 days	120	70	30	220	70
28 days	160	130	40	200	100

throughout the entire experiment which was terminated after 28 days.

Table 4 shows the results of this experiment. The average daily weight gains of lambs fed the control ration and those fed the fish solubles plus milk products ration were 200 g/day and 100 g/day, respectively. The combined results indicate that the ration containing 15% freeze-dried menhaden solubles only produced a 58% growth response as compared to that of the control ration. At the 15% level of incorporation, dried fish solubles will not effectively replace the DSM protein. It should be noted that this level of incorporation corresponds to 30% on an "as is" basis (before freeze drying) which is an extremely high feeding level for fish solubles.

The College Park Laboratory is continuing to study the feasibility of using fish proteins, such as partially hydrolyzed press cake, defatted fish meal, and lower grade forms of FPC as substitutes for milk products in liquid rations for neonatal animals.

CONCLUSIONS

The data indicate that a higher quality protein than that in fish solubles is necessary in order to incorporate significant quantities of fish protein in milk replacer rations.

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