

PELLETING PERFORMANCE AS AFFECTED BY AMMONIUM POLYPHOSPHATE

by

PICHAI (PETE) TANGPRASERTCHAI
B.S., Kansas State University, 1977

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1980

Approved by:


Major Professor

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Introduction

The word "energy" means many dollars to every manufacturer in all kinds of industries. Furthermore, electricity, in terms of kilowatt hours (KWH), represents the value of dollars more than ever before, and it seems there is no indication of anything but increases in costs of utilities.

Energy User News (1980) indicated that electricity cost in terms of dollars per KWH increased from \$0.01 in 1967 to \$0.03 in 1977, which is equivalent to a 300% increase. Steam cost in terms of dollars per 10^6 BTU climbed from \$0.50 to \$2.50 in the same period, a 500% increase.

Many manufacturers have experimented with various methods of reducing costs of energy. For instance, working a 10-hour day four days a week, reducing thermostat setting in the winter, installing a solar energy device, and appointing an energy committee to study the energy utilization in their plants. Feed manufacturers have concentrated on reducing production energy cost which, in turn, means more profit for them.

The American Feed Manufacturers Association (AFMA) set up an Energy Committee to express concern for energy saving by members. Recently, the Energy Committee presented a symposium on "Energy Management" at the 1980 AFMA Regional Feed Production in Kansas City, Missouri. The committee gave an overview of various topics relating to energy saving in the feed production area. Among topics

addressed were

- reduce KWH demand
- reduce transportation fuel usage
- decrease boiler usage
- recycle heat from boiler in buildings

These are some of the direct and indirect factors which can minimize the production energy cost and maintain profit.

Many chemical research companies are developing new additives or ingredients to be mixed in feed products which will maintain the same or provide improved nutritive values of feed. Concurrently, the new ingredients may reduce the energy required in the manufacturing process and produce the same or better feed quality. A liquid solution called "Ammonium Polyphosphate" has been used as a phosphorus source in various animal rations and is fairly new to the feed industry. The investigations reported here concentrate on the performance of this phosphorus source in terms of energy usage in production of a pelleted dairy supplement.

Background Information

Phosphorus

Allied Chemical Corporation of New York manufactures a polyphosphate in the acid form called "super phosphoric acid" which is then combined with nitrogen to form ammonium polyphosphate (APP). The product is recognized for use in ruminant rations by the Association of American Feed Control Officials (AAFCO) (1970). NRC - 6-08-042 is the permanent number assigned by the National Research Council's subcommittee on feed composition. Allied Chemical's APP has a commercial name called "COMPEN"^R. It must be used under the restriction provided by Allied Chemical that:

"If a premix, concentrate, or supplement contains more than 2.0% of equivalent crude protein from APP, the label must contain adequate directions for use and a prominent statement, 'WARNING---This feed must be used only in accordance with directions furnished on the label'."

COMPEN^R is a clear, dark green, non-corrosive liquid that can be easily handled. Storage and handling equipment may be made from iron, carbon steel, or stainless steel. The product chemical and physical properties are given in Appendix A.

The Feed Industry Red Book (1973) defined APP solution as the product resulting from the neutralization of super phosphoric acid with ammonium hydroxide. It must contain not less than 9% nitrogen and 13% phosphorus. It must contain not more than one part of fluorine to 100 parts of

fluorine to 100 parts of phosphorus, 75 parts per million (ppm) of arsenic, and 30 ppm of heavy metal reported as lead.

Dicalcium Phosphate (DCP) is sold on the market as two different types of compound (according to the Feed Industry Red Book (1973)). One is made by dissolving bone meal or rock phosphate in acid and precipitating the phosphorus as DCP. The other form is made by adding calcium compounds to phosphoric acid and thus precipitating DCP. They are both excellent sources of calcium and phosphorus and are readily soluble in the digestion system. They are also low in fluorine content. Both forms contain 18-21% phosphorus and 26-28% calcium. The higher the phosphorus content is, the lower is the calcium. The AAFCO Official Publication (1979) declares that DCP (NRC - 6-01-080) labels must specify minimum amount of calcium and phosphorus and that it must not contain more than one part of fluorine to 100 parts of phosphorus.

Phosphorus is an extremely important element in ruminant animals for the proper metabolism and health. For ruminants, two phosphorus requirements must actually be considered; one for the animal itself and the other for the rumen microorganisms (Bartter 1964, Church 1971, Cromwell, et al. 1976, Irving 1964, and White 1968).

Phosphorus deficiency appears to be a widespread problem throughout the world as Preston, et al. (1977) indicated. Most of the forage that ruminants consume is only adequate in phosphorus content whereas the weathered, leached

forages are always marginal or deficient in phosphorus. Consequently, phosphorus is usually one of the most limiting of the mineral nutrients for ruminants in many situations.

Feed Processing

It is general felt that finely ground materials have an advantage in mixing and, in turn, affect the pelleting of formula feed. Williams (1958) reported that the feed pellets made with finely ground ingredients will have a lower breakage susceptibility than those made with coarse materials.

Uniformity of mix and ingredient segregation were influenced by the particular feed mix being handled. Sucher, et al. (1969) indicated that addition of animal fat to a mix containing a high percentage of soybean meal was found to improve uniformity of mix and reduce the amount of segregation which occurred during in-process handling.

Pfost, et al. (1976) gave a particle size definition as follows:

- Material remaining on 3/8, 4, and 8 mesh screens designated as "coarse".
- Material remaining on 14 and 18 mesh screens designated as "medium".
- Material remaining on 48 and 100 mesh screens designated as "fine".

Wilcox, et al. (1970) reported a method for determining and expressing the size of feed particles by sieving with a Ro-Tap sifter. After sieving, the weight of the

product from each sieve was recorded for further calculations. This method has been adopted by the American Society of Agricultural Engineers (ASAE) as their official method (ASAE: S319).

Headley, et al. (1966) developed a method for describing the particle size distribution of feed materials by small particle statistics. Application of this method of small particle statistics to actual sieving data can be shown on a typical data sheet with determination of the necessary lognormal parameters. This provides geometric mean particle size by weight distribution and the surface area per gram of product can be obtained to give more detail on the particle size.

Smith (1962) indicated that particle size of meal products may effect the pelletability of a diet. As particle size was reduced, more surface area was exposed to steam during conditioning, causing a greater compaction in the pellet mill die and more uniform liquid absorption.

Carlson (1960) gave a definition of 100% mixing efficiency as a 100% distribution of any ingredient with all other ingredients in a formulation. The actual percentages of each ingredient are known and mixing efficiency can be checked comparing several samples from a batch of feed or premix. The accuracy of an assay method must be known and considered when mixing efficiency of a certain mixer is tested.

Every nutritionist and feed manufacturer hope to blend the ingredients to insure uniform dispersion throughout the entire mix. Methods of determining degree of mixing uniformity usually involving using one or more components as a tracer. Headley (1967) used sodium chloride as a tracer in his mixing study. Sodium chloride, when used to detect degree of mixing, can be quantitated by weight or by titration techniques.

Headley compared a sedimentation technique (Pfoest, et al. 1966), a potentiometric method (Luhman 1955), and use of a commercial Quantab^R (Ames Company, Ames, Iowa) - Chloride Titrator. He concluded that all the three assay methods may be used effectively to measure sodium chloride concentration in ground feedstuffs.

Mixing is one of the more important operations in the feed operation. Pfoest (1964) suggested that criteria might be considered in arriving at a decision regarding the degree of mixing desired.

1. The mix should provide each animal with a given percentage of his daily requirement.
2. It should be adequate to prevent frequent occurrence of toxic levels.
3. It should be adequate to insure that a sample will be within limits set by control organizations.
4. Inaccurate sampling or assay technique should not be considered.

5. Loss of a material from the mixture, as through dust collector systems.

According to Leaver (1980), the moisture present in ingredients to be pelleted is introduced in two forms.

1. Bound Moisture---the moisture within the ingredients. It varies with the source of supply and the manner in which the ingredient has been handled.
2. Added Moisture---the moisture which is added at the conditioning chamber of the pellet mill, principally for lubrication. In this instance, the purpose is to coat each particle of feed with moisture. This process enables material to pass through the die easier, reducing functional heat and increasing die life.

This added surface moisture on the particle is also used to enhance the natural adhesives and begin certain chemical changes that will assist in pellet quality. Experience indicated that the maximum moisture introduced into the conditioner should be 6%. Beyond this level, most materials become too slippery to be trapped by the roll and forced through the pellet mill die, and the natural adhesives become too dilute, reducing the pellet quality.

Stroup (1959) reported that proper conditioning in one of the more important factors in realizing high capacity in pelleting dairy feed; higher temperatures obtained through proper conditioning are also very important in acquiring optimum capacity. The conditioned mash for most formulas

will generally give best results between 70-80°C.

The high steam level, which corresponded to a temperature rise of 50°C, reduced energy consumption less than energy required to pellet at medium steam level, where the temperature rise was 32°C (Young 1963). The medium steam level showed the same trend with respect to the low steam level, which corresponded to a temperature rise of 15°C. The medium steam level increased the pellet durability over that of the low steam level. Durability was increased most at the high steam level.

McBain (1966) reported that ingredients are effected by local humidity conditions and by climatic conditions in the region of origin. Since the humidity changes from hour to hour and day by day, the pellet mill operator must be ready to adjust the amount of steam added on each ration. The added amount of steam for conditioning should be approached in each pelleting run from a view point of a new formulation, in order to get the proper conditioning and maximize the production rate.

Insufficient conditioning can be indicated by high power requirement with more horsepower per pound and lower production rates. Operating at low temperature (less steam) results also in excessive wear on the die and the rolls (Stroup 1959).

