

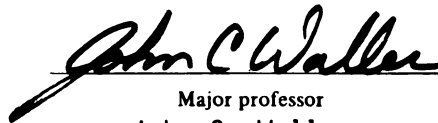
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EVALUATION OF APPLE POMACE AS A FEED
INGREDIENT FOR BEEF CATTLE

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Roberto Valdez Lopez

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of the requirements for

Masters degree in Animal Science



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EVALUATION OF APPLE POMACE AS A FEED
INGREDIENT FOR BEEF CATTLE

By

Roberto Valdez Lopez

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
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ABSTRACT

EVALUATION OF APPLE POMACE AS A FEED
INGREDIENT FOR BEEF CATTLE

By

Roberto Valdez Lopez

Apple pomace was treated with 4.38, 8.75, 13.13 and 17.5 g NH_3 /kg DM and stored in experimental laboratory silos with samples taken at 0, 4, 8, 16 and 32 days of ensiling after treatment. Dry matter and organic matter significantly decreased ($P < .01$) with time, resulting in an apparent increase of crude protein, ADF, NDF, ADL, Hemicellulose and cellulose with time of ensiling. Fiber components were not affected by ammoniation; pH decreased with time and then stabilized; Lactic acid increased with ammonia level and time of ensiling; IVOMD was increased ($P < .01$) by ammoniation effect. Diets containing untreated or anhydrous ammonia treated (3.5% on a DM basis) apple pomace at 30% of the DM were fed to steers and compared to corn silage diet (control). Dry matter and organic matter, crude protein, ADF, NDF, cellulose and ADL were significantly higher for apple pomace diets. Digestibility of nutrients were higher in the corn silage diet. However, intake of digestible nutrients for the apple pomace diets surpass that of the control diet. No apparent effect on pH, ammonia and volatile fatty acids in the rumen was observed by the inclusion of apple pomace in the diet.

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INTRODUCTION

Low quality roughages are characterized by their low protein content, high lignin content and in some roughages a high silica content. Poor intake and low digestibility have been associated with this type of roughages. For that reason, much of the research has been oriented toward improving their nutritive value. Physical and chemical treatments have been used with satisfactory results. Use of these low quality roughages as animal-feeds provides alternatives to burning and thus reduces environmental pollution.

Most of the studies on apple pomace have been designed to determine its' nutritive value when fed to wintering beef cows. Apple pomace supplemented with cottonseed meal or soybean meal has been shown to have potential as a feed ingredient. Unfortunately, apple pomace supplemented with NPN and fed to pregnant beef cows or ewes produced a large percent of stillborn calves and those calves born alive died shortly after birth. The cause of these adverse effects have not been determined, thus apple pomace supplemented with NPN is not recommended for pregnant beef cows or ewes.

Research has been conducted to explore the connection between pesticide content in the apple pomace and the accumulation of residues in the fat tissues in animals fed with apple pomace and the adverse effects on reproductive performance. Since, most of chlorinated hydrocarbons, such as DDT, have been banned from the market, restrictions placed on apple pomace use as a feed ingredient in the past need to be

reevaluated. Recently, interest has renewed in using apple pomace in beef cattle rations.

Limited research has been conducted using apple pomace in growing and finishing rations for steers. Furthermore, the use of anhydrous ammonia as a chemical treatment in apple pomace to improve its' nutritive value, has not been reported in the literature. Therefore, the objectives of this study were:

- a) To evaluate the intake and digestibility of diets fed to steers, containing either untreated or ammonia treated apple pomace as 30% of the diet dry matter.
- b) To study the effect of diets containing either untreated or ammonia treated apple pomace as 30% of the diet dry matter on pH, ammonia and volatile fatty acids in the rumen.
- c) To characterize fermentation pattern of untreated and ammonia treated apple pomace.

REVIEW OF LITERATURE

Apple pomace is that by-product of the processing industry which remains after cider or juice has been extracted or apple sauce has been produced from small whole apples. The composition of apple pomace is a mixture of the stems, seeds, peelings and possible press aids remaining after processing.

Michigan is one of the major fruit producing states in the United States. This is due to the moderating influence that the Great Lakes have on the weather. The fruit industry is concentrated along the western coast of the lower peninsula where the "lake effect" is strongest. In 1981, Michigan's apple production was 299.6 million kilograms, of which 190.7 million kilograms were utilized in the processing industry (canned, frozen, juice, cider, etc.). Approximately 52% of the apples processed were for the juice and cider industry, ranking the state of Michigan third nationally (Michigan Agricultural Statistics, 1982). The processing season extends from early September until February for apples held in common storage, and until late spring for those held in controlled atmosphere storage (Sargent et al., 1982).

Production of Apple Pomace

A brief description of cider production is presented to provide insight into the physical composition of apple pomace. Prior to pressing, whole apples are ground either by a grater or a hammermill. Twenty years ago, the only method employed was based on the use of a hydraulic press

fitted with wooden racks and a pressing cloth. In this method the pulped or comminuted apples are discharged through a hopper onto a press bed. The apple pulp is prepared for pressing by building up layers of ground fruit with each layer wrapped in a special press cloth and with wooden racks separating adjacent layers. Each wrapped layer is known as a "chesse". During the pressing operation the pressure should be increased gradually until the final pressure is reached (Lopez, 1981).

Another method described by Lopez (1981) produces juice by using a screening centrifuge. The apples are fed continuously into the centrifuge, the juice is forced through a screen and the pulp is discharged by a helix. In both methods, the final by-product is "apple pulp", which is composed of stems, seeds and peels.

A press recently introduced into the juice extraction industry, is the continuous plate press. A layer of ground apples are squeezed between moving vertical plates. The addition of a press aid to the ground apples has been found necessary to overcome the slippery nature of the apple pulp and provides channels for juice flow. Various types of press aids or mixtures of press aids have been used with screw presses. Purified wood pulp has been used as a press aid at the rate of 1.5 to 4.0% of the initial weight (as-is basis) of apples being processed as the pulp enters a horizontal mixer. Rice hulls have been the most commonly utilized press aid and are added at the same rate as purified wood pulp. Also a mixture of 0.5 to 1% rice hulls and 2% purified wood pulp has been used. Ash is the major inorganic component of rice hulls, ranging from 13.2 to 20.0% of the dry weight, and silica content accounts for 94 to 96% of the ash (Houston, 1972). This high silica content makes rice hulls the most satisfactory material as a press aid, because it retains

practically no moisture, compared to well desintegrated wood pulp, which is more absorbent (Lopez, 1981). Nelson and Tressler (1980) suggest that regardless of the material selected as a press aid, special care must be exercised to avoid imparting a foreign flavor to the juice. When processing methods include press aids the resulting by-product is referred to as "apple pomace". Apple pomace is composed of a press aid plus apple pulp. There are other methods such as pneumatic presses, horizontal basket presses, etc. to process apple juice. However, further descriptions are not presented.

After juice extraction, the pomace is basically a cellulosic material, consisting of the carpel and cortex tissue, peels, seeds, stems and the press aid. The final moisture content varies with the type of press used. The screw press which is widely used in continuous operations, produces a final product with a moisture content of approximately 65%. Another press, the belt press, adds water to the pomace and results in a high moisture final end-product.

Apple pomace has had many different uses which range from disposal in landfills to use as an orchard mulch. However, growers who spread pomace in their orchard, periodically incorporate lime into the soil to neutralize the acidity added by the pomace. Rumsey (1978) reported pomace pH ranging from 3.6 to 4.0, therefore neutralization has been highly recommended. Apple pomace was formerly used as a source of pectin in the preserve industry where the pectin was used in making jams and jellies, and has since been replaced by the citrus industry (Burris, et al., 1957).

Recently, Kranzler et al. (1981) conducted a study to evaluate the energy potential of fruit juice processing residues. Results indicated

that thermochemical conversion of fruit pomace appears to offer significant energy potential. Available biomass energy (kJ/kg) for apple pomace in direct combustion has been shown to be 2,300 kJ/kg, compared to anaerobic digestion and fermentation which release 740 and 88 kJ/kg, respectively. Sargent et al. (1982) analyzed the technical feasibility of utilizing apple pomace as a fuel supplement for food processors. They concluded that apple pomace has a definite potential for use as a supplemental fuel source. However, selection of handling and combustion components for a specific processor is dependant upon an analysis of the mass/energy flows and physical constraints of the processing plant and the availability of pomace. Therefore, the final decision to adopt a system rests upon the economic viability of the system by itself. These observations have provided renewed insight into alternative uses for apple pomace and have renewed interest in apple pomace as a livestock feed. Burris and Priode (1957) suggested the proximity of cider presses to local areas of cattle production provide a natural market for apple pomace as a palatable material for livestock feed.

Chemical Composition of Apple Pomace

Apple pomace has been defined as a highly palatable feed, medium in energy, but very low in protein (Bath et al., 1982).

The chemical composition of apple pomace from different sources is presented in Table 1.

Although low in crude protein, the apple by-product has high levels of carbohydrates as indicated by the relatively high levels of nitrogen-free extract. (Fontenot et al., 1977; Prokot, 1979).

Table 1. Chemical Composition of Apple Pomace

	Dry Matter	Crude Protein	Crude Fiber	Ether Extract	Nitrogen Free Extract	Ash
	—— % of Dry Matter ——					
Apple Pomace Silage Fontenot et al., 1977	28.60	5.90	27.60	7.40	54.40	2.00
Apple Pulp Silage Bath et al., 1982	21.4	7.80	20.60	6.30	-	4.90
Apple Pomace N.A.S., 1958	21.8	7.90	20.10	6.40	60.50	5.10
Apple Pomace Rumsey et al., 1977	17.0	6.00	-	-	-	-
Apple Pomace, dried Burris and Priode, 1954	95.87	5.25	20.29	7.10	61.76	1.47
Apple Pomace, dried Prokot, 1979	88.60	4.00	20.00	3.00	59.80	1.80
Apple Pomace, dried Bath et al., 1982	89.00	4.90	17.00	5.10	-	2.20

Apple pomace is equivalent to corn silage in total digestible nutrient content (TDN), deficient in digestible protein and higher in pectin, pentosans and ether extract than most common feedstuffs (NRC, 1971). According to NRC, (1971) apple pomace (IRN 300 420) contains only 7.8 protein on a wet basis, and only 3.3% of this is digestible.

Apple pomace properly supplemented has been used successfully in dairy cattle and feedlot rations (Bath et al., 1982) and in beef cows rations (Fontenot et al., 1977). Estimates of digestible energy (DE) kcal/kg for apple pomace have been reported by Wilson et al. (1971a,b), Prokot (1979) and Bath et al. (1982) reported net energy (NE) values for dried apple pomace of NE_m 1.58 to 1.63 Mcal/kg and NE_g .97 to 1.10 Mcal/kg on a dry matter basis. The pH of apple pomace is similar to

that of corn silage ranging from 3.6 to 4.0 (Oltjen et al., 1977; Rumsey, 1978).

Performance of Breeding Ruminants Fed Apple Pomace

An evaluation of dried apple pomace (DAP) as a roughage for wintering beef cows was conducted by Burris and Priode (1957). Dry matter intake showed that those fed DAP consumed an average of .454 kg/day more than those fed silage. In another trial, pregnant beef cows were fed either apple pomace silage (APS) or alfalfa-barley silage (ABS), supplemented with CSC and hay. Results showed that average daily gains of calves and cow weight losses did not differ greatly between treatments. However, animals fed APS had equal or slightly better condition than animals fed ABS.

Fontenot et al. (1977) conducted a feeding trial to compare the effect of feeding urea, biuret and cottonseed meal (CSM) supplements to apple pomace or corn silage. Results showed that cows consumed the feed offered, except for those fed apple pomace supplemented with NPN. Cows fed either apple pomace or corn silage supplemented with CSM during the prepartum period had similar average daily intake and weight gain. The most significant effect observed in the pregnant cows fed apple pomace with NPN was on birth weight and mortality of the calves. Six of eight calves from the cows on this diet, were stillborn, and none of the calves survived the two week postpartum period. Calves from cows fed apple pomace supplemented with CSM had similar birth weight as those calves from cows fed corn silage supplemented either NPN or CSM. No visual evidence of toxicity in the cows were reported for all the treatments, and length of gestation was normal for all cows. Burris and

Priode (1957), reported no toxic effect from the feeding of apple pomace supplemented with cottonseed cake. Furthermore, the calves from pregnant cows were thrifty. These results agree with those obtained by Fontenot et al. (1977) with cows fed apple pomace supplemented with cottonseed meal.

Because large feed refusals (29%) were recorded in cows fed apple pomace supplemented with NPN, Fontenot et al. (1977) conducted another trial to study the effect of increasing the energy intake in thirty two pregnant cows. Two levels of apple pomace supplemented with either CSM or urea combinations were fed. Results showed that cows fed the low level of apple pomace generally consumed the feed offered. Cows fed the higher level of apple pomace supplemented with either CSM or CSM-urea combination usually consumed the pomace offered. However, when only urea was used as nitrogen supplement large refusals were recorded. The marked effect of the combination of apple pomace and urea on calf mortality was also apparent, regardless of the level of energy fed to the cows.

Since these two studies were conducted with animals of similar genetic background and under a single management system a third trial was conducted by Fontenot et al. (1977) to determine whether urea supplementation of apple pomace would produce the same results with animals unrelated to those animals used in Trials 1 and 2. The cattle were also fed under different management systems than those used in Trials 1 and 2. Apple pomace was supplemented either with CSM or corn-urea. Twenty-two pregnant cows were fed during the last 3.5 months of gestation. A condition score and vitality score was recorded for the cows and calves respectively. Results showed that both diets were consumed by

the cows. Mineral consumption was over three times as high for cows fed apple pomace plus urea as for those fed apple pomace plus CSM. All the cows calved and all calves were born alive. However, two of the calves from cows fed urea died after birth. No marked differences in condition scores of the cows were recorded. The calves from cows fed apple pomace urea were lighter at birth (28.4 vs 23.1 kg) and showed lower vitality scores.

Bovard et al. (1977) conducted an anatomical study with the calves from the intake and performance feeding trials reported by Fontenot et al. (1977). Results showed that skeletal abnormalities consisting of shortened long bones, enlarged joints and splayed front feet in newborn calves were associated with cows fed apple pomace supplemented with NPN during late gestation. No skeletal abnormalities in calves from cows fed either apple pomace supplemented with CSM or corn silage supplemented either with CSM or NPN were reported.

In an effort to determine whether the adverse effects of an apple pomace-urea diet can be reduced by the dietary addition of a commercial trace mineral premix, corn starch, or wheat straw; a study was conducted by Rumsey (1979). Sixty-five pregnant cows were assigned to six different combination diets and fed for approximately 15 weeks prepartum. Results indicated that no feed refusals occurred on any treatments. Cows fed diets without supplemental trace mineral premix or starch had similar weight changes and calving problems as those reported by Fontenot et al. (1977). Calves had similar abnormalities as those calves described by Bovard et al. (1977).

Cows fed trace mineral premix did not have improved performance relative to the performance of cows fed apple pomace-urea diets. Calves

from cows fed apple pomace supplemented with urea and starch were weaker than calves from cows fed no starch. Mortality rate for calves from cows fed apple pomace plus urea was 20%, and 50% at two weeks post-partum for starch and no-starch addition, respectively. Addition of straw to apple pomace-urea diets eliminated the adverse affects noted in the apple pomace-urea diets. Calf birth weight and vitality score were similar than those obtained in apple pomace-CSM diets. Retained placentas were a general problem in all groups that were fed apple pomace-urea supplemented either with starch or trace mineral premix. However, this problem was not observed in apple pomace supplemented either with CSM or urea plus straw.

