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Bulletin 497
Agricultural Experiment Station

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AGRICULTURAL EXPERIMENT STATION

University of Idaho
Moscow, Idaho

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TN 2M 4-68

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Cattle feeding has become an industry of major importance in Idaho. During recent years, numbers of cattle being fed have increased more than 300 percent, with approximately 28 percent of Idaho farmers feeding out some beef cattle (Bell and Hemstrom, 1962).

Feeds available for cattle feeding in Idaho include grains and roughages. High protein supplements and mineral supplements are shipped in from other sections of the country. Many of these commercially produced protein supplements contain urea as a part of the total nitrogen content. Research work in recent years has shown the possibility of using other nitrogen-containing materials to meet a part of the protein requirements of ruminants. Some of these materials have supplied phosphorus as well as nitrogen.

Ammonium polyphosphate, a liquid nitrogen- and phosphorus-containing material, is produced and is available in Idaho. This study was designed to investigate the feasibility of its use as a supplemental source of protein and phosphorus in cattle rations.

The first clear evidence that cattle could utilize urea to supply a part of their protein needs for growth was reported by German research workers (Fingerling et al., 1937). Its utilization for growth by sheep and for milk production by dairy cattle was established shortly thereafter (Harris and Mitchell, 1941; Rupel et al., 1943).

In the years that followed, a great deal of research was conducted on nitrogen metabolism in ruminants. The formation of ammonia in the rumen following ingestion of nitrogen-containing feedstuffs established the proteolytic properties of the rumen contents. The breakdown and synthesis of protein in the rumen was reported by Pearson and Smith (1943) and the detailed studies of McDonald (1948) formed the basis for the present concept of nitrogen metabolism in the ruminant. This concept, which is often referred to as the nitrogen cycle in the ruminant, includes the breakdown of nitrogenous compounds in the rumen, the formation of ammonia, absorption of some ammonia directly from the rumen, microbial protein synthesis and some recycling of absorbed ammonia back into the rumen as urea via the saliva. Nitrogen metabolism in the ruminant has been extensively discussed in the literature. (Annison and Lewis, 1959; Chalmers, 1961; Lewis, 1961).

Although urea has received most of the attention of research workers as a source of non-protein nitrogen, a considerable amount of work has been done with other nitrogen compounds. The role of non-protein nitrogen in the biochemical processes that occur in the rumen, as well as possible mechanisms of toxicity, has been reviewed by Hale (1956). He discussed both **in vitro** and **in vivo** studies of a considerable number of nitrogenous compounds, and suggested that the most useful non-protein compounds are those from which the ammonia nitrogen is easily released. In some instances, he noted that the rate of ammonia release appeared to exceed the rate of utilization by rumen microorganism, with a resultant toxicity.

More recent experimental work has been directed toward the use of compounds which provide both a source of non-protein nitrogen and of phosphorus (Cowman and Thomas, 1962; Russell et al., 1962; Oltjen et al., 1963; Johnson and McClure, 1964). These studies have dealt with comparisons of monoammonium phosphate and diammonium phosphate with urea, buiret and conventional sources of protein. The phosphorus-containing nitrogenous compounds when fed at normal levels have not produced toxic symptoms. However, they have been slightly less efficient as protein sources than urea.

Research indicates that a variety of compounds may serve as phosphorus sources in the cattle ration. (Beeson et al., 1946; Hodgson et al., 1947; Long et al., 1956; Ammerman et al., 1957; Tillman and Brethour, 1958; Richardson et al., 1961; Wise et al., 1961). These compounds have been fed to livestock with varying degrees of animal response. Each new material prepared as a livestock feed ingredient ultimately must be fed to animals to determine acceptability, animal response in terms of growth, fattening, wool or milk production and the evidence of any toxicity symptoms.

Objectives

The objectives of these studies of ammonium polyphosphate as a source of nitrogen and phosphorus in cattle finishing rations were:

1. To determine the acceptability of rations containing various levels of ammonium polyphosphate.

2. To compare the gains and carcass qualities of cattle on a conventional finishing ration with those on rations in which one-half and all the supplemental nitrogen are supplied by ammonium polyphosphate.

3. To compare the performance of cattle on a finishing ration using a commonly utilized source of phosphorus with rations in which one-half and all the supplemental phosphorus are supplied by ammonium polyphosphate.

4. To determine if toxic symptoms may result in feedlot cattle consuming ammonium polyphosphate.

Experimental Procedures

These studies were conducted in cooperation with the J. R. Simplot Co. at their feeding yards near Paul, Idaho. The studies included 390 head of yearling steers of predominantly Hereford breeding with a small percentage of Hereford-Angus crosses. These cattle were randomly divided into six lots (65 head per lot) and fed the rations shown in Tables 1 and 2.

