UNIVERSITY OF MANITOBA

THE EFFECT OF AMMONIATION ON NUTRIENT AVAILABILITY OF SUNFLOWER SEED

BY

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ABSTRACT

Two in situ trials were carried out to determine the effect of ammonia treatment on the rate of disappearance of nutrients in sunflower seed. The specific objective in each trial was to measure the effect of ammoniation on nutrient disappearance of a, b and a + b fraction as well as c which is the rate of degradation of b. The a fraction is the rapidly soluble material (%), b is the slowly degraded material (%), and a + b is the potentially degraded material (%). The four treatments in trial 1 were whole sunflower seed, ground sunflower seed, ammoniated whole sunflower seed and ammoniated ground sunflower seed. Ammonia treatment did not affect ($P>0.05$) the disappearance of dry matter (DM), crude protein (CP) in the a, b and a + b fraction as well as c of ground sunflower seed. The four treatments in trial 2 were control and ammoniated kernel and control and ammoniated hull. The disappearances of DM and neutral detergent fibre (NDF) in the kernel were greater than those of the hull ($P<0.05$). Ammoniation reduced ($P<0.05$) the DM disappearance in the a + b fraction of the kernel. Ammoniation did not affect ($P>0.05$) the disappearance of DM and NDF in the a and b fractions in the kernel and hull. Ammonia treatment reduced the CP disappearance in the b fraction of the hull ($P<0.05$). Sheep were used to further examine the effect of ammoniation on digestion.

Eight male lambs were used in a double 4 x 4 latin square design to determine the effect and level of ammonia treatment of sunflower seed on dry matter intake (DMI), CP intake, fat intake, nitrogen balance and nutrient digestibility. The treatments were ammoniated and control sunflower seed included at two levels (16 and 25%) in the diets. Dry matter intake and CP intake were not different ($P>0.05$) for all

treatments. The intake of fat for the control diet containing 25% sunflower seed was higher ($P<0.05$) than fat intakes for the rest of the treatments. Dry matter intakes kg^{-1} body weight were not different ($P>0.05$) among treatments. Nitrogen in the urine as a percentage of nitrogen intake as well as nitrogen balance were not different ($P>0.05$) among treatments. The digestibilities of DM, CP, fat and acid detergent fibre (ADF) were not affected by treatments ($P>0.05$). Digestibility of NDF tended ($P<0.06$) to increase with the lower level of sunflower seed in the diet when the seed was treated with ammonia. The ammoniated seeds were fed to lactating cows to further examine its utilization by high producing lactating cows.

Twenty Holstein cows were used to determine the effect of supplementary fat in the form of ammonia treated sunflower seed on feed intake, milk production, milk composition, rumen environment and blood urea nitrogen. Twenty cows at 21-23 d post partum were allocated equally to control or 5.6% ammoniated sunflower seed diets. Cows were fed ad libitum, an iso-nitrogenous and iso-NDF total mixed ration of concentrate and alfalfa silage with calculated NE_L value of 1.67 and 1.75 Mcal/kg for control and treated sunflower seed diets respectively. Milk yield, fat corrected milk and feed intake were similar ($P>0.05$) for the two treatments. Milk fat, crude protein and solids-non-fat percentages were not different ($P>0.05$). The molar percentages for C10:0, C12:0, C14:0 and C16:0 fatty acids in milk fat were reduced ($P<0.05$) for cows receiving the ammoniated sunflower diet while the percentages of C18:0, C18:1, C18:2 and C20:0 fatty acids were increased ($P<0.05$). The levels of acetic, propionic and butyric acid in the rumen were not different ($P>0.05$) between treatments. Rumen

acetate:propionate ratios, pH, and ammonia levels were not different ($P>0.05$) between treatments. Blood urea nitrogen levels were not different ($P>0.05$) for the two diets.

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Dedicated to My Wife, June

For Her Love and Encouragement

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ABBREVIATIONS

ADF	acid-detergent fibre
CP	crude protein
d	day
DM	dry matter
DMI	dry matter intake
EE	ether extract
FCM	fat corrected milk
g	gram
h	hour
kg	kilogram
KOH	potassium hydroxide
l	litre
Mcal	megacalories
mg	milligram
NaOH	sodium hydroxide
NDF	neutral detergent fibre
NE_L	net energy for lactation
NH_4OH	ammonia hydroxide
NH_3	ammonia
NPN	non-protein nitrogen
SE	standard error
SNF	solids non-fat
wk	week
w/w	weight per weight
VFA	volatile fatty acid

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INTRODUCTION

Dairy cows in early lactation need a high energy diet to meet their energy requirement for milk production. This high energy diet can be provided by feeding grain, but when the percentage of grain is above 55 to 60% of the ration dry matter, digestive disturbance and low milk and fat yield (Linn, 1987) may result. Palmquist and Jenkins (1980) concluded that 3 to 5% fat can be added to the diet to increase the energy density. This allows for the use of less grain or starch feed thereby increasing the ratio of forage to concentrate, which may reduce milk fat depression.

In 1987 Manitoba grew 70,000 acres of sunflower and this acreage more than doubled (150,000 acres) in 1990 (Personal communication). Thus sunflower seed in Manitoba could become an important ingredient as a fat source for dairy rations. McGuffey and Schingoethe (1982) recommended that 10% of whole sunflower seed can be used in the rations for lactating dairy cows. Drackley et al. (1985) reported that when whole sunflower seed constituted 10% of the ration dry matter (DM) for Holstein steers, cellulose digestion was depressed, but digestibility of DM, lipid, gross energy, calcium and magnesium were not affected. The reduction in cellulose digestion could be due to the fat released from the seed, which can reduce fibre digestibility (Devendra and Lewis, 1974).

Ammoniation has been used to increase the digestibility and/or intake of low quality feedstuffs (Grotheer and Cross, 1986). Anderson et al. (1984) compared cotton seed, extruded soybean and sunflower seed in the diets fed to lactating dairy cows and concluded that the diet containing whole sunflower seed (12% of ration DM) was not as

satisfactory for lactating dairy cows as those containing whole cotton seed (10% ration DM) or extruded soybean (5.0% ration DM). This may be due in part to the hard seed coat of sunflower seed, since it is high (6 to 8%) in lignin (McGuffey and Schingoethe, 1982). Sharma et al. (1988) found that the digestibility of sunflower hulls was improved when treated with potassium hydroxide (KOH) and sodium hydroxide (NaOH) at 2.45% on a w/w basis. Rumen in situ studies carried out on high moisture barley by Robinson and Kennelly (1988b) showed that ammoniation increased the degradation of neutral detergent fibre (NDF). If ammonia treatment of whole sunflower seed improves fibre digestibility and/or reduced rumen degradation of protein then it may be more advantageous to use ammoniated sunflower seed in dairy rations as a fat source.

The objective of this study was 1) to measure the effect of ammoniation on rumen in situ DM, CP, NDF, ADF and fat disappearance from sunflower seed, hull and kernel; 2) to measure the effect of ammoniation of sunflower seed on sheep in vivo dry matter intake, digestibility of DM, crude protein (CP), NDF, acid detergent fibre (ADF) and fat and nitrogen balance; 3) to measure the effect of ammonia treated sunflower seed on intake, milk yield and milk composition for dairy cows in early lactation.

LITERATURE REVIEW

AMMONIA TREATMENT OF FEEDSTUFFS

Ammoniation is the process of applying ammonia to feed sources such as straws, cereals and oilseeds in order to improve their nutritive value. The methods of applying ammonia to feedstuffs especially straws have been reviewed by Tembo (1987) and Subiyatno (1989).

Ammoniation increased straw cellulose and hemicellulose digestibility (Streeter and Horn, 1984). Van Soest (1982) reported that ammonia and other alkaline compounds hydrolyse the ester and hydrogen bonds between uronic acid groups of hemicellulose and cellulose with lignin. Solubilization of hemicellulose makes it a readily available substrate that can be used by microorganisms. This may lead to increased dry matter and fibre digestibility and hence increased intake of the feedstuff can be expected (Mertens, 1985).

Investigations were carried out on the duration of ammoniating, moisture content that is most suitable for treatment with ammonia, temperature and the level of ammonia to use. Thorlacius and Robertson (1984) reported that the treatment of high moisture hay at a rate of approximately 2% on a w/w basis is an effective means of preserving and enhancing forage quality. Treatment of low quality forage with 3-4% ammonia on a w/w basis at 30-32°C for 1-4 weeks is recommended by Sundstol and Coxworth (1984). Sundstol and Coxworth (1984) reported that the effect of ammoniation is accelerated by increasing the temperature up to 45°C with a short treatment time (3-7 d). On the other hand, at low temperatures (approximate to or below the freezing point of water) the action of ammonia is very slow. This means that the low treatment temperatures must be compensated for by increasing the

time of treatment (Sundstol et al. 1978).

The moisture content of the material influences the effect of ammonia. Grotheer and Cross (1986) reported that the concentration of nitrogen after ammoniation was greater in high moisture hay than dry hay. They concluded that the higher moisture content facilitated the introduction and absorption of ammonia in the forage. Horn and Streeter (1984) suggested that the level of moisture should not exceed 24% in order to avoid mould growth and difficulty in handling the ammoniated material.

No studies were found that examined the effect of ammoniation relative to the different moisture levels in grain. The moisture content of different grains varied when they were treated by different researchers. Robinson and Kennelly (1988a) and Rode et al. (1986) ammoniated high moisture barley when the moisture content was 30%. These studies were carried out just after harvesting. Srivastava and Mowat (1980) ammoniated shelled corn when the moisture content was 28%, and this was just after harvesting. Low and Kellaway (1983) reconstituted whole wheat grain to 15% moisture before adding ammonia to the grain.

There are several benefits that can be derived from the ammoniation of feedstuffs especially straws. They are usually low in crude protein and digestibility. Extensive research has shown that they can be treated with ammonia to improve their utilization. Horton (1979) reported that ammoniation of barley, oat and wheat straw increased dry matter consumption by as much as 21%, and increased organic matter digestibility by 2.2, 3.7 and 6.3 units, respectively. Doornbos et al. (1985) reported that beef heifers fed ammoniated hay consumed 17% more

dry matter than animals fed untreated hay. They reported that ammoniation raised the crude protein content of straw from 3.9% to 10.8%. Feeding ammonia treated straw showed improvement in animal production as well. Doornbos et al. (1985) found that beef heifers consuming ammoniated hay gained 0.21 kg/d more than animals fed untreated hay.

ALKALINE TREATMENT OF GRAINS AND OILSEEDS

Berger et al. (1981) treated reconstituted whole oats (30% moisture) with 3% NH_4OH on a w/w basis, and obtained an in situ DM digestibility of 16.6% at 24 h of incubation. The DM digestibility was increased to 22.5% when the level of NH_4OH was increased to 6% on a w/w basis.

Berger et al. (1981) also treated high moisture whole shelled corn (30% moisture) with 3% NH_4OH on a w/w basis. They noted a 3 fold increase in in situ DM digestibility compared with the untreated high moisture whole shelled corn. Srivastava and Mowat (1980) treated whole high moisture shelled corn (28% moisture) with ammonia at a level of 2% on a w/w basis. The untreated whole corn did not digest much even after 48 h of rumen incubation compared to 80% digestibility of DM for the same period when the corn was ammoniated. When a mixture of acetic:propionic acid (1.5% on a w/w basis) treated whole corn and ensiled ground corn were compared with ammoniated whole corn (all treatments constituted 40% of ration total dry matter for steers), ammoniated whole corn resulted in similar starch and energy digestibilities compared to ensiled ground corn, but there was a decrease in starch digestibility of acid-treated whole corn.

Digestibility of ADF was greater with both ammoniated and acid-treated whole than ensiled ground corn (Mowat et al. 1981).

Orskov et al. (1980) treated whole wheat grain with 2.5-3% NaOH on a w/w basis, and found that the organic matter digestibility was increased from 79 to 92% when the treated grain was fed to steers. Low and Kellaway (1983) treated whole wheat grain at a level of 4% with ammonia on a w/w basis. The ammoniated whole grain, cracked grain, and whole grain were fed to steers to compare their relative digestibilities. There was an improvement in DM and NDF digestibility and nitrogen retention due to ammoniation. A rumen in situ study indicated that the untreated whole wheat was degraded at a significantly slower rate than either the cracked or NH_3-treated wheat. The rate of disappearance of DM for the ammonia treated wheat was intermediate. It was concluded that when the whole grain was ammoniated, it was utilized as efficiently as cracked grain when fed as a sole diet to cattle, and resulted in fewer digestive disturbances than cracked wheat.

Berger et al. (1981) treated high moisture whole barley grain (30% moisture) with 3% NH_4OH on a w/w basis, and obtained a rumen in situ digestibility of 10.7% after a 48 h incubation period. When the level of ammonia was increased to 6% on a w/w basis the digestibility of increased to 20.8%. Rode et al. (1986) investigated the effect of ammonia treatment on high moisture barley (30% moisture). These researchers compared rolling, ammoniating, and addition of 6% urea to the whole barley grain. A study with steers showed that starch apparent digestibility was 86.8% for the rolled grain, and this was greater than that of the ammoniated whole grain (76.9%), and that of urea treated grain (69.1%). There was no observed difference among treatments with

respect to DM digestibility. A rumen in situ study indicated that after 36 h of incubation, the average percentage of DM remaining in the bags were 85.6 for the whole untreated barley, 46.9 for the rolled barley, 67 for urea treated barley and 50 for the ammonia treated barley.

Robinson and Kennelly (1988a) observed that ammoniation of high moisture whole barley (30% moisture) resulted in a net reduction of the rate of DM disappearance in the rumen as well as an increase in the whole tract true DM digestion. Similar studies (Robinson and Kennelly, 1988b) showed that the rumen degradation rate of DM in high moisture barley decreased as the level of ammonia was increased, but the nitrogen component was not affected and NDF degradation increased.

Recently the use of NaOH to protect protein from rumen degradation has shown some potential (Bowman et al. 1988). Mir et al. (1984a) treated soybeans and soybean meal with NaOH, and rumen in situ data showed that soybean protein can be effectively protected from degradation in the rumen without adverse effect on protein in vivo digestibility. Further research (Mir et al. 1984b) demonstrated that NaOH treatment of soybean meal resulted in production of more milk in high yielding cows during early lactation.

Mir et al. (1984a) reported that when canola seed and canola meal were treated with 3% NaOH on a w/w basis, the protein fraction was effectively protected from degradation in the rumen without adverse effect on protein in vivo digestibility.

Studies carried out on ammonia treatment of grains and oilseeds are much more limited than those conducted on straws. However, studies showed that some additional benefits can be derived from ammoniation. Ensiling high moisture barley can lead to spoilage due to aerobic

fermentation (Krall, 1972) and ammonia treatment has the potential of reducing this problem. Peplinski et al. (1978) noted a reduction in aflatoxin when 1.1% NH_3 on a w/w basis was added to shelled corn (17.6% moisture). Similarly, Srivastava and Mowat (1980) reported a reduction in fungal and bacterial growth when high moisture corn (28% moisture) was treated with ammonia at a rate of 2% on a w/w basis.

