THE USE OF AMMONIATED FEEDSTUFFS
IN BEEF CATTLE RATIONS

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INTRODUCTION

The feeding value of molasses for livestock is well known. However, molasses and other similar sugar-containing feeds are, in general, very low in protein. Consequently, when large amounts of these products are included in a ration, it is particularly important that sufficient protein be supplied by other feeds in order to meet the protein requirement of the animal. In the past, it has been customary when using molasses and similar feeds, to make up the protein deficit by incorporating in the ration expensive protein-containing feeds such as soybean oil meal, cottonseed meal, etc.

Recently, a process has been developed whereby ammonia can be combined with molasses and other products which contain sugar. This is done by blowing anhydrous ammonia (NH_3) into blackstrap molasses, or other feeds, under heat and pressure. The product thus obtained retains the advantageous properties of the original material with the added advantage that it is no longer deficient in nitrogen. It has been demonstrated that the bacteria in the rumen of cattle and sheep can take certain non-protein nitrogen compounds such as ammonium salts and urea, and in the presence of carbohydrates synthesize protein. Therefore, it was thought that the ammoniated products could furnish a source of nitrogen for ruminants.

Cane molasses, having an original value of 3 percent crude protein, will gain almost 2 percent nitrogen from the ammoniation process. The final product has a protein equivalent value of 15 percent. It is also possible to invert molasses by a chemical process which splits the cane sugar. After such inversion the molasses will take up enough ammonia to give it a value of 33 percent protein equivalent. Beet pulp, citrus pulp, and other such feedstuffs will, in general, gain less nitrogen from the ammoniation process and therefore have a lower crude protein value than ammoniated molasses.

That ammoniated products could have economic importance is obvious. In most beef cattle enterprises, the cost of supplementary protein is one of the major expense items. Consequently, the discovery of any protein substitute that proves satisfactory for practical use will be valuable in reducing the cost of producing beef. By combining practical husbandry with scientific research, it may be possible to discover a protein substitute that is both practical and economical to use - a field worthy of extensive research and study.

REVIEW OF LITERATURE

Early Work with Ammoniated Products

Wartime scarcity of feeds high in protein stimulated experiments toward the development of synthetic protein substitutes suitable for practical feeding conditions. Many of these early experiments were conducted to determine the value of urea when used to replace a portion of the protein in the rations of ruminants. Reid (1953) has extensively reviewed the numerous early experiments which demonstrate the value of urea as a source of nitrogen for rumen bacteria. The results of experiments in which nitrogen balance, growth response, milk yield, and body composition were examined suggest that the urea nitrogen was converted to protein nitrogen and used to satisfy the needs of the body.

Taking a different approach to the problem, Millar (1944) studied the growth of calves fed ammoniated sugar beet pulp (9.2 percent protein equivalent). All experimental animals received a low-protein basal ration consisting of plain beet pulp, grass hay, starch, and molasses. Calves fed the basal ration supplemented with ammoniated beet pulp gained almost as well as those fed the basal ration supplemented with soybean oil meal. Animals fed a diet in which starch was substituted for molasses gained as rapidly as those fed molasses. This suggests that the soluble carbohydrate was not superior to starch in furthering the use of nitrogen by the microorganisms.

Connell *et al.* (1944) compared ammoniated dried beet pulp, urea and goo quality alfalfa hay as sources of protein in cattle fattening rations.

Two-year-old steers were fed a basal ration of ground snapped corn, ground barley, plain beet pulp, ground oat straw and vitamin A oil, plus a source of supplementary protein. Steers fed the basal ration supplemented with chopped alfalfa hay, ammoniated beet pulp or urea gained 2.33, 2.26 and 2.10 lbs. per head daily, respectively. Feeding a protein combination of ammoniated pulp and alfalfa hay showed a slight advantage over the ammoniated beet pulp alone.

The above work demonstrated the possibility of using ammoniated products as protein substitutes in beef cattle rations. However, these experiments were not extensive and did not give a complete, critical evaluation of ammoniated products as sources of nitrogen for ruminants. Little other work has been done with ammoniated products until recently.

Ammoniated Molasses

The results of several early trials with ammoniated molasses indicate the possibility of using ammoniated products as sources of nitrogen in ruminant rations.

Culbertson and associates (1950) fed ammoniated molasses to yearling steers in amounts to replace one-half of the linseed meal in fattening rations. The gains of steers fed a protein supplement consisting of 1.35 lbs. of ammoniated molasses plus 0.75 lb. of linseed meal per head daily were significantly greater than the gains made by the steers in a check group fed 1.50 lbs. of linseed meal.

Tillman (1953) studied the value of ammoniated cane molasses, ammoniated furfural residue, and cottonseed meal in fattening-type rations in digestion trials with beef cattle. When fed to supply 10 percent of the total nitrogen in grain rations, these three products were found to be of about equal value as sources of nitrogen in the amounts used in this experiment. The digestion coefficients for protein, organic matter, and energy were 64.1, 77.2, and 77.2, respectively, for the ammoniated molasses ration; 63.7, 79.1, and 76.7 for the ammoniated furfural residue ration; and 66.0, 80.1, and 78.4 for the cottonseed meal ration.

Knodt _et al_. (1950) included ammoniated molasses at a level of 10 percent of the grain ration and fed 6 lbs. per head daily of the mixture to four-month-old dairy calves. The nitrogen in the ammoniated molasses successfully replaced up to two-thirds of the nitrogen in soybean oil meal and normal growth was obtained in calves receiving the 10 percent level of ammoniated molasses as a replacement for an equivalent amount of protein from oats and soybean oil meal.

that the amount of free ammonia associated with the breakdown of ammoniated molasses did not increase significantly with prolonged fermentation, nor was it increased by the presence of the enzyme urease. Stallcup suggested that these results might indicate that the nitrogen of ammoniated molasses is not available to ruminants. However, it seems possible from a theoretical standpoint that no free ammonia might be detectable as such, but during degradation would be absorbed, along with soluble carbohydrate from molasses by the rumen bacteria. Following absorption, the bacteria might unite the ammonia and the carbohydrate to form protein leaving no free ammonia to be released.