Pelleting

Leaver (1980) defined pelleting as an extrusion type thermo-plastic molding operation in which the finely divided particles of feed rations are formed into a compact and easily handled pellet. It is thermo-plastic because starches of feed ingredients become plastic when heated and diluted with moisture. The molding part of the operation occurs when the heated and moistened feed is formed into shape, held in the die for a short period of time for compaction, and then extruded. Pressure for both molding and extrusion comes from the rolls which trap feed on the surface of the die and force it through the die holes.

The pelleting process contains many variables and it is difficult to set a standard in feed pelleting with high accuracy. Wornick (1959) indicated variables in pelleting production which include:

- | | |
|------------------------------|-----------------------------|
| - feed composition | - operator's experience |
| - feed texture | - pelleting pressure in die |
| - mash uniformity | - pelleting temperature |
| - ingredients particle sizes | - time feed in the die |
| - steam temperature | - equipment used |
| - steam pressure | - die condition |
| - steam rate | - pellet size |
| - ambient condition | - fines recycled |

Pellet mill operation at optimum efficiency is defined by Zarow (1980) as "operate at full load" or "plugged point". With suitable die characteristics on the operating mill and proper conditioning, the amount of moisture that can be added to obtain maximum production and consistent quality with minimum friction on the die and without shrinkage is critical. In other words, moisture is the variable which affects production rate and friction. The source of moisture; steam, hot water, or a combination should be selected with regard to maximum production, friction, quality, and shrinkage and/or gain.

Die selection is one of the most important factors affecting efficiency in the production of pellets (Neseth 1962, Stroup 1959); the use of the wide die (15 cm width) permits more holes than a narrow die (12.5 cm width) and thus increased production, the wide die provides more surface area with the rolls and for higher conditioning (more steam added). In manufacturing dairy pellets, a small diameter (6.25 mm) hole is often used; a straight continuous bore is usually adequate. The thicker the die, the more horsepower will be consumed per pound for extrusion, and the better durability of the pellet, but the production rate is decreased. The thickness of the die is an important factor in producing a satisfactory, hard and tough pellet. In industry, it is desirable to select a die suitable for several formulas to reduce the number of die changes.

Young (1962) reported that the more steam added in the conditioning process, the better the pellet durability, as it also reflected less energy consumption during pelleting.

The steam added during conditioning also is reported to bring the natural oil present in most grains to the surface of the mash particles (Wake 1959). This provides lubrication of the pellet die and also results in greater pelleting capacity and better pellet quality.

Gutekunst (1962) constructed a tumbling can device driven by a 50 rpm motor, to test the mechanical durability of feed pellets which would give a high degree of correlation when compared with damage sustained by pellets in a typical mechanical handling system. The pellets could be tested before or after cooling.

A pellet durability testing device was developed by H.B. Pfost (1963) at Kansas State University, accepted in 1963 by the Feed School Production Committee of AFMA as a standard method of measuring pellet durability for production control.

Storability

Wornick (1959) suggested that in order to establish meaningful specification for microingredient stability and to properly interpret testing results, it is essential to know the expected shelf-life of each specific type of feed. Most feed manufacturers know how long various feeds are held in their own warehouses. To cope with an unexpected

long holding period, it would not be unreasonable to insure 2 to 3 months storability.

Headley (1969) reported that storage of pelleted feeds with an initial moisture from 7-9% (w.b.) at a relative humidity greater than 75%, quickly developed molds at storage temperatures greater than 10°C; however, all pelleted feeds stored at or below 75% relative humidity were held 30 days at temperatures ranging from 10°C to 32°C with no visible molds appearing.

Theoretical Aspects of Processing

Heat Balance of Steam for Pellet Processing (Pfof 1976)

Under normal conditions in which steam is used in processing, such as in conditioning mash for pelleting, it may be assumed that the steam is used efficiently. If the steam is used efficiently and not lost in the form of vapor, or if large heat loss does not occur, then the computation of steam requirement is relative simple as follows:

Heat removed from steam = Heat added to product to be processed

Heat removed from steam will be determined by following the steam heat content backwards. Heat required will usually be determined by knowing the temperature increase required. The mixing of steam and product will result in the final temperatures of condensed steam and product being equal. The amount of heat required to raise the temperature from T_1 to T_2 can be calculated based on the specific heat equation:

$$q = CW(T_2 - T_1)$$

q = amount of heat, BTU/lb

C = specific heat of rproduct, BTU/lb °F

W = weight of steam, lb

T_1 = initial temperature, °F

T_2 = final temperature, °F

(Appendix B)

Power Requirement for Pellet Processing (Pfof 1976)

An equation was derived by H.B. Pfof to calculate electrical power consumption of the 25 HP California pellet mill installed in the Kansas State University Feed Mill in terms of KWH/ton.

$$P = \frac{k \times n \times \text{Rev.}}{\text{lb of pellets}}$$

P = power require, KWH/ton

k = a constant

n = ratio of batch weight (1000 lb) to tonnage

Rev. = # of revolutions, reading from the electrical counter

(Appendix C)

Materials and Methods

Facilities

The pilot feed mill facilities of the Department of Grain Science and Industry, Kansas State University (Illustration I) were used. Raw ingredients were blended in a mixer, transferred by a screw conveyor to a bucket elevator where they could be directly delivered to the sackoff bin for the mixing experiment or sent to a bin above the pellet mill. The meal was regulated by a feeder into a conditioning chamber located above the pellet mill. Steam was injected into the conditioning chamber for the "proper conditioning" (Stroup 1959) before the meal entered the pellet die. The feeder rate and the steam flow were set by the pellet mill operator. After the pellet mill, the hot pellets were dropped onto a horizontal cooler and conveyed to a screener (shaker) where fines were separated from the pellets. The pellets were sacked separately from the fines.

Experimental Design

The initial tests included two levels of Sodium Bentonite as a binder (1% and 0%) and as one of the variable factors. After the first trial which included all variables, statistical analysis indicated no significant effect on pellet performance between the rations with binder and the one without binder. Therefore, the binder was eliminated through the rest of the trials.

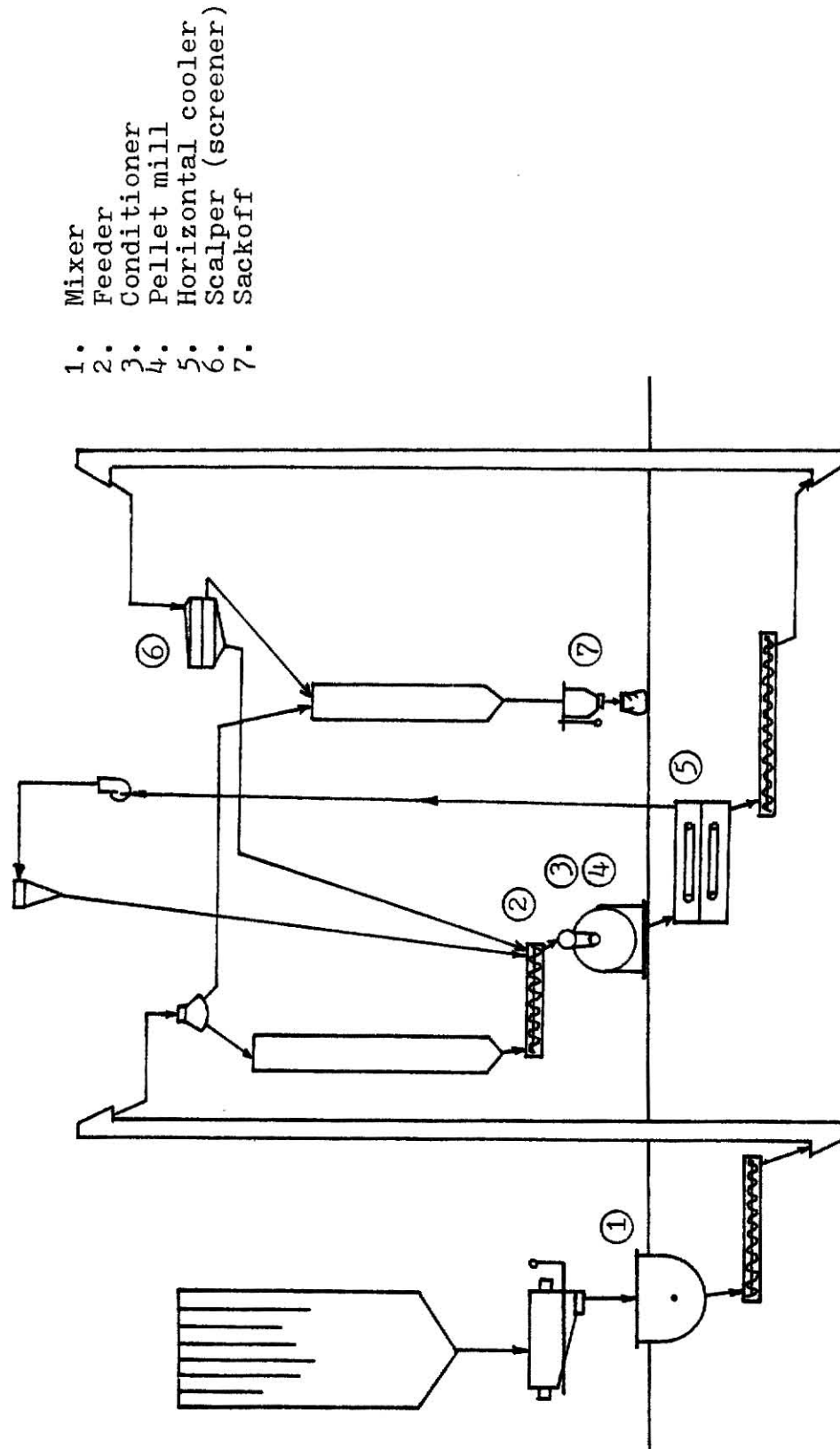


Illustration I. Pelleting flow diagram, Department of Grain Science and Industry, Kansas State University.