LIPID METABOLISM IN THE RUMINANTS

The Effect of Dietary Fat on Digestibility

The results on the effect of dietary fat on ration component digestibility by ruminants are conflicting especially as they relate to fibre digestibility. Czerkawski et al. (1966) reported that when sheep were fed 30 and 50 g of glyceride and fatty acid derived from linseed oil, there was a significant decrease in cellulose digestion. However, Palmquist and Jenkins (1980) found no effect of protected tallow on the digestibility of dietary components, particularly when dietary calcium levels were maintained. Feeding graded levels (0, 5, 10, 15%) of protected tallow in the grain mix for lactating Holstein cows did not affect the digestibility of DM, CP ADF, calcium and magnesium (Sharma et al. 1978).

Smith et al. (1981) fed graded levels (0, 5, 15, 25%) of whole cotton seed as part of the total ration to lactating cows, and found an increase in the digestibility of nitrogen, energy and lipid as the levels of cotton seed were increased. The digestibility of fibre was not significantly affected although there was a trend towards decreased cellulose digestibility as the levels of whole seed were increased. Murphy et al. (1987) fed 2 kg/d of full fat crushed rapeseed to

lactating cows, and found that there was a decrease in rumen and total dry matter digestibilities. Rumen cellulose digestibility was decreased as well.

The increase in lipid digestibility as the levels of dietary fat were increased was reported by Sharma et al. (1978) and White et al. (1987a). This can be explained by the fact that the level of endogenous fat remain fairly constant even when the level of lipid in the diet is increased, thus apparent digestibility increases.

Earlier research carried out at the University of Manitoba showed when rapeseed oil, sunflower oil and animal tallow replace 5% of the grain mix by weight in steers' diets they did not affect DM digestibility (Roberts and McKirdy, 1965). Drackley et al. (1985) fed whole sunflower seed (10% of ration dry matter) to Holstein steers, and found that cellulose digestion was depressed. However, digestibility of DM, organic matter, lipid, gross energy, calcium and magnesium were not affected. Recent research by White et al. (1987a) demonstrated that 4% sunflower oil and graded levels (10, 20%) of whole sunflower seed as part of the total ration DM did not affect the apparent digestibility of DM, CP, energy and fibre. The fat digestion coefficients increased with increased dietary intake of fat. The fat in the diet may not be totally associated with a reduction in the digestibility of fibre in the diet as Park et al. (1982) found that when graded levels of sunflower hulls (0, 10, 20, 30, 40%) of the total ration were fed to Holstein heifers, there was a corresponding linear decline in nutrient digestibility of dry matter, acid detergent fibre and crude protein. This is expected because the hull contains about 56% ADF and has a low digestibility.

Mechanisms By Which Dietary Fat Affect Digestion

The exact mechanism whereby lipids interact with fibre to bring about reduced digestibility of the latter is not clear. Four general theories have been proposed (Devendra and Lewis, 1974). These are:

1. Coating of the fibrous parts of the diet by lipids thereby reducing accessability to fibre by micro-organisms.
2. Lipid supplementation changes the rumen microbial flora that is associated with cellulose digestion.
3. Fatty acid may inhibit growth due to an influence on cell wall permeability brought about by adsorption of fatty acid on the cell wall.
4. Reduced availability of minerals for microbial activity brought about by formation of mineral complexes such as a reduced retention of calcium due to excessive excretion of soaps in the faeces.

In addition to the above theories, Palmquist and Jenkins (1980) suggested that fatty acids particularly polyunsaturates are inhibitory to microbial growth, and this can lead to reduced fibre digestibility. Palmquist and Conrad (1980) found that increasing grain in the diet decreased DM and ADF digestibility as well.

Methods of Reducing the Negative Effects Due to Feeding Fats

The effect of supplementing buffers in ruminant diets on rumen pH, acetate:propionate ratio, and dry and organic matter digestibilities has been reviewed elsewhere (White et al. 1987b). Research on the effect of feeding $NaHCO_3$ in combination with 9% whole sunflower seed to Holstein cows was carried out by White et al. (1987b). They found that $NaHCO_3$ had no effect on total DMI and milk yield, levels of milk protein or

lactose, total VFA's, molar percent of individual VFA, and on rumen ammonia levels.

Jenkins and Palmquist (1982) found in an in vitro experiment that when 2% of dicalcium phosphate was added to a substrate that contained 10% tallow, there was a significant increase in the soluble fatty acid soap content as well as a slight increase in cell wall digestibility. They suggested that this increase in cell wall digestibility was due to the formation of insoluble calcium salts or soaps of polyunsaturated fatty acids. The formation of the insoluble calcium salts reduced the levels of fatty acid which inhibit bacterial growth, and thus may lead to increased fibre digestibility. However, Drackley et al. (1985) fed 3 diets containing sunflower seed which constituted 10% of the ration DM and a soybean meal based diet to Holstein steers. Three and a half percent limestone or 2% calcium hydroxide were added separately to each diet. They found that although there was an improvement in cellulose digestion with the addition of limestone or calcium hydroxide, there was no increase in the concentration of insoluble fatty acids or soaps when limestone or calcium hydroxide was added to the diet. They suggested that improved digestion of fibre with calcium could not be attributed to increased formation of fatty acid soaps in the rumen. This was confirmed by Finn et al. (1985) who fed 3.5% additional limestone and whole and rolled sunflower seed (10% of ration DM) to lactating Holstein cows. They found that the insoluble salts of fatty acids were increased in ruminal fluid DM from cows fed sunflower seed, but were not increased further by additional limestone. The formation of soaps does not seem to totally explain the increased digestibility.

Kent and Arambel (1988) fed rations containing 13.2% whole cotton

seed on a DM basis with or without added calcium salts of long chain fatty acids to dairy cows in early lactation. The addition of calcium salts of long chain fatty acids had no effect on yield of actual and fat corrected milk, percent milk fat and lactose. Neutral detergent fibre and ADF digestibilities were unaffected by treatment.

Mabon (1988) fed lactating Holstein cows an experimental diet consisting of 7.5% extruded canola seed and 0.6 % $CaCl_2$ as part of the ration DM. The additional calcium chloride did not improve feed intake, milk production, milk protein, lactose and fat when compared with the control diet.

Emery (1978), concluded in a review that the addition of fat to dairy rations decreased the milk protein concentration, and that to increase protein, additional dietary energy had to come from carbohydrates or other materials capable of increasing blood glucose. Ketosis in dairy cows is characterized by elevated ketones in blood and milk, and reduced glucose in the blood. Waterman et al. (1972) treated subclinical ketotic cows with varying doses of nicotinic acid, and after 14 d the level of ketone bodies began to return to normal. Ruegsezzer and Schultz (1986) found that nicotinic acid was beneficial in treating cases of subclinical ketosis. Thornton and Schultz (1980) found that the administration of nicotinic acid in pharmacological doses to ruminants resulted in an increase in glucose and insulin in the blood. From a number of experiments involving five herds and 240 cows fed 6 g of niacin per day during the summer, Muller et al. (1986) found an increase in milk yield and fat corrected milk, but no effect on milk composition. Perhaps the feeding of oilseeds together with niacin can lead to an increase in milk protein % and yield. Horner et al. (1986)

found no additional benefits in terms of milk yield, total milk solid and milk fat percentage when 0.03% of niacin was supplemented to a dairy ration containing 15% whole cotton seed as part of the total ration DM. This result was confirmed by Mabon (1988) who fed lactating Holstein cows an experimental diet of which extruded canola seed constituted 7.6% and niacin 0.027% of total ration DM. No difference was found in feed intake, milk production, milk protein, lactose and fat levels compared with cows receiving the control diet.

The administration of bovine somatotropin (bST) to dairy cows increased milk production (Richard et al. 1985; Poccious and Herbein, 1986). Milk production in response to feeding of dietary fat have been variable (Palmquist and Conrad 1980). Perhaps the utilization of bovine somatotropin (bST) in conjunction with supplemental fat in diet may stimulate the metabolic process needed for higher milk yield. However, Lough et al. (1988) reported that the feeding of fat with the injection of bST in Holstein lactating cows had little effect on production responses. Casper and Schingoethe (1989) proposed that lipid inhibits somatotropin release from the anterior pituitary, thereby reducing mammary gland uptake of amino acid because of the role of somatotropin in helping amino acid uptake. They suggested that the administration of exogenous somatotropin with added fat in the diets may reduce milk protein depression. Lough et al. (1988) results do not support the above concept.

Lipid metabolism in ruminants has been extensively reviewed elsewhere (Palmquist and Jenkins, 1980; White et al., 1987b; Mabon, 1988). The feeding of protected lipids is to protect them from fermentative digestion as well as to prevent biohydrogenation of the

fatty acids in the rumen. This protection may reduce the negative effect of fat on fibre digestion which may lead to an increase in milk fat % and milk yield. Protection may also result in milk fat containing more unsaturated fatty acids. The level of protection must ensure that these lipids are susceptible to hydrolytic digestion in the small intestine.

Changes in the fatty acid composition of milk fat were consistent in several studies when protected lipids were fed. Mattos and Palmquist (1974) fed formaldehyde treated full fat soyflower to lactating Jersey cows, with the result that linoleic acid (C18:2) absolute yield increased (106.7 to 171.6 g/d) in milk fat from animals receiving the protected supplement. This should suggest protection from biohydrogenation in the rumen. In the above study, the C6-C16 fatty acids percentages were reduced and butyrate and all 18C fatty acids were increased. Yang et al. (1978) and Dunkley et al. (1977) reported similar results. In the study carried out by Dunkley et al. (1977), nuclear magnetic resonance indicated the butter from the control group would be harder than that from cows fed protected tallow. Handy and Kennelly (1983) fed lactating cows "Protec", a canola based lipid supplement (75% whole canola seed + 25% canola meal treated with formaldehyde) at a level of 3.6% of the ration. They observed that the fatty acid composition of milk from cows fed protected lipid diet showed significantly lower levels of 12:0, 14:0 and 16:0 fatty acids and significantly higher levels of 18:0, 18:1, 18:2 and 18:3 fatty acids compared with milk from cows fed the control diet.

Megalac is one form of protected fat containing mainly soaps of fatty acids. Recent studies indicated that it can be a beneficial source of energy for early lactating cows. Ballenger and Palmquist

(1990) fed Megalac (600 g/d) to early lactating cows and found that there was an increase in milk yield and a significant decrease in milk protein percent. Milk fat percent and yield and FCM yield were not affected when compared with a control diet. Kim et al. (1990) compared the feeding of fat from extruded soybean and Megalac with a control soybean diet. They found that milk production was higher for cows fed the added fat diets. Milk protein percentages were significantly higher from cows fed soybean meal and fat from extruded soybean. Milk fat percent was statistically higher for cows fed Megalac when compared with those fed control or fat from extruded soybeans. Dry matter intake was similar for all the diets.

USE OF OILSEEDS IN LACTATION RATIONS

The fat content of oilseeds ranges between 18-44% and so they can be used in dairy rations to increase the energy density. Oilseeds such as soybean, canola, cotton seed and sunflower seed have different chemical compositions (Table 1). Because of these differences, it is expected that they would have different effects on dry matter intake, milk production and composition when used in dairy rations.

Dry Matter Intake

Dry matter intake as a result of the inclusion of oilseeds as fat source in the diet of lactating dairy cows is variable. Rafalowski and Park (1982) fed graded levels of whole sunflower seed up to 30% of the concentrate DM, and found little change in dry matter intake. Drackley and Schingoethe (1986) did not find any difference in intake when sunflower seed constituted 19% of the total ration. However, Park and Rafalowski (1983) found that as the levels of whole sunflower seeds were

Table 1. Analysis of whole canola, soybean, cotton and sunflower seed on a DM basis (%) and fatty acid composition of the oils

Item	Canola seed[3]	Soybean seed[1]	Cotton seed[1]	Sunflower seed[2]
CP	24.4	42.8	25.0	19.0
EE	44.5	18.8	23.8	40.0
ADF	13.4	10.0	26.0	34.0
Fatty acids				
Palmitic† C16:0	4.8	10.5	22.7	5.9
Palmitoleic† C16:1	0.5	0.2	0.8	trace
Stearic† C18:0	1.6	3.8	2.3	4.5
Oleic† C18:1	53.8	22.8	17.0	19.5
Linoleic† C18:2	22.1	51.0	51.5	65.7
Linolenic† C18:3	11.1	6.8	0.5	trace

1-NRC (1988).
2-McGuffey and Schingoethe (1982).
3-7th Progress Report 1983. Research on canola seed, oil, meal and meal fractions. Canola Council of Canada. Publication No. 61. p. 78.
4-National Research Council, 1984.

increased in the ration for Holstein heifers from 0 to 30%, they consume significantly less total DM, even when DMI was expressed for body weight $kg^{.75}$ (g/day).

Smith et al. (1981) found no change in dry matter intake when graded level of whole cotton seeds (up to 25% of ration DM) were fed, and this is in agreement with research carried out by DePeters et al. (1985) when they fed up to 20% whole cotton seed. Bernard and Amos (1985) compared pelleted and whole cotton seed (2.72 kg DM/d) fed to lactating dairy cows, and found no difference in dry matter intake.

Handy and Kennelly (1983) compared whole, ground and protected canola seed (3.6% of ration DM), and found that treatment had no effect on dry matter intake. However, Grumpelt (1987) fed whole canola seed 1.0 and 1.5 kg/cow/d) and found a significant positive effect on dry matter intake. Generally heat treatment decreases the solubility of protein in feed ingredients thereby reducing their susceptibility to ruminal degradation. Jet-Sploding uses high temperature (315°C) for a short period of time to treat seed. Khorasani et al. (1989) reported that when Jet-Sploded whole canola seed was fed beyond 10% of the concentrate DM there was a reduction in DM intake.

Anderson et al. (1984) compared whole cotton seed, extruded soybean seed and sunflower seed for early lactating dairy cows. The results showed that dry matter intake was highest for the extruded soybean diet followed by the whole cotton seed diet, and was lowest for the whole sunflower seed diet. The variability in DM intake among these oilseeds may be due in part to their palatability.

Body Weight

The feeding of oilseeds does not appear to have an influence on

body weight changes during lactation. Research carried out on sunflower seeds by Rafalowski and Park (1982) showed that body weight was not affected when the seed was included up to 30% of concentrate. Drackley and Schingoethe (1986) and Mabon (1988) demonstrated that when whole sunflower seed constituted 19 and 9% respectively of the total DM of the diet of lactating cows, there were no changes in body weight relative to control diets. DePeters et al. (1985) found a similar response when whole cotton seed was fed up to 20% of the ration DM. Grumpelt (1987) compared whole and extruded canola seed in diets for lactating cows (7.9% of total diet) and found no difference in body weight change relative to a control diet. The feeding of heat treated soybean versus unheated soybean did not influence weight change in lactating cows (Mielke and Schingoethe 1981). However, Van Dijke et al. (1983) found that feeding extruded soybean resulted in a gain in cows' weight when compared with the feeding of raw ground soybean (Van Dijketal. 1983). The references cited above do not indicate major change in body weight due to the feeding of oilseeds.