Barrentine and Darnell (1954) fed weanling steers a growing ration with cottonseed meal or silage treated with 33 percent ammoniated molasses as sources of protein. Over a 56-day feeding period, steers fed the treated silage lost 4.5 lbs. more than those fed untreated silage, grass hay, and no supplemental protein, and 56 lbs. more than animals receiving 0.90 lb. of cottonseed meal, untreated silage, and grass hay. This would indicate that the treated silage had little, if any, protein value. In a second test to study detrimental effects, it was found that ammoniated molasses had no harmful or depressing effect on rate of gain as long as adequate protein was supplied. This may be further evidence that the cattle could not use the nitrogen of ammoniated molasses under the conditions of this experiment.

In a later test, these same workers fed ammoniated molasses (15 percent protein equivalent) in growing rations to weanling heifers and found that it had no protein value, but appeared to exert a depressing effect on gains. Heifers fed a basal ration of grass hay and silage supplemented with cottonseed meal, as compared to those supplemented with cottonseed meal and ammoniated molasses, gained 0.7 lb. per day and .16 lb. per day, respectively. Heifers receiving their total supplement as ammoniated molasses lost 0.37 lb. per day. It is possible that stimulation was one cause of the weight loss in this last group.

Davis _et al._ (1955) conducted a series of studies on the _in vitro_ and _in vivo_ utilization of nitrogen from ammoniated molasses and other ammoniated industrial by-products. Results of both types of studies indicated that nitrogen from ammoniated products is not available to rumen bacteria or to the host to the same degree as is nitrogen from urea or other natural protein sources.

The literature discussed above indicates that ammoniated molasses may furnish a source of nitrogen which can be utilized to a certain degree by ruminant microorganisms. The use and availability of nitrogen from ammoniated molasses still require considerable investigation before a thorough knowledge will be obtained.

Other Ammoniated Products

Numerous feedstuffs other than molasses have also been ammoniated in an effort to increase their crude protein value for ruminants. As already stated, these feeds contain less sugar than molasses and consequently gain less nitrogen from the ammoniating process. They have, therefore, a lower crude protein value. Although the various feeds discussed below have not undergone as extensive tests as ammoniated molasses, attempts have been made to utilize these feeds in ruminant rations. As in the case with ammoniated molasses, these efforts have met with varying degrees of success.

Tillman and Kidwell (1951) tested the value of ammoniated condensed distillers molasses solubles as a feed for growing cattle. No significant differences in gain were noted when condensed distillers molasses solubles replaced 25 and 50 percent of the molasses in normal growing rations. A check lot receiving 6.8 lbs. of concentrates plus 18.6 lbs. of hay gained 1.39 lbs. per head daily, while replacing the molasses in the check lot with 0.73 or 1.50 lbs. of condensed distillers molasses solubles resulted in daily gains of 1.21 and 1.11 lbs. per head, respectively. Weights taken at fourteen-day intervals showed the greatest difference between lots to be at the end of the first period, with less difference for each successive period. This might indicate that time is required to alter the rumen media in order to obtain best utilization of rations containing ammoniated products.

Neuman (1954) fed an ammoniated molasses-sugar cane pith product in an effort to determine if adding this feed to a check ration of corn, soybean oil meal, and mixed hay (fed to steers already on full-feed) would prevent the usual slump in appetite during the hot summer months. Steers fed the ammoniated product showed keener appetites, greater feed consumption and more rapid gains than those fed the check ration.

Kirk *et al.* (1954) fed ammoniated citrus pulp (12 percent protein equivalent) in steer fattening rations and found it to be a satisfactory source of protein in the amounts used in this experiment. Gains of 2.13 lbs. daily were obtained from steers fed a fattening-type ration with a supplement of 3 parts of ammoniated citrus pulp and 1 part cottonseed meal.

Magruder, Knodt and Williams (1953b) compared an ammoniated hemicellulose extract with soybean oil meal in rations for non-pregnant dairy heifers. The ammoniated product was fed at a 10 percent level in the grain ration and supplied 20 percent of the daily nitrogen requirement. Considering body weight gains and efficiency of feed conversion, there was little difference in value between soybean oil meal and ammoniated hemicellulose extract as protein supplements in this experiment.

McCall and Graham (1953) fed ammoniated cane molasses, ammoniated citrus pulp and ammoniated furfural residue to fattening steers and found these ammoniated feedstuffs to be satisfactory protein substitutes in fattening rations when fed at a level of 40 percent of the protein supplement. Average daily gains over a 166-day fattening period were 2.63 lbs. for steers fed a protein supplement containing one-fifth ammoniated molasses, one-fifth ammoniated furfural residue, and the remainder as a conventional protein supplement; 2.58 lbs. for steers fed two-fifths of their protein supplement as ammoniated furfural residue; and 2.54 lbs. for a control group fed a conventional source of protein.

Magruder and Knodt (1953a) compared dairy rations containing blackstrap molasses and soybean oil meal to rations of equal nitrogen content containing 10 percent ammoniated industrial by-products. Materials studied were ammoniated wood sugars, ammoniated condensed distillers molasses solubles and ammoniated molasses. All rations tested contained 13 percent protein. Milk production and changes in body weight indicated no significant differences among the rations.

The available literature discussed above is evidence that ammoniated products may be valuable feedstuffs under conditions favorable for nitrogen utilization. However, these products also appear to have little, if any, value in some tests. The conditions necessary for optimum utilization of the nitrogen of ammoniated products are not completely understood and tests are still needed to determine them. However, such tests must be conducted at critical protein levels for the test animals. If these conditions can be determined, ammoniated products may well prove to be valuable and economical sources of nitrogen under certain feeding programs.

Adverse Effects from Feeding Ammoniated Products

Ammoniated molasses containing either a 15 or 33 percent protein equivalent have caused stimulatory effects in cattle fed various rations. Barrentine and Darnell (1954) describe the stimulated animals as first having a "wild look" and then starting to run. They may run into fences and other objects. After this short "run" the animals outwardly appear to be normal. Several theories have been advanced as to the cause of stimulation. Among these are high blood lactic acid, high blood ammonia, high blood alcohol, absorption of excessive amounts of potassium and the absorption of some unknown toxic material. All of these theories, however, are mere postulations and, as yet, none have been proven. At present, the cause of stimulation is still unknown.

Magruder *et al.* (1953b) fed a dairy heifer high levels of ammoniated molasses to determine any adverse effects. The ammoniated product was first included in the grain ration at a level of 20 percent. The percentage was then increased weekly by 10 percent until a 60 percent level was reached. Feed refusal occurred only at the 60 percent level. During the entire feeding period the heifer appeared normal and in good health and no ill effects were noted.

