AN ABSTRACT OF THE THESIS OF

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Title: EVALUATION OF MEADOWFOAM (Limnanthes alba) MEAL AS A FEEDSTUFF FOR RABBITS, POULTRY AND SHEEP

Abstract approved: Redacted for privacy

P.R. Cheeke

Meadowfoam (Limnanthes alba) is a winter annual oilseed crop native to the Pacific Coast states. Seven experiments were conducted to evaluate extracted meadowfoam meal (MFM) as a feedstuff for poultry, rabbits and sheep.

Three experiments were conducted to evaluate MFM as a protein supplement for broiler chicks and weanling rabbits. In experiment 1, chicks were fed diets in which 30% of the dietary protein was supplied by raw, steam-cooked (SC), SC plus 3% sodium carbonate (SC+), or aqueous acetone extracted (EXT) MFM. Weight gains and feed efficiency were severely depressed ($P<0.01$), with 60% mortality, for birds fed the raw MFM, primarily due to refusal to consume the diet. Performance of other treatments was similar to controls. Liver and thyroid weights at 6 weeks were increased ($P<0.01$) on SC and SC+ MFM diets, but organ weights on EXT-MFM were similar to controls. In experiment 2, chicks were fed diets in which SC-MFM isonitrogenously replaced 50% of the soybean meal in the control diet. Treatments were dietary additions of iodine, iodinated casein, and lysine. Weight gains and feed efficiency were reduced (P<0.01) on all diets containing SC-MFM. Performance on SC-MFM without dietary additions varied less than 0.5% between experiment 1 and 2. Liver weights were increased (P<0.01) on all diets containing SC-MFM, and thyroid weights were increased on all treatments (P<0.01) except for the iodinated casein addition, indicating that iodinated casein was effective in overcoming the goitrogenic effect of MFM. In experiment 3, weanling rabbits were fed diets in which SC-MFM replaced 25, 50, 75 and 100% and raw MFM replaced 25-50% of the alfalfa and soybean meal in the control diet. These levels corresponded to 20, 40, 60 and 80% of the dietary protein being supplied by MFM. Weight gains and feed efficiency were similar to controls when SC-MFM was added at the 25% replacement level, and decreased approximately 12 and 28% at the 50 and 75% levels respectively. Performance was very poor at the 100% replacement level due to a reluctance to consume the diets. At the 25 and 50% replacement levels, raw MFM decreased weight gains by 18 and 26% (P<0.05), and feed efficiency by 22 and 20% (P<0.05) compared to controls. The results suggest that rabbit performance also is improved by steam cooking MFM, although the differences in performance on raw and SC-MFM were not as dramatic as with broiler chicks. In short term feeding trials, SC-MFM appears to be a satisfactory feedstuff for broiler chicks and weanling rabbits when incorporated at moderate dietary levels.

Four experiments were conducted to evaluate MFM as a protein supplement for sheep. In experiment 1, a digestion trial was conducted with lambs comparing raw and steam-cooked (SC) MFM with cottonseed meal (CSM). Raw MFM reduced ($P<0.01$) the apparent digestibility of energy, dry matter, crude protein, acid detergent fiber and ash by 4, 6, 8, 52 and 55% respectively compared to CSM. Steam cooking caused additional (nonsignificant) reductions of all values except fiber and ash. In experiment 2, a growth trial was conducted with lambs comparing diets in which raw MFM replaced 50 to 100% of the CSM in the control diet. No reduction ($P>.05$) in weight gain or feed efficiency was evident at either replacement level. In experiment 3, a finishing trial was conducted comparing MFM and CSM as the supplemental protein source. No differences in weight gain, feed efficiency, or backfat thickness resulted but a slight improvement in dressing percentage ($P<0.05$) on the MFM diet was found. Histological evaluation of thyroid, liver and kidney showed no specific changes caused by MFM. In experiment 4, ewes consumed raw MFM during the last 7-9 weeks of pregnancy; no differences ($P>.05$) in serum thyroid hormone values were found between treatment and controls. However, one of seven ewes gave birth to a lamb with a goiter after 9 weeks on the MFM diet. The results of these experiments indicated that raw MFM is a satisfactory feedstuff for growing lambs when used at moderate levels, but should not be fed to pregnant ewes until further research can resolve the problem of goiter development in newborn lambs. Overall, MFM appears to be a satisfactory protein supplement for poultry, rabbits and sheep when incorporated

into diets to provide approximately 30% of the dietary protein. Until further research can resolve whether MFM is safe for laying hens, breeding does and pregnant ewes, the use of MFM as a feedstuff should be restricted to use in animals destined for slaughter.

Evaluation of Meadowfoam (*Limnanthes alba*) Meal as a Feedstuff for Rabbits, Poultry and Sheep

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ABSTRACT

Three experiments were conducted to evaluate meadowfoam meal (MFM) as a feedstuff for broiler chicks and weanling rabbits. In experiment 1, chicks were fed diets in which 30% of the dietary protein was supplied by raw, steam-cooked (SC), SC plus 3% sodium carbonate (SC+), or aqueous acetone extracted (EXT) MFM. Weight gains and feed efficiency were severely depressed (P<0.01), with 60% mortality, for birds fed the raw MFM, primarily due to refusal to consume the diet. Performance of other treatments was similar to controls. Liver and thyroid weights at 6 weeks were increased (P<0.01) on SC and SC+ MFM diets, but organ weights on EXT-MFM were similar to controls. In experiment 2, chicks were fed diets in which SC-MFM isonitrogenously replaced 50% of the soybean meal in the control diet. Treatments were dietary additions of iodine, iodinated casein, and lysine. Weight gains and feed efficiency were reduced (P<0.01) on all diets containing SC-MFM. Performance on SC-MFM without dietary additions varied less that 0.5% between experiment 1 and 2. Liver weights were increased (P<0.01) on all diets containing SC-MFM, and thyroid weights were increased on all treatments (P<0.01) except for the iodinated casein addition, indicating that iodinated casein was effective in overcoming the goitrogenic effect of MFM. In experiment 3, weanling rabbits were fed diets in which SC-MFM replaced 25, 50, 75 and 100% and raw MFM replaced 25 and 50% of the alfalfa and soybean meal in the control diet. These levels corresponded to 20, 40, 60 and 80%