Milk Production

The response in milk production when oilseeds are included in dairy rations is variable. White et al. (1987b), Mabon (1988) and Casper et al. (1988) observed little change in milk production when whole sunflower seed constituted 9% of the ration total DM. McGuffey and Schingoethe (1982) and Finn et al. (1985) did not observe any change in milk production when extruded or rolled sunflower seed made up 10% of the total ration. Nineteen % whole seed as part of the ration did not influence milk yield and FCM (Drackley and Schingoethe, 1986). However, the yield of 4% FCM from cows fed sunflower seed tended to be lower

(Finn et al. 1985). On the contrary, Rafalowski and Park (1982) observed an increase in milk yield and 4% FCM when the sunflower seed constituted 10% of the concentrate, but milk yield and FCM were not different from the control when the seeds were increased to 20 and 30% of the concentrate DM.

The response to milk yield from whole cotton seed seems to be different from sunflower seed. Smith et al. (1981) and DePeters et al. (1985) fed graded levels of whole cotton seed, and observed increases in the yield of 4% FCM. Anderson et al. (1979) observed an increase in milk yield, but yield of 4% FCM was not significant when graded levels of whole cotton seed were fed (up to 20% of concentrate DM) to lactating dairy cows. Bernard and Amos (1985) reported that when cotton seed was fed as pellets (2.72 kg DM/d), cows tended to yield a higher percentage of fat corrected milk than when it was fed as the whole seed. Grumpelt (1987) fed 9.7% whole and extruded canola seed as part of the total ration DM and found that cows receiving the extruded ration gave more milk than cows receiving the control diet. Handy and Kennelly (1983) fed whole ground and protected canola seed (3.6% of ration DM), and found that milk yields were similar for all the diets when compared to a control diet. Khorasani et al. (1989) concluded that canola seed up to 10% of the concentrate mix had a positive effect on milk production.

Research carried out on the use of whole soybean (Van Dijk et al. 1983) indicated that feeding extruded soybean to dairy cows had no advantage over feeding raw ground soybean in terms of milk production. Rakes et al. (1972) fed roasted and raw soybean (38% of concentrate DM) and found no difference in FCM production. Faulkner and Pollock (1989) fed soybean oil (400 g/d) to lactating dairy cows, and found that milk production was not affected when compared to a control diet. The

response in milk production to the feeding of oilseeds is variable and would appear to depend on the kind of oilseed and degree of processing which the seed received. Generally the addition of oilseeds to the diet does not appear to reduce milk production and in some cases has increased milk yield.

Milk Fat Percent

The response of milk fat % from oilseed feeding is variable. White et al. (1987b) and McGuffey and Schingoethe (1982) did not observe any significant change in fat percentage in milk when whole sunflower seeds were fed at a level of about 9% of the total diet. The addition of sunflower oil in place of seed causes a decrease in fat test (White et al. 1987b). Casper et al. (1988) and Mabon (1988) observed a decrease in the percentage milk fat when the same level (9%) was fed to lactating cows. When the level of sunflower seed constituted 19% of the total diet, there was a decrease in the milk fat percentage (Drackley and Schingoethe, 1986).

Whole cotton seed appears to be superior to sunflower seed with respect to sustaining milk fat yield. DePeters et al. (1985) and Smith et al. (1981) observed increases in milk fat yield and percentages when graded levels of whole cotton seeds were fed up to 20% of the total ration. Pelleting the whole cotton seed did not affect fat test when compared with feeding the whole seed to lactating cows (Bernard and Amos, 1985). Howeve Mohamed et al. (1988) noted a reduction in fat test when cotton seed oil was fed (4% of the total diet) when compared with a control cotton seed meal diet. The whole and roasted whole cotton seed did not affect milk fat % in the same experiment (Mohammed et al. 1988).

Grieve (1973) observed little change in the fat percent of milk when whole canola seed constituted 8.5% of the dry matter of dairy ration. Later Handy and Kennelly (1983) fed whole, ground and protected canola seed (3.6% of total DM) and observed little change in percentage of fat in milk. Grumpelt (1987) compared whole and extruded canola seed (3.2% added fat to total mixed ration), and observed a reduction in milk fat for the extruded seed relative to the whole seed.

Block et al. (1981) fed heat treated whole soybean (6 kg/d) and noted a reduction in fat test of the milk when compared with a control diet. However, Mielke and Schingoethe (1981) compared ground heated and unheated soybean (24.3% of concentrate DM) and found no depression in milk fat when compared with a control soybean meal based diet. Feeding whole and roasted soybean (20% of ration DM) did not affect milk fat percentage, but when the soybean oil was fed (4% of total ration) there was a significant reduction in milk fat percent when compared to a control soybean meal diet (Mohamed et al. 1988). The variability in milk fat % for the different oilseeds may be associated with the processing of the seeds. If the oil is free of the seed in general fat test was decreased. The reduction of milk fat % when high fat diets are fed to lactating cows can be due to several reasons. Storry et al. (1973) showed that feeding of fats and their subsequent uptake by the mammary gland inhibited de novo synthesis of short-chain fatty acids in the mammary gland, thus reducing the potential to increase fat production by feeding fat. Palmquist and Jenkins (1980) suggested that fat depression may occur when rumen fermentation is shifted to a lower acetate/propionate ratio whether by feeding less fibre or by feeding polyunsaturated oil. Selner and Schultz (1980) proposed that trans acids or compounds produced in the rumen during their formation from

polyunsaturated fatty acids are responsible for milk fat depression from unsaturated oils.

Milk Protein

The feeding of lipids or protected lipid supplements appear to be associated with a reduction in the percent CP in the milk (Dunkley et al. 1977 and Sharma et al. 1978). Although decreased concentration of CP in the milk may be due to a dilution effect because of increased milk volume, Dunkley et al. (1977) observed that the effect was specifically on the casein fraction. Rafalowski and Park (1982) and McGuffey and Schingoethe (1982) noted little change in the percent CP in the milk when sunflower seed was fed (9% and 10% of ration DM respectively). However, Drackley and Schingoethe (1986) reported a decline in the CP % of the milk when sunflower seed was fed to lactating Holstein cows.

The feeding of whole cotton seed appeared to depress the % CP in milk (Smith et al. 1981 and DePeters et al. 1985). However, Bernard and Amos (1985) observed that feeding the pelleted whole cotton seed (2.72 kg DM/d) did not affect the CP % in the milk. Mohamed et al. (1988) did not observe a depression in milk CP when cotton seed meal plus oil (4%), whole and roasted whole cotton seeds compared with cotton seed meal as the control diets were fed to lactating cows. Handy and Kennelly (1983) fed whole, ground and protected canola seed (3.6% of ration DM) and observed little change in the percent crude protein of milk. Mielke and Schingoethe (1981) fed unheated and heated soybean (24.3% of concentrate DM) and noted a reduction in the percent crude protein when compared to a control soybean meal based diet. The feeding of soybean oil (4% of diet), whole and roasted soybean (20% of ration DM) depressed crude protein percent in milk when compared to a soybean meal based diet

(Mohamed et al. 1988).

Generally the feeding of oilseeds is associated with a depression in the milk protein level. The mechanism by which high levels of dietary fat reduce milk protein remain to be solved (Smith et al. 1981). However, Emery (1978) suggested that in order to maintain protein levels in milk, the extra energy in the diet must be carbohydrate or other materials capable of increasing blood glucose. Palmquist and Moser (1981) suggested that high dietary fat may impair amino acid transport in the mammary gland and milk synthesis. This concept was later supported by Casper and Schingoethe (1989) who proposed that lipids inhibit somatotropin release from the anterior pituitary, thereby reducing mammary gland uptake of amino acid because of the role of somatotropin in helping amino acid uptake. This may be responsible for the reduction in milk CP % when oilseeds are fed to dairy cows.

Solids Non-Fat Percent

Solids non-fat refers to mainly the protein, lactose and mineral component of milk. Casper et al. (1988) and McGuffey and Schingoethe (1982) did not observe any change in the SNF of milk when whole sunflower seed was fed. However, Drackley and Schingoethe (1986) noted a reduction in SNF % when sunflower seed constituted 19% of sunflower seed for lactating cows. Anderson et al. (1979) observed an increase in the SNF % when whole cotton seeds were fed to lactating cows as well. This is not in agreement with studies carried out by Smith et al. (1981) and DePeters et al. (1985) who found no change in the percentage of the SNF in the milk when whole cotton seed were fed.

Handy and Kennelly (1983) fed whole, ground and protected canola seed (3.6% of ration DM) and found no change in the percentages of

lactose of milk for all treatments. Mielke and Schingoethe (1981) fed whole and heated soybean (24.3% of concentrate DM), and found little change in the percentage of SNF when compared with a control soybean meal diet. Although protein levels tended to decrease with added fat these changes were not reflected in changes of SNF levels in milk.

Milk Fatty Acids

When vegetable fats are fed to lactating cows, the fatty acid composition in the milk fat can change. Rafalowski and Park (1982) fed graded levels (0, 10, 20 and 30%) of whole sunflower seed in the concentrate ration and found a decrease in C6-C14 fatty acid percentages and an increase in the percentage of oleate at 30% level in the concentrate. McGuffey and Schingoethe (1982) reported that when sunflower seed constituted 10% of the ration DM, there was an increase in stearic, oleic and linoleic acid percentages in milk fat when compared to a control diet. Drackley and Schingoethe (1986) fed a diet containing 19% sunflower seed to lactating cows and found that milk fat contained fewer short- and medium-chain fatty acids and was more unsaturated than fat from cows fed a control soybean meal diet. These results were later confirmed by Mabon (1988) and Casper et al. (1988). They fed sunflower seed based diets to lactating cows and found there was a decrease in the short- and medium-chain fatty acids in the milk fat.

Smith et al. (1981) and DePeters et al. (1985) found the same pattern of milk fat fatty acid composition as above when whole cotton seed was the dietary fat source. Kennelly and Fenton (1982) fed graded levels of whole canola seed (6, 12 and 18% of the concentrate) to lactating cows, and found a reduction in the proportion of the short-

chain fatty acids, and an increase in the proportion of 18:0, 18:1 fatty acids in the milk fat. Later research carried out by Handy and Kennelly (1983) indicated that when the seeds were fed whole, ground and protected (3.6% of the ration DM) there were significantly lower levels of 12:0 and 14:0 and significantly higher levels of 18:0, 18:1, 18:2 and 18:3 fatty acids in the milk fat than the milk fatty acids of the control diet. When increasing levels of Jet-Sploded whole canola seeds (7.5, 15, 22 and 29% of the concentrate) were fed to lactating dairy cows, there was a significant reduction in C6, C8, C10, C14, C15 and C16 fatty acids in the milk fat, and significant increases of C18:1 and C18:2 in the milk fat (Khorasani et al. 1989). Mielke and Schingoethe (1981) fed ground unheated and heated soybean (24.4% of concentrate DM) and found an increase in long-chain unsaturated fatty acids in the milk fat when compared with a control diet. When soybean oil (400 g/d) was fed to lactating cows, there was a reduction in short and medium chain fatty acids in the milk fat (Faulkner and Pollock, 1989).

Generally the feeding of oilseeds to dairy cows appears to reduce the molar percentages of the short-chain fatty acids and an increase in the molar percentages of the long-chain fatty acids in the milk. Storry et al. (1973) showed that feeding of fat and their subsequent uptake by the mammary gland inhibits de novo synthesis of short-chain fatty acids, and at the same time there is an increased uptake of long-chain fatty acids from dietary fat. The inhibition is probably by feedback inhibition on acetyl-CoA carboxylase by increased concentrations of long-chain acetyl-CoA in the mammary gland.

Rumen Volatile Fatty Acids

The addition of lipids to diets of lactating cows influences the

rumen fermentation pattern which in turn may have effects on milk fat secretion. The observed responses in proportions of volatile fatty acids in the rumen to dietary fats vary from one research trial to another, and much of this variation is due to differences in the nature of the basal diet, in the level of fat and in the fatty acid composition of the fat supplement (Devendra and Lewis 1974). Earlier research carried out on the effect of feeding linseed oil to sheep indicated a significant reduction in cellulose digestion and methane production (Czerkawski et al. 1966), decrease in the proportion of acetic and butyric acid and a concomitant increase in propionic acid with increasing fat content of the ration (Czerkawski 1973). Further studies in the feeding of linseed oil to sheep (Czerkawski et al. 1975) indicated that the number of protozoa decreased and bacteria increased in the rumen of the animals receiving high fat diets. There was a decrease in the concentration of VFA's as well. Varman et al. (1968) noted a decline in the acetate:propionate ratio when safflower and cod liver oil were added to the diet.

However, the ratio of acetate:propionate did not appear to change when whole sunflower seed was fed to lactating cows (Rafalowski and Park 1982). McGuffey and Schingoethe (1982), Finn et al. (1985), White et al. (1987b) observed little change in this ratio when sunflower seed (0 to 10%) was included in the diet. Casper et al. (1988) observed a non-significant decrease in the acetate:propionate ratio when the diet contained 9% sunflower seed. Conversely, Drackley and Schingoethe (1986) observed an increase in the acetate:propionate ratio, but a decrease in the concentration of total volatile fatty acids. In this case whole sunflower seed made up 19% of the total diet DM.

Anderson et al. (1979) observed little change in VFA's in the rumen

when whole cotton seed was fed. However, the feeding of cotton seed oil (4% of total ration) roasted and whole cotton seed (20% ration DM) resulted in a higher molar percentage of propionic acid in the rumen liquor of cows (Mohamed et al. 1988) when these diets were compared to a cotton seed meal diet. Khorasani et al. (1989) fed graded levels (7.5, 15, 22 and 29% of concentrate DM) of Jet-Sploded whole canola seed, and found that there was a linear depression in the level of acetic, isobutyric and butyric acid in the rumen liquor while the concentration of other volatile fatty acids were not affected when compared with a control diet. The feeding of soybean oil (4% total ration) in the rations of lactating cows resulted in a non-significant but higher molar proportion of propionic acid when compared with whole seed, roasted whole seed and cotton seed meal diets (Mohamed et al. 1988). The increased or sustained acetate:propionate ratio when sunflower and cotton seed were fed may be due to a slow release of oil or increased cellulytic digestion because of the fibrous encapsulated seed coat. The feeding of soybean and cotton seed oil or the increased fat from higher levels of canola seed may have affected the microbial population. Henderson (1973) as well as Palmquist and Jenkins (1980) reported that polyunsaturated fats are toxic to certain cellulytic and methanogenic bacteria of the rumen, and this can lead to decreased fibre digestibility (Drackley et al. 1985). The feeding of whole oilseeds appeared not to have a negative effect on cellulytic activity, but the effect of oil only may decrease cellulytic activity.

