Investigation on the Optimum Level of Salmon Meal for Use in Dairy Cow Diets

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Circular 83 December 1990

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INTRODUCTION

Why Salmon Meal ?

The feeding of processed fish meal to livestock is a relatively new concept in the United States. European farmers have successfully used fish meal in their livestock rations for decades. Although various types of fishmeal are available in the U.S., including whitefish meal, herring meal, menhaden meal, bottomfish meal, and shellfish meals, this report concentrates on the nutritional characteristics and use of salmon meal (SM) in livestock rations, particularly dairy cow rations. In Alaska, SM is readily available. Salmon meal is manufactured from the processing wastes from the state's salmon fisheries. The meal is cooked during the processing and an antioxidant is added to retard fat oxidation and rancidity.

The interest in feeding SM arises from several factors related to SM's chemical composition. First, SM is an excellent source of high quality protein, well balanced with respect to its amino acid content. Compared to soybean meal (SBM), which is and has been the protein source most commonly used in dairy cow rations, SM is higher in crude protein (65% vs. 48%) and also higher in the amino acids methionine and lysine (Husby and Krieg, 1987; NRC, 1982). Methionine and lysine are most often implicated as being the limiting amino acids with regard to supporting optimum milk production (Satter, 1986). These characteristics make SM an attractive alternative protein source to complement commonly used plant protein sources such as SBM. It is conceivable that a combination of SM and SBM could improve the quality and quantity of amino acids available to the producing animal, resulting in improved milk production.

Another characteristic of SM that makes it an attractive protein source for high producing dairy cows is that it is a low rumen-degradable protein, or is high in rumen *escape* or *bypass* protein. This is likely due to the heat applied to the meal during processing. The term *escape* or *bypass* protein describes dietary protein that is resistant to degradation or fermentation by the rumen bacterial population. This resistant dietary protein escapes being digested in the rumen and after digestion in the small intestine would then be potentially available to meet the protein needs of the dairy cow. Approximately 60-70% of the SM protein will escape degradation in the rumen, whereas only 30-35% of SBM protein will escape rumen degradation (NRC, 1989; Windschitl, unpublished data). With rumen bypass proteins in the diet, it may be possible to increase the quantity and improve the quality or balance of amino acids entering the small intestine, thus improving milk production, and/or improving the efficiency of milk production. High quality dietary proteins appear to be utilized more efficiently if they are digested in the small intestine via intestinal enzymes, rather than degraded or fermented in the rumen via the action of the rumen bacterial population. Compared to intestinal digestion, rumen fermentation of high quality proteins is a relatively inefficient energy costing process. During the fermentation process, energy is lost in the form of carbon dioxide and methane. The excess release of ammonia-nitrogen during the rumen fermentation of proteins results in a loss of nitrogen from the body through urinary tract urea excretion.

In addition to being an excellent source of high quality protein and rumen bypass protein, SM is also nutritionally rich in several minerals (Husby and Krieg, 1987). These include Ca, P, and various trace minerals.

Salmon meal contains approximately 5.5% Ca and 3.2% P. Calcium and P are extremely important in dairy cattle nutrition. The fact that SM is a good source of these minerals is often overlooked by both nutritionists and farmers.

Fish oils may also play a role in increased disease resistance in some animals, particularly chickens and pigs (Anonymous, 1990). The omega-3 fatty acids in the fish oils have been shown to increase antibody production. Dietary fish oil omega-3 fatty acids can be readily transferred into the blood and milk of pigs. Salmon meal contains appreciable levels of omega-3 fatty acids. It is possible that these omega-3 fatty acids could also be transferred into the milk fat of cows which consume salmon meal. Continued research at the Agricultural and Forestry Experiment Station (AFES) will examine this possibility. From a human health standpoint, fish oils (omega-3 fatty acids) are thought to lower the risk of coronary heart disease.

The oil in salmon meal can also provide a source of additional energy to lactating cows. The meal contains approximately 13-14% oil. This becomes important with regard to early-lactation, high-producing cows, since they are normally in a state of negative-energy balance during the early part of lactation.