of the dietary protein being supplied by MFM. Weight gains and feed efficiency were similar to controls when SC-MFM was added at the 25% replacement level, and decreased approximately 12 and 28% at the 50 and 75% levels respectively. Performance was very poor at the 100% replacement level due to a reluctance to consume the diets. At the 25 and 50% replacement levels, raw MFM decreased weight gains by 18 and 26% ($P<0.05$), and feed efficiency by 22 and 20% ($P<0.05$) compared to controls. The results suggest that rabbit performance also is improved by steam cooking MFM, although the differences in performance on raw and SC-MFM were not as dramatic as with broiler chicks. In short term feeding trials, SC-MFM appears to be a satisfactory feedstuff for broiler chicks and weanling rabbits when incorporated at moderate dietary levels.

EVALUATION OF MEADOWFOAM (Limnanthes alba) MEAL AS A FEEDSTUFF FOR BROILER CHICKS AND WEANLING RABBITS

INTRODUCTION

Meadowfoam (Limnanthes alba L) is a winter annual herb native to the Pacific Coast states. Gentry and Miller (1965) have described the agronomic characteristics of meadowfoam. Its adaptation to low temperatures and low-lying waterlogged soils (Calhoun and Crane, 1978) make it a potential crop for the very clay soils of the Pacific Northwest which currently are limited to annual ryegrass seed production. The potential economic value of meadowfoam is related to the unique fatty acid composition of the seed oil. At least 95% of the fatty acids present are 20 and 22 carbon chains, with unsaturation primarily at the 5th and sometimes at the 13th carbon atom. These characteristics impart stability to the oil at high temperatures, and make it a potentially continual source of raw material for production of wax esters, fatty alcohols, and long-carbon-chain fatty acids which are used in various industrial applications (Miwa and Wolff, 1962) as contrasted to such materials as sperm whale oil. To increase the economic potential of this crop, research was initiated to evaluate the use of extracted meadowfoam meal (MFM) as a feedstuff for domestic livestock. Potential problems associated with the use of MFM as a feedstuff include the presence of glucosinolates. Tookey et al. (1980) have reviewed the chemistry and biological effects of glucosinolates. Unpalatability, thyroid enlargement, liver and kidney damage are problems related to glucosinolate-containing feeds. This paper reports the results of experiments designed to evaluate MFM as a feedstuff for broiler chicks and weanling rabbits, and to determine the effect of processing methods and dietary additions on growth rate, feed efficiency, and liver and thyroid weights of animals consuming MFM.

MATERIALS AND METHODS

Source and preparation of MFM

Approximately 1800 kg of cleaned seeds harvested in 1976 and 1977 in the Willamette Valley were flaked and extracted in cold hexane, yielding 1350 kg of deoiled residue (raw MFM). Chemical analysis of raw MFM is shown in Table 1. Steam cooked (SC)-MFM was prepared by mixing 16% water by weight with raw MFM and cooking at 110° C and .56 kg per square cm pressure for 40 minutes. Sodium carbonate treated (SC+)-MFM was prepared by adding 3% sodium carbonate by weight to the raw MFM and cooking as for SC-MFM. Aqueous acetone extracted (EXT)-MFM was prepared by adding 50% water by weight to raw MFM and soaking for 3 hr at room temperature (26°C), and then exhaustively extracting with acetone in a Soxhlet apparatus.

Chick Management and Experiment Design

Day-old Hubbard type broiler chicks purchased from a commercial hatchery were housed in electrically-heated, thermostaticallycontrolled battery brooders with raised wire floors. Both experiments 1 and 2 were completely randomized designs with 50 male and 50 female chicks randomly allotted to 1 of 5 treatments with 20 chicks per treatment housed in 2 groups of 10 chicks per replicate with equal numbers of each sex per pen. Feed and water were supplied ad libitum. The experiments lasted 42 days, with gain determined as the difference between initial and final weights of chicks that survived the total period. Feed:gain ratios were determined by total pen gain (including chicks that died) divided by total feed consumed. At the end of 42 days, 6 chicks (experiment 1) and 10 chicks (experiment 2) per treatment were killed and their livers and thyroids excised, weighed, and examined.

The objective of experiment 1 was to compare the effects of various processing methods on utilization of MFM. Raw and processed MFM (SC, SC+, EXT-MFM) were incorporated into broiler chick diets to provide 30% of the dietary crude protein (Table 2). Previous research indicated that steam cooking, sodium carbonate, and aqueous-acetone extraction reduced the glucosinolate content of crambe meal (VanEtten et al. 1968; Mustakas et al. 1976).

Based on the results from experiment 1, experiment 2 was designed to determine the effects of addition of iodine, iodinated casein, and lysine to SC-MFM diets. The control diet was the same as in experiment 1. In the MFM diets, SC-MFM was increased to a level that replaced 50% of the soybean meal (47.5% CP) on an isonitrogenous basis, and methionine hydroxy analog was added at a level formulated to balance methionine levels based on the analysed amino acid composition of SC-MFM (Table 1) and solvent extracted soybean meal (Ref. #5-04-604, NAS/NRC 1971). Seven mg/kg of iodine in the form of potassium iodide, a level 20X higher than the recommended requirements for chicks (NAS/NRC 1977) was added to the iodine supplemented diet (+KI). Iodinated casein (Protamone, Agri-Tech, Kansas City, MO.) was added to SC-MFM at a level of 300 mg/kg (+IOC). The diet with additional lysine (+LYS) was formulated to balance the level of lysine in a SC-MFM diet with the control diet based on amino acid analysis (Table 1) and studies by Mustakas et al. (1976) which showed 13% reduction in available lysine when crambe meal was steam cooked. Lysine was added to the SC-MFM at a level of 0.17% in the form of L-lysine-HCL.