The basal mix for the protein study included a low protein barley, molasses, ground alfalfa and ground straw. The calculated protein analysis of the basal ration based on a preliminary analysis of the feed before the start of the feeding period was approximately 8.8 percent crude protein. However, sampling and analysis of the feeds and rations during the feeding period indicated that the basal ration contained close to 9 percent crude protein. These analyses are given in Appendix Tables 1 and 2.

The ammonium polyphosphate used in the studies was produced by the J. R. Simplot Co. and is commonly known as "11-37-0" since it contains approximately 11 percent nitrogen and 37 percent phosphorus pentoxide. The method of preparation of the material and the reactions involved are given in the appendix.

Dried molasses beet pulp and ground corncob were used primarily as carriers for the ammonium polyphosphate and other supplemental

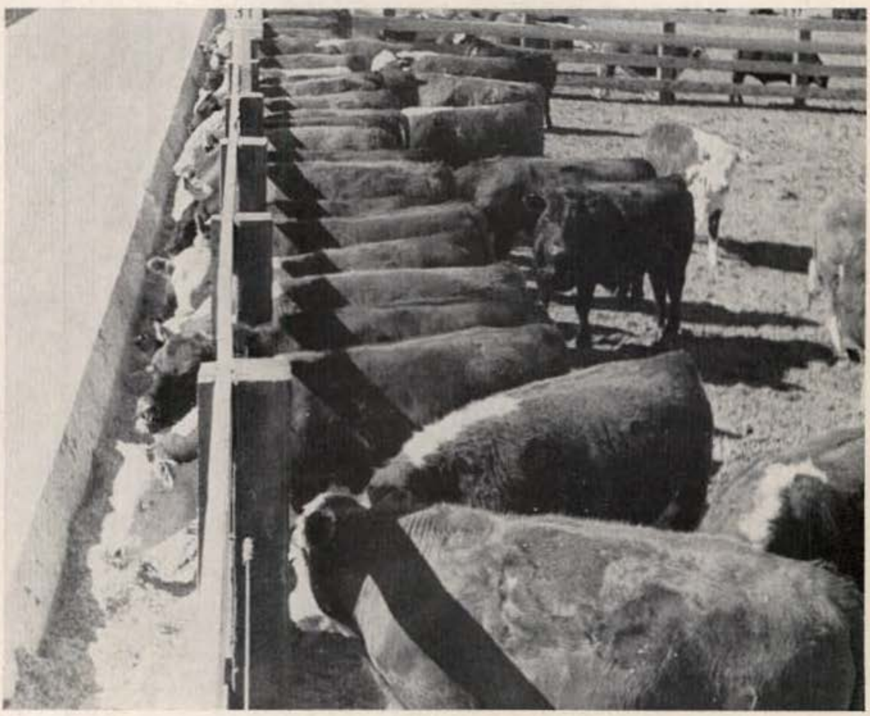

Table 1. Composition and calculated analyses of rations in the protein study.

	Lot 1	Lot 2	Lot 3
Basal mix (pounds per ton)			
Barley	900	900	900
Molasses	200	200	200
Ground alfalfa	100	100	100
Ground straw	300	300	300
Supplements (pounds per ton)			
Cottonseed meal	100	50	......
Ammonium polyphosphate	......	30	60
Dried molasses beet pulp	300	300	300
Ground corncobs	100	120	140
Salt (iodized)	10	10	10
Vitamin A (million IU)	2	2	2
Stilbestrol (mg)	1000	1000	1000
Calculated analyses			
Crude protein (percent)	10.39	10.43	10.47
Phosphorus (percent)	0.24	0.45	0.67
Calcium (percent)	0.57	0.57	0.57
Ca : P ratio	2.3 : 1	1.3 : 1	0.8 : 1

Table 2. Composition and calculated analyses of rations in the phosphorus study.

	Lot 4	Lot 5	Lot 6
Basal mix (pounds per ton)			
Mixed grain	900	900	900
Molasses	200	200	200
Ground alfalfa	150	150	150
Ground straw	250	250	250
Dried molasses beet pulp	400	400	400
Supplements (pounds per ton)			
Sodium phosphate	4	2	......
Ammonium polyphosphate	......	3	6
Dried molasses beet pulp	100	100	100
Salt (iodized)	10	10	10
Vitamin A (million IU)	2	2	2
Stilbestrol (mg)	1000	1000	1000
Calculated analyses			
Crude protein (percent)	10.66	10.77	10.88
Phosphorus (percent)	0.20	0.20	0.20
Calcium (percent)	0.73	0.73	0.73
Ca : P ratio	3.6 : 1	3.6 : 1	3.6 : 1

additives for the protein study. The basal ration, plus the supplements, was calculated to contain approximately 10.4 percent crude protein based on analysis of the feed constituents before the feeding period. Samples of the total ration taken in each of the three lots during the trials indicated a protein content slightly above this figure (Appendix Tables 1 and 2).