Richardson *et al.* (1954) found that ammoniated molasses was unsatisfactory as a protein concentrate in the wintering ration of beef calves from the standpoint of rate of gain or welfare of the animals. Certain of the calves receiving part of their protein in the form of ammoniated molasses were "stimulated". These stimulatory effects occurred in about one-third of the calves fed ammoniated molasses after the eighth day of feeding.

Rusoff *et al.* (1954) fed ammoniated molasses to determine whether levels above 10 percent in a grain ration fed with hay would cause stimulation. Dairy steers weighing 180 lbs. were stimulated at the 15 percent level while the 25 percent level caused stimulation in animals weighing 325 to 500 lbs. From 1.5 to 3.8 lbs. of ammoniated molasses per 100 lbs. of body weight were required to produce stimulation, which occurred from two to five days after the initial feeding and lasted from one to three hours. Non-protein nitrogen values of the blood prior to feeding and immediately after stimulation showed no consistent variations. The pH of the ammoniated molasses and grain-to-roughage ratios did not appear to be causative factors. Ammonium carbonate administered by stomach tube or fed in blackstrap did not produce stimulation.

Barrentine and Darnell (1954) fed ammoniated molasses in growing rations to weanling heifers to test its value as a protein substitute. In this experiment, the results indicated that ammoniated molasses had no protein value for the heifers, but rather had detrimental effects. Heifers fed either 1.2 or 2.4 lbs. of ammoniated molasses showed such a high incidence of stimulation that the experiment was terminated at the end of 28 days.

Although numerous reports have shown that the nitrogen from ammoniated products may be utilized by ruminants under certain conditions, there is still no answer to the stimulatory effects caused by the feeding of ammoniated molasses. If research can produce a method of checking the occurrence of stimulation, ammoniated products may prove to be a valuable source of nitrogen for ruminants.

EXPERIMENTAL

Objectives:

The objectives of this experiment were:

I. To study the value of ammoniated furfural residue when fed to replace one-half of the cottonseed meal in a fattening ration for steer calves.

II. To study the value of 16 and 33 percent protein equivalent ammoniated molasses as replacement for one-half of the cottonseed meal in rations for fattening steer calves.

III. To study the value of ammoniated cane molasses as a protein replacement for wintering beef cows on dry, native grass and to evaluate two different methods of feeding the ammoniated cane molasses.

IV. To compare the utilization of the nitrogen from ammoniated molasses and urea by feeding low protein rations to growing beef cattle with the ammoniated molasses or urea as the sole source of supplementary protein.

V. To study certain aspects of the problem of "stimulation" resulting from feeding ammoniated molasses.

PROCEDURE

Fattening Trials with Steer Calves

In the fall of 1952, a feeding trial was initiated to study the value of an ammoniated furfural residue as a replacement for one-half of the cottonseed meal supplement in fattening rations for steer calves. The steers used in this test were choice feeder calves obtained from the E. C. Mullendore ranch at Pawhuska and from the experimental herd. On arrival at the feeding shed at Stillwater, the calves were given oat hay and prairie hay, free choice. After a few days, they were started on silage and a small amount of cottonseed meal and grain. After the steers were given about two and one-half weeks to recover from weaning and shipping, the feeding trial was started.

The calves were divided into two lots of ten head each on the basis of grade and body weight. An average of three consecutive afternoon weights was used for the initial and final weights. The calves were full-fed coarsely ground shelled corn, 1.0 lb. of alfalfa per head daily, and a limited amount of sorghum silage. In addition, they received the following protein supplements per head daily:

Lot 1 - 1.5 lbs. cottonseed meal

Lot 2 - 0.75 lb. cottonseed meal and 0.90 lb. ammoniated furfural residue.

The amount of supplement fed was adjusted to provide the same protein intake for each lot.

In addition to the above ration, the steers had free access to a mineral mixture of 2 parts salt and 1 part steamed bonemeal. The chemical composition of feeds is shown in Appendix Table I. The steers received 2 lbs. of corn per head daily at the start of the test and this amount was increased at the rate of 0.5 lb. every third day until they were on full-feed. The steers were consuming from 14 to 18 lbs. of grain daily during the last 60 days of the experiment. They were sprayed twice with rotenone for the control of grubs and once with DDT for the control of lice. At the completion of the feeding trial, the steers were sold on the Oklahoma City market. After slaughter, dressing percentage, carcass grades, selling price, and shrink to market were obtained.

In the fall of 1953, a second feeding trial was initiated to study the value of ammoniated molasses as a replacement for one-half of the cottonseed meal in rations for fattening steer calves. Choice Hereford steer calves were used in this test and were obtained from a group purchased at the Ardmore Feeder Calf Sale or from the Ft. Reno experimental herd. All lots were full fed rolled milo, 1.2 lbs. of alfalfa and a limited amount of sorghum silage. A mineral mixture of 2 parts salt and 1 part steamed bonemeal was available to the steers at all times. In addition, the calves received the following amounts of protein supplement per head daily:

Lot 1 - 1.35 lbs. of cottonseed meal.

Lot 2 - 0.7 lb. of cottonseed meal and 1.7 lbs. ammoniated cane molasses (16% protein equivalent).

Lot 3 - 0.7 lb. of cottonseed meal and 0.9 lb. of ammoniated cane molasses (33% protein equivalent).

The steers were fed twice daily, with the ammoniated cane molasses poured over the grain and roughage. A 16-hour shrink in drylot preceeded the initial and final weights to reduce differences in fill. The steers were sold on the Oklahoma City market and shrink to market, selling price, dressing percentage and carcass grades were obtained.

Wintering and Growth Trials

In an attempt to determine the value of ammoniated cane molasses as a supplement for range beef cattle, two wintering trials were conducted at the Ft. Reno station. The first trial was initiated in November, 1953, to study the value of 15 percent ammoniated cane molasses as a replacement for one-third of the cottonseed meal in a protein mixture for wintering beef cows on dry, native grass; and also to study the relative value of two different methods of feeding the ammoniated cane molasses. In this trial, thirty open two-year-old heifers were used which had weaned calves in October and were to be bred during the winter of 1954. They were divided into three lots of 10 head each on the basis of body weight. The following supplements were fed per head daily:

Lot 1 - 2.0 lbs. of cottonseed meal.