Rabbit Management and Experimental Design

Experiment 3 was a growth trial, using a completely randomized design conducted with 70 male New Zealand White weanling rabbits approximately 4-5 weeks of age. The rabbits were randomly allotted to 1 of 7 treatments with 10 rabbits per treatment. The treatment diets (Table 3) were formulated so that raw or SC-MFM isonitrogenously replaced 25, 50, 75 and 100% of the alfalfa meal and soybean meal in the control diet. SC-MFM was used at all replacement levels. An adaptation period of 6 days prior to the trial consisted of 3 days of ad libitum Purina rabbit chow, plus tetracycline provided in the drinking water, followed by 3 days in which the experimental diets were incorporated by thirds to achieve full feed by day 6. Rabbits were caged individually in a controlled temperature environment (18°C) with feed intake, feed spillage, and body weights recorded over a 35 day period.

Analyses

Dry matter, crude protein, ether extract, calcium, phosphorus, and ash were determined by methods according to the Association of Official Analytical Chemists (1970) and acid detergent fiber was determined by the micromethod of Waldern (1971). Amino acid analysis was performed by the method of Moore and Stein (1963) with a Beckman automatic amino acid analyzer. Samples were hydrolyzed in 6 N HCl at 110°C for 22 hr. Glucosinolates were measured by M.E. Daxenbichler at the Northern Regional Research Lab., Peoria, Ill. Data were analyzed by one way analysis of variance using unequal class numbers and treatment means compared by Duncan's multiple range test.

RESULTS AND DISCUSSION

The results of chemical analyses of MFM are presented in Table 1. The crude protein (N X 6.25) and fiber levels are similar to solvent extracted safflower seeds (#5-08-501, NAS/NRC 1971). Unique characteristics of MFM are the presence of high levels of ash and higher levels of calcium than would be expected in a seed meal. Comparison of amino acid composition between soybean meal (#5-04-604, NAS/NRC 1971) and MFM on an isonitrogenous basis indicates that MFM contains approximately equal levels of methionine, 70% less cysteine and 30% less lysine, suggesting that supplementation with lysine and sulfur amino acids might be beneficial. MFM also contains glucosinolates that are of both the thiocyanate and goitrin type (Daxenbichler and VanEtten 1974).

Experiment 1.

Composition of the broiler chick diets are shown in Table 2. The effects of feeding raw and processed MFM to broiler chicks are shown in Table 3. Because deaths occurred among both sexes, and no sex X treatment interaction could be detected, the data were combined. The chicks fed the raw MFM had very poor growth rates and high mortality. This was primarily due to a refusal to consume the diet (11.4g/chick/day vs. 56.3g for controls), presumably due to the unpalatability imparted to raw MFM by glucosinolates present in the meal. This finding is in contrast to feeding studies conducted with rabbits (experiment 3) and sheep (Throckmorton, et al. 1980) where raw MFM was readily consumed at similar levels in the diet. The poor feed/gain ratio appeared to indicate starvation. Chicks that died showed prominent breast bone, muscle wasting and lack of subcutaneous fat. Since intake was very low, the level of glucosinolates ingested were insufficient to elevate thyroid weights. The reason for increased liver weights in the raw MFM group is not apparent, but may have been related to the poor physical condition of the chicks at the end of the trial. Steam cooking or aqueous-acetone extraction overcame the palatability problem, and resulted in growth and mortality rates similar to the control. The feed/gain ratio was

16-19% higher for birds on the treated MFM diets than for the controls, presumably due to the higher fiber content of the MFM rations (Table 2). Liver and thyroid weights on SC-MFM were both increased (P<0.01) compared to their control. Since VanEtten et al. (1969) and Srivastava (1975) both showed that nitrile fractions from either crambe or rapeseed meal elevated liver weights, it is suggested that the increase in liver weights on SC-MFM could be attributed to the nitrile content of the MFM meal. Aqueous-acetone extraction of raw MFM eliminated the growth depressing effects and did not increase liver or thyroid weights, suggesting successful removal of both the goitrogenic and nitrile fractions. This is in agreement with VanEtten et al. (1969) who showed that this process prevented increases in thyroid and liver weights in rats fed crambe meal. The results of experiment 1 indicated that raw MFM is unsuitable as a feedstuff for broiler chicks. Steam cooking does make MFM a satisfactory protein supplement when fed at moderate levels (28.5% of diet) for 6 weeks although feed efficiency is reduced due to increased fiber levels and thyroid and liver weights are elevated.

Experiment 2.