A possible negative effect of feeding SM is that milk fat percentage may be decreased if the level of SM in the diet is too high. This is particularly important if a milk fat differential price is paid to the farmer, as is the case in the Lower 48 states. This effect may be due to the polyunsaturated fatty acids in salmon oil. These oils, if fed in excess amounts, may be toxic to certain rumen bacteria (Palmquist and Jenkins, 1980). The oils may also have a specific inhibitory action on the uptake of fatty acids by the mammary gland (Storry et al., 1974). Fiber digestion in the rumen may also be depressed by fish oils due to the inhibitory action against the cellulose digesting bacteria. Goldhor and Regenstein (1988) suggested it is possible that the addition of SM to the dairy cow diet may raise milk production levels to a point where the percentage of milk fat cannot keep up, causing farmers and researchers alike to think that a milk fat depression is occurring, even when total pounds of milk fat produced has increased.

Milk flavor is not adversely affected by the feeding of fish meal or fish oil to dairy cows, particularly at the relatively low levels of fish meal commonly used in the diet (Brundage, 1983; Goldhor, 1988).

Finally, salmon meal and certain other fish meals are readily available to Alaskan farmers. The availability of a locally produced protein source for use in livestock rations is beneficial since less reliance on imported protein sources is necessary. Salmon meal can also be considered as a renewable protein source, making use of a potential waste product of the fishing industry. The key to successfully using salmon meal in livestock diets is to determine what quantity and what feeding conditions are best to obtain optimum use of the meal. These objectives can only be achieved through continued research efforts including both basic and applied research projects.

This circular reports on results of a recently completed milk production trial at the Palmer dairy research center involving the feeding of low levels of SM to early-lactation dairy cows. Previous research at the experiment station has shown both advantages (Bruce et al., 1989) and disadvantages (Windschitl and Randall, 1990) to feeding SM to dairy cows. In all previous studies, milk fat percentage was generally decreased when SM was fed in the diet. Relatively high levels of SM (from 2.2-5.7 lbs/day or 5.5-11.6% of the diet) were fed in these studies. The current study limited the SM intake to a maximum of 7.5% of the concentrate mix or 4.2% of the total diet (less than 2 lbs of SM per day).

MATERIALS AND METHODS

This trial was initiated in August, 1989. Animal work and data collection were completed July, 1990. Only feed intake and milk production data will be summarized. Data related to rumen fermentation patterns, blood plasma metabolite content, and fatty acid composition of milk fat will be summarized in a later report.

Twenty-four mature Holstein cows and 12 first-calf heifers were used in a 13-week lactation trial to study the effects of adding low levels of salmon meal into the diet on lactational performance. Treatments were: SBM = soybean meal control diet; SM1 = 1.4% salmon meal; SM2 = 2.8% salmon meal; SM3 = 4.2% salmon meal in the total diet dry matter. A total mixed ration (TMR) consisting of 55% concentrate mix (Table 1) and 45% bromegrass silage was fed twice daily. Nutrient content of the concentrate mixes and bromegrass silage is given in Table 2.

Cows were assigned to their experimental diets beginning week four postpartum and remained on the diet through week 15. Week three postpartum was used as a preliminary period for adjustment of milk production and composition data. The amount of feed consumed was measured daily. Milk weights were recorded daily and milk samples collected weekly for analysis of fat, protein, lactose, solids-not-fat, and total solids. Feed samples were collected weekly and composited by month for nutrient analysis. Animals were weighed at the beginning and end of the experimental period and approximately every month during the trial.