Lot 2 - 1.3 lbs. of cottonseed meal + 1.8 lbs. of ammoniated cane molasses fed in bunks.

Lot 3 - Same as Lot 2, except the ammoniated cane molasses was sprayed on dry, cured grass.

The supplements were fed on alternate days, with twice the daily allowance given at each feeding. A mineral mixture of 2 parts salt and 1 part steamed bonemeal was available to the cattle at all times. Bulls were placed with the cows on January 1. All lots were rotated among the pastures every 28 days to reduce any possible variation caused by a difference in pastures. In order to spray the ammoniated cane molasses on dry, weathered grass, a sprayer was constructed from a tractor butane tank. The ammoniated molasses was mixed with an equal amount of hot water and poured into the sprayer tank. The pressure inside the tank was built up to a level of 90 to 125 pounds per square inch. The sprayer was operated from the back of a pick-up truck as it was driven through the pasture. Approximately thirty square yards of grass per cow were sprayed on alternate days.

In November, 1954, a second wintering trial was initiated to study the value of ammoniated cane molasses in comparison to blackstrap molasses. The procedure followed in this trial was very similar to that of the 1953 wintering trial. The cattle (six yearling heifers and eight three-year-old cows per lot) were divided into three equal lots of fourteen head each on the basis of age and body weight. All lots received 1.0 lb of cottonseed meal per head daily fed in bunks. In addition, Lot 1 cattle received 1.5 lbs. per head of blackstrap molasses poured over the cottonseed meal. Lot 2 cattle received 1.5 lbs. of a mixture of three parts ammoniated molasses and one part blackstrap, poured over the cottonseed meal in bunks. Lot 3 cattle were fed the same ammoniated molasses-blackstrap mixture as Lot 2, with the mixture sprayed on dry, weathered grass. The ammoniated molasses (33 percent protein equivalent) proved to be somewhat unpalatable and it was necessary to add 25 percent straight molasses to assure consumption when sprayed on the dry grass. An area of approximately 8 square yards was sprayed on alternate days. The supplements were fed on alternate days, with twice the daily allowance being given at each feeding. A mineral mixture of 2 parts salt and 1 part steamed bonemeal was available to the cattle at all times.

Since the availability of the nitrogen in ammoniated molasses appeared questionable from the results of the second wintering trial, it seemed desirable to study the utilization of the nitrogen from ammoniated molasses by cattle under more carefully controlled conditions. It seemed probable that ruminants would better utilize the nitrogen from ammoniated products when fed low-protein rations. In the majority of previous tests, ammoniated molasses was fed as a part of the supplemental protein rather than as the sole source. It seemed possible that previous tests have not given a critical evaluation of ammoniated molasses from the standpoint of its potential utilization.

On March 4, 1955, an experiment was initiated at the Ft. Reno station to determine how well the nitrogen is utilized from ammoniated molasses as compared to urea when fed as the sole source of supplemental nitrogen. Since urea has been extensively studied, a comparison of the utilization of the two sources of nitrogen seemed desirable. Eighteen yearling heifers were divided into three equal lots on the basis of body weight and previous winter treatment. Individual shrunk weights were taken three times during the experiment.

The heifers of all lots received, per head daily, 12 lbs. of wheat straw and 1.1 lbs. of a milo mix which contained ground milo plus enough steamed bonemeal and dry, stabilized vitamin A to meet their minimum requirements. Lot 1 cattle received no further protein supply but were fed 2.5 lbs. of blackstrap molasses. Lot 2 cattle received 2.5 lbs. of ammoniated molasses in addition to the straw and milo mix. Lot 3 cattle received 2.2 lbs. of molasses and 0.29 lb. of urea in addition to the straw and milo mix. The urea was mixed with blackstrap molasses and was fed as a urea-molasses mixture. In all lots, the molasses product used was poured over the milo mix fed in bunks. All lots were fed once daily.

Stimulation Trials

Several workers (Barrentine and Darnell, 1954, and Richardson et al., 1954) have reported that when ammoniated molasses is fed in ruminant rations, symptoms of "stimulation" may result. Little is known concerning the cause(s) of this stimulatory effect, or the various situations in which it is apt to be produced. However, the occurrence of "stimulation" prevents the widespread use of ammoniated molasses in practical rations. Consequently, it seemed desirable to conduct certain controlled experiments to further study the stimulatory effects of ammoniated molasses and to attempt to determine, if possible, the causative agent(s). During the summer of 1955, two trials were conducted with lambs in an effort to determine the specific amount of ammoniated molasses necessary to produce stimulation. In the first trial, six lambs were drenched daily for four days with varying amounts of 33% ammoniated molasses. The ammoniated product was mixed with an equal amount of water to facilitate handling in an ordinary sheep drenching syringe. The amount of ammoniated molasses given daily per lamb ranged from 0.25 lb. to 1.50 lbs. In the second trial, four lambs received 33% ammoniated molasses fed in a mixture with cottonseed hulls. The lambs were fed a ration consisting of 40% ammoniated molasses and 60% cottonseed hulls in an effort to obtain maximum consumption of the ammoniated product.

Recently, a new "high-test" ammoniated molasses has been produced. This material gains more nitrogen from the ammoniation process than ordinary blackstrap due to its higher free sugar content. To study possible stimulatory effects, this product was fed as part of the protein supplement in a growing-type ration for yearling cattle (5 steers and 1 heifer). The cattle received 1.0 lb. of this product per head daily for three days, whereupon the daily amount was increased to 2.0 lbs. per head. The "high-test" ammoniated molasses was also given to rats and rabbits in an attempt to produce stimulatory effects similar to those observed with cattle. The ammoniated product was administered by means of a syringe and stomach tube.

An effort was made to ammoniate a d-glucose solution by the patented method described by Stiles (1952)*. This product was fed to a heifer in a growing type ration to determine any detrimental effects.

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*Aqueous ammonia was added to a d-glucose solution and heated for 4 hours at 70°C. Excess NH_3 was then driven off by heating the solution for 1 hour at 90°C. in a large flat container under constant stirring.