Based on the favorable results obtained with SC-MFM in experiment 1, a second growth trial was conducted to determine the effects of dietary additions of iodine, iodinated casein (IOC), or lysine on organ weights and performance. The results are summarized in Table 4. Again, deaths occurred among both sexes and a sex X treatment interaction could not be detected, so data were combined. Although growth rates on SC-MFM were reduced ($P<0.01$) compared to controls, growth rate and feed efficiency differed by less than 0.5% between experiments 1 and 2 for chicks fed SC-MFM without sodium carbonate or dietary additions. The reasons for the improved performance of the controls in experiment 2 is not apparent. Addition of iodine (KI) at a level that was 20X the recommended requirement for growing chicks (NAS/NRC 1977) did not reduce thyroid weights. Compared to other diets containing MFM, addition of IOC reduced thyroid weights ($P<0.01$) to a level lower than controls, suggesting that the active component in IOC created a feedback inhibition causing the thyroids to atrophy. The results of experiment 2 are similar to the results of Klain et al. (1956) who fed rapeseed meal to chicks and found no increase in growth rate with dietary additions of iodine or IOC, but found that IOC reduced thyroid weights while iodine did not. Addition of lysine had no effect on thyroid weights which is in agreement with studies of May and McNaughton (1980) who found no differences in serum thyroxine (T4) or triiodothyronine (T3) in chicks fed inadequate, adequate or excess lysine. Weight gains and feed:gain ratios on diets containing SC-MFM were similar in all treatments. May (1980) reported that chicks responded differently to T3 than to T4, with supplemental T3 reducing both weight gain and feed efficiency, but T4 not adversely affecting performance, suggesting that the dominant active component in IOC is T4 since weight gains and feed efficiency were not adversely affected as compared to the other MFM rations. Liver weights were increased ($P<0.01$) on all diets containing SC-MFM but there was no evidence of liver hemorrhage in any of the chicks in either experiment.

Experiment 3.

Analyses of the diets fed rabbits is summarized in Table 5. Results of feeding various levels of raw and SC-MFM to growing rabbits are summarized in Table 6. Weight gains were similar to controls when SC-MFM replaced 25 or 50% of the alfalfa and soybean meal in the control diet. At the 50% replacement level, SC-MFM caused a decrease in feed efficiency of 12 percent. At the 75% level gain and feed efficiency were reduced ($P<0.05$) by 27 and 29% respectively. The 100% replacement level resulted in very poor performance, primarily due to a reluctance of the animals to consume the diet. Mortality on this treatment was related to starvation. It is interesting to note the marked difference in performance between the 75 and 100% replacement levels, indicating that fairly high levels (48.2%) of SC-MFM are accepted by rabbits as long as there is a small percentage of palatable protein supplements (soybean and alfalfa meal) still present in the diet. Raw MFM decreased gain by 18 and 26%, ($P<.05$) and feed efficiency by 22 and 20% at the 25 and 50% replacement levels respectively. Comparing performance between raw and SC-MFM, there was a trend suggesting better performance with SC-MFM at both the 25 and 50% levels. Comparison of rabbit with chick performance indicated that rabbits are much more tolerant to raw MFM than chickens. Amounts of MFM in the chick diets (28.5%) were similar to the 50% replacement level (32.2%) in the rabbit diets. Studies with bitter substances such as saponins indicate that rabbits are more tolerant of certain unpalatable ingredients than are other non-ruminant animals (Cheeke et al. 1977).

In summary, steam cooked MFM was a satisfactory protein supplement for growing rabbits and broiler chicks when used at moderate levels (25-30% of the diet). The increase in thyroid weights due to glucosinolates can be overcome with addition of iodinated casein, but the problem of increased liver weights still exists. Although this did not adversely affect short term performance, longer feeding trials and reproduction trials should be conducted before the use of MFM in laying hen and breeding doe diets can be recommended.

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Table 1: Chemical Analysis of Meadowfoam Meal

Composition	(%)
Dry Matter	92.7
Protein (N X 6.25)	21.1
Acid detergent fiber	26.6
Ash	13.1
Ether extract	1.9
Calcium	1.14
Phosphorus	0.82
Alanine	0.71
Arginine	1.35
Aspartic acid	1.21
Cysteine	0.09
Glutamic acid	2.78
Histidine	0.41
Isoleucine	0.60
Leucine	1.11
Lysine	0.96
Methionine	0.28
Phenylalanine	0.70
Proline	.80
Serine	0.64
Threonine	0.63
Valine	0.78
Glucosinolates	4.2

Table 2: Percent composition of broiler diets used in experiment 1 and 2

Ingredients	Control	Meadowfoam Meal Diets Exp.1	Exp.2
Ground Corn	64.7	49.4	47.0
Soybean Meal (47.5% protein)	28.9	16.4	14.5
Meadowfoam Meal (21.1% protein)	--	28.5	32.8
Dehydrated alfalfa meal	2.0	2.0	2.0
Defluorinated phosphate	1.9	1.9	1.9
Limestone	1.7	1.0	1.0
Iodized Salt (70 mg/kg I)	0.3	0.3	0.3
Vitamin Premix[a]	0.2	0.2	0.2
Mineral Premix[b]	0.05	0.05	0.05
Coccidiostat[c]	0.05	0.05	0.05
Zinc bacitracin (88 g/kg)	0.005	0.005	0.005
Methionine hydroxy analog	0.17	0.17	0.23
Analyzed composition (as fed)			
Crude protein	20.8	19.8	20.3
Acid detergent fiber	3.3	11.5	12.5

[a]Vitamin premix contained (mg/g): riboflavin, 1.65; pantothenic acid, 2.75; niacin, 11.0; choline, 95.47; vitamin K, 0.28; folacin, 0.11; (iu/g): vitamin A, 1650; vitamin D, 550; vitamin E, 0.55 and vitamin B12, 2.75 mcg/g.

[b]trace mineral premix contained (mg/g): manganese, 120.0; iron, 40.0; copper, 4.0; iodine, 2.4; zinc 55.0; calcium, 195.0; cobalt, 0.40.

[c]Zoamix 25 - Salsbury Lab, Charles City, Iowa.