RESULTS

Milk production and dry matter intake data are presented in Table 3. Actual milk production tended to be higher with the salmon meal containing diets. Milk fat percentage tended to decrease as the level of salmon meal in the diet increased. Fat percentage was significantly lower with the SM3 diet compared to the SBM, SM1, and SM2 diets. Total pounds of milk fat produced daily was also lowest with the SM3 diet. Milk protein percentage, lactose percentage, and solids-not-fat (SNF) percentage were not significantly affected by diet, although protein percentage tended to be higher with the SBM diet. Total solids percentage was decreased as the level of dietary salmon meal increased due to the tendency for lower milk fat percentage with the salmon meal containing diets. Milk production corrected to a 4% milk fat basis (4% FCM) was highest with the SM2 and SM1 diets. The lower fat percentage with the SM3 diet resulted in a lower production of 4% FCM compared to the SM2 and SM1 diets. Solids corrected milk (SCM) production followed a similar trend as that of 4% FCM production.

Efficiency of milk production, measured as pounds of milk produced per pound of dry feed consumed, was generally higher with the salmon meal containing diets compared to the SBM diet. All salmon meal containing diets resulted in some improvement in the conversion of feed to milk on a pound to pound basis.

Lactation curves for actual milk production and 4% FCM production are presented in Figures 1 and 2. Milk fat percentage curves are presented in Figure 3. In general, cows peaked higher with the salmon meal containing diets. Persistency of milk production was greatest with the SM2 diet. However, all salmon meal diets tended to support higher levels of milk production throughout the trial than did the SBM diet. Production of 4% FCM tended to be slightly higher throughout the trial for the SM1 and SM2 diets compared to the SBM diet. Due to the lower milk fat percentage, production of 4% FCM was consistently lowest with the SM3 diet. Milk fat percentage tended to be higher with the SBM and SM1 diets. The SM3 diet resulted in a consistently lower milk fat percentage throughout the trial compared to all other diets. Lactational efficiency curves for actual milk and 4% FCM production are presented in figures 5 and 6. Efficiency of milk production was generally higher throughout the trial for the salmon meal containing diets.

Dry matter (DM) intake tended to decrease slightly as the level of salmon meal in the diet increased. DM intake curves are shown in Figure 4. The SM3 diet resulted in the lowest DM intake throughout the trial, and was significantly lower than the SBM diet. The amount of salmon meal consumed on the SM1, SM2, and SM3 diets was .63, 1.3, and 1.8 lbs/day, respectively. DM intake expressed as a percentage of body weight (BW), was also lowest with the SM3 diet. Body weights of cows on the salmon meal diets tended to decrease as the level of salmon meal increased. This may be due to a combination of factors, including lower DM intake, higher milk production, higher efficiency of feed to milk conversion, and also lighter body weights at the beginning of the trial.

Calculation of income over feed cost is shown in Table 4. Milk prices have been adjusted for a 16.4 cent fat differential deduction whenever the milk fat percentage dropped below 3.2%. Income was calculated using the adjusted milk price and average milk production for each diet. Feed costs include both concentrate and silage costs. The silage cost of $43/ton was obtained from the June, 1990 Alaska Agricultural Statistics summary booklet. Income over feed costs was greatest with the SM2 diet at $10.57/day. All salmon meal containing diets showed a higher income over feed cost compared to the SBM diet. Even after considering the higher cost of salmon meal compared to soybean meal, it appears that it may still be advantageous to feed 1-2 lbs of salmon meal per day. This is similar to recommendations suggested by British researchers when feeding fish meal to dairy cows (Goldhor, 1986).

SUMMARY AND CONCLUSIONS

Under conditions of this study, the addition of low levels of salmon meal (.6 to 1.8 lbs/day) into the diet of early lactation cows resulted in an improvement in milk production, efficiency of milk production, and income over feed costs. Overall, the greatest benefits were realized with the SM2 diet (approximately 1.3 lbs salmon meal/day, or 2.8% of the total ration dry matter). Although a reduction in milk fat percentage was observed with the salmon meal containing diets, all diets except the SM3 diet maintained milk fat percentage levels above 3.2%. Therefore, no penalty for lower milk fat percentage was assessed to the SBM, SM1, or SM2 diets. As the level of salmon meal was increased in the diet, actual feed intake tended to decrease.