Rumsey and Lindahl (1982), conducted a series of trials feeding apple pomace supplemented with soybean meal (SBM) or cornmeal-urea mixture (CU) to 404 gestating ewes. Results showed that when apple pomace supplemented with CU, ewes had the same adverse effects observed by Fontenot et al. (1977) in cows fed a similar diet. Lambs from the apple pomace supplemented with CU, appeared to have the same structural abnormalities as those described by Bovard et al. (1977) in calves from cows fed a similar diet. The addition of straw to the apple pomace supplemented with CU diminished the adverse affects observed in animals fed only apple pomace supplemented with CU. When apple pomace was the primary diet ingredient an inadequate nutrient intake was observed, regardless of the type of protein supplement. However, when apple pomace supplemented with either natural protein or NPN, and fed up to 50% of the dry matter in the diet, intake, gain, lamb mortality rate, and viability of lambs were normal. These results suggest that the adverse effect of an apple pomace supplemented with cornmeal-urea are similar among both cattle and sheep.

Rumsey (1978), conducted additional research in search of an explanation of the adverse affects of apple pomace-urea diets reported by Fontenot et al. (1977). He observed a high ethanol concentration in the rumen from steers fed apple pomace diets. However, ethanol was not directly involved as a causative factor in the production of abnormal calves since calves from cows fed AP-CSM diets, which produced the highest ethanol concentration were normal.

Fontenot et al. (1977) conducted a study in an effort to determine if the adverse effects produced by feeding apple pomace in combination with NPN was due to the high ether extract or pesticide content of the apple pomace. The following pesticides have been found in apple pomace in variable amounts: 1, 1, 1-trichloro-2,2-bis(p-chlorophenyl ethane (DDT); 1,1-dichloro-2,2 (bis(p-chlorophenyl) ethane (DDD); 1,1-dichloro-2,2-bis (P-chlorophenyl) ethylene (DDE); 4,4'-dichloro- α -(trichloromethyl) benzhydrol (Dicofol); p-chlorophenyl 2,4,5-trichlorophenyl sulfone (Tetradifon); isopropyl 4,4'-dichlorobenzilate (chloropropylate); 1,2,3,4,5,6-hexachlorocyclohexane (benzene hexachloride); 0,0-diethyl 0-(p-nitrophenyl) phosphorotionate (Paration); 0,0,0',0'-tetraethyl s,s'-methylene bis (phosphorodithioate) (Ethion); 0,0,0',0'-tetraethyl bis (phosphorodithioate) (Dioxathion); 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonaphtalene (Dieldrin); dicofo¹; 1,1-bis-(p-chlorophenyl) 2,2,2-trichloroethanol (kelthane).

Semipurified diets were fed to 48 pregnant cows. These diets contained corn silage and corn cobs supplemented either with CSM or corn-urea as the source of protein, and corn oil to simulate the ether

extract level usually present in apple pomace, and a mixture of pesticide residues at concentrations similar to those previously found in apple pomace. Cows fed different combinations of additives to simulate apple pomace readily consumed the feed offered. Average total weight loss for the entire trial, including the weight loss during calving was 47 kg and 197 kg for the cows fed CSM and corn-urea as supplement, respectively. Birth weights and calving were normal in all the cows. However, two stillborn calves from cows fed CSM supplement were reported.

Pesticide Residue in Apple Pomace

Chemical residues are an important consideration when incorporating by-products into animal diets. The main deterrent to utilization of apple pomace in meat-animal rations has been the presence of pesticides (Wilson et al., 1971b). Research with feeding apple pomace in the early 1960's indicated deposition of excessive residues in the fat of animals fed these wastes (Bovard, 1961). Wilson et al. (1971a) stated that the chlorinated hydrocarbons such as DDT and its analogues (DDD, DDE, TDE) are primarily deposited in the fat tissues of animals fed apple pomace. A ten-fold excess of the U.S. Food and Drug Administration (FDA) permissible legal tolerance of DDT were detected in fat samples from animals self-fed dried apple pomace known to be contaminated with 103 parts per million (ppm) DDT. (Bovard et al., 1961). The FDA tolerance of DDT residues is 7.0 ppm in animal fat (Rumsey et al., 1969).

Pesticide residue variation in apple pomace has been reported by Rumsey et al. (1977). Pesticide concentrations determined in fresh and stored apple pomace from different orchards are presented in Table 2.

Table 2. Residue Concentration in Fresh and Stored Apple Pomace

Measurement	Residue				
	Dicofol	Tetradifon	DDT	DDD	DDE
Analysis of apple pomace before storage, October 1968, VDAC laboratory					
^a Mean content of 14 loads, ppm	1.43	.07	2.27	.12	.15
Range of load means, ppm	.25-3.25	.00-.40	.50-7.35	.00-.65	.03-.33
^b Standard error of samples within loads, ppm	1.28	...	.79	.09	.05
Analysis of six monthly stored apple pomace samples collected as fed during 1967-68 feeding trial, Beltsville laboratory					
Mean content of all samples, ppm	.85	.21	2.10	.52	.43
Range of sample means, ppm	.36-1.66	.07-.53	1.00-3.57	.38-.94	.30-.74
Standard error of samples ppm	.46	.15	.16	.18	.16

Source: Rumsey et al. (1977).

^aResidue content among loads was different ($P < .01$).

^bTetradifon was not detected in several samples, therefore, a meaningful standard error could not be computed.

Results indicated that residue content variations among loads of fresh apple pomace were significant ($P < .04$) for DDT, DDD and DDE. A ten-fold difference between the low and high means for all residues was observed. The mean residue concentrations in the apple pomace stored was similar to the fresh samples. The authors concluded that the residue problem in apple pomace is compounded by the variation in the concentration of pesticides in the apple pomace. Differences in residue concentration obtained from apple pomace were probably a result of differences

among orchards in pesticide application rates as dictated by pest infestation levels.

Pesticide residue variation in apple pomace reported by others were: 103 ppm DDT (Bovard et al., 1961); 1.10 ppm DDT (Rumsey et al., 1969); 0.61 to 2.15 ppm DDT (Wilson et al., 1971b).

Pesticide deposition in beef cattle has been investigated by several researchers. Rumsey et al. (1969) fed apple pomace silage containing 1.2 ppm DDT residues on as-fed basis to pregnant cows for 18 weeks postpartum. Results indicated that DDT residue in perianal fat tissue of cows fed apple pomace increased from 4.9 ppm to 13.7 ppm for samples in 0 and 24 weeks, respectively, and dropped to 4.2 ppm at 40 week samples after apple pomace silage feeding started. Similar results were obtained from blood samples, except that concentrations were much lower (parts-per-billion, ppb).

Pesticide residues in the milk produced by the cows fed apple pomace after parturition were 0.18 ppm at one day postpartum and decreased to 0.07 ppm 16 weeks later. The elimination of these residues via the milk was reflected in the blood residue level of the calves. Perianal fat tissue samples of the calves at 16 weeks of age gave a DDT residue accumulation of 7.2 ppm and decreased below 3.0 ppm at 26 weeks of age. Similar trends were observed in a second trial. However, pesticide deposition level was less, due to the lower pesticide content in the apple pomace.

The decrease in DDT residues in the animal reported by Rumsey et al. (1969) was similar to that observed by Martin et al. (1977). In this study cotton gin trash containing DDT was fed to steers during 216 days. A 56-day pesticide elimination was conducted. Total DDT

residue (DDT + DDE + DDD) mean from all treatment decreased from 10.13 ppm to 5.54 ppm, which represented a 45.3% decrease in pesticide residue content.

Pesticide concentrations of fat tissues of steers fed apple pomace silage during part or all of the finishing period were determined by Wilson et al. (1971b). Twenty-four yearling steers were allotted to four groups. The trial was divided into two phases; 80 days and 75 days, in which fat samples were analyzed for pesticide residues. Results showed that in steers fed apple pomace then control rations for phases I and II, the total DDT concentration in fat tissue samples decreased significantly ($P < .05$) from 0.68 ppm to 0.51 ppm. The reverse effect on pesticide deposition was observed in steers fed control ration then apple pomace ration for phase II (0.09 ppm versus 0.56 ppm). Steers fed apple pomace during the entire experiment had 1.07 ppm total DDT accumulation.

Wilson and Cook (1970) demonstrated that activated carbon given to ruminants at the level of 2 to 4 g per kg of body weight prevented the normal absorption of dieldrin, a pesticide in use since DDT was removed from the market, from the gastro intestinal (G.I.) tract into the animal's body. Wilson et al. (1968) demonstrated that dieldrin is recycled from the blood to the G.I. tract in ruminants. Later, Cook (1970) demonstrated that dieldrin is recycled from the blood to the G.I. tract via the saliva, bile and pancreatic juice.

In an effort to reduce the pesticide accumulation in fat tissues, Wilson et al. (1971c) conducted an experiment adding activated carbon to apple pomace silage rations fed to steers. Results indicated that activated carbon reduced dieldrin and total DDT absorption by 43% and 24%, respectively. The dieldrin results obtained by Wilson et al. (1971c)

agree with those obtained by Wilson et al. (1968) and Wilson et al. (1970). However, the DDT results did not agree with those obtained by Martin et al. (1977) when activated carbon was added to a cotton gin trash containing DDT residues.

Wilson et al. (1971b) found that steers fed an apple pomace diet for 80 days had an accumulation of dieldrin of 0.11 ppm. However, the levels of dieldrin decreased to 0.06 ppm 75 days after apple pomace was removed from the steers diets.

Other pesticide residues have been found as a result of feeding apple pomace. Residues less than 0.05 ppm for heptachlor epoxide, aldrin and dieldrin have been reported by Wilson et al. (1971b). Dicofol (Kelthane) and tetradifon have been detected in apple pomace. Concentrations of 1.43 ppm and 0.07 ppm, respectively have been reported in apple pomace by Rumsey et al. (1977). Fat deposition of 0.03, 0.10 and 0.17 ppm for dicofol and 0.05, 0.11 and 0.16 ppm for tetradifon were found in beef cows fed apple pomace (Rumsey et al., 1977).

Archer and Toscano (1971), conducted laboratory experiments to investigate the levels of Kelthane deposited on apples, site and form of these deposits, as well as to study decontamination procedures. Apples were sprayed with 2 liters of acetone containing 1.6g of Kelthane. After the apples were sprayed, the Kelthane residues were 6.4 ppm on the whole weight basis. The peels contained 84.5%, whereas, the core-peduncle area contained 13.8% and the flesh 1.7%. The forms detected were kelthane and 4,4'-dichlorobenzophenone (4,4'D) a decomposition product of kelthane, which is less toxic than kelthane. Solvent washing of the apples with ethyl alcohol accounted for 98% of the removal of total kelthane residues, whereas alkaline wash and benzene removed 58% and

92%, respectively.

Performance of Growing and Finishing Ruminants:

The nutritive value of apple pomace was established in research by Burris and Priode (1957). Later Rumsey et al. (1969) concluded that apple pomace can constitute a major portion of beef cow and finishing steer rations.

Wilson et al. (1971a) conducted an experiment to determine the value of apple pomace fed to steers as a replacement in standard finishing rations. The apple pomace was composed of peelings, seeds, cull apples and rice hulls at an approximate ratio of 1:13 of dried rice hulls: pomace. Steers were fed apple pomace and haylage in equal amounts (50:50) on an as-fed basis and a ration of haylage plus concentrate was used as a control. Another group of steers were fed apple pomace plus concentrate with a ration of haylage plus concentrate as a control. Results showed that average daily gains (ADG) were not significantly different ($P < .01$) between apple pomace and control rations. In 71% steers fed apple pomace, indications of ruminal parakeratosis, abnormal rumen tissue, were observed. However, this condition apparently did not reduce the growth or efficiency of the apple pomace fed steers. Results in carcass characters indicated no difference across treatments.

In another study conducted by Wilson et al. (1971a), steers received an alfalfa-orchard grass silage plus concentrate as a control; and comparison rations consisting of a combination of apple pomace, alfalfa and orchard grass silage plus concentrate. Average daily gain (ADG) for control and apple pomace rations were not different. Thus, estimates of DE were quite similar for the two rations. There were no

indications of ruminal parakeratosis in this study. Carcass characters were not significantly different.

Prokot (1979) conducted a study to determine the net energy for maintenance (NE_m) and the net energy for gain (NE_g) using apple pomace as an energy source in cattle finishing rations. In the experimental ration apple pomace replaced 20% of barley with all other ingredients remaining constant. Daily gain was not affected by the presence of apple pomace in the ration. Average daily intake increased slightly by the addition of the apple pomace in the ration (9.02 versus 9.60 kg/day). There were no significant differences in carcass characters between treatments. The resulting estimate of net energy for apple pomace was 1.61 Mcal/kg for NE_m and 1.10 Mcal/kg for NE_g . Other researchers have reported excellent dry matter intakes with diets containing apple pomace.

Effect of Apple Pomace Diets on Rumen Fermentation

The ruminant is well adapted to utilize feedstuffs that are largely noncompetitive with those feeds consumed by monogastric animals. However, much of the usefulness of these feedstuffs depends on the fermentation process in the rumen. The chemical composition of apple pomace would indicate that the ruminant animal should be able to more effectively utilize nutrients present in apple pomace compared to the monogastric.

Oltjen et al. (1977), found lower molar percentages of propionic, isobutyric and isovaleric acids and higher molar percentages of acetic and valeric acid in rumen fluid of cows fed apple pomace diets, than those cows fed corn silage. These results are consistent with those obtained by Rumsey et al. (1978) after feeding apple pomace diets to steers.

Rumsey et al. (1978) also observed a high ethanol concentration in ruminal fluid of steers fed apple pomace diets, especially those supplemented with cottonseed meal. These results indicate that apple pomace digestion in the rumen results in slightly different end products compared to corn silage.

Oltjen et al. (1977), observed that cows fed apple pomace plus corn-urea supplement had lower plasma amino acids. Furthermore, plasma branched chain volatile fatty acid, especially isovaleric acid, were greatly reduced when apple pomace diets were fed.

Ruminal pH was lower when apple pomace diets were fed to cows than when corn silage was fed (Oltjen et al., 1977). Rumsey et al. (1978), reported ruminal pH values ranging from 6.0 to 6.5 when apple pomace diet was fed to steers, whereas, steers fed corn silage diets had ruminal pH ranging from 6.4 to 6.6. Oltjen et al. (1977), observed that a further decrease in ruminal pH as apple pomace level was increased in the diet. However, when apple pomace was supplemented with NPN, ruminal pH tended to raise.

Oltjen et al. (1977), observed that ruminal ammonia concentration was higher in cows fed either apple pomace or corn silage diets supplemented with corn-urea, than when apple pomace or corn silage were supplemented with corn-biuret or cottonseed meal.

Rumen ammonia concentrations was evaluated using diets where the rumen contents of cattle consuming apple pomace was altered. Rumsey (1978), fed apple pomace diets with trace mineral or starch or a combination of both to evaluate rumen ammonia concentration. The ruminal ammonia concentration for cattle fed apple pomace supplemented with urea was reduced by the addition of either trace minerals or starch or a combination of both.

Oltjen et al. (1977), observed that levels of plasma urea and plasma ammonia were higher in cows fed apple pomace diets supplemented with corn-urea, than when apple pomace diets were supplemented with cottonseed meal. Rumsey (1978), reported that concentrations of plasma ammonia from steers fed apple pomace diets did not increase, suggesting that the normal ammonia utilization mechanisms were not overloaded.

Rumen microbial population, movement of ingesta from the rumen, and water intake were studied by Rumsey et al. (1979), in steers fed apple pomace supplemented with several sources of nitrogen using corn silage supplemented with cottonseed meal (CSM) as a control for comparison. Total microbial protein and total bacterial numbers were similar for steers fed corn silage plus CSM and apple pomace plus CSM and both were lower for the apple pomace plus urea diets. No differences in morphologic classification of ruminal bacteria and protozoa or in ruminal protozoal numbers were related to feeding either apple pomace or corn silage. However, when corn starch was added to the apple pomace plus urea diet to change the source of carbohydrates a trend toward a greater number of gram positive cocci was observed.