Table 3: Percent Composition of Diets for Growing Rabbits - Experiment 3

Ingredient	1	2	3	4	5	6	7
Alfalfa meal	28.0	21.0	14.0	21.0	14.0	7.0	0
Soybean meal (47.5% protein)	16.0	12.0	8.0	12.0	8.0	4.0	0
Raw MFM	-	-	-	16.0	32.2	-	-
S-C MFM	0	16.0	32.2	-	-	48.2	64.3
Ground corn	51.0	46.0	40.8	46.0	40.8	35.8	30.7
Vegetable oil	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Molasses	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Dicalcium phosphate	0.42	0.41	0.41	0.41	0.41	0.40	0.40
Trace Mineralized salt[a]	0.4	0.4	0.4	0.4	0.4	0.4	0.4
D-L-Methionine	.18	.19	.19	.19	.19	.20	.20
Analyzed composition (as fed)							
Crude protein	16.5	17.3	17.5	16.8	17.5	18.1	17.7
Acid detergent fiber	13.4	15.5	16.5	14.5	16.4	18.0	22.1

[a]Provides in addition to NaCl, the following mg/kg elemental levels to the complete diet: Zn, 14.0; Mn, 11.2; Fe, 7.0; Cu, 1.4; I, 0.3; Co, 0.3.

Table 4: Performance of Broiler Chicks on various processed MFM meals

Mean ± SD

Diet	Percent Total Glucosinolates in diet	ADG (g)	Mortality	Feed/Gain Ratio	Thyroid wt. mg/100g. BW	Liver wt. g/100g. BW
Control	0.0	27.2 ± 3.0^{a}	2/20	$2.07\pm.01^{a}$	14.1 ± 3.3^{a}	$2.97\pm.25^{a}$
Raw MFM	1.20	3.1 ± 3.8^{b}	12/20	$3.68\pm.01^{b}$	15.7 ± 3.9^{a}	$3.65\pm.21^{b,c,d}$
SC-MFM	0.43	24.3 ± 4.1^{a}	2/20	$2.38\pm.15^{a}$	32.2 ± 6.4^{c}	$3.75\pm.54^{c,d}$
SC-MFM+3%Na_2CO_3	0.29	23.4 ± 3.4^{a}	2/20	$2.55\pm.22^{a}$	23.7 ± 6.6^{b}	$4.09\pm.51^{d}$
EXT-MFM	0.14	24.7 ± 1.8^{a}	2/20	$2.41\pm.01^{a}$	12.7 ± 1.3^{a}	$3.26\pm.30^{a,b,c}$

Means followed by different superscript are different ($P<.01$)

Table 5: Performance of broiler chicks on SC-MFM plus dietary additions

	Mean ± SD				
Diet	Average daily gain (g)	Mortality	Feed/Gain Ratio	Thyroid wt. mg/100 g BW	Liver wt. g/100g BW
Control	31.5±2.0[a]	1/20	1.91±.02[a]	12.8±2.1[a]	2.70±.40[a]
SC only	24.3±3.4[b,c]	1/20	2.39±.01[b,c]	27.3±7.1[b]	4.50±.58[b]
SC + KI	23.5±2.6[c]	4/20	2.48±.08[b,c]	27.5±6.8[b]	4.96±1.42[b]
SC + IOC	24.4±1.9[b,c]	4/20	2.58±.07[c]	2.7±0.5[a]	4.26±.36[b]
SC + LYS	26.0±2.4[b]	3/20	2.32±.08[b]	28.2±6.9[b]	3.94±.36[b]

Means followed by different superscripts are different ($P<0.01$)

Table 6: Performance of Rabbits fed various levels of raw and SC MFM

Diet	% alfalfa and SBM replaced by MFM	Average daily gain (g)	Mortality	Feed/Gain
1	0	43.5±5.1[a]	3/10	1.89±.23[a,b]
2	25-S-C	42.9±2.4[a,b]	2/10	1.76±.27[a]
3	50-S-C	38.0±6.1[a.b]	1/10	2.15±.28[b]
4	25-Raw	35.8±7.0[b]	1/10	2.42±.22[b,c]
5	50-Raw	32.0±4.2[b]	0/10	2.36±.36[b,c]
6	75-S-C	31.0±6.9[b]	0/10	2.60±.32[c]
7	100-S-C	8.3±4.6[c]	6/10	5.29±4.00[d]

Means followed by different superscripts are different ($P<.05$)

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EVALUATION OF MEADOWFOAM (*Limnanthes alba*) MEAL AS A FEEDSTUFF FOR SHEEP.

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ABSTRACT

Four experiments were conducted to evaluate Meadowfoam meal (MFM) as a protein supplement for sheep. In experiment 1, a digestion trial was conducted with lambs comparing raw and steam-cooked (SC) MFM with cottonseed meal (CSM). Raw MFM reduced ($P<0.01$) the apparent digestibility of energy, dry matter, crude protein, acid detergent fiber, and ash by 4, 6, 8, 52 and 55% respectively compared to CSM. Steam cooking caused additional (nonsignificant) reductions of all values except fiber and ash. In experiment 2, a growth trial was conducted with lambs comparing diets in which raw MFM replaced 50 or 100% of the CSM in the control diet. No reduction ($P>.05$) in weight gain or feed efficiency was evident at either replacement level. In experiment 3, a finishing trial was conducted comparing MFM and CSM as the supplemental protein source. No differences in weight gain, feed efficiency, or backfat thickness resulted but a slight improvement in dressing percentage ($P<0.05$) on the MFM diet was found. Histological evaluation of thyroid, liver and kidney showed no specific changes caused by MFM. In experiment 4, ewes consumed raw MFM during the last 7-9 weeks of pregnancy; no differences ($P>.05$) in serum thyroid hormone values were found between treatment and controls. However, one of seven ewes gave birth to a lamb with a goiter after 9 weeks on the MFM diet. The results of these experiments indicated that raw MFM is a satisfactory feedstuff for growing lambs when used at moderate levels, but should not be fed to pregnant ewes until further research can

resolve the problem of goiter development in newborn lambs.

EVALUATION OF MEADOWFOAM (<u>Limnanthes alba</u>) MEAL AS A FEEDSTUFF FOR SHEEP.