Rumen Ammonia

White et al. (1987b), Casper et al. (1988) did not observe any change in the concentration of ammonia in the rumen when whole sunflower

seed was fed up to 9% of the total diet. However, Drackley and Schingoethe (1986) found that the concentration of ammonia was significantly reduced when whole sunflower seed made up 19% of the total ration. Conversely, Finn et al. (1985) found that the ammonia concentration was higher but non-significant when whole sunflower seed constituted 10% of the total ration.

Grumpelt et al. (1987) fed whole canola seed (7.9% of the total ration DM) and did not observe any change in the ammonia level in the rumen when compared to a control diet. Mielke and Schingoethe (1981) fed heat treated and untreated soybean (24.3% of concentrate DM) to lactating cows, and found the level of rumen ammonia was significantly lower for the heat treated and untreated soybean when compared with a control soybean meal diet. Van Dijk et al. (1983) fed extruded and ground soybean and found no difference in rumen ammonia levels. Mohamed et al. (1988) fed soybean meal, soybean oil, whole soybean and roasted soybean to Holstein cows, and found that the rumen ammonia levels were not affected. Although the feeding of oilseeds did not indicate reduction in the level of rumen ammonia, it is possible that higher levels of fat can reduce the fermentation in the rumen which can lead to a reduction in ruminal ammonia.

Rumen pH

Rafalowski and Park (1982) did not find a change in the rumen fluid pH when up to 30% sunflower seed made up the concentrate DM. When the level of sunflower seed was increased to 19% of the total ration, there was an increase in the rumen fluid pH relative to the pH of a control diet (Drackley and Schingoethe 1986).

Grumpelt (1987) did not observe any change in rumen fluid pH when

whole canola seed (7.9% of ration DM) was fed to lactating cows. Van Dijk et al. (1983) noted no difference in rumen fluid pH when extruded and ground soybean (2.27 kg/d) were fed to lactating cows. Mohamed et al. (1988) reported no difference in rumen fluid pH in dairy cows when they were fed 4% soybean oil, 20% whole or roasted whole soybean, 12% cotton seed oil and 20% whole or roasted whole cotton seed in separate diets for lactating cows. Varman et al. (1968) fed safflower and cod liver oil to cows and observed no change in the rumen fluid pH. When whole sunflower seed was fed to lactating cows. Rafalowski and Park (1982) observed no change in the levels of rumen fluid pH when whole sunflower seed were fed up to 30% of the concentrate. The feeding of oilseeds does not appear to influence rumen pH when fed within recommended levels.

Blood Urea Nitrogen

When whole sunflower seed was fed to lactating cows, White et al. (1987b) and Rafalowski and Park (1982) observed no change in the levels of blood urea nitrogen. However, Park and Rafalowski (1983) found an increase in the levels of blood urea nitrogen when sunflower seed was fed at levels of 20 and 30% of the ration DM. The type or nature of oilseed fed in a diet has an indirect influence on the levels of urea nitrogen in the blood. Abou-Akkada and Osman (1967) concluded that concentration of blood urea nitrogen tended to follow the concentration of ammonia in the rumen which is dependent on the solubility of the nitrogen fraction of the oilseeds. If the nitrogen fraction of sunflower seed is very soluble in the rumen, it may contribute to an increase in the blood urea nitrogen when fed. The solubility of the nitrogen fraction may depend on the kind of processing the seeds were

subjected to. This may be demonstrated when Mielke and Schingoethe (1981) fed heat treated and untreated soybean (24.3% of concentrate DM) to lactating cows, and found that the level of rumen ammonia was reduced, and this was followed by a non-significant reduction in serum urea. The diets were compared with a control soybean meal diet.

Results on the use of oilseeds as a source of fat for supplementation of rations have been variable. This may be due to the fat source used, level of supplementation, productivity of cows that were fed the test rations and/or non controlled dietary variations. Feeding the whole seeds appear to have a desirable effect on rumen fermentation and fat yield as opposed to feeding the oil. Selected fats can be used in rations to influence milk composition which is predictable. However, more research is required in order to fully explain changes in milk fat, milk protein and milk yield in general.

EXPERIMENT I

Effect of Ammonia Treatment of Sunflower Seed on In Situ Digestibility

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ABSTRACT

Two in situ trials were carried out to determine the effect of ammonia treatment on the rate of ruminal disappearance of nutrients in sunflower seed. The specific objective in each trial was to measure the effect of ammoniation on nutrient disappearance of the a, b and a + b fraction as well as c which is the rate of degradation of b. The a fraction is the rapidly soluble material (%), b is the slowly degraded fraction (%), and a + b is the potentially degraded fraction (%). The four treatments in trial 1 were whole sunflower seed, ground sunflower seed, ammoniated whole sunflower seed and ammoniated ground sunflower seed. Ammonia treatment did not affect ($P>0.05$) the disappearance of dry matter (DM) and crude protein (CP) in the rapidly or slowly degradable fraction as well as the rate of degradation of ground sunflower seed. The four treatments in trial 2 were control and ammoniated kernel and control and ammoniated hull of sunflower seed. The disappearances of DM and neutral detergent fibre (NDF) in the kernel were greater than those of the hull ($P<0.05$). Ammoniation reduced ($P<0.05$) the DM disappearance in the a + b fraction of the kernel. Ammonia treatment did not affect ($P>0.05$) the disappearance of DM and NDF in the a and b fractions in the kernel and hull. Ammonia treatment reduced the CP disappearance in the b fraction of the hull ($P<0.05$).

INTRODUCTION

Sunflower seed has a hard seed coat which contains about 6 to 8% lignin (McGuffey and Schingoethe, 1982). Park et al. (1982) found that when graded levels of sunflower hulls (0, 10, 20, 30, 40% of ration DM) were fed to Holstein heifers, there was a corresponding linear decline

in dietary nutrient digestibility for DM, ADF and CP. If ammonia treatment of sunflower seed can improve the digestibility of the hull without adversely affecting the digestibility of the other component of the seed, then it may be advantageous to use sunflower seed as a feed ingredient for ruminants in general.

The objective of this experiment was to measure the effect of ammonia treatment on DM, CP, fat, ADF and NDF disappearance from sunflower seed in the rumen.

MATERIALS AND METHODS

Trial 1

Whole sunflower seeds (22.7 kg) were reconstituted to achieve a moisture level of 15%. The seeds were evenly spread on a concrete floor, and a measured amount of water (2.61 kg) was uniformly added to the seed by use of a water can with a sprinkler nozzle. A sample taken the next day contained 14.9% moisture. Two kg of reconstituted seed were saved and used in the control treatments.

The seeds were then placed in two plastic bags (gauge 14) one within another. A rubber hose was used to deliver a weighed amount of anhydrous ammonia from a tank to the seed. The bag was thoroughly sealed to prevent loss of ammonia. Anhydrous ammonia (0.645 kg) was metered out from the tank to achieve 3% of ammonia added to the seed on a w/w basis. The temperature of the ammoniated seed was maintained at an average of 32.2°C for six days after which it dropped to 23.4°C (Appendix 1). The bag was opened on the eighth day, and was left opened for the unabsorbed ammonia gas to escape. The ammoniated seeds were mixed before samples were taken. Samples were prepared by grinding for

30 seconds in a Max Braun coffee blender Model MX3.

The methodology for the in situ study followed that outlined by Nocek (1988) with modification. In situ bags contained about 15 mg/cm^2 of sample as compared to the suggested 10 to 20 mg/cm^2. No correction was made for bacterial contamination and the bags were not soaked in water or buffer prior to ruminal incubation. The cannulated steers were not fed the sunflower seed. Approximately 5 g of experimental samples were placed in nylon bags measuring 15 cm x 11 cm with a pore size of 50 ± 2 micron. The bags were placed in a laundry bag measuring 30 cm x 30 cm, with a pore size of 2 mm x 3 mm. Weights were placed in the laundry bags in order to prevent them from floating in the rumen. Three steers fitted with rumen cannula were used. They were fed a diet of alfalfa hay ad libitum. Two runs with 3 steers were carried out with a rest period of one day between runs resulting in a total of 6 bags per time period. The four treatments were whole sunflower seed (WSS), ground sunflower seed (GSS), ammoniated whole sunflower seed (AWSS), ammoniated ground sunflower seed (AGSS).

The incubation times for each run were .1, 4, 8 and 24 h. The bags were inserted to achieve the above incubation periods, such that all bags were removed as a group. After removal they were washed in an old wringer washing machine (water temperature was 4°C) for 5 minutes and dried in a forced air oven at 55°C for 4 days. Dry matter, CP, ADF and EE disappearance were determined.

Nitrogen was determined by Method No. 147.021, ADF by Method No. 7.076 and EE by Method No. 7.062 (Association of Official Analytical Chemists, AOAC, 1984). Neutral detergent fibre was determined by the method developed by Van Soest and Wine (1967) with modification. Two

reagents, decalin and sodium sulphite were omitted in the analysis. The kinetics of degradation were estimated from the following first order equation (Orskov and McDonald, 1979).

$$p = a + b\ (1-e^{-ct})$$

where:

p = the amount of degraded material at time t (%),

a = the rapidly soluble material (%),

b = fraction that will degrade in a given time (%),

c = the rate constant for the degradation of b,

t = time of incubation (hr),

a + b = potential degradable fraction (%).

All statistical analysis was carried out by using the Analysis of Variance (ANOVA) procedure. General linear model (GLM) procedure was used where data were missing. Non Linear Model (NLM) together with Orskov and McDonald (1979) equation were used to find the estimated value of a, b and c (Statistical Analysis System Institute Inc. 1986). T Test was used to compare the difference between two means for the first in situ trial.

Trial 2

Whole sunflower seeds (1560 kg) were placed in an experimental concrete silo measuring 1.5 m x 2.1 m. The inner surface of the silo was lined with polyethylene (gauge 6) to prevent the loss of ammonia during the ammoniation procedure. Water was sprinkled on the seed by the use of a garden bucket with a sprinkler nozzle as the seeds were placed in the silo. The amount of water added was measured so as to achieve a final moisture content of 15%. Three thermocouples were

inserted during the filling of the silo. One was placed near the bottom, one at the middle, and one near the top of the silo. The top of the silo was sealed with polyethylene. A polyvinyl pipe of 6 inch diameter with holes in the walls was embedded at about one third of the silo height. This was designed to facilitate easy diffusion of ammonia gas into the silo. Anhydrous ammonia was introduced into the silo through the pipe to achieve a 3% level on a w/w basis on a DM basis. The required amount of ammonia was metered into the silo from a pressurized tank mounted on a trailer. After ammoniation, the hose was removed, and the aperture in the silo was quickly sealed with a rubber stopper. The temperature was taken on a daily basis for 14 days (Appendix 2). The silo was opened 30 days after treatment.

About 5 kg of ammoniated seeds were dehulled using a Seedburo barley pearler (Serial No. 109B, Seedburo Equipment Company, 1022 West Jackson Blvd., Chicago). The large hulls were separated from the kernel by the use of an air-classifier (Model D, Serial No. 175, E.L. Erickson Products, Brookings, South Dakota). The different fractions after dehulling are shown in Table 2. The small hull consists of a mixture of small broken hull and small fragments from the kernel. The large hull is the actual seed coat, and the kernel is the endosperm of the sunflower seed. The large hull is the fraction of the seed that was used in this trial and will be referred to as the hull in the discussion. The large hull represented about 14.6% and the kernel about 41.3% of the total seed (air dried) by weight. Samples were prepared by grinding for 30 seconds in a Max Braun coffee blender, Model MX3. The four treatments were control kernel (CK), control hull (CH), ammoniated kernel (AK) and ammoniated hull (AH).

Table 2. Relative composition (% on an air dry basis) of the hull and kernel of sunflower seed when separated by a Seedburo barley pearler, Serial No. 109B

Component	Control sunflower seed		Ammoniated sunflower seed	
	Weight (g)	%	Weight (g)	%
Small hull†	1766	42.4	2199.7	45.6
Large hull	613	14.7	695.3	14.4
Kernel	1779	42.7	1920.8	39.9
Sunflower seed	4158	100.0	4815.8	100.0

†Consist of a mixture of fragments of hull and kernel, but more hull.

The rumen in situ methodology for this study was the same as outlined in Trial 1. However, in this study, the incubation times were 0.1, 0.5, 2, 4, 8, 16 and 48 h. Dry matter, CP and NDF disappearances were determined for both the hulls and kernel, and ADF for the hulls only. Fat disappearance was not determined for kernel and hull.

Statistical analysis procedure was the same as that used in Trial 1. Means comparisons were carried out using Duncan's multiple range test.

RESULTS AND DISCUSSION

An attempt to evaluate nutrient disappearance in the whole and ammoniated whole sunflower seed was not successful. This was not successful because the disappearances of nutrients from the whole and ammoniated whole seed were small compared with disappearance from the ground and ammoniated ground seed (Table 3). When the data was used to find estimated value for the a and b fraction as well as c, the rate of disappearance of b, using non-linear least squares iteration, the convergence criterion was not met (NLM). An attempt was made to evaluate the a and b as well as c, the rate of disappearance of the b fraction for ADF in the whole and ground seeds. This was not successful because of the reason given above. When finding the estimated value of a, b and c for DM disappearance, an average was taken for each of the three steers used in this experiment, and the T-test between the ground and ammoniated ground sunflower seed disappearance was based on 3 observations per treatment. When finding the estimated value of a, b and c for CP disappearance, an average was taken for each of the two days of the in situ trial, and T-test between the ground and ammoniated

Table 3. In situ nutrient disappearance (%) of control and ammoniated sunflower seed during various incubation times in the rumen of steers

Nutrients	Incubation time (h)	Control whole seed	Control ground seed	Ammoniated whole seed	Ammoniated ground seed
Dry matter	.1	.85	44.5	2.5	18.2
	4	.81	61.6	4.0	57.6
	8	3.3	76.5	6.4	70.3
	24	10.5	77.7	14.2	82.2
	Average	3.9	65.1	6.8	57.1
Crude protein	.1	3.8	59.7	9.4	41.3
	4	2.7	76.4	17.3	74.1
	8	2.9	86.3	21.9	83.3
	24	15.1	94.8	27.4	93.7
	Average	6.1	79.5	19.0	73.1
Acid detergent fibre	.1	14.8	4.8	15.9	0
	4	13.2	4.7	11.2	0
	8	19.3	19.0	10.3	5.3
	24	21.4	40.8	22.7	44.1
	Average	17.2	17.3	15.0	12.4
Fat	.1	.6	68.6	.8	50.8
	4	.1	82.5	1.9	76.8
	8	.6	92.0	6.0	87.4
	24	5.0	98.5	6.0	98.4
	Average	1.6	85.4	3.7	78.4

ground sunflower seed was based on 2 observations per treatment. No statistical analysis was performed on EE disappearance because of the necessity to composite samples to obtain significant sample for analysis.