The variables tested in the dairy ration are given below. Each ration was processed in triplicate on different days (one replication per day).

1. Phosphorus source (3): 1% DCP, 1% APP,
 $\frac{1}{2}\%$ DCP + $\frac{1}{2}\%$ APP
2. Nutrient energy source (2): Wheat middling (wheat midds), dehydrated alfalfa (dehy alfalfa)
3. Pellet size (2): 6.25 mm and 18.75 mm

The order of the pelleting trials was based on the pellet die sizes. Each trial consisted of 6 rations to include the 2 energy, 3 phosphorus sources and of one pellet size, due to practical operation of the pellet mill and time consumed in die changing. The order of ration production was random to avoid any bias results in case of carryover or environmental changes. Each trial was completed in a day to assure similar environmental condition (temperature in the mill varied from 18°C to 35°C, relative humidity varied from 44% to 75% during the period that the experiment was conducted).

Feed Formulation

A dairy supplement ration was designed and formulated to compare the processing efficiency of liquid APP with generally used dry DCP as a phosphorus source. The formula was made iso-nitrogenous by varying the urea because APP also supplies non-protein nitrogen. The ration contained soybean meal, urea, limestone, and salt. The phosphorus

and energy sources were supplied as shown below:

<u>Ration designated as</u>	<u>Phosphorus and energy sources</u>
DCP with wheat midds	1% DCP + 0% APP + wheat midds
APP with wheat midds	0% DCP + 1% APP + wheat midds
D+A with wheat midds	$\frac{1}{2}\%$ DCP + $\frac{1}{2}\%$ APP + wheat midds
DCP with dehy alfalfa	1% DCP + 0% APP + dehy alfalfa
APP with dehy alfalfa	0% DCP + 1% APP + dehy alfalfa
D+A with dehy a falfa	$\frac{1}{2}\%$ DCP + $\frac{1}{2}\%$ APP + dehy alfalfa

Mixing

A double ribbon mixer with a capacity of 455 kg (1000 lbs) was used for the mixing process. Rations with DCP were mixed for three minutes; rations with two levels of APP were mixed three minutes before APP was added and then for two additional minutes.

Segregation

To determine if segregation occurred in conveying the meal from the mixer to the sackoff point, sodium chloride was used as a tracer in two rations: APP with wheat midds and DCP with wheat midds. Fifteen samples were collected from the mixer discharge and 15 samples at the sackoff point for each ration. Both the potentiometric method and the Quantab^R (Ames Company, Ames, Iowa) - chloride titrator method were used to analyze the mixing performance of the rations with APP and with DCP.

Luhman (1955) designed a potentiometric method which requires solubilizing the salt tracer (NaCl) and then titrating with AgNO_3 solution. The potential between a calomel reference electrode and a silver electrode was read with a potentiometer. A rapid decline in millivolt reading indicated the end point.

Quantab^R - chloride titrator is a method using a chloride titrator to measure salt (NaCl) in water solution. A plastic strip containing a sensitized capillary column absorbs a small quantity of solution and reacts with chlorides to give a color change which indicates percent salt in solution.

Conditioning

The meal products were agitated in the conditioning chamber for a period of 10 to 20 seconds. Steam with an average reading of 10.3 kgm/cm^2 (90 psi) was injected into the conditioner. The steam was controlled by the pellet mill operator to correlate with the feeder rate for proper conditioning. For each batch, the temperature of a sample from the chamber was recorded before and after the conditioning. Also, moisture content was determined on the samples.

Because the facilities did not include equipment to measure the actual amount of steam added in conditioning the meal product, the temperature of meal before and after the conditioning was used to calculate the steam usage.

The calculation was based on the theory of heat balance of steam and is shown in terms of kg-cal/kg (BTU/lb) of meal product and converted into electrical power in terms of KWH/MT (KWH/ton). (Appendix B)

The moisture content determination of the meal samples before and after the conditioning was used to indicate the amount of moisture added to the meal in the conditioning process.

Pelleting

The pellet mill operator regulated the steam usage and feeder rate for maximum performance using 100% amperage load as an indicator. To achieve maximum pelleting capacity, a procedure suggested by H.B. Pfof was used.

To adjust steam input for maximum pelleting (i.e., amperage load at 100%) capacity for each batch, steam flow was increased to the conditioning chamber in small increments. During the adjustment process, with amperage load at 100%, additions of steam caused the load to drop 10-25% for every 5-10°C increase in temperature of meal in the conditioning chamber. The amperage load was raised to 100% by increased feed rate, and steam again admitted. By alternating these two functions, a point was reached at which added steam caused the load to increase rather than decrease and the meal choked the pellet die. The amount of steam was reduced to lower the conditioned meal temperature 3-5°C and amperage load maintained at 100%. This steam input was

used as "maximum performance" (Zarow 1980). Each ration was handled in the same manner to reach the optimum conditioning temperature and 100% amperage load. The reading on an electrical panel (# of revolutions counter) was used for calculating power consumption in KWH/MT (KWH/ton) of production (Appendix C).

The production rate was obtained by recording the weight of total product in the run and the time in pelleting, and expressing the ratio in terms of MT/hour.

Cooling

A double pass horizontal cooler was used in the process with ambient air used to cool the pellets. The cooling time was approximately 20 minutes. The cooled pellets were separated on a screener (shaker) into finished product and fines. Weights were recorded for calculations.

Durability

A finished pellet sample was randomly collected for the durability test, moisture determination, and for storability test. The pellet durability test was conducted using the tumbling can device proposed by Pfost (1963).

Sampling Points (Illustration II)

a. Segregation test

- 1a. At the mixer discharge, one sample was collected every 10 seconds for a total of 15 samples.
- 2a. Fifteen samples were randomly picked from the top of the sacks at the sackoff point.

b. Pelleting process

- 1b. A sample was obtained at the feeder.
- 2b. A sample was collected after conditioning.
- 3b. Hot pellets were collected at the pellet die.
- 4b. Samples of cool pellets were collected at the sackoff.

Storability

The storability of supplement feeds containing dicalcium phosphate and ammonium polyphosphate was studied by inoculating feed samples with Aspergillus repens spores, storing the feed at controlled temperatures and relative humidity for 45 days, and observing the samples for mold growth.

Aspergillus repens, a species of A. glaucus group, was selected as the test organism because this group of molds are frequently encountered storage organisms. The fungi grow at moisture content in equilibrium with relative humidity above 70%, equivalent to 14-14.5% for corn, wheat and sorghum, and 12.5-13% MC for soybeans.

Samples of feed pellets were inoculated by placing 8-10 wheat kernels heavily infested with A. repens in a plastic bag with 400 gm of pellets and shaking vigorously for several minutes. The pellets were dispensed into a wire-screen cylinders containing approximately 10-20 gm each. Cylinders were placed in desiccators over appropriate concentrations of sulfuric acid to provide relative humidity of 70% and 80%, and desiccators were stored in

rooms maintained at 25° and 40°C for 45 days. Non-inoculated pellets were similarly dispensed into cylinders and stored under controlled conditions (25° and 40°C and 70% and 80% RH). All samples were stored in duplicate. Inoculated and non-inoculated materials were held at room conditions in tightly closed plastic bags to provide control samples.

At the conclusion of the storage period, pellets were tested for Equilibrium Moisture Content (EMC) by drying a 10 gm sample at 103°C for 72 hours; the remainder was air dried and ground, and the duplicate samples were combined for determination of spore count.

Mold growth in selected samples was quantitated by a standard dilution-count test which measured the number of viable units (i.e., spores of storage fungi). A 5 gm sample was added to 45 ml of sterile water-agar (0.15% agar) in a milk dilution bottle. After two minutes of vigorous shaking, a 5 ml aliquot was transferred to 45 ml water-agar and mixed by shaking for 1 minute. Ten-fold dilutions were continued as needed. One ml aliquots of appropriate dilutions were pipetted in duplicate into sterile petri dishes. Cooled malt agar containing 4% sodium chloride and 300 ppm tetracycline was added to the petri dishes and mixed with the diluted samples. Agar plates were incubated at room temperature for 5-7 days and mold colonies identified and counted.

Results and Discussion

Particle Size

The particle size analysis of the meal product at the mixer (table 1) showed that both the average particle size and the surface area per gram of the wheat midds rations varied; the average particle size ranging from 562 to 932 μ , and the surface area also varied from 57 to 144 cm²/gm. The three rations made with dehy alfalfa were more uniform with particle size ranging from 499 to 539 μ , and the surface area per gram ranged from 112 to 131 cm²/gm. Because particle size variation in the wheat midds rations might suggest difficulty in mixing, the wheat midds rations with APP and DCP were tested for mixing performance and possible segregation during transfer to the sackoff bin.

Mixing

The mixing performance data was obtained by analyzing of 15 samples. The results from both the potentiometric and Quantab^R techniques indicated there was less uniformity in the DCP rations from the mixer and sackoff than for the APP rations. The data analysis (table 2a and 2b) shows there were no significant differences in the degree of mixing with the APP rations, but there were significant differences in the DCP rations.