INTRODUCTION

Meadowfoam (Limnanthes alba Benth.), a winter annual native to California, Oregon and Vancouver Island is currently being developed as a potential oilseed crop. Meadowfoam grows well on waterlogged soils (Gentry and Miller 1965; Calhoun and Crane 1978) and the unique fatty acid composition of the oil lends itself to various industrial applications (Miwa and Wolff, 1962). The oil-extracted meal has been studied as a feedstuff for broiler chicks and rabbits (Throckmorton et al. 1980). One problem associated with the use of meadowfoam meal (MFM) is the presence of glucosinolates, which are both the thiocyanate and goitrin type (Daxenbichler and VanEtten 1974). This paper reports results of experiments designed to determine the digestibility of MFM in sheep, its effect on performance of growing lambs, and the effects of MFM glucosinolates on newborn lambs when ewes were fed MFM during late pregnancy.

MATERIALS AND METHODS

<u>Source and preparation of meadowfoam meal.</u>

Approximately 1800 kg. of cleaned seeds harvested in 1976 and 1977 in the Willamette Valley were flaked and extracted in cold hexane, leaving 1350 kg. of deoiled residue called raw meadowfoam meal (MFM). Steam cooked (SC) MFM was prepared by mixing 16% water with raw MFM by weight, and cooking at 110°C and .56 kg pressure per square cm for 40 minutes.

Experiment 1.

A digestion trial was conducted using 20 crossbred wethers averaging 49 kg with five animals per treatment. The four treatments consisted of corn, ryegrass straw, cottonseed meal (CSM) basal ration, and diets in which CSM, raw MFM and SC-MFM replaced 10, 20 and 20% of the basal diet (Table 1). The trial consisted of a 14-day preadjustment period where animals were group-fed 2 kg/head/day of the test diets, and a 7-day adjustment and 10-day collection period where animals were individually housed in metabolism cages. During the adjustment and collection periods, animals received 500 g of the test diet twice daily. Trace mineralized salt and water were available at all times. Feces were collected and weighed daily and a 10% aliquot was stored at 2°C until the collection period ended. Dry matter and total nitrogen in feeds and feces were determined by standard methods of the Association of Official Analytical Chemists (1970). Gross energy was determined in an adiabatic bomb calorimeter, acid detergent fiber (ADF) determined by a modified method of Van Soest described by Waldern (1971), and acid insoluble ash by the method of Van Keulen and Young (1977).

Experiment 2.

A growth trial was conducted using 30 crossbred wether lambs weighing 20-25 kg with 10 lambs per treatment. The three treatments consisted of a barley-grass hay based diet with 30% of the dietary protein in the control diet supplied by CSM (41% CP) and 50 or 100% of the CSM replaced with raw MFM on an isonitrogenous basis (Table 2). Because the lambs had been consuming large amounts of a barley-based creep ration prior to the trial, no adaptation period was used. Lambs were housed together in groups of ten and fed the pelleted diets ad libitum for 42 days. Weights were recorded every 14 days and initial and final weights were recorded as the mean of three weights taken over three consecutive days.

Experiment 3.

A finishing trial was conducted with 20 crossbred wether lambs of 37 kg initial weight, with 10 animals per treatment. The treatments consisted of an alfalfa-barley based ration with CSM or raw MFM supplying 30% of the dietary protein (Table 2). Because the lambs had previously been on pasture, the diets were gradually changed over a period of 14 days from grass hay to ad libitum pelleted diets. Lambs were weighed every 14 days and slaughtered when live weights exceeded 46 kilograms. Initial weights were recorded as the mean of weights taken on 3 consecutive days, and final weights were recorded after a 15 h shrink without feed. After 55 days, four lambs from each treatment were slaughtered and liver, kidney, and thyroid tissue samples were placed in buffered formalin and submitted to the Oregon State University Veterinary Diagnostic Laboratory for histopathologic evaluation.

Experiment 4.

A feeding trial was conducted with 14 pregnant crossbred yearling ewes within 7-10 weeks of lambing. The ewes were randomly alloted to one of two treatments with the seven control ewes being managed according to regular Oregon State University sheep flock husbandry. The test group was penned together and fed grass hay and 1.5 kg/head/day of pellets with the following composition: 30% raw MFM, 44% barley, 22% alfalfa, and 3% molasses. The diet was formulated to exceed requirements for protein and energy during late gestation, and the intake of raw MFM was formulated to match the intake of raw MFM by lambs in Experiment 3. Ewes received the test diet until they lambed. Loose trace mineralized salt containing both iodine and selenium was available free choice. Blood samples were taken from ewes and lambs within 24 h after parturition. Blood was allowed to clot for 24 h at room temperature (26°C) and serum was recovered by centrifugation. Samples were frozen until analyzed for total thyroxine (T4) and unsaturated binding capacity of thyroxine-binding globulin (T3% uptake) by radioimmunoassay procedures (T4: Quantitrope, Kellestad Labs, Chaska, MN.; T3%: Tri-Tab, Nuclear Medical Labs, Dallas, TS). A further calculation was made by multiplying T4 by T3% values. This calculation, termed Free Thyroxine Index (FTI) has gained wide acceptance and is considered a better indicator of thyroid status than T3 or T4 values alone (Rosenfeld 1974). All experiments described were completely random in design. All data were subjected to analysis of variance and differences between treatments means were compared by

Duncan's Multiple Range test.

RESULTS AND DISCUSSION

Experiment 1.