Ammonia treatment did not affect ($P>0.05$) the a fraction of the ground seed DM. However, the data indicate that there was a tendency towards reduction in the solubility of DM (Table 4). Ammoniation did not affect the b fraction as well ($P>0.05$). The a + b fractions were not different ($P>0.05$) for DM disappearance as well as c (rate of disappearance of b) (Table 4).

The CP disappearance for the a, b, a + b and the rate of disappearance of b were not affected ($P>0.05$) by ammonia treatment of the ground seed (Table 4). Although ammonia treatment of the ground seed did not significantly affect DM and CP digestibility in the rumen, there was a general tendency for ammonia treatment to reduce the solubility of nutrients in the a fraction, and to increase disappearance in the b fraction with little change in the rate of disappearance of the b fraction.

Trial 2

The DM solubilities as represented by the a fraction were not different ($P>0.05$) for all treatments (Table 5). The DM lost for b and a + b fraction was greater for the kernel than for the hulls ($P<0.05$). This is expected because the hull contains 56% ADF that has a low digestibility (Park et al. 1982). Disappearance of fraction a + b of the kernel DM was reduced ($P<0.05$) by ammoniation although the a and b fractions alone were not affected ($P>0.05$) by ammoniation. Reduction in

Table 4. Effect of ammoniation on rumen degradation of DM and CP in ground sunflower seed

Item	Treatment	Parameter† a	SE	b	SE	a + b	SE	c	SE
DM‡	GSS	40.12	5.67	36.05	3.85	79.18	2.23	21.94	0.30
	AGSS	16.94	2.06	64.99	2.31	82.09	1.33	23.59	0.33
CP‡	GSS	58.88	0.72	36.74	4.74	93.31	0.16	17.08	0.40
	AGSS	40.36	6.48	52.99	0.7	95.62	0.17	23.72	1.20

†a=the rapidly soluble material (%), b=the slowly degraded material (%), a + b=potentially degraded material (%), c=rate of degradation (%/hr), Orskov and McDonald (1979).

‡3 observations per treatment.

‡2 observations per treatment.

GSS=ground sunflower seed, AGSS=ammoniated sunflower seed.

Table 5. Effect of ammoniation on rumen degradation of DM, NDF, ADF and CP of sunflower seed, kernel and hull

Item	Treatment‡	Parameter† a	b	a + b	c
DM	CK	18.7	65.2a	83.9a	8.5
	AK	14.7	61.4a	75.1b	7.4
	CH	14.2	18.1b	32.8c	9.0
	AH	13.7	21.5b	33.5c	5.6
	SE	1.1	2.7	1.9	1.1
NDF	CK	26.4a	68.5a	91.8a	7.5
	AK	28.6a	59.9a	86.7a	8.7
	CH	-1.4b	15.7b	14.6b	10.2
	AH	-2.5b	12.4b	15.3b	4.8
	SE	2.4	2.1	4.7	3.4
ADF	CH	0.10	18.6	18.6	10.63a
	AH	-6.6	18.7	11.4	6.36b
	SE	1.3	3.3	1.9	0.49
CP	CK	17.3	77.4a	99.0	7.9
	AK	15.5	66.3a	94.8	7.5
	CH	58.7	58.7a	81.8	7.7
	AH	44.0	29.4b	73.4	8.0
	SE	4.6	5.3	2.5	1.1

†a=the rapidly soluble material (%), b=the slowly degraded material (%), a + b=potentially degraded material (%), c=the rate of degradation (%/hr).

‡CK = control kernel, AK = ammoniated kernel, CH = control hull, AH = ammoniated hull, SE = standard error.

a,b,c-Means in the same column having different superscripts differ ($P<0.05$).

the rate of DM disappearance in the rumen when high moisture barley was treated with ammonia was reported by Robinson and Kennelly (1988b). Robinson and Kennelly (1988b) suggested that the reduction in rate of degradation of DM may be due to a change in the chemical structure of the components of the ammoniated barley or a change in the ruminal microorganisms degrading the barley. In the present experiment the ruminal micro-flora would be similar, thus suggesting the difference is due to chemical structure. Pun et al. (1980) reported that starch granules of potatoes are enclosed by a lipid membrane. If sunflower seed has a similar membrane, then it is possible that ammonia can react with, and stabilize the phospholipid portion. Maeda et al. (1978) suggested that the stabilization of the phospholipid can reduce access of bacterial alpha-amylase to the starch, thus slowing its rate of ruminal degradation. The a, b and a + b for NDF in the kernel were greater ($P<0.05$) than in the hull (Table 5). There was an apparent accumulation of rapidly degradable NDF in both the treated and untreated hull. This negative value could be due in part to contamination of the samples by entry of other NDF fractions in the nylon bags. The NDF disappearance was small, and one would expect less accuracy when measurement is made on such a small biological variable. In general ammonia treatment did not affect the disappearance or rate of disappearance of NDF from the kernel and hull.

Ammoniation did not affect ($P>0.05$) the disappearance of ADF from the hull fractions, but the rate of degradation of the b fraction was reduced ($P<0.05$) for the ammoniated hull (Table 5). The rate of degradation appeared to be very high. Generally one would expect ammonia treatment to increase the disappearance of ADF in the hulls.

The low digestibility of DM and fiber in the hull is due to an association between lignin and carbohydrates in the cell wall. Lignin has alkaline-labile linkages, and ammonia and other alkaline compounds hydrolyse the ester and hydrogen bonds of cellulose and hemicellulose with lignin (Van Soest, 1982). On the contrary in this case, the rate of degradation of the b fraction was reduced by ammoniation.

Ammoniation reduced CP disappearance in the b fraction of the hull ($P<0.05$) (Table 5). The data indicate that about 50% CP in the a fraction of the hull was soluble. This 50% of CP in the hull represent a small percent of CP of the entire sunflower seed because the hull nitrogen makes up about 1% of the total seed nitrogen (Table 2, Appendix 3). The CP disappearance in the a and a + b fraction were not different ($P<0.05$) for all treatment. One of the possible reasons for this significant reduction of CP disappearance in the b fraction of the hull may be due to chemical changes of the protein as a result of ammoniation. Provansal et al. (1975) reported that the treatment of sunflower protein isolates with (NaOH) reduced their content of cystine, arginine, threonine, serine, isoleucine and lysine and unusual amino acids such as alloisoleucine, ornithine, lysinoalanine and lanthionine were formed. The presence of the latter two compounds indicates the formation of cross-links in the protein and may explain observed changes in in situ proteolytic digestibility. The rate of nitrogen disappearance did not appear to change (Table 5).

In conclusion ammonia treatment did not affect the disappearance of DM in the ground seed. When the seed was dehulled, and the kernel and hull were studied separately it was found that the kernel accounted for more DM disappearance than the hull as expected. Ammonia treatment

reduced the DM disappearance from the potentially degradable fraction of the kernel of sunflower seed, reduced the rate of ADF degradation of hull for the b fraction and reduced the CP degradation of hull for the b fraction.

EXPERIMENT II

Effect of Ammonia Treatment and Dietary Level of Whole Sunflower Seed on Intake and Digestibility

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ABSTRACT

Eight male lambs were used in a double 4 x 4 latin square design to determine the effect of ammonia treatment and level of sunflower seed on dry matter intake (DMI), crude protein (CP) intake, fat intake, nitrogen balance and nutrient digestibility. The treatments were ammoniated and control sunflower seed included at two level (16 and 25%) in the diets. DMI were not different ($P>0.05$) for all treatments. The intake of fat for the control diet containing 25% sunflower seed was higher ($P<0.05$) than fat intakes for the rest of the treatments. Dry matter intake per kilogram of body weight were not different ($P>0.05$) among treatments. Nitrogen in the urine as a percentage of nitrogen intake as well as nitrogen balance were not different ($P>0.50$) among treatments. The digestibilities of dry matter (DM), CP and acid detergent fibre (ADF) were not affected by treatments ($P>0.05$). There was a trend suggesting ammoniation increased NDF digestion for diets containing 16% sunflower seed.

INTRODUCTION

The inclusion of sunflower seed as 10% of the ration DM has been recommended for lactating dairy cows (McGuffey and Schingoethe, 1982). White et al. (1987a) demonstrated that 4% oil and graded levels (10, 20%) of whole sunflower seed as part of the ration DM did not affect the apparent digestibility of DM, CP, energy and fibre. These results are not in total agreement with research carried out by Drackley et al. (1985) when they fed whole sunflower seed which constituted 10% of ration DM to Holstein steers. They found that cellulose digestion was depressed, but digestibilities of DM, organic matter, lipid, gross

energy, calcium and magnesium were not affected. The reduction in cellulose digestion could be due to the fat released from the seed, which can reduce fibre digestibility (Czerkawski et al. 1966; Johnson and McClure, 1973; Devendra and Lewis, 1974). The reduction in fibre digestibility may also be due to the hard seed coat as these are high (6 to 8%) in lignin (McGuffey and Schingoethe, 1982). Park et al. (1982) found as graded levels of sunflower hulls (0, 10, 20, 30, 40% of ration DM) were fed to Holstein heifers, there was a corresponding linear decline in nutrient digestibility for DM, ADF and CP.

Rumen in situ studies carried out on high moisture barley by Robinson and Kennelly (1988a) showed that ammoniation increased the degradation of neutral detergent fibre. Sharma et al. (1988) found that the digestibilities of sunflower hulls were improved when treated with KOH and NaOH at 2.45% on a w/w basis. Ammonia treatment of shelled corn (Srivastava and Mowat, 1980) and wheat (Low and Kellaway, 1983) resulted in an increase in dry matter digestibility. If ammonia treatment of whole sunflower seed improves its fibre digestibility, then it may be practical to increase the level of sunflower seed beyond 10% of ration DM. The objective of this experiment was to determine if increased levels of sunflower seed as well as ammonia treatment of the seed affected DMI, digestibility of DM, CP, NDF, ADF and fat, and nitrogen balance of sheep.

MATERIALS AND METHODS

Eight crossbred Suffolk x Outaouais male lambs with an average initial body weight of 33.6 ± 2 kg, and 29 weeks of age were assigned to a double 4 x 4 latin square design. The animals were housed in

individual metabolism crates with free access to water. Diets (Table 6) were formulated to meet the sheep nutrient requirements (NRC, 1985) (Table 7).

Two treatments consisted of 25 and 16% of whole sunflower seed as the control and the other two consisted of 25 and 16% of whole ammoniated sunflower seed (3% ammonia on a w/w basis) (Table 6). The diets were fed ad libitum once per day at 9:00 h.

Each period consisted of 9 d adaptation to the diet, 7 d intake measurement, 3 d adjustment to 90% of voluntary intake and 6 d for digestibility and nitrogen balance measurements (Heany et al. 1969 with modification). The modification is that Heany et al. (1969) recommended 7 days for digestibility measurement. During the adjustment and intake period, diets were fed to provide a 10% weigh back. Weigh back samples were taken daily and dried in a forced air oven for 3 d at 60°C in order to calculate daily intake during the intake period.

Fecal samples were collected twice daily at 9:30 and 15:30 h using fecal collection bags. Urine was collected daily. Twenty-five ml of 10 N sulfuric acid were added to each urine collection container. Feed samples and a 10% aliquot of fecal and urine samples were stored (-20°C) immediately after collection during digestibility measurement for each period. At the end of each collection period, feed and fecal samples were composited and dried in a forced air oven for 3 d at a temperature of 60°C. Feed and feces were ground to pass through a 1 mm screen. Eight analyses were carried out for each nutrient (4 periods x duplicate). Analyses were carried out for DM, CP, ADF, NDF, fecal soap, Ca and P of feed, and DM, CP, ADF, NDF and fecal soaps for faeces. Nitrogen was determined by Method No. 147.021 and ADF by Method No.

Table 6. Ingredient composition of experimental diets used to measure the effect of ammoniation of sunflower seed on digestibility (% DM) by sheep

Ingredients	Experimental diets			
	Control 25%	Control 16%	Ammoniated 25%	Ammoniated 16%
Barley	67.6	76.75	68.0	77.0
Sunflower seed (non-ammoniated)	25.0	16.0	-	-
Sunflower seed (ammoniated)	-	-	25.0	16.0
Alfalfa (dehydrated)	5.0	5.0	5.0	5.0
Urea	0.4	0.25	-	-
Mineral†	1.0	1.0	1.0	1.0
Salt (cobalt iodized)	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0

†Provided per kg of diet: 220 g calcium, 140 g phosphorus, 35 mg iron, 1.25 mg iodine, 5 mg copper, 23 mg zinc, 0.50 mg cobalt, 55 mg manganese, 1,800 IU vitamin A and 450 IU of vitamin D_3.

7.076 (Association of Official Analytical Chemists, AOAC, 1984). Neutral detergent fibre was determined by the method developed by Van Soest and Wine (1967) with modification. Two reagents, decalin and sodium sulphite were omitted in the analysis. Fecal soaps were determined according to Marcello et al. (1971) with some modification. The chloroform-methanol solution containing the homogenized fecal sample was centrifuged to separate the supernatent from the filtrate instead of being vacuum filtered as outlined by Marcello et al. (1971). Gross energy was determined by using a Parr Adiasatic oxygen bomb calorimeter. Calcium was determined by Method No. 7.101 and phosphorus by Method No. 7.127 (AOAC, 1984).

The data collected during intake measurement were used to analyze DMI and DMI/kg body weight. The data collected during digestibility measurement were used to analyze CP and fat intake, nutrient digestibility, nitrogen in the urine and nitrogen balance. Nitrogen balance was calculated by subtracting fecal and urinary nitrogen from nitrogen intake, and it was expressed as a percentage of nitrogen intake.

All statistical analysis was carried out using the ANOVA procedure. Means comparison were accomplished by using Duncan multiple range test (Statistical Analysis System Institute Inc., 1986).

RESULTS AND DISCUSSION

Although the experimental diets were balanced to meet the protein requirements of the lambs weighing an average of 33.6 kg and 7 months of age, later in the experiment the diets did contain CP in excess of lambs requirement. This is because as the lambs grew older they would require

less protein. The recommended NRC (1985) level of CP in the diets (on a DM basis) for sheep weighing between 40-50 kg is between 11.6 and 10%. At the end of the experiment the sheep weighed 51.6 kg on average, and the CP level in the diets were about 13% (Table 7). The proximate analysis of all the experimental diets show the ratio of Ca:P was below the NRC (1985) level of 2.

The DMI (Table 8, Appendix 4) for the four treatments were not different ($P>0.05$). Dry matter intake per kg body weight were not different ($P>0.05$) among treatments as well (Table 8, Appendix 5). The non-significant reduction of DMI for ammoniated sunflower seed may be due to the presence of ammonia (Tembo, 1987). The intake of CP was different ($P>0.06$) among diets (Table 8, Appendix 5). The intake of fat was higher ($P<0.05$) for the control diet containing 25% sunflower seed when compared to the rest of the diets (Table 8, Appendix 4). The 25% vs. 16% diets contained 4.1 to 3.4 more percentage points of fat compared with the 16% diets. This higher intake of fat also may be explained by about a 1% higher EE found in the 25% control diet (Table 7) compared with the 25% ammoniated diet and a non-significant ($P>0.05$) higher DMI (Table 8). The nitrogen in the urine as a percentage of nitrogen intake was similar for all treatments ($P>0.05$) (Table 8, Appendix 6). There were no differences among treatments with respect to nitrogen balance (Table 8, Appendix 6).