The coefficient of variation indicates that results from the Quantab^R method were more variable than the

TABLE 1. PARTICLE SIZE ANALYSIS OF
WHEAT MIDDINGS AND DEHYDRATED ALFALFA RATIONS

Phosphorus Source	Primary Ingredient	Surface Area (cm ² /gm)	Average Particle Size (μ)	Std. Error
DCP	Wheat Midds	57.35	923.36	1.74
APP	Wheat Midds	144.92	562.70	2.95
D+A	Wheat Midds	70.18	859.77	2.12
DCP	Dehy Alfalfa	118.85	516.26	2.17
APP	Dehy Alfalfa	131.54	499.69	2.36
D+A	Dehy Alfalfa	112.99	539.11	2.15

TABLE 2.

a. MIXING ANALYSIS FOR RATION* WITH APP

Sample Location	Potentiometric % Salt	Std. Error	C.V.	Quantab ^R % Salt	Std. Error	C.V.
Mixer	4.74 ^a	0.26	5.40	5.92 ^c	0.61	10.24
Sackoff	4.60 ^a	0.50	9.77	5.62 ^c	0.64	11.47

b. MIXING ANALYSIS FOR RATION* WITH DCP

Sample Location	Potentiometric % Salt	Std. Error	C.V.	Quantab ^R % Salt	Std. Error	C.V.
Mixer	4.37 ^a	0.45	10.24	4.27 ^c	0.93	21.73
Sackoff	4.94 ^b	0.59	11.88	4.78 ^d	0.85	17.83

- Values are average of 15 samples at each site.
- Values within a column with the same subscripts are not significantly different ($P < 0.05$).
- * 5% salt added.

potentiometric method in analyzing the salt tracer in both the wheat midds and the dehy alfalfa rations; the reason is because the potentiometric method is a laboratory analytical titration procedure with more accurate results, where the Quantab^R is just a quick and simple chloride titrator method.

Conditioning

Steam conditioning results in increased moisture in the meal and is often described in terms of moisture added and conditioning temperature. It can be expressed in kg-cal (BTU) of steam per kilogram (pound) of meal and equivalent electrical power in KWH/MT (KWH/ton).

Knowing that the APP solution has a moisture content of 41%, and the rations containing APP have the greatest surface area per gram of sample (table 1) as compared to the DCP or the D+A rations, this characteristic might result in a more uniform mixing and require a conditioning temperature which is 5-10°C lower (table 3). This means a saving of steam by 3.40 to 5.24 kg-cal/kg of meal or a saving of equivalent electrical power of 1.55 to 2.39 KWH/MT in production. A meal conditioned from 32° to 67°C using 6.33 kg/cm² of steam (90 psi) (0.90 steam quality), would need steam of 11.84 kg-cal/kg (25.19 BTU/lb) or 5.63 KWH/MT (5.12 KWH/ton) of electrical power (Appendix B) in the conditioning process of this study. The statistical results indicated a significant difference between the APP and the DCP and D+A rations in steam requirement. There was no

significant difference in the DCP to the D+A rations.

The data in Table 3 show the overall average values of the conditioning process using the phosphorus sources. The data for 6.25 mm and 18.75 mm (1/4" and 3/4") pellets with energy sources of wheat midds and dehy alfalfa are shown in Table 4 and 5. The results indicated that with either energy source or pellet size, APP rations required a lower conditioning temperature. Also APP rations required less electrical power (KWH/MT) in conditioning than the DCP and the D+A rations. The bound moisture of APP and the greater surface area of meal product, assisted in obtaining the proper conditioning at lower temperature with less moisture added. The added moisture was lower for the APP rations at 2.23% as compared to 2.95% of DCP rations, there was a significant difference between the two results.

Pelleting

The overall average electrical power consumption (table 6) of the APP ration was comparable with the DCP ration. The DCP ration required 15.06 KWH/MT and the APP ration required 15.55 KWH/MT. The statistical analysis did not indicate a significant difference between the three phosphorus levels. The D+A ration results were usually in the range between those of the APP and DCP rations. However, in some batches, the D+A ration had an electrical power requirement higher than either the APP or DCP rations. This may be due

TABLE 3. OVERALL AVERAGE VALUES OF CONDITIONING PROCESS

Ration	Conditioning Temp. °C		Steam Required		Moisture Added %
	Before	After	kg-cal/kg	Elect. KWH/MT*	
DCP	23	64	13.67 ^a	6.23 ^d	2.95 ^h
APP	23	52	8.43 ^b	3.84 ^e	2.23 ^f
D+A	23	58	11.83 ^a	5.39 ^d	2.57 ^f

- Values with the same subscripts are not significantly different ($P < 0.05$)

* Electrical power equivalent

TABLE 4. CONDITIONING PROCESS FOR RATIONS WITH WHEAT MIDDLLINGS

Phosphorus Source	Pellet Size		Conditioning Temp. °C		Steam Required		Moisture Added %
	mm	inch	Before	After	kg-cal/kg	Elect. KWH/MT*	
DCP	6.25	1/4	22	57	11.77 ^a	5.37 ^a	2.67 ^a
APP	6.25	1/4	21	43	6.69 ^b	3.05 ^b	1.98 ^{b,c}
D+A	6.25	1/4	21	53	10.80 ^a	4.92 ^a	2.17 ^{a,c}
DCP	18.75	3/4	23	63	13.53 ^a	6.16 ^a	2.70 ^a
APP	18.75	3/4	25	54	8.77 ^b	3.99 ^b	2.13 ^a
D+A	18.75	3/4	23	61	13.40 ^a	6.11 ^a	2.11 ^a

- Values with the same subscripts are not significantly different ($P < 0.05$)

* Electrical power equivalent

TABLE 5. CONDITIONING PROCESS FOR RATIONS WITH DEHYDRATED ALFALFA

Phosphorus Source	Pellet Size		Conditioning Temp. °C		Steam Required		Elect. KWH/MT*	Moisture Added %
	mm	inch	Before	After	kg-cal/kg			
DCP	6.25	1/4	23	66	13.80 ^a	6.29 ^a	3.41 ^a	
APP	6.25	1/4	25	51	7.48 ^b	3.41 ^b	2.40 ^{b,c}	
D+A	6.25	1/4	24	58	11.26 ^c	5.13 ^c	3.07 ^{a,c}	
DCP	18.75	3/4	24	72	15.58 ^a	7.10 ^a	3.02 ^a	
APP	18.75	3/4	22	61	10.78 ^b	4.91 ^b	2.40 ^b	
D+A	18.75	3/4	24	62	12.41 ^b	5.64 ^b	2.75 ^a	

- Values with the same subscripts are not significantly different (P < 0.05)

* Electrical power equivalent

TABLE 6. OVERALL AVERAGE ELECTRICAL POWER CONSUMPTION
WITH VARIOUS PHOSPHORUS SOURCES OF WHEAT
MIDDLINGS AND DEHYDRATED ALFALFA

Phosphorus Source	Electrical Consumption KWH/MT	Production Rate MT/hr	Pellet Durability %
DCP	15.06 ^a	1.38 ^a	97.62 ^f
APP	15.44 ^a	1.26 ^b	97.54 ^f
D+A	16.54 ^a	1.26 ^b	98.03 ^f

- Values with the same subscripts are not significantly different ($P < 0.05$)

to some internal reactions of APP and DCP with the urea during the conditioning process which we were unable to predict.

The pellet durability was similar for all rations. It did not show any significant difference in the statistical analysis.

The statistical analysis shows a significant difference in the production rate, where the DCP rations have a better production rate of 1.38 MT/hr as compared to 1.26 MT/hr of the APP rations.

The data of the pellet sizes and energy sources were obtained from the averages of the triplicate runs. The specific details of the pelleted products are presented below.

The 6.25 mm Pellets

The 6.25 mm pellets of the wheat midds ration indicated that the electrical power consumption (table 7) required to produce the pelleted APP ration was about 1.90 KWH/MT lower than the DCP and D+A rations, and it was 1.35 KWH/MT lower than the overall average for all rations containing APP. However, the statistical analysis indicated no significant difference in all levels of phosphorus. The production rate of the APP ration was lower than the DCP and the D+A by about 0.22 and 0.14 MT/hr, respectively; where our analysis indicated a significant difference of the DCP to the APP rations. The pellet durability was approximately the same in the 90% range, there was no indication of significant differences from the analysis. The lower energy

required in pelleting could be the result of the proper conditioning and good absorption characteristic of wheat midds and the combination of APP in rations.

Theoretically, higher electrical power requirements in pelleting yield a lower production rate (Appendix D). The 6.25 mm pellets made with wheat midds and APP gave unexpected results, figure A, as this ration did not result in the expected electrical power to production rate ratio. The experiment was repeated on three consecutive days with similar results. During the processing, it was difficult to maintain the maximum production load, as the "plugged point", in terms of conditioning temperature, varied from 41° to 48°C. It was impossible to maintain the full amperage load. The amperage load reading ranged from 85-100%. In a trial run during the summer where the conditioning temperature was 50°C, the 100% load was achieved with no difficulty. From visual observation and the overall results, it was assumed that the relative humidity of the ambient air had an effect on the meal product prior to conditioning, or that there was a difference in moisture content of the individual ingredients during trial.