The chemical composition of MFM is shown in Table 3. Compared to CSM, MFM contains approximately half as much crude protein and twice as much fiber (NAS/NRC 1975). Compared to the diet with added CSM, raw MFM reduced ($P<0.01$) the apparent digestibility of energy, dry matter, and crude protein by 4, 6 and 8%, respectively (Table 4). Steam cooking caused additional (nonsignificant) reduction in digestibility of these components. Due to the design of the experimental diets, it was possible to theoretically subtract out the basal portion of the diets, and calculate digestibility by difference based on methods described by Schneider and Flatt (1975). These calculations estimated energy, dry matter, and crude protein in raw MFM to be 61.3, 55.1 and 57.7% digestible, respectively. Assuming that the basal portion of the diet was digested equally well by all lambs, MFM would contain 13.1% digestible protein and 2.36 Mcal/kg of digestible energy on a dry matter basis, giving it a value similar to mid-bloom alfalfa hay (NAS/NRC 1975). There was a large reduction in both fiber and ash digestibility of MFM compared to CSM, suggesting an association between the ash and fiber fractions of MFM. If meadowfoam seed were dehulled, it would probably increase the nutritive value of MFM, as has been shown to occur with dehulled rapeseed (Leslie et al. 1973). An interesting observation during the digestion trial was that raw

MFM was readily accepted by lambs, even when it was added as a topdressing to the basal diet. This is in direct contrast to observations with broiler chicks (Throckmorton et al. 1980) which refused to consume MFM-containing diets unless the meal was steam cooked.

Experiment 2.

Based on satisfactory acceptance and digestibility of raw MFM in experiment 1, a growth trial was conducted with young feeder lambs to compare CSM and MFM as protein supplements. The diets were formulated to contain minimum required amounts of protein (NAS/NRC 1975) and equal levels of fiber, so that differences in protein source might be reflected in performance. The results (Table 5) showed no reduction ($P>.05$) in average daily gain or feed efficiency when raw MFM replaced 50 or 100% of the CSM in the control diet. A suggested improvement in gain and feed efficiency ($P>.05$), at both levels of MFM may be attributed to the slightly higher analyzed protein levels (12.2 vs 11.1%) of the MFM diets compared to the control diets, or to the increased levels of grass hay added to the CSM-containing diets to balance fiber and protein levels. The variation in protein content of the rations may have been related to variation in the grass hay. The results indicate that although MFM is less digestible than CSM when fed on a restricted basis (Experiment 1), it supports satisfactory gains in lambs when fed on an ad libitum basis.

Experiment 3.

Based on the favorable results in experiment 2, a finishing trial was conducted to determine what effect MFM might have on carcass characteristics and liver, kidney, and thyroid histology in comparison to diets supplemented with CSM. The results (Table 5) showed no differences in average daily gain, feed efficiency, or backfat thickness ($P>.05$). Based on 48 h chilled carcass weights, dressing percentage was decreased ($P<0.05$) by 2% on the CSM diet. This reduction may have been due to the addition of 12.4% ryegrass straw to balance fiber levels (Table 2) which may have increased gut fill. Histological examination of tissues from lambs fed the diets for 55 days revealed that there were non-treatment related changes in all tissues. Four CSM and two MFM fed lambs showed mild portal lymphocytic infiltrates in the portal region of the liver, although these changes were considered to be pathologically insignificant. Two CSM and four MFM fed lambs showed tiny necrocalcific foci in the epithelium of the collecting ducts of the kidney. Renal changes were compatible with the type of change induced by leptospirosis. Since none of the lambs showed any signs of illness during the trial, it is likely that these changes occurred at an earlier age. Surprisingly, all four lambs on the CSM diet and only one MFM fed lamb showed thyroid changes. The changes were similar in all lambs; several enlarged follicles were filled with inspissated colloid and contained a few epithelial cells throughout the colloid. Affected follicles had stratified squamous epithelium, representing squamous metaplasia of the normal columnar or cuboidal lining. The reasons for these changes in the controls were not apparent. The diets were analyzed by M.E. Daxenbichler at the Northern Regional Research Lab, Peoria, Ill. for the presence of glucosinolates. The results confirmed the absence of glucosinolates in the control diet, and the presence of 1% glucosinolates in the MFM diet.

Experiment 4.

Although the results of experiments 1, 2 and 3 indicated that raw MFM is a satisfactory feedstuff for lambs, the presence of glucosinolates in the meal may pose a hazard to ewes consuming the meal during pregnancy. Experiment 4 attempted to assess this hazard by measuring serum thyroid hormones in ewes and lambs after the ewes had consumed raw MFM during the last 7-9 weeks of pregnancy at a level similar to the lambs in experiment 3. Two of the control ewes were not pregnant. The results (Table 6) indicated that mean values for thyroxine (T4), triiodothyronine (T% uptake) and free thyroxine index (FTI) were not reduced (P>.05) in MFM ewes and lambs compared to the control group. However, one ewe gave birth to a lamb with definite goiter after 9 weeks on the MFM diet. All values in the ewe were higher than the mean control values, but values in the affected lamb were markedly reduced compared to controls (FTI=1.28 vs 4.86). This finding suggested that hormone levels in ewes may be of little value in assessing thyroid status of the fetus. This is in agreement with studies by Andrewartha et al. (1980), who found that serum thyroxine levels in newborn lambs were more sensitive than levels in ewes as an indicator of hypothyroidism associated with iodine deficiency. The lamb died 48 h after birth and thyroids were removed and weighed. Fresh weight per thyroid was 15.1 grams. Another ewe on MFM for 9 weeks gave birth to twins which appeared to have moderately hyperplastic thyroids. One lamb died within 18 h and its thyroids weighed 3.3 grams each. Although a blood sample was not obtained from this lamb, its twin and the ewe had values similar to controls. Studies by Sinclair and Andrews (1961) with pregnant ewes consuming goitrogenic kale (Brassica oleracea) during the last 9 weeks of pregancy indicated that if fresh thyroid weights in newborn lambs exceeded 2.8 g, they were hyperplastic (1.3 g was considered normal). Six of nine lambs born to five of seven ewes consuming MFM were vigorous at birth and showed no signs of enlarged thyroids. It is possible that the ewes with goitrogenic lambs may have been unusually sensitive to the glucosinolates. When Sinclair and Andrews (1961) prevented goiter in ewes by injecting with iodized poppyseed oil, some lambs were still born with goiter. These results indicated that raw MFM may cause problems in pregnant ewes. Experiments with broiler chicks (Throckmorton et al. 1980) showed that addition of iodinated casein to MFM diets eliminated increases in thyroid weights. Addition of iodinated casein to MFM diets for pregnant ewes might overcome the problem of goiter in newborn lambs. Until further research can resolve this question, MFM should be restricted to diets for sheep destined for slaughter.