In the phosphorus study, the basal ration contained mixed grain (wheat and barley), molasses, ground alfalfa, ground straw and dried molasses beet pulp. This basal ration was calculated to contain about 0.12 percent phosphorus based on preliminary analysis of the feedstuffs. Analysis during the experiment indicated that the actual phosphorus content of the basal ration was well below this figure (Appendix Tables 1 and 2).

The calculated analysis for protein, phosphorus and calcium in the total ration agreed closely with the analyses of samples made during the study (Appendix Tables 1 and 2).

These cattle were group fed, with feed kept before them all the time for a period of 127 days. Individual live weights were taken at start and end of feeding as well as prior to slaughter at the Swift Meat Packing Plant at Boise. At slaughter, the following information was obtained for each carcass:

1. Conformation score
2. Maturity score
3. Marbling score
4. Estimate of percent kidney, pelvic and heart fat
5. Fat thickness
6. Loin eye area
7. Yield grade
8. Carcass weight

The first four observations in the carcass evaluation phase were made by personnel of the Federal Meat Grading Service and based upon their standards. Thickness of fat covering and loin eye area at the 12th rib were measured on acetate tracing. Area of loin eye was measured using a compensating planimeter. The USDA yield grade was derived from fat thickness, estimated percent kidney and pelvic fat, loin eye area and carcass weight using the USDA Beef Carcass Yield Grade Finder.

Results and Discussion

Beginning and final weights, total gain, pounds of feed consumed and cost per 100 pounds of gain for each lot in both the protein and phosphorus studies are shown in Table 3.

In the protein study (lots 1, 2 and 3) initial average weights ranged from 725 pounds in lot 3 to 744 pounds in lot 2. Total feed consumed per steer was somewhat less in lot 3 than in lots 1 and 2, indicating there was a slight depression of appetite where the higher level of ammonium polyphosphate was fed. There was an apparent increase in the amount of feed required per 100 pounds of gain where ammonium polyphosphate replaced one-half of all of the supplemental plant protein. This decrease in feed efficiency was reflected in a higher cost per pound of gain in lots 2 and 3 compared to the costs of gain in lot 1.

In the phosphorus study (lots 4, 5 and 6) initial weights ranged from an average of 731 pounds in lot 4 to 753 pounds in lot 6. Total feed consumed per steer, pounds of feed consumed per 100 pounds gain and costs of gain were very similar in all three lots.

Least squares means were calculated on individual steer data for total feedlot gain, average daily gain, carcass grade and carcass weight (Table 4).

All lots of cattle performed well on the rations in both the protein and phosphorus studies. Not a single animal died or became seriously ill during the study. The average daily gains, ranging from 2.73 to 2.97 pounds for the six lots, would be considered excellent by most feeders.

Table 3. Gains, feed per hundredweight gain and cost of gain for the six lots of cattle.

Lot	Avg initial weight (lb.)	Avg final weight (lb.)	Total feed per steer (lb.)	Feed per cwt gain: Total (lb.)	Basal mix (lb)	Supplement (lb)	Cost per cwt gain[1]
			Protein Study				
1	733	1117	3397	896	669	227	$21.86
2	744	1093	3392	955	713	242	23.31
3	725	1088	3317	948	707	241	23.12
			Phosphorus Study				
4	731	1118	3206	842	794	48	19.47
5	739	1117	3209	844	796	48	19.61
6	753	1114	3206	851	802	49	19.74

[1] Prices of feeds, labor charges and milling charge were made on the following basis:

Alfalfa hay	@ $23.50 per ton
Straw	@ 20.00 per ton
Barley	@ 2.42 per cwt.
Molasses	@ 34.00 per ton
Mixed grain	@ 2.42 per cwt.
Milling cost	@ 5.00 per ton of hay, straw and grain
Labor	@ 13.00 per man day

Table 4. Least squares means of total gain, average daily gain, grade and carcass weight of steers in protein and phosphorus studies.