None of the treatments influenced ($P>0.05$) the digestibility of the diet DM (Table 9, Appendix 4). Protein digestibility was not affected as well ($P>0.05$). However, the CP digestibility of the diet containing 25% control ammoniated seed tended ($P<0.06$) to be higher than the 25% ammoniated diet. This may be explained in part by a 1% higher level of

Table 7. Nutrient composition of experimental diets used to measure the effect of ammoniation of sunflower seed on digestibility (% DM) by sheep

Nutrients	Experimental diets			
	Control 25%	Control 16%	Ammoniated 25%	Ammoniated 16%
Crude protein	14.5	13.1	13.6	13.3
Ether extract	13.9	9.8	13.0	9.6
Acid detergent fibre	9.4	8.4	8.6	8.2
Neutral detergent fibre	21.1	21.3	20.5	21.0
Calcium	0.49	0.45	0.45	0.43
Phosphorus	0.61	0.55	0.59	0.55
Energy (kcal/g)	4.48	4.34	4.43	4.34

Table 8. Nutrient intake, urinary nitrogen loss and nitrogen balance (%) of experimental diets used to measure the effect of ammoniation of sunflower seed on digestibility by sheep

	Experimental diets				
Nutrients	Control 25%	Control 16%	Ammoniated 25%	Ammoniated 16%	SE
Dry matter intake (kg)ǂ	8.6	8.6	8.1	7.9	.39
Crude protein intake (g)†	1031.5a	947.4	805.2	912.5	6.1
Fat intake (g)†	1036.4a	793.3b	778.7b	676.4b	6.8
N in urine (% of intake)†	46.3	45.9	47.0	42.6	3.8
N balance (% of intake)†	32.8	30.2	27.1	33.0	4.1
DMI kg^{-1} body weight (g)	186.5	181.2	173.7	167.3	7.5

a,b-Means in the same row with different letters are significantly different ($P<0.05$).

†For six days.

ǂFor seven days.

n=8 (8 analyses were done for each sample).

Table 9. Nutrient digestibility (%) of experimental diets used to measure the effect of ammoniation of sunflower seed when fed to sheep

Nutrients	Experimental diets				
	Control 25%	Control 16%	Ammoniated 25%	Ammoniated 16%	SE
Dry matter	78.2	79.2	78.5	81.0	0.9
Crude protein	80.5a	75.2b	73.9b	75.6ab	1.6
Fat	77.8	81.7	77.2	74.9	1.9
Neutral detergent fibre	44.5ab	41.8b	48.3ab	53.6a	2.9
Acid detergent fibre	27.6	22.9	28.6	33.1	2.9

a,b-Means in the same row with different letters are significantly different ($P<0.06$).

CP in the diet (Table 7) because DMI was similar for all diets and digestibility of CP would tend to be higher with an increase in the CP percentage in the diet. The digestibility of ADF was not affected ($P>0.05$) by treatment (Table 9, Appendix 8). The results indicate that the digestibility of NDF tended ($P<0.06$) to increase with the lower level of sunflower seed in the diet when the seed was treated with ammonia. Fat digestibility was not different ($P>0.05$) among treatment (Table 9, Appendix 7).

In conclusion ammonia treatment as well as increasing the level of sunflower seed up to 25% of ration DM did not affect DMI. The digestibility of nutrients in the ration was not affected as well. Although the effect of ammonia on NDF and ADF was not significant, it improved the fibre digestibility of the ration to a small extent.

EXPERIMENT III

Effect of Ammonia Treatment of Whole Sunflower Seed on Milk Composition and Production by Dairy Cows in Early Lactation

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ABSTRACT

Twenty Holstein cows were used to determine the effect of supplementary fat in the form of ammonia treated sunflower seed on feed intake, milk production, milk composition, rumen environment and blood urea nitrogen. Twenty cows at 21-28 d post partum were allocated equally to either of two treatments based on lactation number and previous milk production. The diets were control and 5.6% ammoniated sunflower seed. To maintain similar neutral detergent fibre (NDF) levels in the diets, dietary level of silage was reduced from 44.5% to 41.5% with the inclusion of sunflower seed. Cows were fed ad libitum, an iso-nitrogenous total mixed ration of concentrate and alfalfa silage with calculated NE_L value of 1.75 and 1.67 Mcal/g for treated sunflower seeds and control, respectively. Acid detergent fibre (ADF) levels for the control and sunflower seed diet were 19.3 and 20.2%, respectively. Milk yield and fat corrected milk (FCM) yield as well as feed intake were similar ($P>0.05$) for the two treatments. Milk fat, crude protein (CP) and solids-non-fat (SNF) percentages were not different ($P>0.05$) between treatments. The molar percentages for C10:0, C12:0, C14:0 and C16:0 fatty acids in milk fat were reduced ($P<0.05$) for cows receiving the sunflower diet while the percentages of C18:0, C18:1, C18:2 and C20:0 fatty acids were increased ($P<0.05$). The levels of acetic, propionic and butyric acid in the rumen were not different ($P>0.05$) between treatment. Acetate:propionate ratio, rumen fluid pH, and rumen ammonia levels were not different ($P>0.05$) between treatments. Rumen fluid pH was reduced ($P<0.05$) and ammonia level increased ($P<0.05$) at prefeeding and 3 h post feeding for both diets. Blood urea nitrogen levels were not different ($P>0.05$) for the two diets, but increased

significantly from prefeeding to 3 h post feeding.

INTRODUCTION

High producing dairy cows in early lactation require a high energy diet to meet the energy requirement for milk production. Additional grain will increase energy density, but when the percentage of grain is above 55 to 60% of the ration dry matter, the change in the rumen fermentation pattern can lead to digestive disturbance and low milk fat yield (Linn, 1987). Energy density of the diet can be increased by adding 3 to 5% of fat (Palmquist and Jenkins, 1980). This allows for the use of less grain or starch feed, thereby increasing the ratio of forage to concentrate, and this reduces milk fat depression.

The responses in milk fat and protein yields were variable with different sources and levels of fat that have been used in diets. McGuffey and Schingoethe (1982) fed whole sunflower seeds at an average of 10% of the ration DM and found that milk production or fat yield were not depressed significantly. However, Mabon (1988) reported that milk protein percent was significantly depressed when whole sunflower seed (9% of ration DM) was fed to lactating cows. Finn et al. (1985) noted that there was a significant reduction in fat test when the sunflower seeds were rolled and included in the diets for lactating cows. Anderson et al. (1984) compared the relative feeding value of whole cotton seed and whole sunflower seed, and found that milk, FCM, fat, protein and SNF production were lower among cows fed the whole sunflower seeds. If ammonia treatment can reduce fermentative digestion of starch (Robinson and Kennelly, 1988b), fat and CP of sunflower seed, and at the same time increase fibre digestion in the rumen, then this may increase

the amount of energy and protein entering the small intestine, and at the same time may maintain a desirable acetate:propionate ratio in the rumen that is required to maintain a normal fat test.

The objective of this study was to determine if ammonia treated sunflower seed can be used as a fat source to increase energy density and energy intake of the diet for early lactating dairy cows without adversely affecting milk fat yield.

MATERIALS AND METHODS

Whole sunflower seeds were reconstituted to 15% moisture, and 3% ammonia on a w/w basis was introduced to the seed in a sealed concrete silo measuring 1.5 m x 2.1 m (Experiment I, trial 2). The temperature increased and stayed at an average of 36°C for the first 14 d after treatment (Appendix 2). The silo was opened after 30 d of storage.

Twenty Holstein cows were used in a two treatment continuous trial. Cows were assigned to treatment at 21 to 28 d after calving except the first 3 cows on each treatment which were assigned at 32 to 58 d after calving. The trial was balanced as far as possible by allocating cows of similar previous milk production and lactation number (Appendix 9). Each cow was weighed at the beginning and end of a 10 wk test period. The concentrate mixture was formulated to contain 9.6% of ammoniated sunflower seed (sunflower diet) or no fat supplement as the control diet (Table 10). Each cow was fed the experimental diets one week before the test period.

The two diets were fed once daily ad libitum so as to achieve a daily weigh back of 2 kg. The concentrate was offered with alfalfa silage as a total mixed ration. Diets were formulated to be iso-

Table 10. Ingredient composition of total mixed lactation diets supplemented with ammoniated sunflower seed (DM basis)

Ingredient	Total mixed ration	
	Sunflower seed	Control
Alfalfa silage	420.3	450.3
Barley	388.3	410.2
Distillers dried corn grain	87.1	82.6
Canola meal	26.8	38.0
Sunflower seed	55.8	
Limestone	9.0	6.9
Trace minerals premix†	4.4	4.4
Urea	1.3	1.3
Dicalcium phosphate	1.9	1.3
Vitamin premix‡	2.2	2.2
Salt	2.9	2.8
Total	1000.0	1000.0

†Provided per kg of diet: 8.5 mg of copper, 0.1 mg selenium, 40 mg of zinc, 36.0 mg of manganese, 34 g of magnesium and 3.1 g of salt-Co-I.

‡Provided per kg of diet: 10,000 IU vitamin A, 2,000 IU vitamin D_3 and 60 IU vitamin E.

nitrogenous with similar levels of NDF, and balanced to meet the nutrient requirement of a 550 kg cow producing 40 kg of milk containing 3.5% fat (NRC, 1988) (Table 11). The control diet was formulated to contain 1.67 Mcal NE_L kg^{-1} and the sunflower diet to contain 1.75 Mcal NE_L kg^{-1}.

Feed intake and milk production were recorded daily throughout the experimental period. Milk samples were taken on two consecutive days during each week of the trial for fat, protein and SNF analysis. Milk fat, protein and SNF were measured with a Multispec Milk Analyser Model M (Whildrake, York, England). A second 100 ml sample was taken for each of the last 2 wk for fatty acid analysis of milk fat. A composite sample was obtained, by adding 37% of p.m. milk and 63% of the a.m. milk (Mabon, 1988) because of an 8 and 16 h milking interval. Dry matter content of the two concentrates and alfalfa silage was determined weekly, and samples were composited every seven weeks for chemical analysis (21 wk were required for all cows to start and complete the experiment).

Rumen liquor samples were taken via a stomach tube (Ingalls et al. 1980) during the fifth and tenth week of test. These samples were taken just before feeding and 3 h after feeding. The pH of the rumen liquor was recorded at the time of sampling using a Model 5985-50 pH meter from Cole-Parmer Instrument Company. Heparinized blood samples were taken from the tail just before feeding and 3 h after feeding on the fifth and tenth week. Rumen and blood samples were centrifuged, and the supernatents extracted and stored (-20°C) for later analysis.

Feed dry matter was determined by drying samples for 3 d at 60°C in a forced air oven. Feed samples were analyzed for nitrogen (Method No.

Table 11. Nutrient composition† of sunflower seed and control diets (DM basis) used to measure the effect of ammoniated sunflower seed as a fat source on milk yield and composition.

	Experimental diets	
Nutrient content	Sunflower seed	Control
Crude protein, %	17.5	17.0
Ether extract, %	5.5	3.2
Acid detergent fibre, %	20.2	19.3
Neutral detergent fibre, %	29.8	29.3
Calcium, %	1.25	1.22
Phosphorus, %	.50	.49
Gross energy (kcal/g)	4.24	4.14

†The value for each nutrient is based on six analyses.

47.021) ether extract (Method No. 7.062), acid detergent fibre (Method No. 7.076), calcium (Method No. 7.101) and phosphorus (Method No. 7.127) (Association of Official Analytical Chemists, AOAC, 1984). Gross energy was determined by using a Parr Adiabatic oxygen bomb calorimeter. Neutral detergent fibre was determined by the original method developed by Van Soest and Wine (1967) except that decalin and sodium sulphite were omitted. Duplicate analyses on 3 samples were completed for each nutrient.

Fat was extracted from milk samples for fatty acid analysis according to Lambert (1964). The molar ratios of milk fatty acids were determined by methylation of milk samples according to Shehata et al. (1970), and separation was done by gas liquid chromatography (GLC) with a Varian Vista 6000 (Varian Canada Inc., Georgetown, Ontario). using a 2.43 meter by 2.43 centimetre column packed with GP 3% SP 2310/2% SP2300 on 100/120 Chromosorb WAW (Supelco Canada Ltd., Oakville, Ontario). Peak areas for each fatty acid were analyzed using a Varian 402 Data System (Varian Canada Inc., Georgetown, Ontario) and expressed as a percentage of total fatty acids detected. Identification of individual fatty acids was accomplished by use of a GLC reference standard (Nu Chek Prep Inc., Elysian, Minnesota) which established retention times for each fatty acid.

Volatile fatty acid levels in the rumen were determined by gas liquid chromatography according to Erwin et al. (1961). Rumen ammonia was analyzed by a Technicon Autoanalyser II, Industrial Method No. 337.74T. Blood urea nitrogen in plasma was analyzed by Technicon Autoanalysers, Industrial Method No. AAII-1.

Experimental data were analyzed statistically as a continuous two

treatment trial with repeated measures for feed intake, milk production and milk composition. The analysis of the data for milk production and feed intake included the following factors in the model: treatment, cow nested with treatments, week, treatment x week interaction, and week x cow nested with treatment. Data were analyzed weekly over the ten week experimental period for each cow for milk production and feed intake.

Milk composition data were collected biweekly and the analyses of these data (milk protein, SNF and fat levels) included the same factors in the model as were present for milk production. Milk samples were collected at the 9th and 10th week and the analyses of these data were based on the same factors in the model as were present for milk production.

The analyses of the data for volatile fatty acids, ammonia levels and pH in the rumen fluid and blood urea nitrogen included the following factors in the model: treatment, cow nested with treatment, week, treatment x week interaction, week x cow nested with treatment, hour, treatment x hour, week x hour and treatment x week x hour.

Weight change was calculated for each cow. The analysis of these data included the following factors in the model: treatment and cow nested with treatment.

All statistical analysis was performed using ANOVA except the SNF and DMI data where General Lineral Model (GLM) was used. Means comparisons were done using Least Square Means Procedure for the SNF and DMI data.

RESULTS AND DISCUSSION

At the beginning of the experiment 30 of 200 observations on DMI

were missing. Dry matter intake (Figure 1) was not (P>0.05) affected by treatment (Table 12, Appendix 10). This is in agreement with results obtained by Rafalowski and Park (1982) and White et al. (1987b) using levels up to 30% of concentrate and 10% untreated sunflower seed in total ration DM, respectively. As formulated the NDF level in both diets was similar (Table 11) with a slightly higher ADF level for the ammoniated sunflower seed diet.