Table 7 shows the averages of data from production of the 6.25 mm pellets with dehy alfalfa and all levels of phosphorus source. The electrical power required was higher than for the rations with wheat midds. The dehy alfalfa ration resulted in increased friction in pelleting due to the high fiber content of the ration. The DCP ration had

TABLE 7. PELLETING PROCESS OF 6.25mm PELLETS WITH
WHEAT MIDLINGS AND DEHYDRATED ALFALFA

Phosphorus	Source of Energy	Electrical Consumption KWH/MT	Production Rate MT/hr	Pellet Durability %
DCP	Wheat midds	15.99 ^a	1.23 ^a	98.25 ^a
APP	Wheat midds	14.09 ^b	1.01 ^b	98.32 ^a
D+A	Wheat midds	16.01 ^a	1.15 ^b	98.63 ^a
DCP	Dehy alfalfa	19.61 ^a	1.09 ^a	98.95 ^a
APP	Dehy alfalfa	21.81 ^b	0.95 ^a	99.20 ^a
D+A	Dehy alfalfa	21.33 ^b	0.95 ^a	99.12 ^a

- Values with the same subscripts are not significantly different (P 0.05)

**THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH DIAGRAMS
THAT ARE CROOKED
COMPARED TO THE
REST OF THE
INFORMATION ON
THE PAGE.**

**THIS IS AS
RECEIVED FROM
CUSTOMER.**

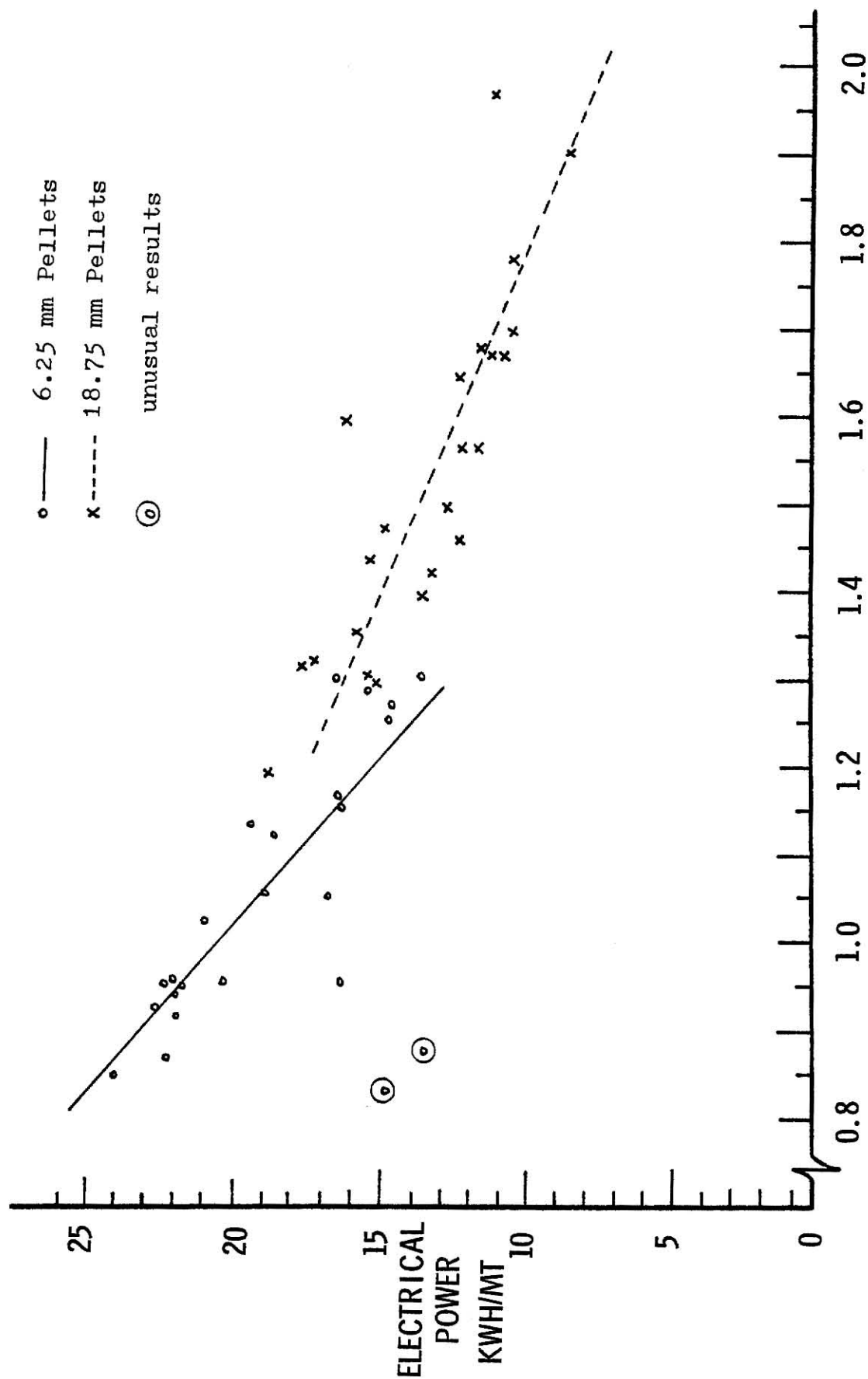


Figure A. Relationship between electrical power for pelleting and production rate.

a better performance in electrical power usage than the APP and the D+A rations by 2.20 and 1.72 KWH/MT, respectively, as it showed a significant difference in our data analysis.

The 18.75 mm Pellets

For the 18.75 mm pellets with wheat midds rations (table 8), the ration with APP had the lowest electrical power consumption of 10.47 KWH/MT, while the DCP ration required 12.27 KWH/MT and the D+A required 11.18 KWH/MT. Power requirements for the three rations were well below the overall average. Also, the APP ration had the best production rate which was due to the lubrication action of the APP solution on the pellet die, resulting in less friction in the die. There was no significant difference in both the power requirement and the production rate on the rations with wheat midds.

The pelleting process for the 18.75 mm pellets of dehy alfalfa and the three phosphorus sources (table 8) required more electrical power than the pellets containing wheat midds. The electrical power requirement for pelleting with APP and D+A was about the same. The electrical power required for the 18.75 mm pellets was lower than that needed for the 6.25 mm pellets, and the DCP ration with dehy alfalfa required the least electrical power at 12.40 KWH/MT with the highest production rate of 1.66 MT/hr. There was a significant difference between the DCP and the APP and D+A rations in both power requirement and production capacity.

TABLE 8. PELLETING PROCESS OF THE 18.75 mm PELLETS
WITH WHEAT MIDLINGS AND DEHYDRATED ALFALFA

Source of Phosphorus	Energy	Electrical Consumption KWH/MT	Production Rate MT/hr	Pellet Durability %
DCP	Wheat midds	12.27 ^a	1.56 ^a	96.47 ^a
APP	Wheat midds	10.47 ^b	1.67 ^a	94.97 ^a
D+A	Wheat midds	11.18 ^a	1.66 ^a	96.53 ^a
DCP	Dehy alfalfa	12.40 ^a	1.66 ^a	96.82 ^a
APP	Dehy alfalfa	13.39 ^b	1.45 ^b	97.70 ^a
D+A	Dehy alfalfa	15.87 ^b	1.31 ^b	97.33 ^a

- Values with the same subscripts are not significantly different ($P < 0.05$).

The total electrical power consumption required in pelletizing was obtained by adding the electrical power required in pelletizing and the electrical power required to produce the steam for conditioning. The data is shown in Table 9. Three rations with wheat midds indicated that the APP ration had an advantage over the DCP ration in total electrical power of both the 6.25 mm and the 18.75 mm pellets by 3.97 and 4.22 KWH/MT, respectively (figure B). This is the equivalent of saving about 20% of energy usage.

For the dehy alfalfa rations, the phosphorus sources had little effect on the total electrical power required for pellet production. The pelleted dehy alfalfa rations did not show a distinct difference (table 10). They were all comparable and they required more electrical power than rations with wheat midds.

Finished Pellets

Shrinkage due to loss of moisture content of the 6.25 mm pellets of both wheat midds and dehy alfalfa was observed. Table 11 shows the moisture content of the two products, including the meal product before and after the conditioning, the finished pellets, and after storage for 45 days in a warehouse. The results indicated that the finished pellets containing APP lost more moisture than the DCP pellets during 45 days of storage in a warehouse. The DCP with wheat midds lost 2.33% moisture content, while the DCP

TABLE 9. TOTAL ELECTRICAL POWER CONSUMPTION FOR
PELLETING WITH WHEAT MIDDINGS

Phosphorus Source	Pellet Size		Conditioning Steam	Pelleting Electrical	Total Energy Consumption
	mm	inch	KWH/MT*	KWH/MT	KWH/MT
DCP	6.25	1/4	5.37	15.99	21.36
APP	6.25	1/4	3.05	14.09	17.14
D+A	6.25	1/4	4.92	16.01	20.93
DCP	18.75	3/4	6.16	12.27	18.43
APP	18.75	3/4	3.99	10.47	14.46
D+A	18.75	3/4	6.11	11.18	17.29