Lot	Total gain	Avg daily gain	Grade	Carcass weight
		Protein Study		
1	379.1a	2.96a*	10.37a	682.8a
2	355.2b	2.77b	10.34a	657.5b
3	349.8b	2.73b	10.03a	645.2b
		Phosphorus Study		
4	380.8a	2.97a	10.43a	678.3a
5	380.0a	2.97a	10.34a	676.2a
6	376.6a	2.94a	10.41a	680.9a

* Those means within a column with the same letters are not significantly different. Those means with different letters do differ significantly. ($P \leq .05$)

In the protein study (lots 1, 2 and 3), total gain and average daily gains were significantly higher in lot 1, where the plant protein was fed, than in lots 2 and 3 where one-half and all of the supplemental protein was provided by ammonium polyphosphate. Carcass weights were also significantly higher in lot 1.

In the phosphorus study (lots 4, 5 and 6), there were no significant differences in total gain, average daily gain or carcass weight between the steers in lot 4 where sodium phosphate was fed as the phosphorus supplement and the steers in lots 5 and 6 where one-half and all of the supplemental phosphorus was supplied by ammonium polyphosphate. There was no significant difference between lots for USDA carcass grade. All lots averaged low choice (numerical score of 10). Analysis of variance of mean square values for these same traits are listed in Table 5.

Table 5. Analyses of variance of total and average gains, grade and carcass weight.

Source of variation	Degrees of freedom	Total gain	Avg daily gain	Grade	Carcass weight
Rations (Lots)	5	12,511**	.7611**	1.364	14,902**
Regression	1	64.4	.004	.003	2,380
Error	382	2,349.7	.143	1.884	1,919
Total	388				

**Significant at the 1 percent level.

Table 6. Least squares means of carcass traits of steers in protein and phosphorus studies.

Lot	Conformation score	Marbling score	Fat thickness	Loin eye area (sq. in.)	Yield grade	Maturity score	Estimated % kidney, pelvic fat
				Protein			
1	11.65 ab*	10.61	.614 a	12.15 a	.330	2.11	2.80 a
2	11.61 ab	10.11	.579 ab	11.89 ab	.315	2.08	2.47 b
3	11.30 b	9.37	.516 b	11.64 b	.298	2.04	2.32 bc
				Phosphorus			
4	11.54 ab	10.59	.565 ab	11.83 ab	.320	2.05	2.45 b
5	11.87 a	10.52	.566 ab	11.96 ab	.312	2.02	2.20 c
6	11.95 a	10.42	.582 a	12.16 a	.308	2.04	2.16 c

* Those means within each column with the same letters are not significantly different. Those means with different letters do differ significantly. ($P \leq .05$)

Table 7. Analyses of variance of carcass measurements and scores.

Source of variation	Degrees of freedom	Confor-mation	Marbling	Fat thickness	Loin eye area	Au fat	Yield grade	Maturity	Kidney, pelvic fat
Rations (Lots)	5	3.221*	13.280	.060	2.344	.100	.00700	.073	3.424**
Regression	1	1.862	.653	.002	1.732	.004	.00006	.037	.0013
Error	366	1.277	14.040	.027	1.151	.049	.00374	.075	.3065
Total	372								

* Significant at the 5 percent level.

** Significant at the 1 percent level.

Table 6 presents the least squares means for most of the carcass traits measured. The "F" values for these same traits are listed in Table 7.

The steers fed the control ration in the protein study (lot 1) had more subcutaneous fat, larger area of loin eye and a higher percentage of kidney and pelvic fat than the steers fed the higher level of ammonium polyphosphate. The steers fed the lower level of ammonium polyphosphate (lot 2) were not significantly different from lots 1 or 3. There were no statistically significant differences for the other variables in Table 6 as far as the protein study was concerned.

In the phosphorus study, the steers which did not receive their supply of phosphorus from ammonium polyphosphate (lot 4) had a greater amount of kidney and pelvic fat. With this exception, no differences existed in the carcass traits shown in Table 7.

Summary and Conclusions

Three lots of 65 yearling beef cattle each were fed finishing rations for a period of 127 days. The rations were designed to evaluate ammonium polyphosphate as a protein supplement when it replaced one-half and all of the supplemental protein needed in a basic ration containing between 8 and 9 percent crude protein.

Three additional lots of 65 head of yearling beef cattle each were fed finishing rations designed to evaluate ammonium polyphosphate as a phosphorus supplement when replacing one-half and all of the supplemental phosphorus in a basic ration containing approximately 0.10 percent phosphorus.

Feedlot performance and carcass qualities were excellent in all lots. However, there appeared at times to be a slight depression of appetite in the lot where all of the supplemental protein was provided by ammonium polyphosphate. Average daily gains were slightly lower in both lots where ammonium polyphosphate was fed than in the lot where cottonseed meal furnished all of the supplemental protein. No difference in carcass quality was shown between cattle receiving cottonseed meal and the lot receiving a combination of cottonseed meal and ammonium polyphosphate. However, the carcasses from both of these lots were slightly superior to those from the lot receiving all supplemental protein in the form of ammonium polyphosphate.