Milk yield was not different (P>0.05) for cows on the two diets (Table 12, Appendix 10). Research carried out by White et al. (1987b), Mabon (1988) and Casper et al. (1988) (feeding iso-caloric diets) indicated no change in milk production when whole sunflower seed constituted about 9% of the ration total DM. McGuffey and Schingoethe (1982) and Finn et al. (1985) observed little change in milk production when extruded or rolled sunflower seed made up 10% of ration total DM. When milk production was expressed as 4% FCM (Table 12, Appendix 10), it was lower, but not different (P>0.05) from that of the control. Rafalowski and Park (1982) observed an increase in milk yield, and 4% fat corrected milk when whole sunflower seed constituted 10% concentrate DM. Since the dietary level of ammoniated sunflower seed (5.6% of total DM) was lower than the levels used in the research mentioned above, a drop in % fat was not expected, and the data showed that the drop in % fat was not significant (P>0.05) (Table 13). The non-significant reduction in fat corrected milk (FCM) might have followed the lower, but non significant (P>0.05), DMI of the sunflower seed diet (Figure 1).

Both diets resulted in a net loss of body weight over the experimental period, but these losses were not different (P>0.05). The cows receiving the sunflower diet tended to lose less weight (Table 12),

Table 12. Effect of ammoniated sunflower seed for dairy cows in early lactation on daily dry matter intake, milk production, yield of 4 percent fat corrected milk and body weight change

Parameter	Experimental diets			
	Sunflower seed	SE	Control	SE
Dry matter intake (kg/day)	19.9	1.1	21.1	1.1
Milk production (kg/day)	31.0	1.7	32.9	1.7
4% Fat-corrected milk (kg/day)	22.2	1.5	24.1	1.5
Body weight change (kg)	-7.1	8.9	-16.2	9.4

SE=Standard error.

Table 13. Effect of ammoniated sunflower seed for dairy cows in early lactation on percent fat, crude protein and solid-non-fat in milk

Parameter	Experimental diets			
	Sunflower seed	SE	Control	SE
Fat (%)	2.85	0.08	2.93	0.08
Crude protein (%)	2.78	0.05	2.86	0.05
Solid-non-fat (%)	8.45	0.11	8.67	0.11

SE=Standard error.

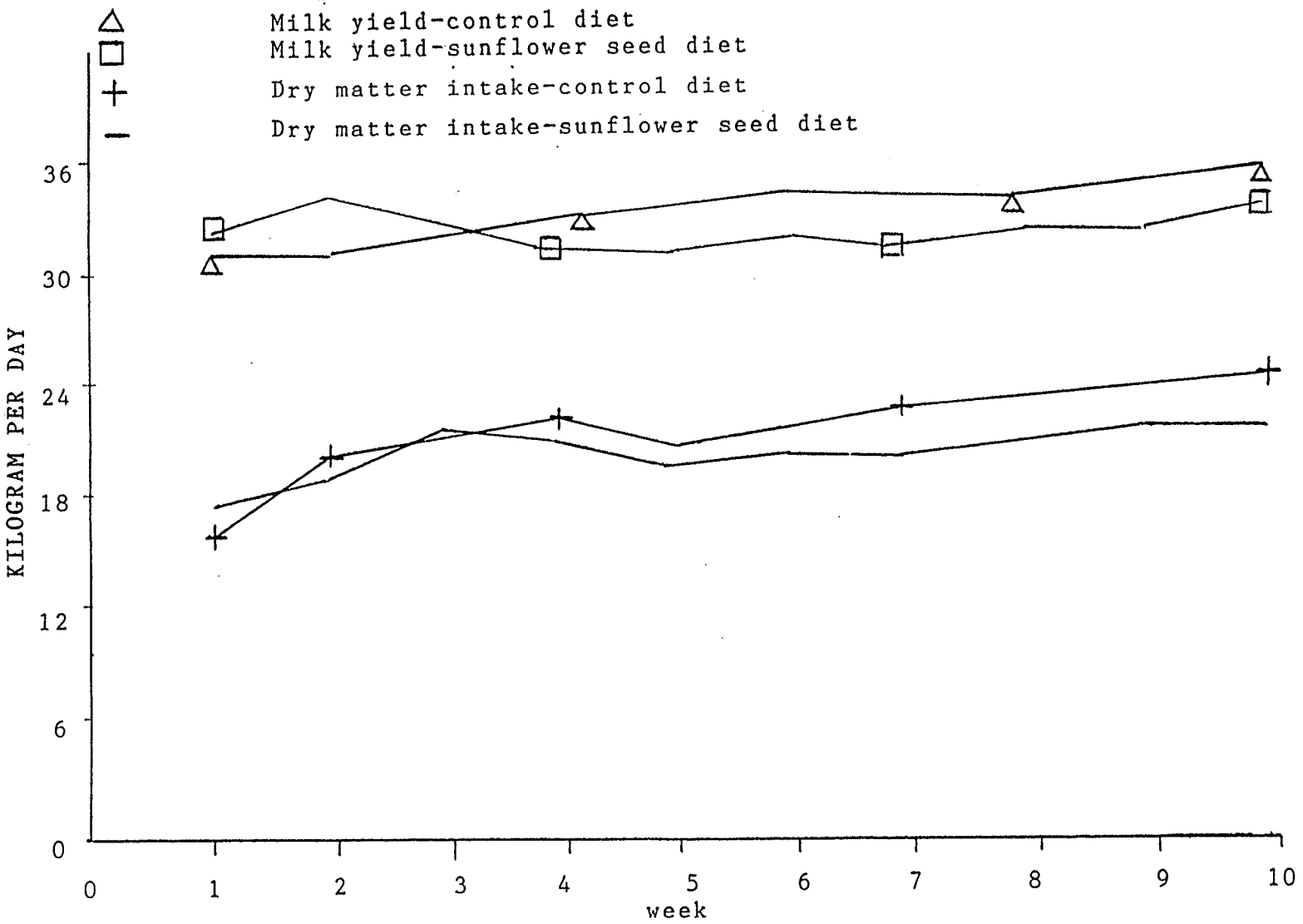

Figure 1. Average dry matter intake and milk yield for cows in early lactation when receiving control or sunflower seed diets.

and it could be that the sunflower seed diet had a sparing effect on the mobilization of body fat.

The percentages of milk fat for the two experimental diets were not different (P>0.05) (Table 13, Appendix 11). The additional whole ammoniated sunflower seed did not depress fat test. This was reflected in little change in the acetate:propionate ratio relative to that of the control diet (Table 14). The levels of fat test were low for both diets. This was not associated with dietary levels of ADF (Table 11) which were adequate based on suggested NRC level (1989). This may be explained in part by silage with a uniform relatively chopped length. White et al. (1987b) and McGuffey and Schingoethe (1982) did not observe any change in the percentage of milk fat when whole sunflower seed was fed at a level of 9% of the total ration DM. Casper et al. (1988) and Mabon (1988) reported a decrease in the fat percentage when the same level (9%) of whole seed was fed to lactating cows.

Milk protein percentages were not affected by diet (P>0.05) (Table 13, Appendix 11). Rafalowski and Park (1982) noted little change in the percent crude protein in the milk when sunflower seed constituted 10% of the concentrate DM. Similar results were obtained by McGuffey and Schingoethe (1982) and Casper (1988) when 9% of sunflower seed were included in the ration total DM. On the contrary Finn et al. (1985) and Mabon (1988) noted a decline in the percentage of milk protein when sunflower seed based diets were fed at 10% and 9% of ration DM, respectively. The level of sunflower seed in the present experiment may have been too small to bring about a significant reduction in milk protein percent.

The SNF percentages were not affected (P>0.05) by diet (Table 13,

Appendix 11). However, fourteen pieces of data (observations) were missing in the statistical analysis for SNF. These results are in agreement with research results by Rafalowski and Parks (1982), McGuffey and Schingoethe (1982), Finn et al. (1985), White et al. (1987b) and Mabon (1988).

The molar percentages of C4:0, C6:0 and C8:0 fatty acids in milk fat were not different ($P>0.05$) for cows receiving the two diets (Table 15). The molar percentages for C10:0, C12:0, C14:0 and C16:0 fatty acids were reduced ($P<0.05$) in the milk with the feeding of the sunflower seed based diet which added 420 g sunflower oil per day to the cows diet. The molar percentages of long chain fatty acids C18:0, C18:1, C18:2 and C20:0 were increased ($P<0.05$) with the feeding of the sunflower seed based diets. The molar percentages of C14:1, C16:1 and C18:3 were not different ($P>0.05$). Palmquist and Jenkins (1980) contended that when the level of lipid is increased in the diet there is a decrease in de novo synthesis of short chain fatty acids in the mammary gland, and at the same time there is an increased uptake of dietary long chain fatty acids. Rafalowski and Park (1982) results on the feeding of sunflower seed indicated a decline in the molar percentage of C6 to C14 fatty acids, and an increase in the molar percentage of C18:1. Similar research on sunflower seed indicated an increase in C18:0, C18:1 and C18:2 fatty acids (McGuffey and Schingoethe, 1982). Similar results on the feeding of sunflower seed were obtained by Mabon (1988) and Casper et al. (1988).

Rumen fluid levels of acetic, propionic and butyric acids were not different ($P>0.05$) for the two diets (Table 14). There was no difference between the acetate:propionate ratio (Table 14). This may be

Table 14. Effect of ammoniated sunflower seed for dairy cows in early lactation on means for rumen pH, rumen ammonia, blood urea nitrogen and rumen volatile fatty acids for 0 and 3 h post feeding

Parameter	Experimental diets			
	Sunflower seed	SE	Control	SE
Rumen pH	7.13	0.09	7.18	0.09
Rumen ammonia (mg/100 g)	6.24	0.65	5.68	0.65
Blood urea nitrogen (mg/dl)	18.81	1.73	20.04	1.73
Acetic acid (mg/100 ml)	220.52	15.66	200.13	15.66
Propionic acid (mg/100 ml)	109.26	12.13	103.21	12.13
n-Butyric acid (mg/100 ml)	64.49	5.15	57.81	5.15
Acetate:propionate ratio (mg/mg)	2.13	0.15	2.18	0.15

SE=Standard error.

Table 15. Effect of ammoniated sunflower seed for dairy cows in early lactation on fatty acids (molar percentage) in milk fat

	Diet			
Fatty Acid	Ammoniated Sunflower seed	SE	Control	SE
C4:0	4.92	0.2	4.60	0.2
C6:0	3.82	0.12	4.19	0.12
C8:0	2.46	0.17	2.65	0.17
C10:0	3.56b	0.27	4.78a	0.27
C12:0	4.08b	0.21	5.43a	0.21
C14:0	12.82b	0.33	14.58a	0.33
C14:1	1.70	0.07	1.92	0.07
C16:0	22.59b	0.65	28.12a	0.65
C16:1	2.53	0.09	2.71	0.09
C18:0	9.38a	0.49	7.47b	0.49
C18:1	23.80a	0.84	17.92b	0.84
C18:2	4.10a	0.13	2.87b	0.13
C18:3	0.36	0.01	0.38	0.01
C20:0	0.52a	0.04	0.31b	0.03

a,b-Row means with different letters are significantly different ($P<0.05$).

SE=Standard error.

an indication that the ammoniated sunflower seed did not depress fibre digestibility. These results are in agreement with results of other research (Rafalowski and Park 1982; McGuffey and Schingoethe, 1982; Finn et al. 1985; White et al. 1987b and Mabon, 1988) when sunflower seeds were fed to cows. However, Casper et al. (1988) did observe a decrease in the acetate:propionate ratio when sunflower seed (9%) was fed, but this decrease was not significant.

Rumen fluid pH was not different ($P>0.05$) for the two diets (Table 14). However, they were high, and rumen fluid may have been contaminated with saliva. The rumen fluid pH taken just before feeding was higher ($P<0.05$) than that taken 3 h after feeding (Table 16). There were increases in the levels of the major volatile fatty acids in the rumen 3 h after feeding (Table 16). This may explain the decline in rumen fluid pH taken 3 h after feeding. Little change in rumen fluid pH when the sunflower seed diet was fed is in agreement with Rafalowski and Park (1982) when sunflower seed (10% of concentrate DM) was fed to lactating dairy cows.

The levels of rumen ammonia were not different ($P>0.05$) for the two diets (Table 14). However, Drackley and Schingoethe (1986) fed sunflower seed (19% of ration DM) and noted a reduction in the level of rumen ammonia when compared with a control diet of soybean meal. The level of ammonia after 3 h of feeding was significantly higher ($P<0.05$) than the level just before feeding (Table 16), and this is expected because the volume of fermentative substrate would increase after feeding. The increase in rumen NH_3 after feeding sunflower seed is supported by earlier researchers when they fed sunflower seeds (Rafalowski and Park, 1982; White et al. 1987b and Casper et al. 1988).

Table 16. The effect of time of sampling (h) on mean rumen volatile fatty acid and ammonia concentration and pH in early lactating cows

Parameter	0	3	SE
Acetic acid (mg/100 g)	182.92b	237.73a	1.36
Propionic acid (mg/100 g)	87.27b	125.20a	3.56
n-Butyric acid (mg/100 g)	47.24b	75.07a	0.63
Rumen ammonia (mg/100 g)	2.33b	9.60a	0.31
Blood urea nitrogen (mg/dl)	17.25b	21.25a	0.26
Rumen pH	7.35a	6.95b	0.006

The levels of blood urea nitrogen were not different ($P>0.05$) for the two diets (Table 14). The level before feeding was lower ($P<0.05$) than the level after feeding. White et al. (1987b) and Rafalowski and Park (1982) observed little change in blood urea nitrogen when sunflower seed was fed. However, Park and Rafalowski (1983) found an increase in the level of blood urea nitrogen when sunflower seed was fed up to 20 and 30% of concentrate DM to Holstein heifers.

The feeding of 5.6% of ammoniated sunflower seed as part of the total diet did not affect DMI, rumen environment and blood urea nitrogen. This level of ammoniated sunflower seed increased the proportion of the long chain and decreased the proportion of short chain fatty acids in the milk fat.

GENERAL DISCUSSION

Ammonia treatment did not affect the disappearance of DM and CP in the a, b, a + b fraction of ground sunflower seed. Ammoniation did not affect the disappearance of NDF, and ADF in the a, b and a + b fraction of hull and kernel. However, it reduced the disappearance of DM in the a + b fraction in the kernel, and since the kernel represents about 40% of the sunflower seed when compared to about 14% for the hull (Table 2), reduction in DM degradation in the a + b fraction of the kernel could result in greater lower gastro-intestinal tract digestion or lower apparent digestibility. The rate of ADF digestion in the hull fraction was decreased. Sheep were used to further examine the effect of ammoniation on digestion by including two levels of control and ammoniated sunflower seed in the diet. The in vivo digestion study suggests that ammoniation may have improved digestion of the fibre fractions of sunflower seed. The difference was greater with the diet containing 16% sunflower seed. The ammoniated seed was also fed to cows (5.6% ration DM) to examine its effect on feed intake, milk production and composition, and blood and rumen environment.