* Electrical power equivalent

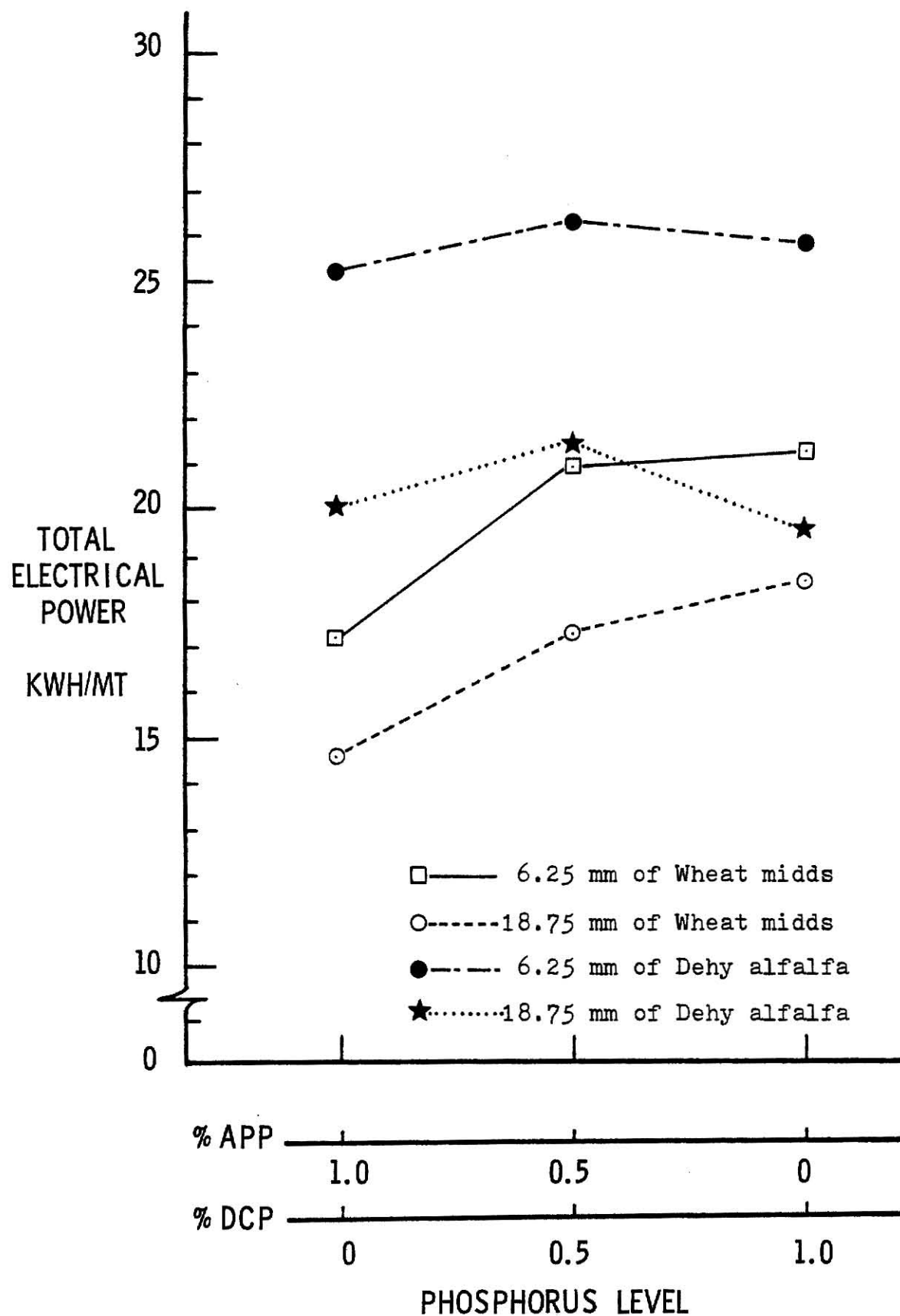


Figure B. Relationship of total electrical power and phosphorus level.

TABLE 10. TOTAL ELECTRICAL POWER CONSUMPTION FOR
PELLETING WITH DEHYDRATED ALFALFA

Phosphorus Source	Pellet Size		Conditioning Steam	Pelleting Electrical	Total Energy Consumption
	mm	inch	KWH/MT*	KWH/MT	KWH/MT
DCP	6.25	1/4	6.29	19.61	25.90
APP	6.25	1/4	3.41	21.81	25.22
D+A	6.25	1/4	5.13	21.33	26.46
DCP	18.75	3/4	7.09	12.40	19.49
APP	18.75	3/4	4.91	15.39	20.30
D+A	18.75	3/4	5.65	15.87	21.52

* Electrical power equivalent

TABLE 11. MOISTURE BEHAVIOR OF 6.25 mm PELLETS DURING PRODUCTION AND STORAGE

Phosphorus	Source of Energy	% Moisture Content			
		Conditioning Before ¹	After ²	Finished Pellet ³	45 Days Storage ⁴ Moisture Lost (3 - 4)
DCP	Wheat midds	9.81	12.47	11.43	9.10 2.33
APP	Wheat midds	12.61	14.58	13.70	11.01 2.61
DCP	Dehy alfalfa	7.55	10.96	10.77	8.42 2.35
APP	Dehy alfalfa	11.13	13.53	13.04	9.78 3.26

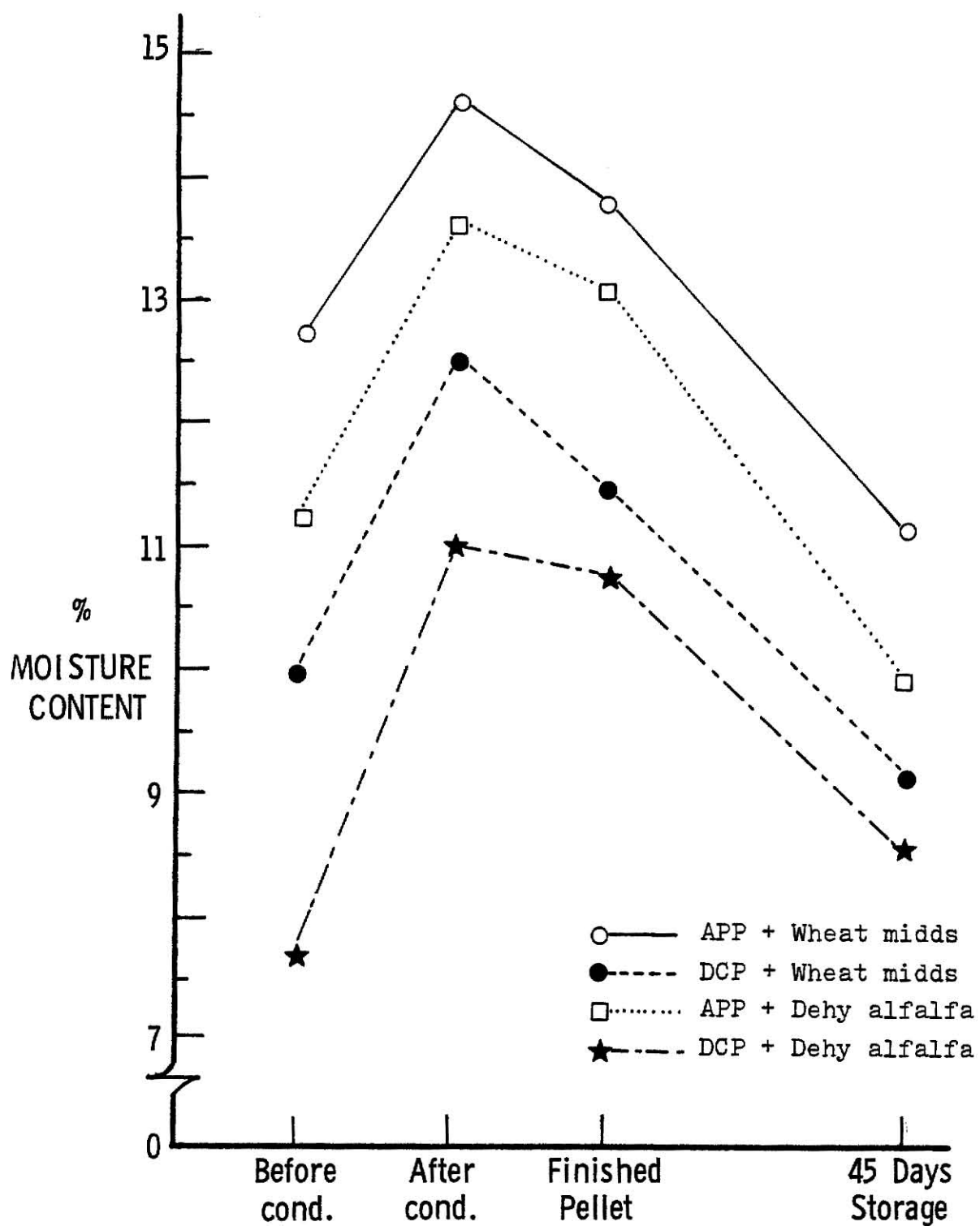


Figure C. Percent moisture content of 6.25 mm pellets during production and storage.

with dehy alfalfa lost 2.35% moisture content. The APP rations with wheat midds and with dehy alfalfa lost 2.61 and 3.26% moisture content, respectively (table 11, figure C). This would be comparable to the shrinkage problem that some feed manufacturers face. The study indicates that the ration containing APP would lose more moisture from the pellets than the DCP ration after 45 days of storage.

Storability

None of the pellets stored in desiccators at 70 and 80% Relative Humidity (RH) appeared moldy at the conclusion of storage period of 45 days at room temperature and 40°C. Pellets stored at 80% RH were friable and easily crushed. The Equilibrium Moisture Content (EMC), shown in Table 12, ranged from 18.0 to 28.8% for feed containing wheat midds, and from 18.6 to 29.4% for feed containing dehy alfalfa for the 70 and 80% RH. Figure D and E show an EMC increase as the RH increased.

Mold Count

Results of the dilution count tests are shown in table 13. There was no increase in the number of viable spores in the stored samples over the initial inoculum. For the pellets stored at 25°C and 80% RH, spore recovery was within the range of the inoculum although the APP ration was higher than average inoculum on pellets with DCP. Spore viability was greatly reduced when feeds were stored at 40°C.