RESULTS AND DISCUSSION

Fattening Trials with Steer Calves

Average results of the 1952 trial with ammoniated furfural residue are shown in Table I. The steers of Lot 2, which received one-half of their protein supplement as an ammoniated furfural residue and the remainder as cottonseed meal, gained an average of 2.02 lbs. per head daily, which was 0.22 lb. less than the daily gain of the control steers of Lot 1. However, statistical analysis failed to reveal any significant difference in gains between the two lots. This may be accounted for, in part, by lack of uniformity in response. Two of the furfural-fed steers showed considerably higher gains than the average of the steers fed the basal ration.

The furfural-fed steers required 61 lbs. more corn and 44 lbs. more roughage per cwt. gain than did the Lot 1 steers, resulting in a $1.82 higher feed cost per cwt. gain. Likewise, the appraised market value was about $0.50 per cwt. less and financial losses were $10.66 per head more than for the Lot 1 steers. It is interesting to note that weight gains by twenty-one day periods show that Lot 2 steers made very poor gains during the first forty-two days of the feeding trial. This early set-back was not recovered during the remainder of the feeding period. This tends to support the postulation made by Tillman and Kidwell (1951) and others to the effect that time may be required to alter the rumen media for optimum utilization of rations containing ammoniated products. Davis *et al.* (1955) determined by direct microscopic examination that the rumen microbial population underwent considerable change when incubated with ammoniated products *in vitro*.

TABLE I. Weight Gains, Rations Fed and Feed Required per Cwt. Gain in the Comparison of Ammoniated Furfural Residue and Cottonseed Meal as Protein Supplements (163 days).[1]

	Lot 1 C. S. Meal	Lot 2 Ammoniated Furfural Residue
Average weights (lbs.)		
Initial 10/26/52	472	472
Final 4/7/53	838	801
Total gain	366	329
Average daily gain	2.24	2.02
Average daily ration (lbs.)		
Ground shelled corn	10.9	11.02
Cottonseed meal	1.50	0.75
Ammoniated furfural residue		0.90
Alfalfa hay	1.00	1.00
Sorghum silage	7.92	7.92
Mineral mixture (fed free choice)	.04	.04
Feed required per cwt. gain (lbs.)		
Corn	485	546
Cottonseed meal	67	37
Ammoniated furfural residue		45
Alfalfa hay	45	50
Sorghum silage	353	392
Feed cost per cwt. gain ($)	21.57	23.39
Marketing data		
Shrink to market (%)	4.5	3.7
Dressing percentage	60.3	60.7
U. S. carcass grades		
Prime		1
Choice	10	6
Good		3
Financial Results ($)		
Appraised value per cwt.	23.25	22.70
Initial cost per steer	132.16	132.16
Feed cost per steer[2]	79.06	77.08
Total steer and feed cost	213.43	211.45
Net return per steer	-24.41	-35.07

[1] 10 steers per lot.

[2] Feed prices used are given in Appendix Table III.

However, the results of this experiment are not in complete agreement with those reported by other workers. McCall and Graham (1953) found that ammoniated furfural residue stimulated appetites and satisfactorily replaced 40 percent of the protein supplement in steer fattening rations. However, since the basal ration contained a high level of protein, this test may not have given a critical evaluation of the ammoniated product. In the trial reported herein, the ammoniated product proved to be somewhat unpalatable, which may, in part, account for the inferior performance of the cattle receiving this product. Tillman (1953) found ammoniated furfural residue and cottonseed meal to be of about equal value as sources of nitrogen in fattening rations for steers, as determined by digestion trials, when fed to supply 10 percent of the total nitrogen. It seems probable that feeding ammoniated products at a higher level as in this trial, would give a more critical evaluation of nitrogen utilization. This may account for the variation in results obtained by different workers.

Slaughter data showed Lot 1 to be more uniform in carcass grades than the furfural-fed lot. The carcass grades of all Lot 1 steers were choice while those of Lot 2 graded 1 prime, 6 choice, and 3 good. Average shrink to market and dressing percentages were 4.5 and 60.3 for the controls and 3.7 and 60.7 for the furfural-fed lot, respectively.

The average results of the 1953 trial with ammoniated molasses are given in Table II. The steers of Lot 2 fed the 16 percent ammoniated cane molasses as a replacement for one-half of the cottonseed meal gained 2.10 lbs. per head daily, while those fed the 33 percent product (Lot 3) made daily gains of 2.11 lbs. Both groups made greater gains than did the controls of Lot 1 which gained 1.95 lbs. per head daily. However, the analysis of variance (Snedecor, 1946) failed to show any statistically

TABLE II. Weight Gains, Rations Fed and Feed Required per cwt. Gain in the Comparison of 16 and 33 percent Ammoniated Molasses to Cottonseed Meal in Fattening Rations for Steer Calves.

Lot No. and Source of Protein Supplement	Lot 1 C. S. Meal	Lot 2 One-half C.S.M. One-half Amm. Molasses (16%).	Lot 3 One-half C.S.M. One-half Amm. Molasses (33%).
Average weights (lbs.)			
Initial 10-21-53	514	513	515
Final 4-6-54	837	862	866
Total gain (166 days)	323	349	351
Average daily gain	1.95	2.10	2.11
Average daily ration (lbs.)			
Rolled milo	12.83	13.71	13.21
Cottonseed meal	1.35	.76	.76
Chopped alfalfa	1.15	1.14	1.13
16% Amm. cane molasses		1.70	
33% Amm. cane molasses			.86
Sorghum silage	8.49	8.80	8.64
2-1 mineral mixture	.03	.02	.03
Feed required per cwt. gain (lbs.)			
Rolled milo	659	652	625
Cottonseed meal	69	36	36
Alfalfa hay	59	54	53
16% Amm. cane molasses		81	
33% Amm. cane molasses			41
Sorghum silage	436	419	409
Feed cost per cwt. gain ($)	21.92	22.66	20.99
Marketing data			
Shrink to market (%)[1]	+0.4	-0.1	+0.3
Dressing percentage	61.22	61.99	61.24
U. S. Carcass grades			
Prime		3	
Choice	9	7	10
Good	1		
Financial Results ($)			
Appraised value per cwt.	22.40	22.85	22.50
Initial cost per steer	97.15	96.96	97.34
Feed cost per steer	70.81	79.09	73.67
Total steer and feed cost[2]	170.11	178.20	173.16
Net return	17.38	18.77	21.69

[1]Calculated from the final shrunk weight to the market weight (approximately two weeks elapsed between the two weights).