In the in vivo digestion trial with sheep, the levels of ammoniated or control sunflower seeds (16 and 25% of ration DM) did not affect DMI ($P>0.05$). DMI was ($P>0.05$) not affected by treatment in the milk production study with cows. Although DMI for the sunflower seed diet was not different form that of the control diet, cows tended to consume less of the sunflower seed diet (Table 12). This may be due to a reduced palatability (Tembo, 1987) as a result of residual ammonia smell due to ammonia treatment of the seed. Rafalowski and Park (1982) and White et al. (1987b) fed levels 10% of concentrate DM and 10% untreated

sunflower seed in total ration DM, respectively. They did not observe any difference in DMI for the sunflower seed based diets when compared to control diets.

Milk production and FCM were not different (P>0.05) when the energy density of the diet was increased from 1.67 to 1.75 Mcal NE_L with sunflower seed. Research carried out by White et al. (1987), Mabon (1988) and Casper et al. (1988) observed no difference in milk production when whole sunflower seeds were fed to lactating cows (10, 9 and 9% of ration DM, respectively). The diets were iso-caloric in these studies. However, Rafalowski and Park (1982) observed an increase in milk yield and 4% FCM when energy density of the diet was increased by incorporating whole sunflower seed as 10% of the concentrate DM.

The percentage of milk fat were not different due to inclusion of ammoniated sunflower seed (P>0.05) (Table 13). There was little difference in the acetate:propionate ratio (Table 14) relative to that of the control diet and thus would not be expected to have an affect on fat test. Results from the in vivo digestion trial indicated that ammonia treatment of the seed resulted in a non-significant improvement in the digestibility of ADF of the ration when 16% of ammoniated sunflower seed was included in the ration (Table 9). Although the level of ammoniated sunflower seed was 5.6% of the total ration for cows, it may still explain the ruminal change in acetate:propionate ratio which is important for maintaining milk fat percentage. This may be due to increased fibre digestibility and/or no negative effect of fat on fibre digestibility. The lack of negative effect of the added fat is supported by the sheep digestion data for the control diet containing 25 vs. 16% added sunflower seed; however, the diets contained little

forage.

The in vivo digestibilities of CP were not different in rations containing 16% and 25% ammoniated or control sunflower seed (Table 8 and 9). Although the metabolism of fat and fibre in the rumen of sheep, may not be exactly the same as cows, sheep may be used as a guide to evaluate fat and fibre metabolism in the cows' rumen. If 25 vs. 16% of sunflower seed in the ration for sheep did not affect the N balance, then 5.6% sunflower seed in the cow's ration is not expected to affect the N utilization by the cow's ration. Also ammoniation had no effect on rumen degradation of N in the kernel of hull fraction (Table 5). The diets were iso-nitrogenous (Table 11) and contained about the same starch level (Table 6) thus these factors were not expected to affect protein level in the milk. The level of sunflower seed fat in the experimental diet might have been too small to bring about a reduction in milk protein percent. Rafalowski and Park (1982), McGuffey and Schingoethe (1982) and Casper et al. (1988) noted little change in the protein percentage in milk when sunflower seed was fed to lactating cows. On the contrary, Finn et al. (1985) and Mabon (1988) observed a significant decline in protein percent in the milk when similar levels of sunflower seeds were fed.

Palmquist and Jenkins (1980) reported that when the level of lipid is increased in the diet, there is a decrease in de novo synthesis of short chain fatty acids in the mammary gland, and at the same time there is an increased uptake of dietary long chain fatty acids. The molar percentages of C10:0, C12:0, C14:0 and C16:0 fatty acids were reduced ($P<0.05$) in the milk with the feeding of the sunflower based diet. The molar percentages of long change fatty acids of C18:0, C18:1, C18:2 and C20:0 were increased ($P<0.05$) (Table 15). This represents a 20%

decrease in C16:0 and increases of 26, 33 and 43%, respectively for C18:0, C18:1 and C18:2, and thus may have a better balance of fatty acids as suggested by some in terms of human nutrition.

The rumen environment was not affected by the feeding of the ammoniated sunflower seed based diet. Rumen pH, ammonia level, acetic, propionic and n-butyric acid levels, and acetate:propionate ratio (Table 14) were not affected ($P>0.05$) by the feeding of sunflower seed diet. However, 3 h after feeding of both diets as compared with prefeeding there were increased levels of acetic, propionic and butyric acid, rumen ammonia levels, and a simultaneous decline in rumen pH as expected. Blood urea nitrogen was not affected by the feeding of ammoniated sunflower seed (Table 14).

The inclusion of 5.6% ammoniated sunflower seed did not improve milk yield when compared with the control diet. It is possible that a higher level (10%) might have improved milk yield. However, it is possible that more can be done to fully utilize this oilseed. Further research should be geared to find out what effect ammoniated sunflower kernel will have on milk yield and composition when fed to dairy cows. Heat treatment of the seed may improve the digestibility of the hull as well as the by-pass value of the kernel. This could be beneficial when fed to high producing cows.

SUMMARY

1) Ammonia treatment of ground sunflower seed did not affect the disappearance of DM and CP in the a, b and a + b fraction in the rumen.

2) Ammonia did not affect the disappearance of NDF and ADF in the hull and kernel of sunflower seed. It reduced the disappearance in the a + b fraction in the kernel for DM, and the b fraction for CP.

3) DMI was not affected by the inclusion of 25% vs. 16% ammoniated or control sunflower seed in sheep diets.

4) The digestibility of DM, fat, CP and ADF was not affected when sunflower seed was included at 25% vs. 16% of the diet.

5) The digestibility of NDF tended to increase with the feeding of 16 vs. 25% of sunflower seed in the diet when the seed was treated with ammonia.

6) Increasing diet energy density from 1.67 to 1.75 Mcal NE_L with sunflower seed had no effect on milk yields, FCM yield or milk composition in this experiment.

7) Including ammoniated sunflower seed in the diet resulted in a reduction in molar percentages of C10:0, C12:0, C14:0 fatty acids and an increase in the molar percentages of C18:0, C18:1, C18:2 and C20:0 fatty acids in milk fat.

8) Supplemental ammoniated sunflower seed in the diet did not affect rumen fluid VFA's, pH and ammonia levels or blood urea nitrogen.

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Appendix 1. Temperature (°C) of sunflower seed in bag after treatment with ammonia as measured by Doric Trendicator, Model 400A

Day	Time	Bottom	Middle	Top	Average
1	a.m.	52.0	48.5	35.8	45.4
	p.m.	43.4	45.1	41.5	43.3
2	a.m.	33.6	36.4	34.4	34.8
	p.m.	33.6	36.2	33.9	34.6
3	a.m.	33.9	32.4	32.6	32.9
	p.m.	33.2	32.4	33.0	32.9
4	a.m.	31.0	32.9	31.8	31.9
	p.m.	31.1	32.8	31.8	31.9
5	a.m.	31.6	30.4	30.6	30.8
	p.m.	33.9	32.3	31.9	32.0
6	a.m.	36.8	33.9	32.0	34.2
	p.m.	34.9	33.8	32.1	33.6
7	a.m.	25.0	22.1	23.0	23.4

Average for the 7 days = 32.2°C.

Appendix 2. Temperature (°C) of sunflower seed in the silo after treatment with ammonia as measured by Doric Trendicator, Model 400A

Day	Top	Middle	Bottom	Average
1	46.0	56.5	46.4	49.6
2	49.6	34.8	33.0	39.1
3	34.7	25.6	40.6	33.6
4	44.6	34.5	40.3	39.8
5	44.3	34.7	33.2	37.4
6	34.8	26.9	35.8	32.5
7	40.2	32.6	33.6	35.4
8	33.8	28.0	30.8	30.8
9	28.3	24.7	20.6	24.5
10	22.2	17.0	36.0	25.0
11	36.8	32.6	27.6	32.3
12	23.2	21.6	34.0	26.2
13	36.0	31.5	34.8	34.1
14	35.6	31.8	22.3	29.9

Average for the 14 days = 36.1°C.

Appendix 3. Proximate analysis of control and ammoniated sunflower seed, hull and kernel (%) on a DM basis

Component	CP		EE		NDF		ADF	
	Control	Ammoniated	Control	Ammoniated	Control	Ammoniated	Control	Ammoniated
Sunflower seed	18.90	23.25	51.38	49.89	37.7	┼	16.05	16.4
Sunflower kernel	23.40	24.66	┼	┼	30.11	32.74	6.93	6.70
Sunflower hull	7.51	11.56	┼	┼	68.6	66.79	57.6	58.6

┼No analysis was carried out on these samples.

Appendix 4. Analysis of variance for dry matter intake and digestibility as well as fat intake for the sheep trial

Parameter	Source	Degrees of freedom	ANOVA SS	F value	Significance level
Dry matter intake	Period	3	49.1301	6.88	0.0028
	Treatment	3	3.1291	0.44	0.7283
	Square	1	0.0488	0.02	0.8877
	Animal (Square)	6	6.2162	0.44	0.8456
	Error	18	42.8291	2.37	
Dry matter digestibility	Period	3	229.0533	10.76	0.0003
	Treatment	3	36.5827	1.72	0.1989
	Square	1	0.0123	0.01	0.9057
	Animal (Square)	6	67.4057	1.58	0.2090
	Error	18	127.7125		
Fat intake	Period	3	22022108.0	1.97	0.1548
	Treatment	3	55967480.0	5.00	0.0107
	Square	1	2530687.5	0.68	0.4208
	Animal (Square)	6	25710725.2	1.15	0.3750
	Error	18	67111830.0		

Appendix 5. Analysis of variance for crude protein intake for 6 days and dry matter intake kg^{-1} body weight over a 7 day period

Parameter	Source	Degrees of freedom	ANOVA SS	F value	Significance level
Crude protein intake	Period	3	5428478.62	0.72	0.5541
	Treatment	3	21096892.12	2.79	0.0702
	Square	1	10566204.50	4.19	0.0555
	Animal (Square)	6	26685494.87	1.76	0.1633
	Error	18	45359204.75		
Dry matter intake	Period	3	5575.67	20.01	0.0001
	Treatment	3	334.63	1.20	0.3378
	Square	1	0.75	0.01	0.9291
	Animal (Square)	6	683.68	1.23	0.3384
	Error	18	552.1533		

Appendix 6. Analysis of variance for nitrogen balance and nitrogen in urine as a percentage of intake for the sheep trial

Parameter	Source	Degrees of freedom	ANOVA SS	F value	Significance level
Nitrogen balance	Period	3	1884.5736	4.66	0.0140
	Treatment	3	183.0260	0.45	0.7184
	Square	1	30.4980	0.23	0.6399
	Animal (Square)	6	397.8704	0.49	0.8057
	Error	18	2424.4409		
Nitrogen in urine	Period	3	896.0238	2.55	0.0883
	Treatment	3	94.4524	0.27	0.8473
	Square	1	3.8503	0.03	0.8583
	Animal (Square)	6	246.6187	0.35	0.9004
	Error	18	2111.6869		

Appendix 7. Analysis of variance for crude protein and fecal soap digestibility for the sheep trial

Parameter	Source	Degrees of freedom	ANOVA SS	F value	Significance level
Crude protein	Period	3	115.0706	1.75	0.1922
	Treatment	3	200.0211	3.05	0.0554
	Square	1	0.4704	0.02	0.8851
	Animal (Square)	6	84.7527	0.65	0.6932
	Error	18	393.9439		
Fecal soap	Period	3	573.3564	6.23	0.0043
	Treatment	3	191.9049	2.09	0.1380
	Square	1	48.5851	1.58	0.2243
	Animal (Square)	6	606.4828	3.30	0.0229
	Error	18	552.1533		

Appendix 8. Analysis of variance for neutral detergent fibre and acid detergent fibre digestibility for the sheep trial

Parameter	Source	Degrees of freedom	ANOVA SS	F value	Significance level
Neutral detergent fibre	Period	3	2036.6450	9.70	0.0005
	Treatment	3	626.2891	2.98	0.0589
	Square	1	6.0465	0.09	0.7723
	Animal (Square)	6	370.5691	0.88	0.5279
	Error	18	1260.8288		
Acid detergent fibre	Period	3	2030.9542	10.08	0.0004
	Treatment	3	420.2476	2.09	0.1378
	Square	1	1.2521	0.02	0.8928
	Animal (Square)	6	310.5951	0.77	0.6025
	Error	18	1208.3246		

Appendix 9. Cows allocated to sunflower or control diet according to an average 305 day milk production (kg) and/or lactation number

Cow Name	Milk Production (kg)	Lactation No.	Cow Name	Milk Production (kg)	Lactation No.
Leora	10101	3	Rosie	10159	3
Gloria	8621	3	Cynthia	8370	3
Joan	5518	3	Faye	7555	2
A. Bambi	5694	2	Jenny	7073	4
Elaine	8966	3	A. Vicky	8841	2
Lottie	8739	3	Nettie	6661	3
Amy	†	2	Venessa	†	2
Pearl	†	1	Joanne	†	1
Lisa	†	1	Loretta	†	1
Quinn	10444	3	Verna	10572	4

†Data not available at the time of allocating animals.

Lactation No. = the lactation the cow was starting when she went on test.

Appendix 10. Analysis of variance for dry matter intake, milk production and fat corrected milk for milk production trial

Parameter	Source	Degrees of freedom	Type III SS	F value	Significance level
FCM yield	Treatment	1	10604.8	0.97	0.3389
	Cow (treatment)	18	197730.7	10.58	0.0001
	Week	9	13594.0	1.46	0.1688
	Treatment x week	9	2723.8	0.29	0.9763
	Error	162	168129.8		
Milk production	Treatment	1	8346.3	0.60	0.4494
	Cow (treatment)	18	251248.0	47.33	0.0001
	Week	9	2927.5	1.10	0.3635
	Treatment x week	9	1744.5	0.66	0.7464
	Error	162	47773.9		
Dry matter intake	Treatment	1	1901.4	0.30	0.5913
	Cow (treatment)	18	102209.1	22.32	0.0001
	Week	9	29852.8	13.04	0.0001
	Treatment x week	9	2941.5	1.28	0.2510
	Error	132	33582.5		

Appendix 11. Analysis of variance for milk protein, milk SNF and milk fat levels for milk production trial

Parameter	Source	Degrees of freedom	Type III SS	F value	Significance level
Milk protein	Treatment	1	0.3625	1.48	0.2393
	Cow (treatment)	18	4.4663	13.96	0.0001
	Week	9	0.6059	3.84	0.0002
	Treatment x week	9	0.0988	0.63	0.7731
	Error	162	2.8402		
Milk SNF	Treatment	1	2.0070	1.70	0.2082
	Cow (treatment)	18	21.2033	31.82	0.0001
	Week	9	0.8834	2.72	0.0071
	Treatment x week	9	0.2206	0.66	0.7454
	Error	148	5.5111		
Milk fat	Treatment	1	0.3244	0.42	0.5228
	Cow (treatment)	18	13.7442	3.43	0.0001
	Week	9	4.6532	2.32	0.0175
	Treatment x week	162	36.0892	2.55	0.0092