Movement of ingesta from the rumen was not affected by treatment. Passage rate of ruminal content was more rapid from 24 to 72 hour than 72 to 120 hours after feeding from both the corn silage and the apple pomace plus urea. Liquid washout rate from the rumen was somewhat greater when steers were fed apple pomace diets than when they were fed corn silage diets. Water intake was generally greater for cattle fed apple pomace than those fed a corn silage diet, particularly when apple pomace plus urea diet was fed. This may explain the greater liquid washout

rate. The addition of straw to the apple pomace supplemented with urea reduced the increased liquid washout rate observed previously.

Most cereal straws are characterized by low crude protein, high lignin and low available energy content, which limits their use to low-energy diets for ruminants, such as those fed to over-wintering cows and growing stock gaining at a slow rate (Horton and Steacy, 1979; Horton, 1979).

Classification of the chemical fractions of forages and feedstuffs according to their nutritive availability to animals was presented by Van Soest (1966). Using detergent solutions feedstuffs are divided into two major fractions. First, a fraction that is easily soluble and digestible by enzymes secreted in the digestible tracts of all animals. This fraction is comprised of sugars, organic acids, starch, lipids, protein, nucleic acids and most of the inorganic content. Second, a insoluble fraction or cell wall which contains substances that can be digested only by microorganisms. These substances are: hemicellulose, cellulose, lignin, keratin proteins, and heat damaged proteins, ash and pectin. Lignincellulose is the complex of lignin, cellulose and hemicellulose existing in close physical and/or chemical association and accounts for most of the cell wall constituents. The main function of lignin is to supply strength and rigidity to plant materials. In general, increasing maturity of the plant leads to greater lignification (Van Soest, 1964; Allinson and Osbourn, 1970; Johnson and Pezo, 1975; Anderson, 1978). Lignin acts as a physical barrier and impedes the microbiological breakdown of its direct linkage to the structural carbohydrates (Kamstra et al., 1958; Van Soest 1964; Van Soest, 1966;

Allinson and Osbourn 1970). Significant negative correlations between lignin content and either dry matter intake or dry matter digestibility have been reported by Gaillard, 1962; Van Soest, 1964; Allinson and Osbourn, 1970, Horton et al., 1982. However the type of structure of lignin rather than quantity may be of major importance, for example, alfalfa has a higher lignin content than grasses of a similar digestibility. (Dehority and Johnson, 1961; Allinson and Osbourn, 1970).

Cellulose is usually the most abundant polysaccharide of the cell wall constituents and the most insoluble (Theander and Per-Aman, 1980). It is a polymer of glucose units. Kamstra et al. (1958) demonstrated an increase in digestibility for isolated cellulose when compared to cellulose in the whole plant. They concluded that the higher and more uniform digestibility of isolated cellulose could be related to removal of lignin more than other cell wall constituents.

Hemicelluloses are amorphous polysaccharides which include short chain glucose polymers, polymers of xylose, arabinose, mannose and galactose plus mixed sugars and uronic and polymers (Theander and Per Aman, 1980).

Another important factor influencing forage nutritive value in many species of grasses is silica. Van Soest (1967) concluded that silica depresses the digestibility of the cellulosic carbohydrates in a manner similar to that of lignin. It was demonstrated by comparing in vivo digestibility with silica or lignin content of reed canary grass collected from four states. The correlation coefficient was -0.86 for silica but only 0.58 for lignin (Van Voest and Jones, 1968). The authors concluded that in grasses decline of three units of digestibility per unit of silica can be expected. It suggests that the availability of

organic constituents are being limited by the silica.

Rice hulls, a product often used as a press aid in apple processing and present in apple pomace, were ground and treated with sodium hydroxide (NaOH) and then washed, which resulted in a considerable amount of dry matter (DM) loss (Hutanuwatr et al., 1974). More than 50% DM washed out was silica, while little or no lignin was removed. Dry matter digestibility of the remaining DM after washing increased. This increase was caused by the removal of the dissolved silica. Similar results were obtained by Van Soest and Jones (1968) with oat plant materials. Therefore, extractable silica has been shown to be an important agent in digestibility depression.

Moore et al. (1973) reported a correlation coefficient between silica and true digestibility IVDMD of -0.39 for ten tropical grasses. This data suggests that in certain species silica effects on digestibility may be variable and similar to that observed for lignin.

Chemical composition of a selected group of crop residues and roughages are summarized in Table 3. In Table 3, values for the different chemical components of crop residues show that cell walls account for 60-80% of the plant dry matter, except for rice hulls and sawdust in which the proportion is 86 and 98%, respectively. Lignin content is higher for sawdust and poplar bark compared to the rest of crop residues. The high degree of lignification present in these plant materials produces a reduction in digestibility. Furthermore, cell contents in sawdust are very low with only 2% whereas, values range from 14 to 33 in the other crop residues. Silica content in rice straw and rice hulls is much higher than in oat, wheat and oat straws. Crude protein values for straws has been established ranging from 2.2 to 4.5% DM (Horton, 1979;

Horton and Steacy, 1979; Garret, 1970).

Table 3. Chemical Composition of Selected Crop Residues and Roughages^a

Crop Residue or Roughage	Cell Content	Cell Walls	Hemi- cellulose	Cellulose	Lignin	Silica
	% Dry Matter					
Barley Straw	19	81	27	44	7	3
Oat Straw	27	73	16	41	11	3
Rice Straw	21	79	26	33	7	13
Wheat Straw	20	80	36	39	10	6
Rice hulls	14	86	14	39	11	22
Sawdust	2	98	14	50	32	1
Poplar bark	33	67	12	34	21	--

^aAdapted from Jackson M.G. 1977.

Intake and Digestibility of Other Crop Residues

Van Soest (1968) reported that as forage cell wall constituents increase above 50% of the dry matter, voluntary intake declined. Low intake of long oat straw relative to hay given ad libitum to cows was reported by Campling et al. (1961). They concluded that low digestability and longer retention time in the rumen were the cause of the lower intake. Mertens (1977) found voluntary intake strongly associated with rate of digesta passage. It is apparent that factors that influence the rate of digesta passage from the reticulorumen control the intake of predominantly forage rations, at least until digestibility reaches 55 to 66% of the dry matter (Van Soest, 1966; Jones, 1972). Whereas, rations higher in digestibility, intake becomes controlled by metabolic functions and not by physical fill.

Plant cell wall content is the most important factor that affects organic matter digestibility of roughages for ruminants. It represents the portion of the plant in which lignin exerts its influence and determines the potential physical size (volume) of a feed (Gaillard, 1962). Hence, high cell wall content has been associated with a decrease in feed intake (Van Soest, 1968; Anderson, 1978). Van Soest (1968) concluded that cell contents of a forage can be almost completely digested, and are independent of the cell wall components, lignin, hemicellulose, and cellulose.

Johnson and Pezo (1975) observed a decline in percentage in in vitro dry matter digestibility and crude protein content, with the concomitant increase in percent cell wall content, ADF, hemicellulose, cellulose and lignin in forty four forages.

The relationship between the cellulose-lignin complex, voluntary consumption and dry matter digestibility of two varieties of Italian ryegrass and two legumes were reported by Allinson and Osbourn (1970). Results indicated that changes in maturity of a forage during a single growth phase, produced differences in voluntary intake and closely correlated with both dry matter and cellulose digestibility and inversely with lignin content.

A number of experiments have been conducted to determine the effect of level of crop residues in the diets of cattle. In a study conducted by Lesoing et al. (1981b), one hundred steers were allotted to diets containing different levels of ground wheat straw (0, 10, 20, 30 and 40%). Results showed that feed intake was highest for steers fed the 30% wheat straw diet. The authors concluded that ground wheat straw stimulates intake up to a certain point, but that at higher levels, it depresses

intake. Similar conclusions were obtained by Brown and Johnson (1981), when chopped wheat straw rations were fed at different levels to goats and lambs.

Utley and McCormick (1972) reported that consumption increased proportionately at the level of peanut hulls increased from 0 to 30% in finishing diets fed to steers.

For illustrative and comparative purposes, the chemical composition and in vitro dry matter digestibility (IVDMD) of some crop residue are presented in Table 4.

Data in Table 4 indicates that IVDMD decreases as cell wall contents (CWC) and lignin content increases. Corn cobs have the highest IVDMD compared to the other residues. Similar results for IVDMD in wheat straws and rice straw are observed, even though the rice straw had lower content of acid detergent fiber (ADL), however rice straw contents had a higher level of silica, which has been demonstrated to have negative correlation with in vitro and in vivo digestibilities.

Methods Used to Improve Crop Residues:

Physical treatment of straws such as grinding and chopping may convert them from an unpalatable material incapable of supporting maintenance into one capable of use as a major constituent in diets for moderately productive animals. The physical change is in the relationship of lignin to structural carbohydrates and results in a freeing of the digestible fractions for microbial attack in the rumen. Campling and Freur (1966) found voluntary intake of ground, pelleted oat straw by cows 26% greater than long straw. However, digestibility of ground materials was lower than for the long form. It is well known that ground

Table 4. The Chemical Composition and In Vitro Dry Matter Digestibility of Crop Residues.

Item	CWC ^a	ADF ^b	ADL ^c	Cellulose	Hemi-cellulose	IVDMD ^d	Reference
	_____ % Dry Matter _____						
Corn Cobs	79	42	5.7	36	37	62	Gard et al., 1968
Wheat Straw	85	59	11.8	47	26	53	Gard et al., 1968
Wheat Straw	83	54	8.2	40	29	48	Johnson and Pezo, 1975
Rice Straw	73	52	5.8	32	21	54	Johnson and Pezo, 1975
White Oak Sawdust	91	68	21.7	46	23	17	Goering and VanSoest, 1975
Wood Sawdust	92	78	20.6	55	14	19	Johnson and Pezo, 1975

^aCWC = Cell wall constituents (Neutral detergent fiber)

^bADF = Acid detergent fiber

^cADL = Acid detergent Lignin

^dIVDMD = In vitro dry matter digestibility

or pelleted feeds have shorter retention times than feeds in long form (Waldo et al., 1972). A reduction on particle size increases the rate of passage. Therefore, there is less time for reticulo-rumen fermentation, which results in a reduction in digestibility. However, Swingle and Maymack (1977) indicated that finely ground wheat straw had a lower dry matter intake than sliced straw (10 cm). This indicated that extreme processing may produce a product that is unacceptable to the animals.

Another method used to improve digestibility of roughages has been steam treatment (Klopfenstein, 1975; Garret et al., 1981). Hart et al. (1981) demonstrated that the highest increase in in vitro digestibility for rice straw, sugar cane bagasse and sugar cane field trash was obtained with a pressure of 21.1 kg/cm^2 . Initial rice straw digestibility was 26% and after 1.5 min at 21.1 kg/cm^2 pressure, digestibility improved to about 47%. When rice straws were treated with NaOH before pressure treatment in vitro digestibility improved from 26 to 64%.

The effect of chemical treatment on improving low quality roughages has been investigated by several researchers. The most commonly used have been: sodium hydroxide (NaOH), ammonium hydroxide (NH_4OH), calcium hydroxide ($\text{Ca}(\text{OH})_2$), and potassium hydroxide (KOH). (Waller 1976; Chandra and Jackson, 1977; Wilkinson and Gonzales Santillana, 1978; Paterson et al., 1980a, Berger et al., 1980; Lesoing et al., 1981^a).

Sodium hydroxide at 4% of the dry matter has been shown to be the most effective in improving in vitro dry matter digestibilities in several crop residues, as well as intake in lambs (Lamm et al., 1976) and cattle Rounds et al., 1975; Acock et al., 1979; Paterson et al., 1980b). Waller, 1976, demonstrated that corn cobs treated with a combination of NaOH with $\text{Ca}(\text{OH})_2$ at 3:1 ratio, respectively, gave similar gains in calves,

as those obtained with corn cobs treated with 4% NaOH. However, NaOH has several disadvantages when compared to $\text{Ca}(\text{OH})_2$ or NH_4OH . Sodium hydroxide is more expensive and requires special equipment when used due to its' highly caustic properties. It has been observed that NaOH treatment causes an increase rate of passage resulting in lower digestibilities in vivo compared to in vitro (Berger et al., 1980). Also the excess of sodium in the manure, could cause problems of soil salinity (Paterson et al., 1980^b).

Calcium hydroxide ($\text{Ca}(\text{OH})_2$) is cheaper, easier to handle and provides supplemental calcium to the ration. Since $\text{Ca}(\text{OH})_2$ is a weaker base than NaOH, it reacts to the cell wall fraction at a much slower rate than does NaOH. Therefore, $\text{Ca}(\text{OH})_2$ must be combined with NaOH in order to maximize the response (Paterson et al., 1980c).

Ammonium hydroxide (NH_4OH), works in a similar manner to that of NaOH, but requires more time to react because caustic nature of NH_4OH is lower than NaOH. Another advantage of NH_4OH compared to NaOH, is the additional nitrogen from ammonium hydroxide can be used as a supplemental source of nitrogen for the normally low crude protein crop residues (Klopfenstein, 1978).

Straws and stovers are considered low energy feeds, containing very little protein or minerals (Jackson, 1977). Much research has been devoted to selecting protein sources to supplement crop residues (Lamm et al., 1977; Pritchard et al., 1981; Martin et al., 1981). Saxena et al. (1971) compared three types of nitrogen supplementation for either untreated or treated alkali oat straw fed to lambs. The supplements were soybean meal (SBM), urea and diammonium phosphate (DAP). Results are shown in Table 5.

The lambs fed treated straw and SBM gained comparable to those expected from high concentrate rations. Alkali treatment of oat straw and supplemented with either source, showed an increase in feed intake, daily gain and improvement in feed efficiency by almost 50% for SBM and urea supplementation and 20% for DAP supplementation.

Table 5. Performance of Lambs Fed Oat Straw or Alkali Treated Oat Straw Supplemented with Different Nitrogen Sources.^a

	Ration					
	S-SBM	TS-SBM	S-Urea	TS-Urea	S-DAP	TS-DAP
Feed Intake (kg DM/day)	0.87	1.27	0.82	1.11	0.69	0.94
Daily Gain (g/day)	61.50 ^{b,c}	177.10 ^e	53.10 ^{b,c}	125.0 ^d	34.40 ^b	77.20 ^c
Feed Efficiency (kg DM/kg gain)	14.60	7.3	15.30	8.8	19.10	16.0

s = untreated straw; TS = alkali-treated straw

^{b,c,d,e} values on a line with different superscripts are significantly different ($P < .05$).

White et al. (1973) observed that addition of 1% urea to a high rice straw ration (79% of the dry matter) improved significantly ($P < .05$) the digestibility of crude fiber and slightly increased dry matter and energy digestibility. However, addition of 2 or 4% of urea gave no further improvement of digestibility.

Beef cows and lambs were fed dry corn stover supplemented with either urea, soybean meal or corn urea (Crawford et al., 1981). Dry matter, neutral detergent fiber (NDF), ADF, and cellulose digestibilities of corn

stover were highest with the SBM supplement compared to urea and corn-urea supplements. Corn-urea supplement was superior to the urea supplement. Energy from the corn-urea supplement may have enhanced urea utilization resulting in improved performance with corn-urea supplement. In other trials, conducted by Horn et al. (1981) to evaluate the effect of supplemental protein and supplement level on intake and digestibility of chopped wheat straw when fed ad libitum to lambs, the results indicated that intake, dry matter and cellulose digestibility increase as supplemental crude protein increased from 58 to 116 g/day. However, a decrease was observed with increasing level of supplement (200, 400, 600 g/day) fed to the lambs.