[2]Includes cost of spraying for grubs and lice plus marketing, excluding trucking cost. Feed prices given in Appendix Table III.

significant difference. As in furfural trials, lack of uniformity in response to treatment may, in part, account for the lack of significant difference in daily gains.

Steers of both Lots 2 and 3 exhibited keener appetites during the latter part of the test. The steers of Lot 2 were noticeably fatter at the completion of the experiment and were appraised at $0.45 per cwt. higher than the control steers of Lot 1. This higher appraised value was borne out by slaughter data. The carcass grades were 9 choice and 1 good, 3 prime and 7 choice, and all choice for Lots 1, 2, and 3, respectively. Dressing percentages were 61.44, 61.99, and 61.24 for Lots 1, 2, and 3, respectively.

It was noticeable that the 16 percent ammoniated molasses was more palatable than the 33 percent product, particularly during the latter part of the feeding period. The small amount of ammoniated cane molasses fed in this trial was considerably higher in cost on a protein-equal basis than the cottonseed meal.

The results of this trial are in agreement with those obtained by other workers who have fed ammoniated molasses in fattening trials. Culbertson et al. (1950) conducted a similar trial and found that replacing one-half of the linseed meal with ammoniated molasses in steer-fattening rations resulted in greater gains than feeding linseed meal alone.

Wintering and Growth Trials

The average results of the 1953 wintering trial with stocker cows are shown in Table III. Replacing one-third of the cottonseed meal with ammoniated cane molasses, on a protein-equal basis, increased the average daily gains of the cows. The analysis of variance (Snedecor, 1946) showed this difference to be significant at the .01 percent level. Orthogonal comparisons showed the differences in gain between the controls (Lot 1) and the two treatments (Lots 2 and 3) and between the two treatments to be statistically significant (P = .01). The analysis of variance is shown in Appendix Table II.

Although the substitution of 1.8 lbs. of ammoniated molasses for 0.66 lbs. of cottonseed meal considerably reduced the feed cost per lb. of gain, the total wintering costs for Lot 2 were increased by $3.13 per head. The amount of total digestible nutrients supplied by the supplements fed was not equalized among the lots. Consequently, Lot 2 cows received more T.D.N. from 1.33 lbs. of cottonseed meal and 1.8 lbs. of ammoniated molasses than did Lot 1 cows from 2.0 lbs. of cottonseed meal. This may, in part, explain the more favorable results obtained from feeding the cottonseed meal-ammoniated molasses mixture. Also, it may be possible that molasses itself supplies certain factors which benefit the rumen microorganisms and thereby enhance the ability of ruminants to utilize poor quality roughage, such as weathered range grass. In vitro work by Burroughs et al. (1951) has given results that tend to confirm this postulation.

The only difference between Lots 2 and 3 was the method of feeding the ammoniated molasses. In Lot 3, the molasses was sprayed on dry, weathered grass in an attempt to encourage the cattle to consume greater

TABLE III. Ammoniated Cane Molasses as a Partial Replacement for Cottonseed Meal for Wintering Beef Cows on Dry Grass (116 days).

	Lot 1 C.S. Meal fed in bunks	Lot 2 C.S. Meal + Amm. Cane Mol. fed in bunks	Lot 3 C.S. Meal + Amm. Cane Mol. Sprayed on dry grass
Number of cows per lot	9[1]	10	10
Average weights (lbs.)			
Initial 11-23-53	725	720	720
Final 3-19-54	742	799	758
Total gain	17	79	38
Average daily gain	0.15	0.68	0.33
Average daily supplements fed (lbs.)[2]			
Cottonseed meal	2.0	1.33	1.33
Ammoniated cane molasses		1.80	1.80
Mineral mixture	.05	.05	.05
Feed cost per cow (dollars)			
Cottonseed meal	7.66	5.09	5.09
Ammoniated cane molasses		5.70	5.70
Mineral mixture	.13	.13	.13
Pasture	5.00	5.00	5.00
Total	12.79	15.92	15.92
Overnight shrink in dry lot at completion of test (%).	4.4	4.9	3.8

[1]One cow in Lot 1 developed lumpy jaw (Actinomycosis) in December and was removed from the experiment.

[2]The protein content of the cottonseed meal was 38.72 percent, and that of the ammoniated cane molasses, 17.48 percent.

amounts of forage with resulting increases in winter gains. This method would also make possible the grazing down of thick stands of tall native grass, which would permit earlier spring growth and more uniform grazing the following year. Such a practice would be preferable to burning if proven successful.

Both lots fed the ammoniated molasses product as a supplement showed greater gains than the lot fed only cottonseed meal. Average daily gains of Lot 3 cows were 0.33 lb. as compared to 0.68 lb. for Lot 2 cows while Lot 1 cows showed gains of 0.15 lb. per day. Nearly all the top growth was removed from the sprayed area as the cows tended to graze these areas heavily. It is probable that the molasses intakes of Lot 2 and Lot 3 cows were not the same since some waste did occur in applying the molasses to the dead grass. This difference, however, is not believed to be great enough to account for the differences observed in average daily gain. Both molasses-fed lots appeared to be in a thriftier condition and showed more bloom of hair coat at the completion of the trial, than the control group.

The results of the 1954 wintering trial are shown in Table IV. It is apparent that the cows of Lot 2 gained essentially the same as those of Lot 1 - hence there was no apparent advantage from feeding the ammoniated molasses. Statistical analysis showed there was no significant difference in gains between the lots. It seems probable that the cows of Lot 1 were receiving less than their minimum recommended allowance for digestible protein from the supplement and dry grass. Consequently, the cows of Lot 2 should have responded to the greater amounts of nitrogen they received in the ammoniated product. This evidence is in support of the postulation made by Davis et al. (1955) to the effect that the nitrogen (crude protein) of ammoniated molasses is rather poorly utilized by beef cows. Lot 3 cattle, receiving ammoniated molasses sprayed on grass, gained less than either Lots 1 or 2, although the difference was not great. This follows the trend noted in the 1953 trial where animals receiving ammoniated molasses sprayed on grass gained less than those receiving it in feed bunks. As in the 1953 trial, complete consumption of the sprayed molasses was not obtained and as a consequence, the Lot 3 cattle might be expected to gain less than the cattle which completely consumed their supplemental feed.