TABLE 12. EQUILIBRIUM MOISTURE CONTENT (EMC) OF 6.25 mm PELLETS AT
DIFFERENT STORAGE CONDITIONS

		% EMC					
Source of		Temp. = 25°C %RH			Temp. = 40°C %RH		
Phosphorus	Energy	50	70	80	50	70	80
DCP	Wheat midds	11.56	17.95	22.77	13.10	20.63	28.79
APP	Wheat midds	12.97	18.61	22.73	13.65	20.57	28.62
DCP	Dehy alfalfa	10.30	18.59	22.60	10.82	20.98	29.13
APP	Dehy alfalfa	11.63	18.98	23.15	12.24	21.20	28.54

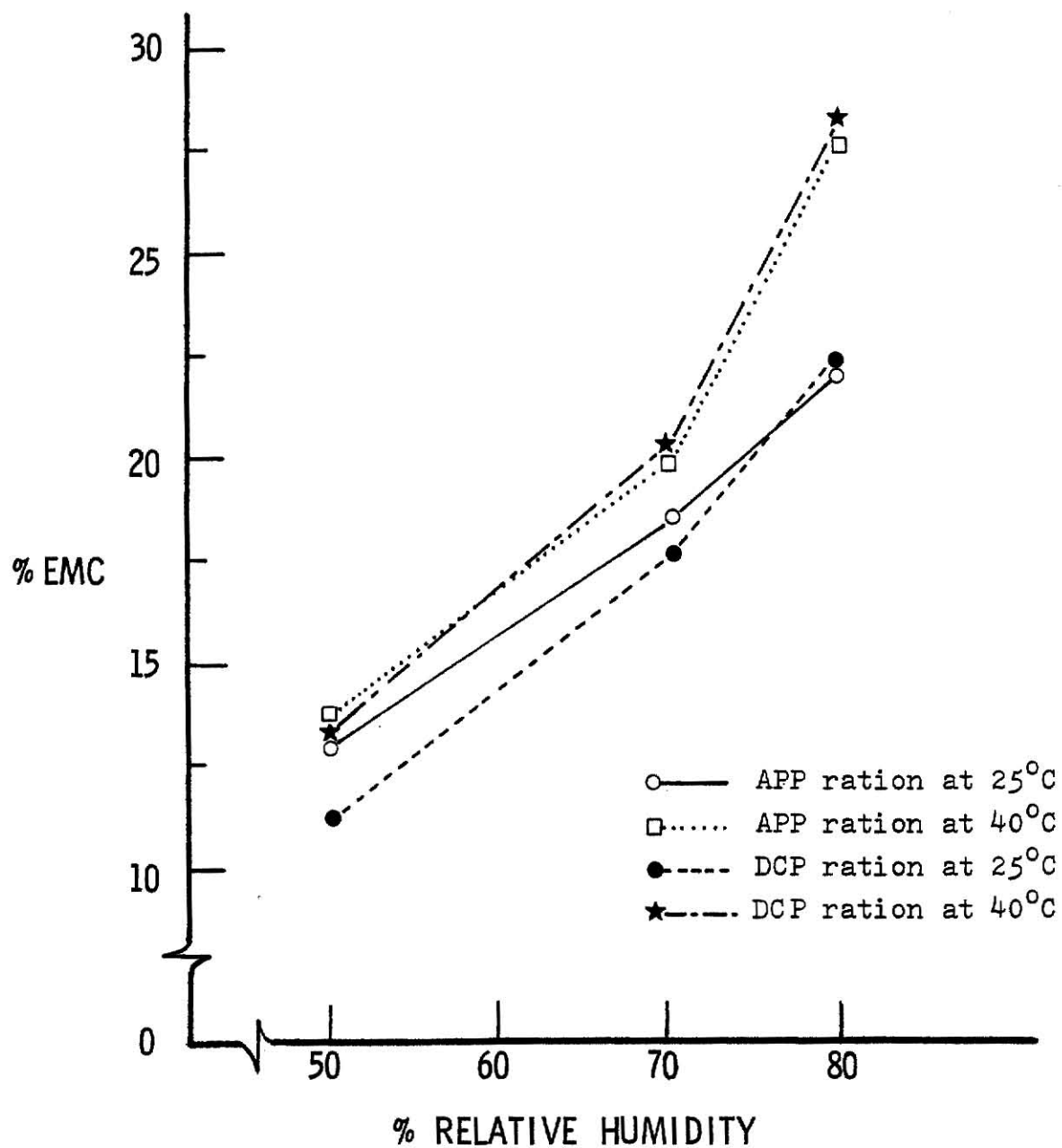


Figure D. Relationship of percent Equilibrium Moisture Content (EMC) and percent Relative Humidity of rations with Wheat middlings.

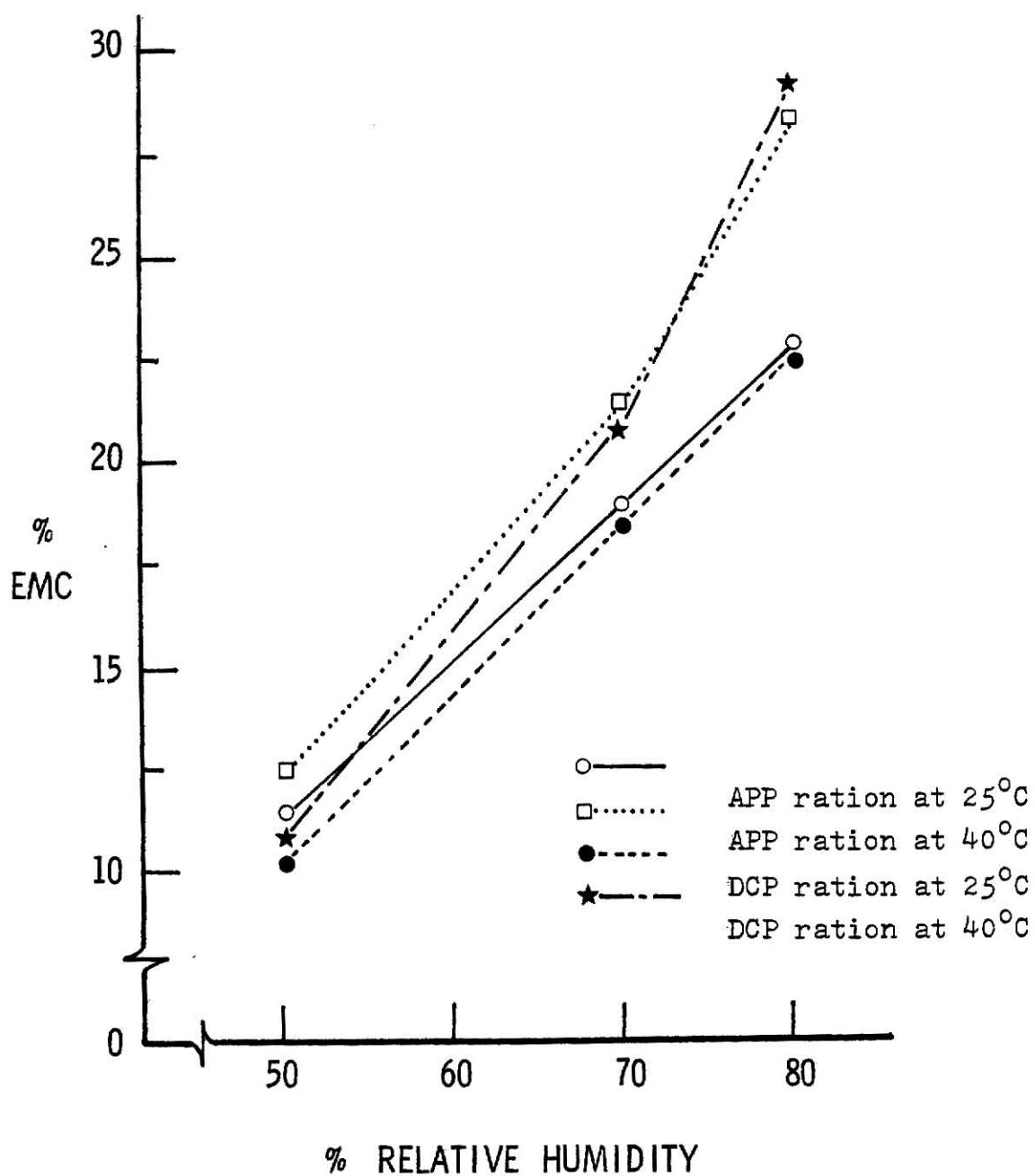


Figure E. Relationship of percent Equilibrium Moisture Content (EMC) and percent Relative Humidity of rations with Dehydrated alfalfa.

TABLE 13. VIABLE SPORES OF ASPERGILLUS REPENS IN PELLETTED FEED
AFTER STORAGE FOR 45 DAYS

Source of Phosphorus		Viable <u>A. Repens</u> spores/gm x 10 ³					
		Temp. = 25°C %RH			Temp. = 40°C %RH		
Energy		50	70	80	50	70	80
DCP	Wheat midds	22.2	21.2	5.5	---	---	1.4
APP	Wheat midds	19.7	21.3	7.8	---	---	2.5
DCP	Dehy alfalfa	16.7	---	2.9	---	---	0.1
APP	Dehy alfalfa	13.4	---	2.9	---	---	0.1

Hygroscopicity of pellets produced by added phosphates, other minerals and urea, increased the EMC and likely created an environment toxic to the mold spores. Colonies which did grow, developed slowly, remained small and had abnormal structures. More colonies grew at higher sample dilutions than the low detections, indicating further that the pelleted feeds, when wet, are inhibitory to storage mold growth. Non-inoculated samples stored at 40°C and 80% RH had low counts; the level of contamination was probably the result of laboratory storage and handling.

The moisture content of the 6.25 mm pellets with wheat midds, ranged from 8.4 to 11.0%. Total mold count from the two bags of the 6.25 mm pellets, containing wheat midds stored for 45 days in the warehouse at temperatures between 15° to 36°C were 100 viable spores/gm for the DCP ration, and 400 viable spores/gm for the ration with APP. Two samples that were collected from each bag indicated some field fungi associated with wheat.

Conclusions

The following conclusions can be reached based upon the studies conducted.

1. Uniform particle size and large surface area per gram of meal to be pelleted resulted in less segregation in mixing and effected the conditioning.
2. The dairy feed supplement containing DCP and wheat middlings mixed better than the ration containing APP and wheat middlings.
3. APP reduced the conditioning temperature by 5° to 10°C resulting in less moisture added from steam.
4. Adding APP in a dairy feed supplement can decrease the steam usage by 3.40 to 5.24 kg-cal/kg or a saving in electrical power of 1.55 to 2.39 KWH/MT in pelleting as compared to the use of DCP.
5. The ration with wheat middlings required a lower conditioning temperature than the ration containing DCP by 6° to 11°C .
6. In the ration with wheat middlings, adding APP reduced the electrical power for pelleting compared with that needed when adding DCP.
7. DCP was proved to be more efficient in electrical power usage in pelleting than APP in dehydrated alfalfa rations.