Effect of Ammonia Treatment on Crop Residues:

Anhydrous ammonia (NH_3 gaseous) and solutions of ammonia in water (NH_4OH aqueous) have both shown positive effects in improving the nutritive value of low-quality-roughage (Nelson and Klopfenstein, 1981; Horton et al., 1982; Herrera-Saldana et al., 1983). Anhydrous ammonia has been used for many years as the most economical source of nitrogen for soil application (Kuhl, 1982). More recently, it has been demonstrated to be a promising method to treat low-quality roughage (Ward et al., 1980; Horton, 1981; Queiroz et al., 1982; Saenger et al., 1982^C; Saenger et al., 1983).

Ammonia treatment has been shown to react in a manner similar to that of NaOH. However, the reaction time is much longer (Klopfenstein, 1981). Waller (1976) proposed as the modes of action of chemical treatment of corn cobs the following: 1) solubilization of hemicellulose; 2) an increase in the extent of cellulose and hemicellulose digestibility

and 3) increasing the rate of cellulose and hemicellulose digestion. The increase in extent of digestion is probably due to breaking of ester bonds between lignin and structural carbohydrates (Buettner et al., 1982; Harbers et al., 1982) without actual removal of lignin (Klopfenstein 1978). Feist et al. (1970) concluded that alkali reduces the strength of inter-molecular hydrogen bonds which bind cellulose molecules together, thus resulting in cellulose swelling. The swollen cellulose should be more easily penetrated by rumen microorganisms and this would account for the greater digestibility of cellulose in treated roughages. The inter-molecular ester linkages between uronic acid groups of hemicellulose and cellulose are probably hydrolyzed by alkali treatment. Also, an increase in acetic acid has been reported in alkali treated and steam-treated low quality roughages (Oji et al., 1977; Oji and Mowat., 1979), which is a result of hydrolytic cleavage of acetyl groups in cell wall polysaccharides (Feist et al., 1970; Oji et al., 1977).

Lignin content has been reported not to be reduced by chemical treatment (Klopfenstein et al., 1972). However, in a study with corn-stalks treated with anhydrous ammonia (Saenger et al., 1982a) a 22% decrease in lignin was observed. Horton (1981), treated cereal straws with 3.5% (wt/wt) of anhydrous ammonia, and lignin content tended to be lower, but cellulose was not affected by ammonia treatment.

In general, crop residues do not contain more than 5% crude protein (Garret, 1970; Horton, 1979; Horton and Steacy, 1979). One of the most important advantages of using ammonia is the value of the residual nitrogen as non-protein nitrogen (Klopfenstein, 1981). Ammonia treatment increases crude protein content of low-quality roughages (Waagepetersen and Thomsen, 1977; Lawler and O'Shea, 1979; Ward et al.,

1980; Nelson et al., 1981; Kernan et al., 1981; Oji and Mowat, 1981; Pace et al., 1982; Saenger et al., 1982b; Saenger et al., 1983; Colenbrander et al., 1983; Herrera-Saldana et al., 1983).

Oji et al. (1977) reported an increase in true protein contents in corn stover treated with alkali treatment and particularly with ammonia. Based on previous studies they concluded that the increase in true protein content was probably due to a decrease in proteolysis.

Ammonia-treated crop residues increase in water insoluble nitrogen (Oji et al., 1977; Solaiman et al., 1979; Saenger et al., 1982b; Buchanan-Smith, 1982). Similar results were observed from ammonia-treated corn silages (Huber et al., 1979a; Huber et al., 1979b; Huber, 1980). Huber et al. (1979a) reported that the presence of considerable ammonia in the water insoluble fraction shows that caution should be exercised in assuming that all of the increase in insoluble nitrogen caused by ammonia addition to silages is protein. They found that 41% of the increase in water insoluble nitrogen was due to indirect action of ammonia on plant material. The cause of the indirect increases was suggested by Bergen et al. (1974) to be a reduction in proteolysis by plant enzymes during the early stages of fermentation.

Ammonia addition to corn silage delays reduction in pH and increases lactic acid (Huber et al., 1979a; Buchanan-Smith, 1982; Glewen and Young, 1982). However, unlike corn silage amounts of lactic acid were contained in NH_3 -treated corn stovers (Oji et al., 1977).

Factors such as moisture, plant species, treatment time, level of ammonia and temperature and pressure have been reported to affect response to ammoniation of plant materials (Waiss et al., 1972; Oji et al., 1979; Kiangi et al., 1981).

The effects of two moisture levels (10 and 35%) and five NH_3 levels (0, 2, 3, 4 and 5%) in the form of ammonium hydroxide in wheat straw were studied by Ward et al. (1980). Percent of NH_3 nitrogen retained as crude protein was higher in straw containing 35% moisture compared to straw at 10% moisture. Although IVDMD was not significantly improved. The NDF and ADF digestibilities increased as ammonia level increased. The increase was greater at 35% than 40% moisture.

Solaiman et al. (1979) sprayed chopped wheat straw having five moisture levels (10, 20, 30, 40 and 50%) with ammonium hydroxide at 3.3% of dry matter. Results indicated that moisture level had a significant linear effect on IVDMD and total nitrogen content.

Recovery of added ammonia after ensiling whole corn plant has been reported to have a direct relationship to moisture content; since water absorbs ammonia. Therefore, the lower dry matter, hence higher moisture, should result in a more efficient absorption of added ammonia (Goering and Waldo, 1981).

Response of crop residues to ammonia treatment has been determined to be fairly specific. Response in terms of increases of nitrogen retention, intake and digestibility have not been uniform across different sources of ammonia. Variation between and within species influence the the effectiveness of NH_3 treatment. Under similar conditions, three varieties of barley, oat and wheat straw were chopped and treated with 3.5% DM anhydrous ammonia (Horton, 1981). Crude protein content increased in wheat and oat straw to about 160%. However, barley straw was more variable and ranged from 50 to 276%. Treated straw was fed to steers to evaluate the effect of ammonia treatment in vivo dry matter and

organic matter digestibilities (Horton and Steacy, 1979). Results indicated that wheat straw diets were better than barley and oat straw.

Anhydrous ammonia was the most effective treatment for improving IVDMD and in vitro organic matter digestibility (IVOMD) in corn stover (Kiangi et al., 1981). Whereas, aqueous ammonia was the most active in increasing IVDMD and IVOMD of wheat straw, and anhydrous and aqueous ammonia were similarly effective on rice straw. These results support the hypothesis that cereal straws do not respond uniformly to treatment with ammonia.

In general, NH_3 treatment is more effective for roughages with low initial digestibility than those with high initial digestibility (Waiss et al., 1972). Corn stalks decrease rapidly in digestibility with time after grain harvest. An evaluation of NH_3 effect and time in cornstalks harvested at two different times relative to high moisture grain harvest was conducted by Paterson et al. (1980d). Results indicated an increase of 5.7 and 11.4 percentage units in IVDMD for early and late stalks respectively. These results support conclusions, that different digestibility feeds respond differently to ammonia treatment, made by Waiss et al. (1972).

The time necessary for the ammonia to completely react with the forage depends on environmental temperature. Ward et al. (1980) concluded that the time for NH_3 treatment is temperature related. They observed that temperature in treated stalks rose rapidly from 26°C to 60°C during summer treatment and the reaction was essentially completed within a few days, however, at 4°C treatment may require three weeks or longer. Kuhl (1982) proposed forages treated with NH_3 need to be kept covered for

only about ten days during hot weather, while 30-40 days in winter conditions.

Selection of the treatment level for ammonia treatment of crop residues has received considerable attention. Optimum results in crop residues response to ammonia treatment have been observed with 3-4% of NH_3 level (Oji et al., 1977; Solaiman et al., 1979; Oji et al., 1979; Horton and Steacy 1979; Ward et al., 1980; Kaman et al., 1981; Horton 1981; Saenger et al., 1983; Herrera-Saldana et al., 1982). However, in a study conducted by Waagepetersen and Thomsen (1977) the effect on IVDMD of barley straw treated with various dosages of NH_3 (2.6 - 5.9%), at various temperatures (15-75° C) for various treatment times (1-14 days) is discussed. Results shown that maximum IVDMD was observed with 2.6% NH_3 , 62° C and 4 days incubation or 5.9% NH_3 , 30° C and 3-7 days incubation. Waiss et al. (1972) observed that rice straw treated with 2.6% or 5.2% NH_3 , at 160° C steam, at different moisture levels (0 to 80%). They observed that IVDMD of rice straw, when heated with steam and treated with 2.6% NH_3 , improved from 50% to 60% and doubling the concentration of NH_3 to 5.2% resulted in only a slight improvement. However, rice straw treated with 2.6% NH_3 , at room temperature (22° C) and after 30 days reaction, IVDMD was approximately 50% regardless of moisture content, but with the addition of 5.2% NH_3 at 30% moisture content, 60% IVDMD was achieved. Therefore, the authors concluded that 5% NH_3 , and 30% moisture level at ambient temperature for 30 days were the optimal conditions to convert rice straw to a more valuable and nutritive feed. These results suggest that besides time-temperature interaction, there is a dosage-time-temperature interaction influencing the effect of ammoniation.

Hence, there are factors other than ambient temperature, treatment duration, ammonia level and moisture content in the crop residues that affect response. Crop residues of annual grasses respond more to ammonia treatment than do those of legumes (Kernan et al., 1981). Legumes frequently have higher lignin content than grasses, however the chemical bonds between lignin and polysaccharides differ (Allinson and Osbourn, 1970). In grasses, the lignin-polysaccharide bonds are mostly ester linkages, whereas in legumes they are mainly glycosidic bonds. Therefore, the minimal response to NH_3 treatment by legume residues is likely to be due to the resistance of glycosidic bonds to alkaline hydrolysis (Kernan et al., 1981).

Nitrogen utilization from crop residues treated with ammonia is somewhat controversial. Oji et al. (1977) observed a decrease in nitrogen digestibility in corn stover treated with 5% NH_3 . Similar results were reported with ammonia-treated rice straw by Garret et al. (1970). Whereas, Horton and Steacy (1979) reported an increase in nitrogen utilization. The cause of the reduced nitrogen digestibility has not been clarified.

Harbers et al. (1982) described that the color changes in ammoniated materials are due to chemical reactions arising from the oxidation of phenols or condensation of aldehydic fractions in sugars with nitrogenous bases. Oji et al. (1977) concluded that presumably some nitrogen that is tied up as a result of these reactions could partly account for the decreased nitrogen digestibility.

The effect of anhydrous ammonia treatment of wheat, oat and barley straw upon apparent digestibility of fiber components is presented in Table 6 (Horton, 1981).

Table 6. Effects of Ammoniation on the Digestibility of Cell Wall Components in Diets Containing Wheat, Oat and Barley Straw by Steers.^a

Item	Straw Treatment	Wheat Straw	Oat Straw	Barley Straw	Pooled Data
NDF	Untreated	47.1	55.4	50.8	51.1
	Ammoniated	54.8 ^d	59.9 ^d	56.0 ^c	56.9 ^d
ADF	Untreated	34.5	46.1	41.6	41.7
	Ammoniated	44.7 ^d	49.6 ^b	44.9	46.4 ^d
Cellulose	Untreated	55.0	61.9	60.6	59.3
	Ammoniated	63.9 ^d	67.1 ^d	64.3	65.1 ^d
Lignin	Untreated	28.6	26.0	28.1	27.6
	Ammoniated	18.4	23.6	26.3	23.0

^aInclude three varieties each of wheat, oat and barley straw.

^bP<.05

^cP<.01

^dP<.001

Pooled data for all varieties show that ammoniation increased NDF, ADF and cellulose digestibility by approximately 5.8, 4.7 and 5.8 percentage units, respectively. Differences were largest for wheat straw diets averaging about 17%, and were similar for oat and barley straw diets at about 8%. In previous results, Horton and Steacy (1979), found that there was a consistent trend of lower hemicellulose levels in treated straws.

Low-quality roughages intake is increased from 15 to 25% by ammoniation. This is the result of an increased rate of passage (Oji et al., 1979; Nelson and Klopfenstein, 1980) of the forage through the digestive tract as well as an improvement in palatability (Lawlor and O'Shea, 1979). Results of crude protein, percent of dry matter digestibility and intake increase are presented in Table 7.

Ammonia has been shown to be highly effective in preserving forages containing up to 25-30% moisture (Kuhl, 1982). Ammonia is an excellent fungicide, so it kills mold and fungus that cause heating and deterioration in hays and crops that have been harvested too wet (Waiss et al., 1972; Britt and Huber 1976; Mowat et al., 1981).

It has been demonstrated that ammoniation of low-quality roughages increases digestibility and feed intake by ruminants. Cattle performance has been evaluated by several researchers. Horton et al. (1982), observed significant effects on intake, gain and feed efficiency on finishing steers fed ammoniated wheat straw diets. Shredded ammoniated straw diets gave higher gains (1.13 kg/day) compared to shredded untreated straw (0.83 kg/day). Feed efficiencies for treated straw and untreated straw were 9.19, 10.20 (kg feed/kg gain) and feed intake 10.39, 8.51, respectively. These results are consistent with those

Table 7. Results of Several Forage Ammoniation Trials.^{1,2}

No Trials	Forage	% Ammonia	% Crude Protein		% DM Digestibility		Increase in intake
			Untreated	Treated	Untreated	Treated	
5	Wheat Straw	1.5-3.25	3.7	9.7	38.9	48.0	18%
4	Corn Stover	2.5-5.0	6.2	11.0	48.0	59.2	22%
1	Corn Cobs	3.0	4.2	9.3	42.7	47.9	70%
1	Milo Stover	5.0	5.4	16.8	46.2	61.3	-
2	Soybean Straw	3.0-5.0	4.9	14.1	41.1	47.1	16%
2	Prairie Hay	3.0-5.0	7.5	17.1	45.2	59.1	-
2	Fescue Hay	3.0	6.6	14.8	39.7	57.7	36%
1	Orchard Grass Hay	3.0	7.1	14.2	46.1	54.3	22%
1	Clover Grass Hay	1.0	12.1	16.4	60.9	61.9	12%

¹Source: Kuhl, 1982.²Studies from Oklahoma, Nebraska, Missouri, Indiana, Illinois, Arkansas, Guelph and Saskatchewan.

obtained by Saenger et al. (1982); Ward et al. (1980); Nelson et al. (1981) and Paterson et al. (1980a). Queiroz et al. (1982) fed three forms of wheat straw to mature pregnant beef cows during 87 days. Results showed a beneficial response to anhydrous ammonia treatment wheat straw compared to untreated wheat straw supplemented with soybean meal or hay (Table 8).

Similar results in weight and condition change were obtained in other trials (Hendrix et al., 1982; Saenger et al., 1983; Pace et al., 1982).

Table 8. Effects of Anhydrous Ammonia Treatment of Wheat Straw Upon Weight and Condition Score Change of Cows.

Straw Treatment	Weight Change ^a Kg	Condition Change ^a Units
1) NH ₃ wheat straw + corn supplement	+ 16.03	- .36
2) Untreated wheat straw + soybean meal supplement	+ 1.91	- .64
3) Untreated wheat straw + hay	- 21.38	- .64

^aInitial cow weight and visual condition score of the three treatments average 563 kg and 3.75, respectively.

Condition Scores: 1 = very thin; 3 = average flesh; 5 = very fat.

Summary of the Literature Review:

Apple pomace is low in protein, but its' high carbohydrate content makes it a potential energy source for ruminants. It has been demonstrated by several researchers that apple pomace supplemented with natural protein source such as cottonseed meal or soybean meal has equivalent nutritive value to grass silages when fed to wintering pregnant cows. However, when apple pomace supplemented with NPN was fed to pregnant cows, a large percentage of calves were stillborn, and those calves that were alive at birth, died shortly after. Research was directed towards understanding a possible linkage between those adverse affects of NPN supplemented apple pomace and pesticides used in the apple industry.