Based on results of this study, recommendations for feeding salmon meal are 1-2 lbs/day, with 1.5 lbs as an appropriate starting level. This amount can be adjusted within the 1-2 lb range as needed. At the relatively low levels of salmon meal used in this study, feed refusal was not a major problem. However, it may be best to feed the salmon meal in a total mixed ration to ensure maximum dry matter intake. In an effort to avoid a severe drop in milk fat percentage, which may in part be due to the type of fatty acids present in the salmon meal oil, ADF levels in the total ration should be a minimum of 19-20%, preferably 20%. It is also important to provide adequate amounts of Ca and Mg in the diet, since the availability of these minerals may be adversely affected by the presence of added dietary oil and fats (Palmquist and Jenkins, 1980).

Further investigations on the use of salmon meal in dairy cow rations are needed. The effect of salmon meal in corn or barley based diets is an area that warrants investigation. In addition, the use of salmon meal in combination with protein sources other than soybean meal should be addressed. The associated drop in milk fat percentage on salmon meal containing diets is an area that needs to be understood further. These, and the effects of salmon meal oil on milk fat fatty acid composition, are currently under investigation at the AFES dairy facility.

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Table 1. *Ingredient content of pelleted concentrate mixes.*

Ingredient	Concentrate mix [1] SBM	SM1	SM2	SM3
	% of dry matter			
Barley	26.6	27.6	28.6	29.6
Corn	26.6	27.6	28.6	29.6
Alfalfa meal	8.3	8.3	8.3	8.3
Animal fat	3.2	3.0	2.8	2.6
Beet pulp	8.3	8.3	8.3	8.3
Soybean meal	22.8	18.9	15.1	11.3
Salmon meal	—	2.5	5.0	7.5
Limestone	1.9	1.8	1.6	1.4
Dicalcium phosphate	1.0	.7	.4	.1
TM salt [2]	.8	.8	.8	.8
Magnesium oxide	.2	.2	.2	.2
Vitamin premix [3]	.3	.3	.3	.3

[1] SBM = soybean meal; SM1 = 1.4% salmon meal; SM2 = 2.8% salmon meal; SM3 = 4.2% salmon meal.
[2] Composition: 98% NaCl, .35% Zn, .28% Mn, .175% Fe, .035% Cu, .007% I, .007% Co.
[3] Composition: 1.6% Mg, 500 ppm Co, 12000 ppm Cu, 600 ppm I, 50000 ppm Fe, 47500 ppm Mn, 60 ppm Se, 48000 ppm Zn, 2 million IU vitamin A/lb, 1.6 million IU vitamin D/lb, 4000 IU vitamin E/lb.

Table 2. *Chemical composition of concentrate mixes, bromegrass silage, and total mixed rations.*

Item	Concentrate mix[1] SBM	SM1	SM2	SM3	Bromegrass silage	Total mixed ration[1] SBM	SM1	SM2	SM3
Dry matter, %	88.0	87.6	88.7	88.2	31.4	—	—	—	—
	% of dry matter								
Organic matter	91.6	91.9	91.5	92.4	92.9	92.2	92.3	92.1	92.6
Crude protein	20.7	20.2	21.0	19.9	13.1	17.3	17.0	17.4	16.8
Neutral detergent fiber	16.4	16.7	16.6	15.8	60.0	36.0	36.2	36.1	35.7
Acid detergent fiber	7.9	8.0	8.0	7.4	34.3	19.8	19.8	19.8	19.5
Ether extract	5.5	5.3	5.2	6.0	2.9	4.3	4.2	4.2	4.6
Ca	1.24	1.19	1.31	1.23	.46	.89	.86	.93	.88
P	.57	.56	.59	.58	.27	.44	.43	.45	.44
Mg	.36	.35	.35	.33	.20	.29	.28	.28	.27
K	1.11	1.06	1.02	.88	1.36	1.22	1.20	1.17	1.10

[1]SBM = soybean meal; SM1 = 1.4% salmon meal; SM2 = 2.8% salmon meal; SM3 = 4.2% salmon meal.

Table 3. Response of cows fed diets containing soybean meal or low levels of salmon meal.