The palatability of the ammoniated molasses was definitely a problem when the cattle received the product sprayed on grass. It was necessary to dilute with straight blackstrap molasses to induce the cattle to graze the sprayed area. This palatability problem was not noticeable in Lot 2 where the molasses was poured over the cottonseed meal in bunks. Had the molasses product been more palatable, a greater area might have been sprayed. Spraying too small an area has led to intensive grazing and removal of nearly all top growth, while spraying a large area has not resulted in an appreciable increase in intensity of grazing, with incomplete consumption of the sprayed grass.

The average results of the 1955 growth trial with yearling heifers are given in Table V. Although all lots lost weight, it is apparent that the heifers of Lot 1 fed the nitrogen-deficient ration, suffered the greatest loss in weight. Lot 2 and 3, fed the basal ration supplemented with either ammoniated molasses or urea, lost considerably less weight during the 50-day trial than did Lot 1. Total weight losses during the entire feeding period were 26 lbs., 13 lbs., and 7 lbs. for Lots 1, 2, and 3, respectively. Although there appears to be a definite difference

TABLE IV. Results Obtained Comparing Blackstrap and Ammoniated Molasses for Wintering Beef Cows on Dry Grass (116 days).

	Lot 1 C.S. Meal and Molasses fed in bunks	Lot 2 C.S. Meal and Amm. Cane Mol. fed in bunks	Lot 3 C.S. Meal and Amm. Cane Mol. Sprayed on Grass
Number of cattle per lot*	14	14	14
Average weights (lbs.)			
Initial 11-8-54	749	745	742
Final 3-4-55	754	753	734
Total gain	5	8	-8
Average daily gain	.04	.07	-.07
Average daily supplements fed (lbs.)			
Cottonseed meal	1.0	1.0	1.0
Ammoniated cane molasses		1.21	1.21
Blackstrap molasses	1.52	.31**	.31**
Mineral mixture	0.5	0.5	0.5
Feed cost per cow (dollars)			
Cottonseed meal	4.53	4.53	4.53
Ammoniated cane molasses		4.00	4.00
Blackstrap molasses	3.88	.79	.79
Mineral mixture	.12	.12	.12
Pasture	5.00	5.00	5.00
Total	13.53	14.44	14.44
Overnight shrink in dry lot at completion of test (%).	5.9	5.9	5.5

*Six yearling heifers and eight three-year-old cows per lot.

**It was necessary to add 1 part blackstrap to 3 parts ammoniated molasses in order to increase the palatability of the product for Lot 3 cows, starting December 6th.

TABLE V. Results Obtained Comparing Ammoniated Molasses and a Urea-Molasses Mixture as Sources of Supplemental Protein for Yearling Heifers Fed a Low-Protein Basal. (50 days).

Lot No. and Designation	Lot 1 Blackstrap Molasses	Lot 2 Ammoniated Molasses	Lot 3 Urea-Molasses
Number of cattle per lot	6	6	6
Average weights (lbs.)			
Initial 3/4/55	650	649	652
Final 4/25/55	624	636	645
Total gain	-26.0	-13.0	-7.0
Average daily gain	-0.52	-0.26	-0.14
Average daily ration (lbs.)			
Blackstrap molasses	2.5		2.2
Milo mix[1]	1.1	1.1	1.1
Ammoniated molasses		2.5	
Urea			0.29
Wheat straw	12.0	12.0	12.0

[1]Consisted of ground milo plus enough stabilized vitamin A and minerals to meet minimum requirements.

between the lots, the differences were not statistically significant. This may, in part, be accounted for by the small number of heifers and lack of uniformity in response. One heifer in Lot 1, receiving the protein deficient ration, showed an actual gain in weight. Since all lots received essentially equal amounts of T.D.N., the difference in weight gain appears to be the result of different amounts of nitrogen utilized from the ration. Hence, it seems that some utilization of the nitrogen from ammoniated molasses did occur, although to a lesser extent than that from the urea-molasses mixture.

In several other growth trials (Tillman and Kidwell, 1951, and Knodt et al., 1951) ammoniated products have been fed only as a part of the supplemental nitrogen. It seems probable that in this trial, using the ammoniated product as the sole source of supplemental nitrogen, gives a more critical picture of nitrogen utilization. The results of this trial do not support postulations made by other workers (Millar, 1944, and McCall and Graham, 1953) to the effect that the nitrogen of ammoniated products is well utilized by ruminants.

Stimulation Trials

Stimulation was produced, but not consistently at any specific level, when ammoniated molasses was administered to lambs as a drench or as a feed. On the third day, one lamb receiving 0.75 lb. of 33% ammoniated molasses daily administered as a drench appeared to be stimulated. Other levels of drenching (both higher and lower) produced no similar effect in the other lambs. On the second day of feeding the ammoniated molasses-cottonseed hull mixture, one lamb consuming approximately 0.40 lb. of 33% ammoniated molasses daily was stimulated. Other lambs in the trial exhibited no ill effects from consuming the ammoniated product. The lambs in both trials exhibited a staggering gait and lack of coordination when stimulated. It is interesting to note the variable effect of ammoniated molasses on different lambs. It appears that some are more tolerant to the product than others.

Feeding the new "high-test" ammoniated molasses to yearling cattle in a growing-type ration resulted in a high incidence of stimulation. On the second day of feeding at the two pound level (5 days after feeding was initiated) four of the six cattle receiving the ammoniated product were violently stimulated. One steer was injured to the extent that it had to be slaughtered. The cattle were turned out to pasture as soon as possible after stimulation occurred to avoid further injury. One steer was killed in the pasture under the influence of stimulation. The next day (30 hours after the last feeding of the ammoniated product) one steer was put back in the feeding pen. Shortly after, this steer was stimulated a second time and injured to the extent that slaughter was necessary. Signs of stimulation were also observed at this time in another steer that had previously shown no ill effects. Of the six animals receiving the ammoniated molasses, five were observed that were stimulated. It is possible that the other steer was stimulated while in the pasture and not observed.

The "high-test" ammoniated molasses produced no observed detrimental effects when administered to rats or rabbits through a stomach tube. The rats were treated 7 days and the rabbits 5 days. Both animals tested were observed for approximately $1\frac{1}{2}$ hours after administration and checked several times daily thereafter.

One yearling heifer was fed 2.0 lbs. daily of an ammoniated glucose solution containing 9.0% crude protein equivalent. Three days of feeding at this level produced no detrimental effects. However, this does not eliminate the possibility that the product could cause deleterious effects if fed for a longer period.