The use of certain pesticides in the apple production and their residues in apple pomace has been considered of importance by several researchers. Chlorinated hydrocarbons are particularly hazardous since they are stored in animal fat and secreted in the milk. Pesticides such as DDT, dieldrin and heptachlor epoxide have been banned from the market by the Food and Drug Administration in the early 1970's. However, kelthane, methoxychlor, thiodan and ethion plus oil, still are available on the market, but there are other insecticides which degrade faster and are not generally stored in the body, that can be used in the pest control programs for apple production. Hence, renewed interest in utilizing apple pomace as a feed ingredient for ruminants has increased.

The effect of ammonia on crop residues has been demonstrated to improve their nutritive value such as dry matter digestibility, nitrogen content and feed intake. However, research is necessary to determine the effect of ammonia treated apple pomace on intake, digestibility, rumen fermentation as well as fermentation patterns after ensiling.

MATERIALS AND METHODS

Ammoniation of Apple Pomace

Preliminary analysis of dry matter (DM) and crude protein (CP) were performed on apple pomace¹ to determine treatment levels of anhydrous ammonia. After preliminary tests the apple pomace was passed through an auger of 18 cm of diameter and 4 meters of length. A U.S. steel cold-flo chamber system was placed on a small anhydrous tank mounted on a scale and the amount of anhydrous ammonia was adjusted to the unloading rate of the mixer wagon supplying apple pomace to the treatment auger.

Experiment I

This experiment was designed to characterize the fermentation patterns of untreated and treated apple pomace with anhydrous ammonia.

Four liter capacity plastic jars were used as experimental silos. A gas release valve was placed in each top. Apple pomace was treated with cold-flo anhydrous ammonia system at 3.5% (W/W) of the dry matter. The TAP was packed and sealed in 200 ℓ doubled plastic lined drums capacity and remained covered for five weeks before the experiment initiated. The UAP was handled the same except without anhydrous ammonia addition.

¹The apple pomace was obtained from the Quality Dairy Cider Processing Plant. The apple consisted of: peels, seeds, stems and rice hulls. The ratio rice hulls: apples was 1:50 kg. The DM and CP were 29% and 4.3%, respectively. The cider was processed in a Howard Rotary press.

After treatment proportional amount of treated apple pomace (TAP) was mixed with untreated apple pomace (UAP), to provide three intermediate levels of treatment. The experimental silos were weighed and stored at room temperature until opened for processing. The following treatment levels of NH_3 were used (1) control or UAP; (2) 4.38 g NH_3 /kg DM; (3) 8.75 g NH_3 /kg DM; (4) 13.12 g NH_3 /kg DM and (5) 17.50 g NH_3 /kg DM.

Duplicate plastic jars for each treatment were opened and samples processed on days 4, 8, 16 and 32 of fermentation according to the following scheme.

Sampling Time Scheme					
Treatment					
g NH_3 /kg DM					
	0	4.38	8.75	13.12	17.50
Day					
0	2	2	2	2	2
4	2	2	2	2	2
8	2	2	2	2	2
16	2	2	2	2	2
32	2	2	2	2	2

For day 0 experimental silos a representative double sample per treatment were collected and used as the day zero control.

Duplicate samples (150g) were taken from each laboratory silo and dried at 60⁰ C oven for 48 hr in a forced air oven to determine dry matter content of each silo. Dried samples were further processed by grinding and stored in an air tight container for laboratory analyses.

Laboratory analysis of ADF, NDF, ADL, Hemicellulose, Cellulose (Goering and Van Soest, 1970), Ash content (600° C oven for 3 hours), IVOMD (Moore modification of the Tilley and Terry Technique).

An additional 20 g wet sample was mixed with 100 ml of distilled water and pH was immediately measured (pH meter Model 7, Corning Scientific Instruments). The mixture was homogenized with a lab omni mixer in an ice bath for 2 minutes, filtered through a double layer of cheesecloth. Twenty seven ml of the homogenate was mixed with 3 ml of sulphosalicylic acid (50% v/v) and centrifuged at 15,000 rpm for 15 minutes. The residue was discarded and the supernatant retained for determining soluble nitrogen (Auto-Kjeldahl System), and lactic acid (Barker and Summerson, 1941). A second wet sample was taken from each silo for crude protein analysis (Auto Kjeldahl System).

This experiment was analyzed as a 5 x 4 factorial with two replicates, five treatments and four times. Initial weight of the experimental silos was used as covariate, according to the following model:

$$Y = \mu + \text{cov} + T + t + T \cdot t + \text{Error}$$

Where: Y = DM, OM, CP, IVOMD, ADF, NDF, hemicellulose, cellulose, PH, nitrogen soluble, Lactic acid, and ADL.

μ = Overall mean

COV = Initial weight

T = Effect of treatment

t = Effect of time

T·t = Effect of treatment-time interaction

Error = Residual error

Dunnett's test was used to compare the means against the control (Gill, 1978).

Experiment II

An experiment was designed to determine ad libitum intake of untreated apple pomace (UAP) and treated apple pomace (TAP) as a portion of diets for growing cattle. Apple pomace replaced one-half of the corn silage of the control diet on a dry matter basis. The composition of experimental diets are presented in Table 9.

Table 9. Composition of Experimental Diets

Ingredients		Diets No.		
		1	2	3
	Int. Ref No	% of Dry Matter		
Corn Silage	(3-07-739)	60	30	30
Untreated Apple Pomace	(3-00-420)	0	30	0
Treated Apple Pomace		0	0	30
High Moisture Corn	(4-02-931)	37	37	37
Supplement ¹		3(S-1)	3(S-2)	3(S-3)

¹ Composition of the supplement is presented in Table 9a.

The apple pomace was treated according to the procedure described above: 2,380 kg of apple pomace (wet basis) was treated with anhydrous ammonia at 3.5% (W/W) of the dry matter. The treatment was two fold the highest level (1.75% W/W) used in experiment I. This level was chosen in an attempt to maximize the affects of ammonia treatment on apple pomace. The TAP was packed and sealed in 200 ℓ doubled plastic lined drums capacity and remained covered for five weeks before the

Table 9a. Composition of Supplements for Experiments II, III and IV.

Ingredient	Int Ref No.	S-1	S-2	S-3
Ground Corn Meal	(4-02-931)	19.51	0.51	30.52
Urea	(4-05-070)	51.00	64.00	35.94
Limestone	(6-02-632)	18.00	20.00	19.05
Salt		8.00	8.00	8.00
Dicalcium Phosphate	(6-01-080)	1.00	5.00	4.00
Vitamin A		0.23	0.23	0.23
Vitamin D		0.28	0.28	0.28
Vitamin E		0.42	0.42	0.42
Selenium-90		1.56	1.56	1.56
Total		100%	100%	100%

experiment was initiated. The UAP was handled the same except without anhydrous ammonia addition.

Six yearling steers averaging 293 kg, were randomly allotted to a balanced incomplete block two period change over design for three treatments. In this design each animal received two of the three treatments sequentially. The steers were confined to individual pens (182 x 244 cm) in the metabolism room at the Beef Cattle Research Center (BCRC). The animals were fed once daily provided with free access to water. Diet ingredients were mixed daily prior to feeding in a horizontal batch mixer.

A preliminary adaptation period of 21 days was used to adjust feed offered to animals to achieve maximum voluntary intake. Voluntary intake adjustment was achieved by adjusting the quantity offered to

each steer daily to provide between one or two kg of orts (refused feed) each day. The twenty second through twenty ninth days were the intake measurement period. On each of these days, a sample of feed was collected representing a constant percentage of the total amount offered to the steers receiving each diet. To produce a total composite feed sample after seven days of 4 to 5 kg 2.8% of the daily feed was taken as a representative sample. Orts were processed by weighing and subsampling a constant amount (0.5 kg) for later analyses. Both feed and orts samples were stored in the freezer at 0° C until further processing.

The following scheme summarizes the experimental calendar discussed above.

Experimental Calendar for Each Period of Experiment II

Day	Action
1	Weigh steers, place in individual pens at the metabolism room.
2-21	Adjust feeding to <u>ad libitum</u> intake, remove orts each day
22	Collect feed sample
23-28	Collect feed sample and collect orts
29	Collect feed sample and collect orts

The daily feed samples were composited, and cut with a Hobart Laboratory Chopper, a subsample (200 g) was dried at 60° C oven for 48 hours. The same procedure was followed for the daily orts samples. The dried feed and orts samples were passed through a 1 mm screen in the Wiley Mill. The following analyses were conducted: Dry matter (DM), Organic matter (OM), Acid detergent fiber (ADF), Neutral detergent

fiber (NDF), Acid detergent lignin (ADL), Hemicellulose (HC), Cellulose (C) (Goering and Van Soest, 1970), Ash content (600° C oven for 3 hours).

A second sample was taken from the wet composite feed and orts for crude protein analysis (Auto Kjeldahl System).

The effect of treatment on intake of DM, OM, CP, ADF, NDF, HC, C and ADL was analyzed as two period changeover design for three treatments, according to the following model:

$$Y = \mu + D_i + P_j + \hat{t}_k + E(ijk)$$

where: Y = DM, OM, CP, ADF, NDF, HC, C, and ADL

μ = Overall mean

D_i = Effect of Subject

P_j = Effect of Period

$\hat{t}_k$ = Effect of Treatment

$E(ijk)$ = Error

Because each animal received only two of the three treatments, it was necessary to adjust treatment means for block effects as in standard intrablock analysis of balanced, incomplete block designs.

Bonferroni's test as described by Gill (1978) was used to compare the means between treatments.

Experiment III

A digestibility study was designed to evaluate the apparent digestibility of the diets presented in Table 9. At the end of the intake measurement (29th day) the animals were moved from the individual pens to collection stalls (91 x 244 cm) for the collection period. The

feed offered to the steers was reduced to 90%. Diet ingredients were daily mixed prior to feeding in a horizontal batch mixer.

The experimental calendar for the digestibility study was according to the following scheme:

Experimental Calendar for Each Period of Experiment III

Day	Action
1-29	Experiment I
30-32	Move animals from pens to individual pens, reduce feed offered to 90%.
33	Collect feed sample
34-35	Collect feed sample and collect feces
36	Collect feed sample and collect feces

During the thirty third and thirty fifth day feed samples (0.5 kg) were collected and stored in the freezer at 0° C. The lignin ratio technique (Harris, 1970) was used to measure the percentage of digestibility according to the following formula:

$$\text{Apparent digestion coefficient (\%)} = 100 \times \frac{\frac{\% \text{ internal indicator in feed}}{\% \text{ internal indicator in feces}} \times \frac{\% \text{ nutrient in feces}}{\% \text{ nutrient in feed}}}{1}$$

Grab samples were collected directly from the rectum of the animals during 72 hours, according to the following time schedule to provide samples representing two hour intervals throughout a 24 hour period.

Sampling Time		
Day 1	Day 2	Day 3
6 pm	4 pm	2 pm
12 am	10 pm	8 pm
6 am	4 am	2 am
12 pm	10 am	8 am

Each fecal sample was stored in the freezer at 0° C in a plastic container until the end of the collection period.

Feed feces samples were each composited and processed as described in Experiment II for feed and ort samples. The feces samples were composited and a subsample was dried at 60° C. In vitro organic matter disappearance (Moore Modification of the Tilley and Terry Technique) was performed on the feed samples to compare in vivo and in vitro digestibility.

The statistical analysis was the same as in Experiment II. At the end of the collection period, the animals were randomly reassigned to a different diet for a second period.

Experiment IV

Because the animals used in Experiment II and III were reassigned to an immediate second period, and to avoid stress if rumen contents were collected by stomach tube, three rumen fistulated Holstein steers were randomly allotted to each of the diets used in Experiment II (Table 9), to determine the effect on pH, rumen ammonia and volatile fatty acids (VFA). The animals were placed in individual pens (182 x 244 cm) in the metabolism room at the BCRC. Diets were mixed prior to feeding in a

horizontal batch mixer. The animals were fed once daily and had free access to water. An adaptation period of 14 days was used and rumen samples were collected on the 15th day at 0, 2, 4, 8 and 12 hours post feeding. The animals were randomly reallocated to diets for a second period.

Rumen fluid was obtained by squeezing the rumen sample through a double layer cheesecloth, the pH was measured on the liquid sample (pH meter Model F, Corning Scientific Instruments). The rumen fluid was acidified with sulfuric acid to obtain a pH of 3 to 4. Five ml of the acidified rumen fluid was mixed with 1 ml of methaphosphoric acid (25% w/v). After standing 20 minutes, samples were centrifugated at 20,000 rpm for 15 minutes, the residue was discarded and the supernatant retained for VFA analysis using a gas chromatography (GLC) procedure (1.8 m long by 2 mm i.d. column packed with 10% SP 1200 and 1.0% phosphonic acid on 80/100 mesh acid washed chromosorb was used for VFA separation. The GLC was equipped with flame ionization detector.

Another 9 ml of the acidified rumen fluid was mixed with 1 ml of sulphosalicylic acid (50% vv/) and centrifuged at 15,000 rpm for 15 minutes. The supernatant was analyzed for ammonia (Auto Kjeldhal System).

This study was designed to observe the effect of treatment on pH, ammonia and VFA. Each animal did not receive all three diets and the sampling times imply a third period which was not conducted. Therefore, the results presented are only trends in these parameters without a statistical analyses.

RESULTS AND DISCUSSION

Experiment I

Apple pomace was treated with four levels of anhydrous NH_3 and stored for various lengths of time up to 32 days to evaluate changes in dry matter, pH, Lactic acid, crude protein, soluble nitrogen, insoluble nitrogen, ADF, NDF, hemicellulose, cellulose, ADL, organic matter and in vitro organic matter disappearance.

An immediate change in color was observed when the apple pomace was treated with anhydrous ammonia. The apple pomace became brown or caramel colored. This characteristic effect of NH_3 treatment of crop residues has been observed in corn stover by Saenger et al. (1982) and in wheat straw by Harbers et al. (1982); Saenger et al. (1983) and Herrera-Saldana et al. (1983). Although the exact cause for this change was not investigated for apple pomace, the change has been related to oxidation of phenol groups or condensation of the aldehydic fractions in sugars in wheat straw by Harbers et al. (1982) and Herrera-Saldana et al. (1983).

Since treatment x time interaction for silos in this experiment was not significant data is presented as pooled either across treatment or across time in the following tables.

A significantly higher ($P < .01$) dry matter content was observed for the 17.5 g NH_3 /kg DM treatment level (Table 10). In comparing untreated and ammoniated corn silage, Buchanan-Smith (1982) concluded that this increase in dry matter content is probably a reflection upon the effluent

losses from the silages during the first week of ensiling. As time of ensiling progressed, a consistent decrease of dry matter was observed (Table 11).

A significant decrease of DM ($P < .01$) was observed between day 0 and the 4th, 8th, 16th and 32nd days of ensiling. This decrease in dry matter content is consistent with results reported by Huber et al. (1979a); Hargreaved (1982). Zimmer and Gordon (1964) proposed that during the first days of ensiling a close relationship between dry matter loss and CO_2 production could account for the apparent loss of DM. In this study, even though the gas production was not measured, an auditable evaluation of the silos during the ensiling process indicated gas production was greatest early in the ensiling period and declined with time of ensiling.