Item	Diet[1]			
	SBM	SM1	SM2	SM3
Milk, lb	75.6	78.0	80.2	76.9
Fat, %	3.79[a]	3.75[a]	3.57[a]	3.09[b]
Fat, lb	2.91[c]	2.95[c]	2.86[c]	2.47[d]
Protein, %	3.13	3.03	3.04	3.06
Lactose, %	5.16	5.14	5.15	5.15
Solids-not-fat, %	8.79	8.65	8.68	8.72
Total solids, %	12.63[a]	12.49[a]	12.21[ab]	11.78[b]
4% Fat Corrected Milk, lb	74.2[cd]	75.3[c]	75.8[c]	68.5[d]
Solids Corrected Milk, lb	74.2	75.1	74.7	69.6
Milk/DM intake[2]	1.72[b]	1.83[ab]	1.84[ab]	1.96[a]
FCM/DM intake[2]	1.67	1.77	1.71	1.69
SCM/DM intake[2]	1.67	1.75	1.70	1.71
Body weight, lb	1269	1238	1212	1190
Body weight change, lb	51[cd]	6[d]	37[cd]	60[c]
Dry matter intake, lb/d	43.4[a]	41.9[ab]	43.4[a]	38.8[b]
Dry matter intake, % of BW	3.37[cd]	3.36[cd]	3.55[c]	3.18[d]

[1] SBM = soybean meal; SM1 = 1.4% salmon meal; SM2 = 2.8% salmon meal; SM3 = 4.2% salmon meal.

[2] lb milk produced per lb dry matter (DM) intake; FCM = fat corrected milk; SCM = solids corrected milk.

[a,b,c,d] Means in same row with unlike superscripts differ ([a,b]P<.01; [c,d]P<.05).

Table 4. Calculation of income over feed costs.[1]

Item	Diet[2]			
	SBM	SM1	SM2	SM3
Milk price/cwt[3]	19.75	19.75	19.75	19.57
Milk income/day	14.93	15.40	15.84	15.05
Feed cost/day	5.23	5.10	5.27	4.71
Income over feed cost/day	9.70	10.30	10.57	10.34

[1] Concentrate costs: SBM $287/Ton, SM1 $290/Ton, SM2 $292/Ton, SM3 $295/Ton, Silage cost: $43/Ton.

[2] SBM = soybean meal; SM1 = 1.4% salmon meal; SM2 = 2.8%; salmon meal; SM3 = 4.2% salmon meal.

[3] Base price $19.75/cwt adjusted for .164/cwt fat differential below 3.2% fat.

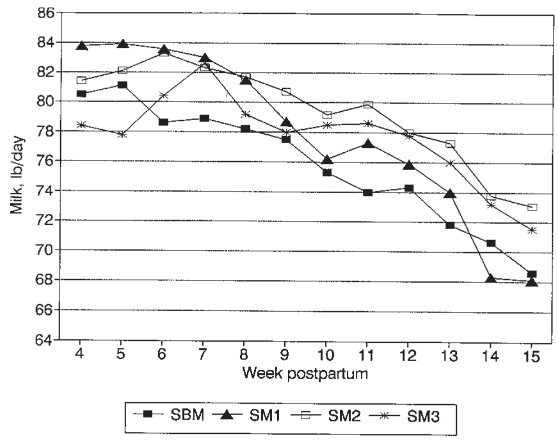

Figure 1. *Milk production curves for cows fed SBM or low levels of salmon meal.*