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Table 1: Percent composition of Digestion Trial Diets Experiment 1

Ingredients	Basal	CSM	Raw MFM	SC MFM
Corn	53.2	47.9	42.6	42.6
Ryegrass straw	21.8	19.6	17.4	17.4
Cottonseed Meal	17.1	35.4	13.7	137.7
MFM	--	--	20.0	20.0
Molasses	5.9	5.3	4.7	4.7
Limestone	2.0	1.8	1.6	1.6
Vitamin A[a]	--	--	--	--

[a]2000 IU/kg.

Table 2: Percent composition of diets for growing and finishing lambs

Ingredient	Experiment 2			Experiment 3	
	1	2	3	1	2
Raw MFM	--	9.0	18.0	--	23.0
Cottonseed meal (41% protein)	9.2	4.6	--	11.0	--
Barley	35.0	35.0	35.0	25.0	25.0
Alfalfa	10.0	10.0	10.0	45.6	46.0
Grass hay	38.8	34.4	30.0	--	--
Ryegrass straw	--	--	--	12.4	--
Molasses	6.0	6.0	6.0	5.0	5.0
Limestone	0.5	0.5	0.5	--	0.5
Dicalcium phosphate	--	--	--	0.5	--
Trace mineral salt[a]	0.5	0.5	0.5	0.5	0.5
Chemical analysis (as fed)					
Crude protein (Nx6.25)	11.1	12.1	12.2	14.6	14.7
Acid detergent fiber	22.6	21.7	22.2	25.2	25.0

[a]Provides in addition to NaCl, the following mg/kg elemental levels to the complete diet: Zn, 17.5; Mn, 14.0; Fe, 8.8; Cu, 1.8; I, 0.4; Co, 0.4.

Table 3: Chemical Analysis of Meadowfoam Meal

Composition	%
Dry matter	92.7
Protein (N x 6.25)	21.1
Acid detergent fiber	26.6
Glucosinolates	4.2
Ash	13.1
Acid insoluble ash	3.9
Ether extract	1.9
Calcium	1.14
Phosphorus	0.82
Gross energy	3570 kcal/kg

Table 4: Apparent Digestibility of Diets by Sheep (Exp. 1) Mean±SD

Diet	Dry Matter	Crude Protein	Gross Energy	Acid Detergent fiber	Ash
Basal	76.8±1.1[a]	74.8±4.0[a,b]	76.9±1.2[a]	37.4±1.9[a]	47.0±4.5[a]
90% Basal + 10% Cottonseed Meal	77.1±1.4[a]	76.5±2.6[a]	76.8±1.4[a]	36.3±2.5[a]	52.3±3.9[a]
80% Basal + 20% Raw MFM	72.4±0.9[b]	70.0±1.9[b]	74.0±1.1[b]	17.4±2.3[b]	23.6±3.3[b]
80% Basal + 20% SC-MFM	70.7±2.1[b]	68.8±4.2[b]	72.9±2.2[b]	19.7±5.2[b]	24.2±5.0[b]

different superscripts indicate differences (P<.01)

Table 5: Performance of lambs fed raw MFM (Mean±SD)

	Experiment 2			Experiment 3	
	1	2	3	1	2
Average daily gain (kg)	0.45±.20	0.58±.18	0.56±.09	0.23±.05	0.23±0.04
Feed/gain ratio	6.7	5.0	5.2	9.0	8.7
Dressing percentage	--	--	--	46.3±2.0[a]	48.5±1.8[b]
Backfat thickness (cm)	--	--	--	0.51±.12	0.54±.08

different superscripts indicate differences ($P<0.05$)

Table 6: Serum thyroid hormone values of ewes and lambs at parturition (Mean±SD)

Group	No. Animals	T3% uptake	T4 (mcg/kl)	Free Thyroxine Index (T3% x T4)
Control Ewes	5	40.7±3.2	7.3±1.2	3.0±0.7
MFM Ewes	7	44.2±3.8	9.0±1.9	4.0±1.1
Control Lambs	6	54.3±5.6	9.1±3.8	4.9±1.9
MFM Lambs	9	48.5±8.7	9.9±2.9	4.9±1.8

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CONCLUSION

The following conclusions can be made in regards to utilization of MFM as a feedstuff.

1. Diets in which 30% of the dietary protein was supplied by MFM supported satisfactory gains in broiler chicks, weanling rabbits and feeder lambs.

2. Raw MFM was very unpalatable to broiler chicks, but this problem was overcome by steam cooking. Palatability problems were not encountered in rabbits or sheep when raw MFM was fed at moderate levels (20-30% of the diet).

3. The glucosinolates in MFM caused thyroid and liver weights to increase, but this did not appear to adversely affect short term (six weeks) performance. However, goiter and death in one lamb born to a ewe fed raw MFM during late pregnancy indicates MFM may be hazardous for breeding stock. Iodinated casein was effective in overcoming the goitrogenic effect of MFM in chicks, suggesting that this additive may be beneficial in overcoming the problem of goiter development in newborn lambs.

4. In the future, long term feeding trials should be conducted to determine what effect MFM would have on breeding stock.