Table 10. Effect of Ammonia on Dry Matter, pH and Lactic Acid in Apple Pomace.^a

Item	Treatment levels ^b (gNH ₃ /kg DM)					SE _±
	0	4.38	8.75	13.13	17.5	
Dry matter (%)	27.56	27.35	27.75	27.86	28.45 ^d	.082
pH	3.97	4.16 ^c	4.39 ^d	4.47 ^d	4.57 ^d	.039
Lactic acid (% DM)	1.06	2.08 ^d	2.86 ^d	4.35 ^d	4.52 ^d	.119

^aValues are averages from 10 experimental silos with two determinations per silo

^bSignificant treatment effect ($P < .01$)

^cSignificantly higher than control ($P < .05$)

^dSignificantly higher than control ($P < .01$)

Treatment x time interaction is not significant

Table 11. Effect of Time of Ensiling on Dry Matter, pH and Lactic Acid in Apple Pomace.^a

Item	Time of Ensiling ^b (Days)					SE _±
	0 ^d	4	8	16	32	
Dry matter (%)	28.79	27.97 ^c	27.57 ^c	27.82 ^c	27.41 ^c	.074
pH	5.28	4.46 ^c	4.29 ^c	4.21 ^c	4.28 ^c	.035
Lactic acid (% DM)	.545	1.90 ^c	2.57 ^c	3.67 ^c	3.75 ^c	.107

^aValues are averages from 10 experimental silos with two determinations per silo

^bSignificant time effect ($P < .01$)

^cSignificantly lower than day 0 ($P < .01$)

^dMeans determined from representative samples at day 0

Treatment x time interaction is not significant

Data presented in Figure 1 on dry matter loss over the ensiling period supports these observations. However, loss of volatile organic acids during oven drying of samples for analysis could account for a portion of the dry matter loss. Therefore, changes in dry matter over time is a result of a number of factors.

As ammonia level increased the recovery of dry matter increased in the laboratory silos (Figure 2). Glewen and Young (1982), proposed that the effect of NH_3 treatment on corn silage to reduce yeast and molds present in ensiled feed, thus reducing the loss of carbohydrates normally converted to CO_2 by these yeast and molds.

The effect of ammonia level in pH is presented in Table 10. As expected pH of ammonia treated apple pomace were higher than control. A significant difference ($P < .05$) between control and 4.38 g NH_3 /kg DM level and a significant difference ($P < .01$) between control and 8.75,

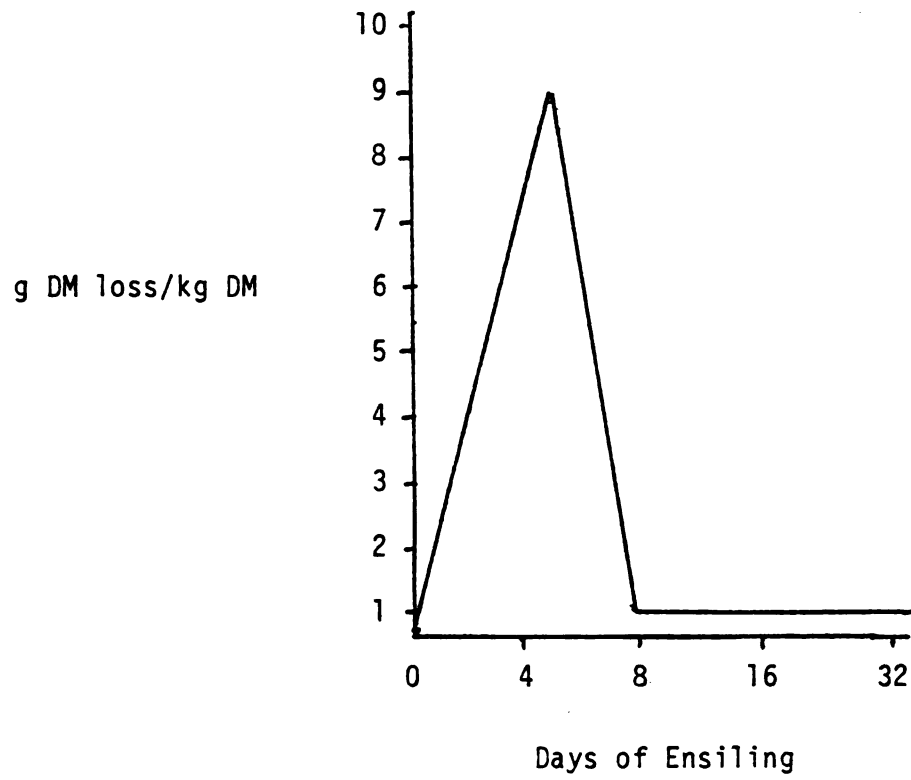


Figure 1. Losses of DM during time of ensiling.

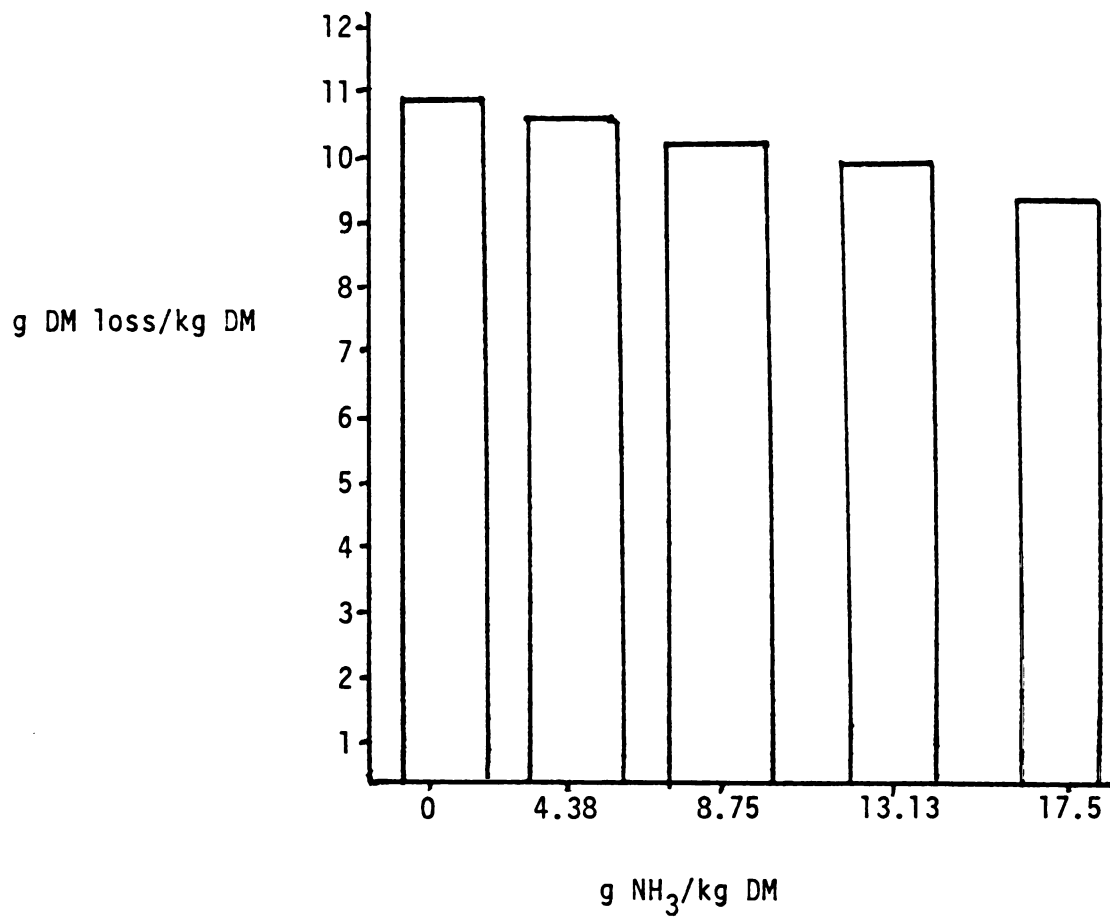


Figure 2. Effect of ammonia level on dry matter loss in apple pomace

13.13 and 17.5 g/NH₃ level was observed. The initial pH of NH₃ treated apple pomace was 5.28 at day 0 (Table 11), and then decreased significantly ($P < .01$) with time. Similar results have been obtained in corn silage (Huber et al., 1979a; Johnson, 1981), corn stalklage (Hargreaves, 1982) treated with ammonia. The final pH for NH₃ apple pomace was typical of other ensiled feeds.

Lactic acid levels were significantly higher ($P < .01$) than control for all treatments and time of ensiling (Tables 10, 11). A trend of increased lactic acid was observed as NH₃ level increased and time of ensiling progressed. Similar results were reported by Huber et al. (1979a) and Johnson (1981) in corn silages. However, Oji et al. (1977) reported negligible levels of lactic acid in ammonia treated corn stover, suggesting an absence of fermentation during storage. Apple pomace may have more readily available carbohydrates than stover, therefore, lactic acid levels would be expected to be higher for the apple pomace.

This is the first study where fermentation of apple pomace has been characterized at different levels of ammonia and time after ensiling. The decrease in pH to about 4.5 and increase in lactic acid to 4-5% of DM, suggests that a substantial lactic acid type of fermentation occurred in apple pomace and fermentation was enhanced by the addition of ammonia.

The addition of ammonia significantly increased ($P < .01$) the amount of crude protein (N x 6.25) in the apple pomace (Table 12). These results were as expected and are consistent with those obtained by Oji et al. (1977) for wheat straw and Kiangi et al. (1981) for rice and wheat straw and corn stover.

Table 12. Effect of Ammonia on Crude Protein and Soluble and Insoluble Nitrogen in Apple Pomace.^a

	Treatment level ^b (g NH ₃ /kg DM)					SE _±
	0	4.38	8.75	13.13	17.5	
Crude protein	5.01	6.50 ^c	7.86 ^c	9.51 ^c	9.73 ^c	0.282
Soluble nitrogen	11.30	28.49 ^c	42.17 ^c	62.59 ^c	72.95 ^c	1.340
Insoluble nitrogen	88.70	71.51 ^d	57.83 ^d	37.41 ^d	27.05 ^d	1.350

^aValues are averages from 10 experimental silos with two determinations per silo.

^bSignificant treatment effect ($P < .01$)

^cSignificantly higher than control ($P < .01$)

^dSignificantly lower than control ($P < .01$)

Treatment x time interaction is not significant

Time of ensiling effect was not significant for crude protein, even though a trend of crude protein increase during fermentation was noted (Table 13). The apparent increase in crude protein as time of ensiling progressed may be a result of the DM loss observed during ensiling. However, Huber et al. (1979a) reported an increase between 5 to 10T in the insoluble non ammonia nitrogen (ISNAN) fraction presumed to be predominantly the "true protein". In another study, Huber (1980) reported an increase between 7 to 14% of the ISNAN fraction, observing that most of the change occurred between days 0 and 3, suggesting that his increase in the ISNAN probably reflects an uptake of a small amount of NH₃ into microbial protein. Oji et al. (1977) reported that NH₃ treatment increased true protein content as compared to control stover silage. These apparent increases in true protein may be the result of ammonia reducing the normal

loss of true protein during the ensiling process rather than incorporation of NH_3 into true protein. Changes in dry matter and crude protein observed for silos in this experiment would support a similar process.

Table 13. Effect of Time of Ensiling on Crude Protein, Soluble and Insoluble Nitrogen in Apple Pomace.^a

	Time of ensiling (Days)					SE _±
	0 ^d	4	8	16	32	
Crude protein	6.99	7.66	7.37	7.78	8.08	0.25
Soluble nitrogen	40.96	39.94	46.65 ^b	39.94	47.47 ^b	1.20
Insoluble nitrogen	59.04	60.06	53.35 ^c	60.06	52.53 ^c	1.20

^aValues are averages from 10 experimental silos with two determinations per silo.

^bSignificantly higher than control ($P < .01$)

^cSignificantly lower than day 0 ($P < .01$)

^dMeans determined from representative samples at day 0.

Treatment x time is not significant.

Soluble nitrogen in apple pomace was significantly higher ($P < .01$) than control with ammonia treatment (Table 12). Similar results were observed by Huber et al. (1972a, 1980) in NH_3 treated corn silage and by Hargreaves (1982) in NH_3 treated corn stalklage.

Soluble nitrogen content of apple pomace on days 8 and 32 were significantly higher ($P < .01$) than day 0, but days 4 and 16 were not significantly different (Table 13). Therefore, soluble nitrogen in treated apple pomace was not consistent across time. Huber et al. (1980) reported that in NH_3 treated silages soluble and insoluble ammonia decreased during fermentation, while non-ammonia nitrogen (soluble and

insoluble) increased. Bergen et al. (1974) reported that non-ammonia nitrogen can be found in the soluble nitrogen, as a result of protein degradation by plant enzymes during the early days of fermentation. Insoluble nitrogen in ammonia treated apple pomace was significantly lower ($P < .01$) than control (Table 12). Whereas, insoluble nitrogen on days 8 and 32 were significantly lower than day 0 (Table 13).

Effect of NH_3 treatment on ADF, NDF and ADL is presented in Table 14. Effect of ammonia treatment was not significant on ADF, NDF or ADL. These results are not consistent with results reported by Horton (1981), Saenger et al. (1982), Herrera-Saldana et al. (1982), Hargreaves (1982) and Saenger et al. (1983) for other crop residues. However, a slight decrease in each of the fractions was observed as ammonia level increased, suggesting that anhydrous ammonia dissolved cell walls to some extent.

Effect of time of ensiling on ADF, NDF, ADL in apple pomace is presented in Table 15. There was a significant time effect ($P < .01$). Days 4, 8, 16 and 32 were significantly higher ($P < .01$) than day 0 for ADF, NDF and only day 32 was higher than day 0 in the ADL.

The increased amount of ADF, NDF and ADL across time may be due to the dry matter loss observed as fermentation progressed thus, causing an apparent increase in the concentration of these cell wall components.

Effect of ammonia treatment and time of ensiling on hemicellulose and cellulose are presented in Tables 16 and 17. There was no significant NH_3 effect on hemicellulose. This result is not consistent with previous results found by others (Horton, 1981; Hargreaves, 1982; Herrera-Saldana et al., 1983) for other crop residues treated with higher levels of NH_3 . These workers reported that ammonia solubilized a portion of the hemicellulose.

Table 14. Effect of Ammonia on Acid Detergent Fiber, Neutral Detergent Fiber and Acid Detergent Lignin on Apple Pomace.^a

	Treatment Level ^b (gr NH ₃ /kg DM)					SE _±
	0	4.38	8.75	13.13	17.5	
	----- % Dry Matter -----					
ADF	61.92	63.39	63.00	62.21	60.50	<u>±</u> .378
NDF	73.86	74.79	73.34	73.46	73.16	<u>±</u> .353
ADL	15.61	15.57	15.91	15.76	15.16	<u>±</u> .248

^aValues are averages from 10 experimental silos with two determinations per silo.

^bTreatment effect is not significant.
Treatment x time interaction is not significant.

Table 15. Effect of Time of Ensiling on Acid Detergent Fiber, Neutral Detergent Fiber and Acid Detergent Lignin in Apple Pomace.^a

	Time of Ensiling (Days)					SE
	0 ^c	4	8	16	32	
	----- % Dry Matter -----					
ADF	59.53	61.34 ^b	61.80 ^b	62.60 ^b	63.15 ^b	<u>±</u> .338
NDF	70.59	73.08 ^b	73.32 ^b	75.02 ^b	73.46 ^b	<u>±</u> .315
ADL	15.24	15.35	15.49	15.23	16.35 ^b	<u>±</u> .222

^aValues are averages from 10 experimental silos with two determinations per silo.

^bSignificantly higher than Day 0 (P<.01).
Treatment x time interaction is not significant.

^cMeans determined from representative samples at day 0.

Several researchers have reported that cellulose of crop residues is not affected by ammonia treatment (Klopfenstein, 1978; Horton, 1981; Hargreaves, 1982). These observations agree with cellulose values reported in Table 16 indicating ammonia did not significantly affect cellulose content of apple pomace.