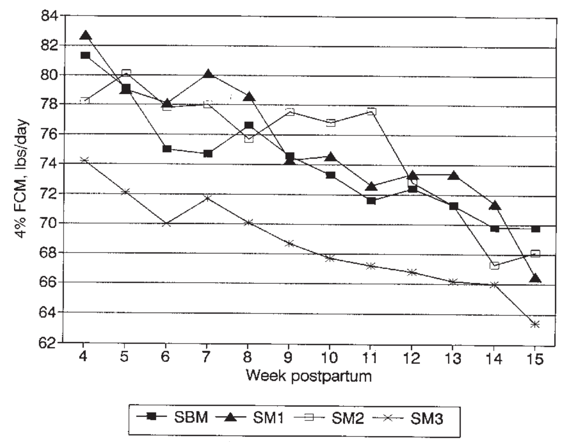

Figure 2. *4% FCM production for cows fed SBM or low levels of salmon meal.*

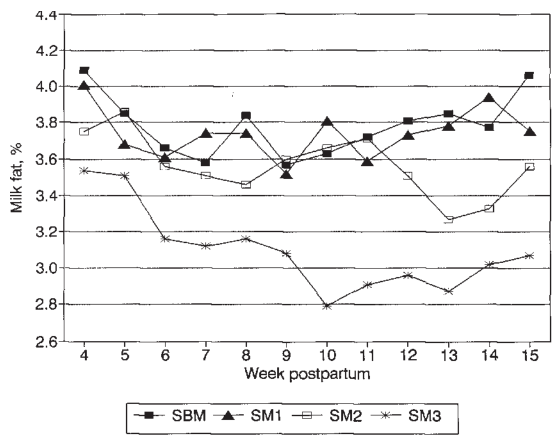

Figure 3. *Milk fat percentage for cows fed SBM or low levels of salmon meal.*

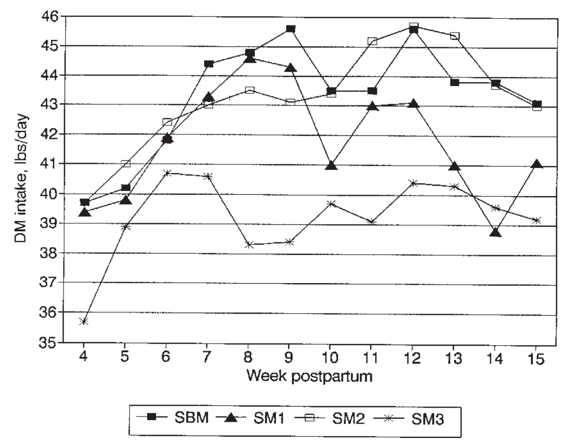

Figure 4. *Dry matter (DM) intake for cows fed SBM or low levels of salmon meal.*

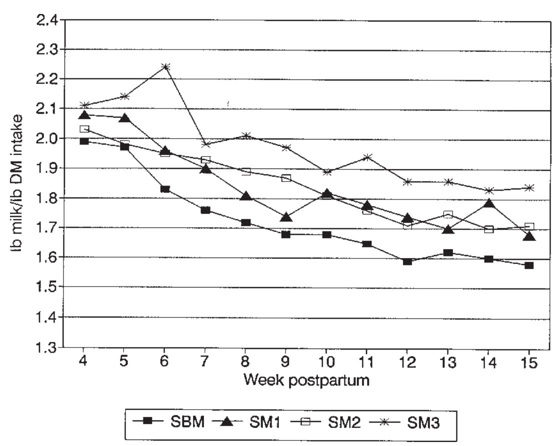

Figure 5. *Lactational efficiency (lb milk/lb/ DM intake) for cows fed SBM or low levels of salmon meal.*

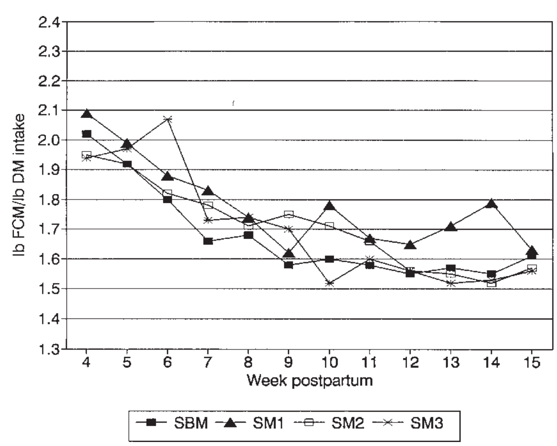

Figure 6. *Lactational efficiency (lb 4% FCM/lb DM intake) for cows fed SBM or low levels of salmon meal.*