In the study designed to evaluate phosphorus sources, the cattle receiving ammonium polyphosphate as all or part of their supplemental phosphorus gained equally well in the feedlot and the carcasses were equal or slightly superior to those cattle receiving sodium phosphate as their entire source of supplemental phosphorus.

Acknowledgments

Funds and feedlot facilities for these studies were provided by the J. R. Simplot Co. Particular recognition is given to John Basabe, Bruce L. Campbell, Dr. R. H. Lundgren and J. A. Whitaker of the Simplot Company for their help in planning and conducting the studies. The authors also would like to acknowledge the assistance of the Federal Meat Grading Service and personnel of the Swift Plant at Boise in obtaining the carcass data.

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Appendix

Preparation and Analysis of the Ammonium Polyphosphate (11-37-0) Used in the Study

Phosphoric acid (wet process phosphoric acid or furnace grade phosphoric acid) is concentrated by evaporization to a high enough concentration (about 68 to 76 percent P_2O_5) to convert about 40 percent of the orthophosphoric acid to polyphosphoric acid. This conversion is accomplished by molecular dehydration. This concentrated acid is called superphosphoric acid.

The superphosphoric acid is then mixed and reacted with ammonia (anhydrous or aqua) and water in a cooler reactor to produce a solution having an analysis of 11 percent nitrogen and 37 percent phosphorus pentoxide.

The reactions involved are as follows:

Superphosphoric Acid

$$nH_3PO_4 \xrightarrow{\text{heat}} H_{n+z}P_nO_{3n+1} + (n-1)H_2O$$

Ortho Phosphoric acid — polyphosphoric acid

11-37-0 Solution

$$2H_3PO_4 + 3NH_3 \longrightarrow (NH_4)_2HPO_4 + NH_3H_2PO_4$$

and

$$H_{n+2}P_nO_{n+1} + NH_3 \longrightarrow (NH_3)_xH_{n+z-x}P_nO_{3n+1}$$

Typical Analysis of Simplot Liquid Ammonium Phosphate

	% By Weight		% By Weight
Nitrogen (N)	11.1	Iron (Fe_2O_3)	0.38
Phosphorus (P)	16.1	Aluminum (Al_2O_3)	1.0
Silica ($Si\ O_2$)	0.22	Sodium (Na_2O)	0.08
Arsenic (As_2O_3)	0.004	Potassium (K_2O)	0.03
Fluoride (F)	0.15	Manganese (MnO)	Less Than 0.01
Sulfate (SO_3)	1.29	Lead	0.0007
Boron (B)	Less Than 0.01	Titanium (TiO_2)	0.37
Chronium (CrO_3)	0.85	Copper (CuO)	Less Than 0.001
Vanadium (VO)	0.104	Zinc (ZnO)	0.007
Calcium (CaO)	Less Than 0.01	Nickel (NiO)	0.01
Magnesium (MgO)	0.137		

Appendix Table 1. Preliminary analysis of feeds used in the study.

Sample	% Protein	% Phosphorus	% Calcium
Barley	8.8	0.31	0.56
Mixed grain	11.2	0.22	0.8
Wheat	9.3	0.18	0.8
Alfalfa	14.9	0.19	1.5
Straw	5.3	0.14	0.7
Corncobs	2.2	0.05	0.4
Dried molasses beet pulp	11.1	0.07	0.6
Ammonium Polyphosphate	69.5	16.1	....
Molasses	10.7	0.02	.16

Appendix Table 2. Analyses of samples taken during the study.

Samples	Protein %	Moisture %	Phosphorus %	Calcium %
Protein Study				
Basal ration	9.1	12.2	0.39	.82
Supplement				
Lot 1	18.3	7.0	0.46	.78
Lot 2	15.2	7.4	1.28	.90
Lot 3	17.9	8.5	2.57	.96
Complete ration				
Lot 1	10.5	10.7	0.21	.50
Lot 2	10.9	11.3	0.48	.48
Lot 3	11.8	11.8	0.35	.56
Phosphorus Study				
Basal ration	10.5	11.5	0.02	.90
Supplement				
Lot 4	8.5	6.0	1.64	.98
Lot 5	11.1	6.2	1.22	.66
Lot 6	12.3	6.6	1.20	.70
Complete ration				
Lot 4	10.6	11.0	0.29	.56
Lot 5	10.9	11.4	0.22	.56
Lot 6	11.0	11.1	0.29	.56