The above work emphasizes that the widespread use of ammoniated molasses is, at present, limited by the occurrence of stimulation. The product cannot be recommended as a practical feedstuff until the occurrence of stimulation is checked, although effects were not noted in most feeding trials reported herein. Much difficulty may be encountered in attempting to determine the causative factor(s) associated with stimulation. It seems probable that many nitrogen compounds may be formed during the ammoniation process, some of which might have toxic effects. Also, it seems feasible that molasses, rather than other feedstuffs, might contain substances which could acquire toxic properties due to the ammoniation process. Rusoff (1953) reported that rats were stimulated when ammoniated molasses was injected directly into the stomach with a hypodermic needle. However, in these trials stimulation was not observed in rats when ammoniated molasses was administered through a stomach tube in the same amounts used by Rusoff. The results of the trials reported herein indicate that ammoniated molasses itself may not cause stimulatory effects in simple stomach animals, and thus it seems possible that stimulation might be a result of bacterial action on, or modification of, the ammoniated product.

SUMMARY

In the fall of 1952, an experiment was initiated at Stillwater to study the value of ammoniated furfural residue when used to replace one-half of the cottonseed meal in steer-fattening rations. Two uniform lots of 10 head each were fed a fattening ration of ground corn, sorghum silage, alfalfa hay, and a protein supplement consisting of either cottonseed meal or cottonseed meal and ammoniated furfural residue. Results of the 163-day trial show that the ammoniated product was inferior to cottonseed meal from the standpoint of weight gains of the cattle, efficiency of feed utilization and net returns. In the fall of 1953, a similar trial was initiated to study the value of 16 and 33 percent ammoniated molasses when used to replace one-half of the cottonseed meal in steer-fattening rations. All lots received a full-feed of rolled milo, limited amounts of sorghum silage and alfalfa hay, and either cottonseed meal or a combination of cottonseed meal and 16 or 33 percent ammoniated molasses. Both groups fed the ammoniated products showed slightly greater gains, increased feed efficiency and higher net returns per steer than the controls fed cottonseed meal as the sole source of supplemental protein.

During the winters of 1953 and 1954, experiments were conducted at the Fort Reno station to study the value of ammoniated molasses as a nitrogen supplement for wintering beef cows on dry, native grass and to study the value of two methods of feeding the ammoniated product. Results of the 1953 trial show that cows fed a cottonseed meal-ammoniated

molasses mixture gained more than those fed straight cottonseed meal, although winter feed costs were increased. Spraying the ammoniated cane molasses on tall, native grass resulted in less weight gain than when this product was fed in bunks. A comparison of blackstrap and ammoniated molasses used to supplement 1.0 lb. of cottonseed meal for wintering beef cows on dry grass in the 1954 trial resulted in no apparent advantage from feeding the ammoniated product. Cattle receiving ammoniated molasses sprayed on grass again gained less than those fed the same product in bunks.

In the spring of 1955, a growth trial was initiated at the Fort Reno station to test the utilization of nitrogen from ammoniated molasses by yearling heifers. Growth rates from a nitrogen-deficient ration were compared with those obtained with rations containing ammoniated molasses, or a urea-molasses mixture, as the sole sources of supplemental nitrogen. Results indicate that some nitrogen from the ammoniated molasses was apparently utilized, although not to the extent of that from the urea-molasses mixture.

Stimulation was produced, but not consistently at any specific level, when ammoniated molasses was administered to lambs as a drench or as a feed. One lamb in each trial appeared stimulated. Feeding a new "high-test" ammoniated molasses to yearling cattle in a growing-type ration resulted in a high incidence of stimulation. However, the same product produced no observed detrimental effects when administered to rats or rabbits via stomach tube. An ammoniated glucose solution produced no deleterious effects when fed to a yearling heifer for 3 days at a level of 2.0 lbs. daily.

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APPENDIX

APPENDIX TABLE I. Chemical Composition of Feeds Used in Fattening Trials with Steer Calves.

	Percent Composition as Fed								
	Water	Ash	Crude Protein	Fat	Fiber	N.F.E.	Ca.	P.	Carotene Mg/lb
1953									
Corn	13.40	1.43	7.94	3.99	1.66	71.58	.06	.11	-
Cottonseed meal	5.99	6.10	39.48	5.05	9.57	33.81	.18	.71	-
Ammoniated furfural residue	5.90	8.11	33.76	-	-	-	.16	.08	-
Alfalfa hay	8.94	9.21	15.97	1.15	30.68	34.05	.91	.15	16.67
Sorghum silage	67.06	5.87	1.42	1.17	8.75	15.73	.11	.01	.44
1954									
Milo	15.22	1.16	10.77	2.25	1.57	69.03	.65	.20	-
Cottonseed meal	7.48	6.17	38.87	7.67	9.22	30.49	-	-	-
16 % Ammoniated cane molasses	33.29	7.07	16.30	-	-	-	.76	.13	-
33% Ammoniated cane molasses	37.24	7.44	30.66	-	-	-	.81	.14	-
Alfalfa hay (No. 2)	8.68	9.54	16.23	3.42	26.11	34.07	-	-	14.5
Sorghum silage	68.34	2.12	1.75	1.45	6.88	19.06	.13	.04	1.4

APPENDIX TABLE II. Analysis of Variance of Weight Gains of Stocker Cows in 1953-54 Wintering Trials with Ammoniated Molasses as a Replacement for Cottonseed Meal

Source of variance	Degrees of freedom	Sum of squares	Mean square
Total	28	2.49	
Treatment	2	1.42	.710*
1 vs. 2 and 3	1	.864	.864*
2 vs. 3	1	.619	.619*
Error	26	1.07	.041

*P = less than .01.

APPENDIX TABLE III. Feed Prices Used in Computing Feed Costs in Trials Using Ammoniated Furfural Residue and Ammoniated Molasses as Protein Supplements for Fattening Steer Calves.

Feed	Price per ton
1953	
Corn	$ 60.00
Cottonseed meal	106.00
Ammoniated furfural residue	53.00
Alfalfa hay	30.00
Sorghum silage	10.00
1954	
Milo	51.40
Cottonseed meal	66.00
16% Ammoniated cane molasses	54.50
33% Ammoniated cane molasses	61.00
Alfalfa hay (No. 2)	30.00
Sorghum silage	8.00

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