There was a significant time effect ($P < .01$) on hemicellulose and cellulose (Table 17). Days 4, 8 and 16 were significantly higher than day 0. However, on day 32 a slight decrease in hemicellulose content was observed, but it was not significant. Cellulose content was significantly higher ($P < .01$) for days 4, 8, 16 and 32 than day 0.

Although the results from the present study are not entirely consistent with other reports, some solubilization of hemicellulose by effect of ammoniation in apple pomace was observed at 8.75 g NH_3 /kg DM (Table 16) which agrees with results reported in other ammoniated crop residues by Waller (1976) and Klopfenstein (1978). The ADL content in apple pomace also slightly decreased with ammoniation (Table 14) which is consistent with results obtained in ammoniated corn stalks by Saenger et al. (1982a).

The increased values for ADF, NDF, ADL, hemicellulose and cellulose during the experiment, probably was a reflection of the DM loss observed as a result of the fermentation processes (Tables 15 and 17).

An additional explanation of the inconsistency of results of this experiment and those reported in the literature may be related to the size of the laboratory silos, treatment levels used and the procedure employed in treating and storing the laboratory silos.

The effect of NH_3 treatment on organic matter (OM) and IVOMD is presented in Table 18. Ammonia treatment did not significantly affect

Table 16. Effect of Ammonia on Hemicellulose and Cellulose in Apple Pomace.^a

	Treatment Level ^b (g NH ₃ /kg DM)					SE ₊
	0	4.38	8.75	13.13	17.5	
	----- % Dry Matter -----					
Hemicellulose	11.95	11.40	10.34	11.25	12.55	.586
Cellulose	35.14	36.20	35.20	34.92	33.92	.353

^aValues are averages from 10 experimental silos with two determinations per silo.

^bTreatment effect is not significant.

Treatment x time is not significant.

Table 17. Effect of Time of Ensiling on Hemicellulose and Cellulose in Apple Pomace.^a

	Time of Ensiling (Days)					SE ₊
	0 ^d	4	8	16	32	
	----- % Dry Matter -----					
Hemicellulose	11.09	11.74 ^b	11.52 ^b	12.42 ^b	10.31 ^c	.52
Cellulose	33.26	34.19 ^b	34.55 ^b	35.27 ^b	35.56 ^b	.32

^aValues are averages from 10 experimental silos with two determinations per silo.

^bSignificantly higher than day 0 (P<.01)

^cSignificantly lower than day 0 (P<.01)

^dMeans determined from representative samples at day 0.

the OM of apple pomace. However, a significant decrease ($P < .01$) in organic matter was observed during ensiling (Table 19). The loss of organic matter during the first days of fermentation is consistent with the energetic losses normally observed during the first stages of fermentation of other ensiled feeds.

The high value for IVOMD was observed at the high level of ammonia treatment, however, also a significant difference ($P < .01$) was observed with the lowest ammonia level (Table 18). Several studies have also reported increased IVOMD in crop residues with ammonia treatment (Solaiman et al., 1979; Lawlor and O'Shea, 1979; Ward et al., 1980; Kiangi et al., 1981; Hargreaves, 1982) and have associated this effect with a reduction of fiber components after ammoniation.

Ash contents in apple pomace were used to correct for organic matter (Table 20). With ash content of greater than 10% apple pomace may be limited in feeding value when fed as a major ingredient in livestock diets.

Ammonia treated apple pomace was evaluated for changes in crude protein and IVOMD. Crude protein content of apple pomace was increased as a result of NH_3 treatment (Table 21). Based upon NH_3 treatment level (3.5% of the DM) and change in crude protein content (10.6 percentage units), 59.34% of the NH_3 -N added during NH_3 treatment procedure was retained by the apple pomace at the time of sampling.

Nitrogen recovery of 50% was observed in corn stover (Oji et al., 1977; Saenger et al., 1982), in wheat straw (Saenger et al., 1983) when treated with anhydrous ammonia. However, Kiangi et al. (1981) reported nitrogen recovery for corn stover, wheat straw and rice straw treated with anhydrous ammonia of 23.8, 30.8 and 37.5%, respectively.

Table 18. Effect of Ammonia on Organic Matter and In Vitro Organic Matter Disappearance in Apple Pomace.^a

	Treatment Level (g NH ₃ /kg DM)					SE ₊
	0	4.38	8.75	13.13	17.5	
	----- % Dry Matter -----					
Organic matter	85.87	85.75	85.80	85.39	86.03	.127
IVOMD	32.92	34.25 ^b	34.03 ^b	34.45 ^b	35.50 ^b	.404

^aValues are averages from 10 experimental silos with two determinations per silo.

^bSignificantly higher than control (P<.01).
Treatment x time interaction is not significant.

Table 19. Effect of Time of Ensiling on Organic Matter and In Vitro Organic Matter Disappearance in Apple Pomace.^a

	Time of Ensiling (Days)					SE ₊
	0 ^d	4	8	16	32	
	----- % Dry Matter -----					
Organic matter	86.78	85.97 ^b	85.87 ^b	85.61 ^b	85.63 ^b	.113
IVOMD	34.38	33.18	33.06	32.49 ^b	38.19 ^c	.361

^aValues are averages from 10 experimental silos with two determinations per silo.

^bSignificantly lower than day 0 (P<.01)

^cSignificantly higher than day 0 (P<.01)

^dMeans determined from representative samples at day 0.

Table 20. Ash Contents of Apple Pomace.^a

	Treatment Level (g NH ₃ /kg DM)				
	0	4.38	8.75	13.13	17.5
Ash	13.33	13.41	13.39	13.45	13.09

	Time of Ensiling (Days)				
	0	4	8	16	32
Ash	12.60	13.38	13.48	13.53	13.69

^aValues are averages from 10 experimental silos with two determinations per silo.

^bMeans determined from representative samples at day 0.

Variation in the nitrogen recovery for corn silage treated under different field conditions was reported by Huber et al. (1979a). A 48% nitrogen recovery was observed when corn silage was treated in the field at the time of harvest, and a nitrogen recovery of 90% was observed with treatment at the time of ensiling. This data suggests that handling of the plant material, once it was treated is an important factor in recovering nitrogen. In this experiment, once the apple pomace was treated with anhydrous ammonia, the filling and packing of the barrels could have represented a decrease in the percentage of nitrogen recovery. Both NH₃

vapor and odor were apparent when the apple pomace was moved to the storage containers.

Table 21. Effect of Anhydrous Ammonia Treatment Upon Crude Protein Content and In Vitro Organic Matter Disappearance of Apple Pomace.^a

	NH ₃ -N Retained	Crude Protein	IVOMD
Untreated apple pomace		3.42	42.76
Treated apple pomace	59.09 ^b	14.02	47.72
Percentage change		304.9	11.60

^aBased upon average of 4 samples taken on the barrels during this experiment.

^bCalculated as follows:

$$[(3.42\% \text{ CP} - 14.02\% \text{ CP}) \div 6.25] \div [(3.5\% \text{ NH}_3 \times .82\% \text{ N})] = .5909$$

An increase of 11.60% in the IVOMD was observed as a result of NH₃ treatment of apple pomace (Table 21). The in vitro system was supplied with adequate nitrogen to assure the difference in IVOMD was related to difference in carbohydrate fractions and not restricted to nitrogen availability for the rumen microbes in the in vitro system. Increases in IVOMD and crude protein content as a result of NH₃ treatment have been reported in rice straw (Waiss et al., 1972), wheat straw (Kiangi et al., 1981; Kernan et al., 1981; Herrera-Saldana et al., 1983), barley straw (Lawlor and O'Shea, 1981), corn stalks (Hargreaves, 1982) and in corn stover (Saenger et al., 1983).

Experiment II

The effects of diets on dry matter, organic matter and crude protein are summarized in Table 22. Dry matter intake (DMI) and organic matter (OMI) were significantly higher ($P < .05$) in diets containing either UAP and TAP than the corn silage (CS) diet. However, no significant difference in DMI and OMI between UAP and TAP diets was observed.

Table 22. Effect of Diets on Dry Matter, Organic Matter and Crude Protein Intakes in Steers.

Diets ^a	Dry Matter	Organic Matter	Crude Protein
	----- kg/day -----		
(1) corn silage	6.74 ^b	6.50 ^b	0.90 ^{bd}
(2) UAP	7.83 ^c	7.40 ^c	1.03 ^c
(3) TAP	7.95 ^c	7.44 ^c	1.10 ^{ce}
SE $\pm$	0.13	0.14	0.014

^a(1) 60% corn silage

(2) 30% corn silage, 30% UAP

(3) 30% corn silage, 30% TAP

All three diets had 37% HMC and 3% supplement.

c-c-d Means in same column with different superscript differ ($P < .05$)

d-e Means in same column with different superscript differ ($P < .01$)

The increased DMI, OMI for the UAP or TAP diets was probably due to the palatability of the apple pomace, which agrees with results obtained by Burris and Priode, (1957) and Prokot (1979) where DMI was greater for diets containing apple pomace.

In Table 23, the intake of the different cell walls components for each of the diets are presented. The presence of the apple pomace in Diets 2 and 3 increased significantly ($P < .01$) the amount of ADF, NDF,

cellulose and ADL intake when compared to the CS diet. The hemicellulose intake was significantly lower ($P<.05$) for the TAP diet than the CS diet, with no significant difference between CS and UAP diets. The ADF, NDF, hemicellulose, cellulose and ADL of the TAP was not significantly different from UAP diet but were consistently lower than the UAP diet.

Table 23. Effect of Diets on ADF, NDF, Hemicellulose, Cellulose and ADL Intakes.

Diets ^a	ADF	NDF	Hemicellulose	Cellulose	ADL
	----- kg/day -----				
(1) corn silage	1.15 ^b	2.15 ^b	1.01 ^d	0.94 ^b	0.19 ^b
(2) UAP	2.19 ^c	3.08 ^c	0.90	1.39 ^c	0.50 ^c
(3) TAP	2.05 ^c	2.91 ^c	0.86 ^e	1.37 ^c	0.45 ^c
SE _±	0.05	0.05	0.025	0.034	0.016

^aSee footnote in Table 11.

^{b-c}Means in the same column with different superscripts differ ($P<.01$).

^{d-e}Means in the same column with different superscripts differ ($P<.05$).

A more extensive evaluation of the cell wall components for both untreated and treated apple pomace is presented in Table 24, when apple pomace was treated with 3.5% anhydrous ammonia, a consistent trend of lower NDF, hemicellulose and ADL was observed. The major change in fiber components occurred in hemicellulose. Ammonia treatment solubilized 37% of the hemicellulose of the apple pomace used in this experiment. This agrees with data reported by Waller (1976), and Oji and Mowat (1979).

Saenger et al. (1982a) reported reduction of lignin content of corn stover as a result of NH_3 treatment.

Table 24. Effect of Ammoniation of the Cell Wall Components of Apple Pomace.^a

	ADF	NDF	Hemicellulose	Cellulose	ADL	Ash
	----- % dry matter -----					
Untreated apple pomace	58.71	70.48	11.78	32.41	16.62	9.67
Treated apple pomace	58.94	66.66	7.46	34.65	14.63	9.96

^aBased upon averages of 4 samples taken on the barreles during this experiment.

The increased DMI of apple pomace diets may be explained as an interaction of palatability and changes in cell wall components. Others have attributed the increase in DMI of NH_3 treated crop residues to an increase in the rate of passage of the treated residue (Oji and Mowat, 1979; Oji et al., 1979; Nelson and Klopfenstein, 1980 and Saenger et al., 1983).

Experiment III

The apparent digestibilities of OM, CP, ADF, NDF, hemicellulose and cellulose were not significantly different ($P < .05$) across diets (Table 25). The highest apparent digestibilities corresponded to the CS diet, followed by the UAP diet and the least digestible was the TAP diet. However, these differences were not significant ($P < .05$).

The DM digestibility for the TAP was significantly lower ($P < .05$) when compared to the CS diet, however no significant differences were observed between CS and UAP diets or UAP and TAP diets. The values for DM digestibilities of the three diets are higher than expected based on other research data. However, the use of a marker technique and possible

variation lignin values between laboratory analyses could account for most of the increase in DM digestibility noted in these diets.

Table 25. Effect of Diets on Apparent Digestibilities of DM, OM, CP, ADF, NDF, Hemicellulose and Cellulose in Steers.

Item	Diets			SE
	Corn Silage	UAP	TAP	
	----- % -----			
Dry matter	86.08	81.78	78.92	1.42
Organic matter ^C	71.31	66.91	64.41	1.80
Crude protein ^C	66.25	60.76	63.90	1.58
ADF ^C	41.53	27.61	25.73	3.51
NDF ^C	48.53	36.53	30.64	6.37
Hemicellulose ^C	54.12	54.76	46.61	7.19
Cellulose ^C	53.08	42.39	41.06	3.47

^bSignificant lower than control ($P < .05$)

^CNo significant difference across diets ($P < .05$)

The inclusion of the treated apple pomace did not increase the digestibilities of DM, OM, CP and the cell wall components when compared to the digestibilities from the UAP diet. However, the CP digestibility was slightly better for the TAP than the UAP even though no significant difference between them was observed. These results disagree with those observed when cereal straws were included in diets by Horton et al. (1982), where DM and OM digestibilities were increased by effect of ammonia treatment.

The decreased digestibility of components observed in the TAP diet may be a result of an increased rate of passage caused by the effect of ammoniation on changes in cell wall components as presented in Table 24.

Rate of passage has been reported to be increased by ammoniation of crop residues. Oji et al. (1979) reported that the mean retention time of particulate matter decreased for ammoniated corn stover fed to lambs, especially with thermoammoniated corn stover. Furthermore, a depress of digestibility of DM in corn cobs fed to lambs was observed by Nelson and Klopfenstein (1981) as level of ammonia increased from 2 to 4% (DM), suggesting that ammoniation increased the rate of passage, thereby reducing the extent of digestion.

Based upon the intake (kg) obtained in Experiment II (Tables 22 and 23) for each of the diets, the corresponding apparent digestibilities of the diets determined in Experiment II, the intake of digestible nutrients for each diet is presented in Table 26.

Table 26. Intake of Digestible Nutrients for Diets Containing Corn Silage, UAP and TAP (kg).

Nutrient	Diet		
	Corn Silage	UAP	TAP
	----- kg -----		
DM	5.84	6.53	6.35
OM	4.63	4.95	4.79
CP	0.59	0.66	0.69
ADF	0.48	0.60	0.53
NDF	1.04	1.13	0.89
Hemicellulose	0.55	0.49	0.40
Cellulose	0.50	0.59	0.56

As was discussed before, intake was presumably increased by the palatability of the apple pomace in the UAP diet, and by the compounded effect of palatability and ammoniation in the apple pomace in the TAP diet. Nevertheless, the digestibility for each nutrient evaluated in both UAP and TAP diets were lower than the digestibilities in the corn silage diet. However, in Table 26 it can be observed that the amount of nutrients digested for the UAP and TAP diets surpass those for the corn silage diet.

This data suggests that either untreated apple pomace or treated apple pomace can substitute for 30% of the corn silage DM in a typical beef cattle diet, without any detrimental effects, since the lower digestibility of apple pomace is offset by a higher intake of apple pomace component to corn silage. Cattle feeders must supply additional crude protein when apple pomace replaces corn silage and provide additional storage of a second high moisture fermented feed. Careful assessment of the cost of the additional crude protein and storage space is essential in establishing the value of apple pomace.

In vitro organic matter disappearance (IVOMD) was determined on samples of diets fed in Experiment III, to compare in vivo vs in vitro digestibility (Figure 3).