8. Addition of APP in dairy feed supplement helps reduce the total electrical power used by as much as 20% in pellet production.
9. Pellets stored at greater than 70% relative humidity demonstrated reduced durability when held at 25°C and 40°C for 45 days.
10. The pellets of the ration containing APP would lose 0.3 to 0.9% moisture content more than the DCP ration after storage in a warehouse for 45 days.

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APPENDIX A

Analysis and Physical Properties of Ammonium Polyphosphate (Allied Chemical Company).

Typical Analysis:

- Phosphorus	14.8%
- Nitrogen	10.0%
- Iron	0.5%
- Crude Protein Equivalent	62.5%

Chemical Analysis:

- Phosphorus		14.8%
- Nitrogen		10.0%
- pH		6.0 - 6.2
- Fluorine	less than	0.148%
- Iron	minimum	0.5%
- Arsenic	maximum	3 ppm
- Heavy Metals, as lead	less than	30 ppm
- Moisture		41%

Physical Properties:

- Specific Gravity @ 60°F	1.414
- Density, lbs per gal @ 60°F	11.7
- Salting out temperature, approx.	0°F
- Nitrogen lbs per gal	1.15
- Phosphorus lbs per gal	1.72
- Density lbs per cubic foot	88.95

APPENDIX B

Heat Balance of Steam for Processing

- H.B. Pfost, Feed Manufacturing Technology, 1976.
p. 59-64, AFMA, Arlington, Virginia.

Theoretical Aspects:Heat balance of steam for processing

- h_f = enthalpy of heat content BTU/lb in liquid (saturated liquid)
- h_{fg} = latent (evaporated steam) BTU/lb
- h_g = total (saturated vapor) BTU/lb
- q = heat required BTU
- C_p = specific heat BTU/lb $^{\circ}$ F
- ΔT = change in temperature $^{\circ}$ F
- W = weight of steam lb
- h_1 = enthalpy of original steam
- h_2 = enthalpy of final stage

Steam condition with guage pressure of 90 psi, the absolute pressure may assume to be = atmospheric + guage:

$$15 + 90 = 105 \text{ psia}$$

- assume a steam quality of 90%
- specific heat of the product to be 0.3998 BTU/lb $^{\circ}$ F
- we find this pressure enthalpy by extrapolating from the steam table we obtained.

$$\begin{aligned} \text{at } 105 \text{ psia} \quad h_f &= 302.1 \\ h_{fg} &= 886.0 \\ h_g &= 1188.1 \end{aligned}$$

at 14.7 (approx. 15) psia

$$h_f = 180$$

$$h_{fg} = 970$$

$$h_g = 1150$$

Since the steam quality is 90%, the original enthalpy of steam will be:

$$\begin{aligned} h_1 &= h_f + (\% \text{ quality}) h_{fg} \\ &= 302.10 + (0.90)(886.0) \\ &= 1099.50 \text{ BTU/lb} \end{aligned}$$

After the conditioning, the final condition of condensed steam will be liquid at 154°F and a pressure of 14.7 psia, and the final enthalpy will be:

$$\begin{aligned} h_2 &= \text{conditioning} - 32 \\ &= 154 - 32 \\ &= 122 \text{ BTU/lb} \end{aligned}$$

The heat required the heating of the product will be:

$$\begin{aligned} q &= C_p W \Delta T \\ &= (0.3998 \text{ BTU/lb}^\circ\text{F})(1 \text{ lb steam})(154 - 90^\circ\text{F}) \\ &= 25.59 \text{ BTU/lb (11.84 kg-cal/kg)} \end{aligned}$$

Weight of steam required per pound of mash:

$$\begin{aligned} (h_1 - h_2)W &= 25.59 \text{ BTU/lb (= } C_p W \Delta T) \\ W &= \frac{25.59}{(1099.50 - 122)} \\ &= 0.0262 \text{ lb steam/lb mash} \end{aligned}$$

Example:

For our CPM 25 hp pellet mill, capacity 2 tons/hr

$$W_{\text{steam}} = (2 \text{ tons/hr})(2000 \text{ lbs/ton})(0.0262 \text{ lb steam/lb mash})$$

$$\text{Total} = 104.80 \text{ lbs/hr at full load}$$

Actual capacity at 3880 lbs/hr

APPENDIX C

Ksu pilot feed mill electrical power calculation in pelleting, equations developed by H.B. Pfost, the information was obtained through personal communication.

Horsepower of Pellet Mill

$$HP = \frac{I \times E \times EFF \times PF \times 1.73}{746 \text{ watts}}$$

where: I = amperage

E = voltage

EFF = efficiency of 90%

PF = power factor of 80%

1.73 = sq. root of 3 (three phases motor)

$$HP = \frac{(34 \text{ amp})(440 \text{ volts})(0.90)(0.80)(1.73)}{746 \text{ watts}}$$

= 24.978 hp. (manufacture specification is 25 hp.)

Electrical Power Calculation in KWH/ton of Production

$$(\text{elec. power}) = \frac{k \times n \times \text{Rev.}}{\text{lbs of pellets}}$$

Derivrd from:

$$P = \frac{1.33 \times 2 \times 10 \times 4 \times \text{Rev.}}{\text{ton}}$$

where: 1.33 = KWH factor

2 = ratio factor (rolls 2:1)

10 = current transformer used

4 = counter per disc revolution

Rev. = number of revolutions on disc

therefore: k = $1.33 \times 2 \times 10 \times 4 = 106.4$

n = $(2000 \text{ lbs/ton}) / (1000 \text{ lbs batch}) = 2$

we have: Electrical Power = $\frac{106.4 \times 2 \times \text{Rev.}}{\text{lbs of pellets}}$ in KWH/ton
(or KWH/MT)

$$\begin{aligned}\text{Steam required} &= \frac{104.80}{4000} (3880) \\ &= 101.87 \text{ lbs/hr}\end{aligned}$$

$$\begin{aligned}\text{Electrical power} &= \frac{(25.59 \text{ BTU/lb})(2000 \text{ lbs/ton})}{10000 \text{ BTU/KWH}} \\ &= 5.12 \text{ KWH/ton} \\ &\quad \text{or } 5.63 \text{ KWH/MT}\end{aligned}$$

APPENDIX D

"Production Rate in Relation to Electrical Power in Pelleting"

The production rate in relationship with electrical power based on a 25 hp pellet mill.

Derived by the author:

$$Y = \frac{2000 \text{ lbs/ton} \times 25 \text{ hp}}{P \text{ KWH/ton} \times 1.38 \text{ hph/KWH}}$$

where: Y = production rate
 25 hp = horsepower of pellet mill
 1.38 = conversion factor of horsepower-hr/KWH
 P = electrical power required in production

This equation shows the inverse relationship of production rate to electrical power required in production.

$$\text{Production Rate} = \frac{2000 \text{ lbs/ton} \times 25 \text{ hp}}{P \text{ KWH/ton} \times 1.38 \text{ hph/KWH}}$$

in terms of ton/hr (or MT/hr).

In other words, the production depends on the electrical power (KWH/ton); higher the electrical power will cause the lower production rate, the lower the electrical power the higher the production rate.

This effect is due to the friction in the pellet die during pelleting, if the meal product is difficult to pellet which means it required more electrical power to force the compact ingredient through the die, resulting lower production rate.

Acknowledgements

The author wishes to express his sincere appreciation and gratitude to Dr. Charles W. Deyoe, his major professor and Head of the Department of Grain Science and Industry, for the financial support and the use of facilities and equipment to perform this research.

The author signifies truthful appreciation to Dr. Harry B. Pfost for initiating and guidance of this project. Thanks are extended to Mrs. Rosemary Burroughs, Dr. George Milliken and Dr. V.G. Rao for their assistance and advice. Thanks are also extended to other faculty in his department and to the members of his advisory committee.

A special recognition to Dr. Keith C. Behnke for his encouragement and endless counseling on this project. Thanks are also due to Mr. Donald Duncan and the KSU feed mill crew for their assistance and understanding throughout his research.

Finally, the author wishes to express sincere appreciation to his parents, Mr. and Mrs. Seri Tangprasertchai, and his sisters and brother, and his special friend, Uraiwan Tangkongchitr, for their moral support and encouragement throughout the course of his work.

PELLETING PERFORMANCE AS AFFECTED BY AMMONIUM POLYPHOSPHATE

by

PICHAJ (PETE) TANGPRASERTCHAI
B.S., Kansas State University, 1977

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1980

Abstract

Studies were conducted to evaluate the effects of using "Ammonium Polyphosphate" (APP) solution as a replacement for dicalcium phosphate (DCP), as the phosphorus source in a dairy feed supplement. The experimental design was based on two phosphorus sources, two sources of nutrient energy, wheat middlings and dehydrated alfalfa, and the production of 6.25 mm and 18.75 mm diameter pellets.

The processing of pelleted feed depends on many variables such as: ingredient composition, particle size, steam and steam quality, ambient conditions, pelleting temperatures and pellet sizes. With these factors in mind, the experiments concentrated on the energy consumption in the production of pelleted feed. The following aspects were considered:

1. Steam required in conditioning the meal before entering the pelleting process.
2. Amount of electrical power required in pellet production.

APP contains 41% moisture as a solution. Some benefit was expected in terms of a reduction in steam added as the bound moisture would likely reduce the friction in the pellet die, therefore, requiring lower electrical power consumption, and increased pellet production.

It was found that the APP with the wheat middlings ration had an advantage over the ration with DCP. A lower conditioning temperature was required which resulted in the saving of total electrical power of nearly 20%. The APP and DCP rations with dehydrated alfalfa indicated the same level of total electrical power required in production.

The finished pellets were stored for 45 days during the period of August through September in a normal warehouse condition. The APP ration lost more moisture (0.3 to 0.9%) than did the DCP ration.