Values for the in vivo digestion were 71.3, 66.9 and 64.4% for the corn silage, UAP and TAP diets, respectively, whereas, in the in vitro results showed 67.2, 61.7 and 63.0%. This high correlation between in vivo digestion and IVOMD of the diets evaluated in this experiment indicates, in vitro estimates may be useful in evaluating diets containing apple pomace. This would enable rapid comparisons of diets for difference in extent of digestibility.

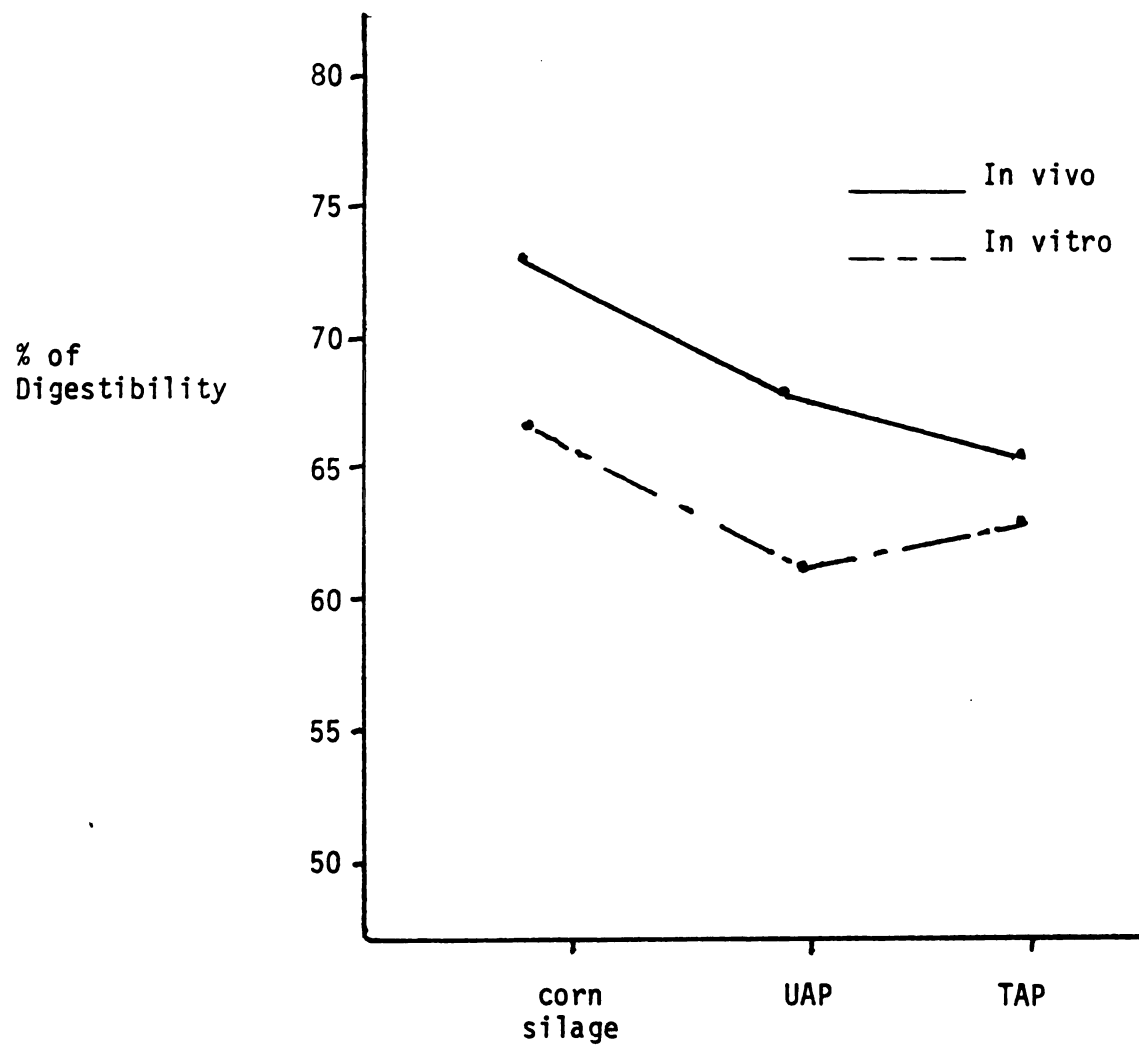


Figure 3. Percentages of digestibility in vivo vs in vitro.

Experiment IV

Ruminal pH with time after feeding the diets used in Experiment I and II are presented in Table 27. Initial pH for all diets was quite similar, however the TAP diet had the highest pH (7.1). These results are consistent to those reported by Rumsey et al. (1979) where initial ruminal pH ranged between 6.8 to 7.0 for corn silage or apple pomace diets prior to feeding.

Table 27. Effect of Diets and Time After Feeding on pH.^a

Diets	Sampling Time (Hr)				
	0	2	4	8	12
Corn silage	6.9	6.8	6.3	6.0	6.1
UAP	7.0	6.8	6.4	5.8	6.1
TAP	7.1	6.8	6.4	6.1	6.1

^aValues are average of two determinations.

The trend of decreasing ruminal pH during the first 8 hours after feeding was similar across diets with apparently little difference between diets at any sampling time.

Oltjen et al. (1979) reported a lower ruminal pH in apple pomace diets compared to corn silage diets. He suggested that perhaps it is a reflection of the acidic nature of apple pomace (pH 4) and/or the type of carbohydrates in apple pomace. In further tests he reported that increasing the apple pomace level (12 kg to 18 kg/day) in the diet, decreased the pH significantly. The diets in Experiment IV did not provide the high levels of apple pomace reported in this research and

resulting pH was not decreased greatly. In general, pH values apparently were not affected by the diets used in Experiment IV since all pH values were within normal range found in the rumen of steers fed diets of this energy level.

Rumen ammonia levels changed with time post-feeding (Table 28). The maximum values were observed at 2 hours after feeding and then decreased with time. The ammonia concentration of the TAP diet was consistently higher than the other two diets. The NH_3 concentration for all diets maintained quite constant between 2 and 4 hours, after that a sharp decrease for all diets was observed. All three diets were supplemented with a urea based supplement and the ammonia concentration patterns were typical for NPN supplemented diets.

Table 28. Effect of Diet on Rumen Ammonia After Feeding.^a

Diet	Sampling Time (Hr)				
	0	2	4	8	12
	----- mg/100 ml -----				
Corn silage	5.67	37.82	33.88	1.45	0.77
UAP	6.00	48.41	31.07	3.03	1.34
TAP	4.06	49.87	32.73	6.70	1.09

^aValues are average of two determinations.

These results agree with those obtained by Rumsey et al. (1979) where ruminal NH_3 increased up to 4 hours and then decreased to prefeeding levels. The most pronounced elevation of ruminal NH_3 (35 mg/100 ml) was observed when apple pomace diet was supplemented with urea. However, in

another trial also conducted, by Rumsey (1979) steers fed apple pomace and corn silage diets had sharp increases in ruminal ammonia from 0 to 1 hour after feeding. This was especially pronounced for the apple pomace-urea diet. This increase was followed by a gradual decrease for the corn silage diet but a tendency for the 1 hour NH_3 concentration to be maintained for the apple pomace diets, suggesting an active ruminal urease activity in animals fed apple pomace-urea-diets. The low ruminal pH probably served to trap NH_3 in the rumen and thus contributed to the elevated ruminal levels.

The effect of diets on volatile fatty acids (VFA) concentration with time post-feeding is presented in Table 29. Total VFA concentrations changed with time after feeding; concentrations generally increased during the first 4 hours after feeding, and then a slight decrease was observed at 8 hours for the corn silage and UAP diets, but not for the TAP diet. Furthermore, for all diets an increase in VFA concentration was observed between 8 and 12 hours.

The molar percentages of acetic acid appeared to be affected by time after feeding. The molar percentage of acetic acid for all diets decreased during the first 4 hours after feeding and then increased slightly at 8 and 12 hours after feeding. However, the molar percentage of propionic acids for all diets increased during the first 4 hours after feeding and remained high. The molar percentage of butyric acid for all diets gradually increased during the 12 hour period after feeding.

Oltjen et al. (1977) reported that feeding apple pomace diets to cows, with apple pomace as the major ingredient, resulted in a ruminal VFA pattern different from that with the feeding corn silage. Molar percentages of propionic, isobutyric, butyric and isovaleric acids

Table 29. Effect of Diets on Ruminal Volatile Fatty Acids Concentration.^a

Diet		Sampling time (Hr)					Average
		0	2	4	8	12	
Corn silage	Total VFA, mM/liter	33.24	48.55	55.96	47.41	56.19	48.27
	Volatile fatty acids, molar %						
	Acetic	56.33	54.19	51.76	49.85	52.55	52.94
	Propionic	24.93	28.86	30.00	28.35	25.86	27.60
UAP	Butyric	18.74	16.95	18.24	21.80	21.59	19.46
	Total VFA, mM/liter	29.31	50.13	57.65	45.18	55.65	47.58
	Volatile fatty acids, molar %						
	Acetic	57.86	51.31	51.60	53.31	52.27	53.27
TAP	Propionic	24.45	27.98	26.95	25.69	26.41	26.30
	Butyric	17.69	20.71	21.45	21.00	21.32	20.43
	Total VFA, mM/liter	29.21	40.28	53.36	53.98	54.25	46.22
	Volatile fatty acids, molar %						
	Acetic	56.93	51.71	47.81	48.23	49.37	50.81
	Propionic	24.49	28.37	29.50	27.34	27.32	27.40
	Butyric	18.58	19.92	22.69	24.43	23.31	21.79

^aValues are average of two determinations.

decreased, whereas molar percentages of acetic and valeric acids increased. However, in this experiment the results show that the substitution of 30% corn silage dry matter with UAP or TAP, did not apparently affect the VFA pattern.

The increase of the propionic acid in UAP and TAP diets in this experiment may have been a reflection of the high moisture corn present in both diets as an extra energy source. This observation agrees with work reported by Rumsey (1979) when corn starch was included in apple pomace diets resulted in a lower molar percentage of acetic and increase in the molar percentage of propionic, valeric and isobutyric acids.

In this study the acetic:propionic ratio tended to be lower for the TAP diet than for the UAP diet, the explanation may be attributed to the effect of ammonia treatment on the apple pomace by increasing the availability of fermentable energy. Oji et al. (1979) reported that the acetate:propionate ratio tended to decrease with time after feeding ammoniated corn stover to lambs.

In this study, results even though were not statistically analyzed, suggest that inclusion of untreated or treated apple pomace in the diet, apparently did not affect VFA pattern, as was observed by Oltjen et al. (1977) and Rumsey (1979). The differences between this study and those reported by others is probably related to the lower level of apple pomace in these diets.

SUMMARY AND CONSLUSIONS

An evaluation of the effect of level of ammonia and time of ensiling on DM, pH, lactic acid, crude protein, soluble nitrogen, insoluble nitrogen, fiber fractions (ADL, NDF, hemicellulose, cellulose and ADL), organic matter and IVOMD in apple pomace was conducted using experimental laboratory silos. Results suggested that the decrease of pH to about 4-5 and the increase in lactic acid to 4-5% of DM, a substantial lactic acid type of fermentation occurred in apple pomace. Furthermore, the fermentation was enhanced by addition of ammonia. A dry matter loss was observed especially during the first days of fermentation, however this DM loss tended to be less as level of ammonia increased.

Crude protein content ($N \times 6.25$) and soluble nitrogen were significantly increased ($P < .01$) by effect of ammonia. Time of ensiling apparently had an effect on crude protein. An increase of crude protein was observed as time progressed and could be related to the dry matter loss described above. Thus, there appears to be an increase in crude protein.

The fiber fractions of the ammonia treated apple pomace in this particular study showed that no significant treatment effect occurred. However, a slight decrease in each of the fractions was observed as NH_3 level increased, suggesting that ammonia dissolved cell walls to some extent. The effect of time of ensiling had the same effect observed for crude protein with an apparent increase in the amount of ADF, NDF, ADL, hemicellulose and cellulose as fermentation progressed. Again, the

dry matter loss observed could lead to this conclusion of apparent increase on the fiber fractions. Nevertheless, the results of ammoniation of apple pomace were not consistent with other results obtained in other ammoniated crop residues. This difference could be related to differences in plant materials and treatment procedures such as levels and handling.

Apple pomace was treated with 3.5% (DM) anhydrous ammonia at 3.5% of the dry matter. As a result of ammoniation of apple pomace, crude protein content ($N \times 6.25$) and IVOMD increased 10.6 and 11.6 percentage units respectively. A decrease in NDF, hemicellulose and ADL was observed in the ammoniated apple pomace. Recovery of the NH_3 -N added to the apple pomace was 59.09 percent. The treated apple pomace probably was subjected to considerable handling after treatment and this could have been an important factor in decreasing the percentage of nitrogen recovery.

Untreated and treated apple pomace was substituted for 30% of the corn silage DM (Table 9) and fed to steers to evaluate the intake of DM, OM, CP, ADF, NDF, hemicellulose, cellulose and ADL. Results showed that the intake of these nutrients were increased significantly ($P < .01$) by either UAP or TAP diets when compared to the corn silage diet with exception of hemicellulose which was significantly higher in the corn silage than treated apple pomace diet. The increased intake observed for the UAP diet may be attributed to the palatability of the apple pomace, and the increased intake in the TAP diet may be the result of an interaction of the palatability of the apple pomace and the effect of ammonia in the cell wall components.

A digestibility study was conducted to evaluate these diets. Results showed that the corn silage diet had higher but not significantly different digestibilities of OM, CP, ADF, NDF, hemicellulose and cellulose than the

UAP and TAP diet. However, the DM digestibility of the corn silage diet was significantly higher ($P < .05$) when compared to the TAP diet. The digestibilities observed in the TAP diet were lower than the UAP diet, with exception of the crude protein digestibility which was slightly higher in the TAP than the UAP diet, suggesting that it could possibly be a result of an increased rate of passage associated with the effect of ammoniation. The intake of digestible nutrients for the diets, indicated the low percentages of digestibility observed in the UAP and TAP diet was offset by an increase in intake, therefore the total digestible nutrients for the UAP and TAP diets surpass those for the corn silage diet. This would suggest that either untreated or treated apple pomace can substitute for 30% of the corn silage DM in beef cattle diets, without any detrimental effects. Additional results from the study evaluating the effect of substitution of UAP or TAP in the diets on pH, NH_3 and VFA pattern in the rumen, indicated no apparent differences in these parameters between UAP and TAP and the corn silage control diet.

In vitro organic matter disappearance (IVOMD) were conducted on the diets fed during the digestibility trial, to compare in vitro with in vivo digestibility estimates. Results showed a high correlation between them, and probably IVOMD may be useful in evaluating diets containing apple pomace.

In summary, the use of apple pomace in beef cattle diets can be used up to 30% of the corn silage DM. Ammoniation of the apple pomace showed an increase of the crude protein content as well as solubilization of cell wall components, resulting in an increase of fermentable energy in the rumen, with the subsequent increase in the nutritive value.

In this study, the pesticide content in the apple pomace as well as the pesticide residue in fat tissues from animals fed with apple pomace, were not studied. Chlorinated hydrocarbons such as DDT, Heptachlor epoxide and dieldrin were banned from the market in the early 1970's and are no longer used. However, still available on the market pesticides such as Kelthane, which has zero tolerance level in the animal's fat tissue, but, there are other pesticides which degrade faster in a short period of time, that may substitute for the use of these pesticides. Furthermore, it is well known that the current insecticides degrade rapidly when in alkaline media. Therefore, increasing the pH of apple pomace by ammoniation, will definitely aid in breaking down any insecticides that are in the pomace.

In conclusion, the use of the apple pomace as a feed ingredient in beef cattle diets has a promising future. However, pesticide content of the apple pomace should be known and combinations of apple pomace and NPN should not be fed to gestating cows and ewes.

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