

PREPARATION OF FEED ADDITIVES CONTAINING LIQUIDS

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TABLE OF CONTENTS

INTRODUCTION .....	1
REVIEW OF LITERATURE .....	4
Liquid-Solid Mixing .....	4
Adsorption .....	7
ADSORPTION OF POLYOL BY VARIOUS MATERIALS .....	10
Description of the Method Used .....	10
The Results and the Analysis .....	12
DEVELOPMENT AND TESTING OF PRACTICAL PREMIXES .....	19
Mixing Test .....	21
Bag Test .....	22
CONCLUSIONS .....	24
ACKNOWLEDGMENTS .....	26
LITERATURE CITED .....	27
APPENDICES .....	29

## INTRODUCTION

Most of the research on bloat has been done in New Zealand and the United States. The most generally accepted theories on bloat will be described here to give some insight on the function of antifoaming agents against bloat.

Bloat is considered to be the foaming of the contents of the rumen and the reticulum. Bloat can be differentiated into: legume-bloat and feedlot-bloat.

In a normal rumen fermentation, microorganisms of the rumen produce a large amount of gas. When cattle are fed bloat-producing rations, this gas is trapped in the ingesta to form a stable foam, which inhibits normal functioning of the rumen. There are two possible ways that the foam can cause a malfunction of the rumen:

- a) Foam inhibits the eructation mechanism of the rumen, and the animal, therefore, cannot ruminate his feed.
- b) The gases formed by the fermentation are retained in the foam and cannot leave the rumen by belching.

Legume-bloat is caused by substances present in the legumes. Proteins, saponins, and pectins play a role in the development of bloat. Legumes contain larger amounts of saponins than grasses. Proteins and saponins have a high surface viscosity and can produce highly stable foams. Legume-bloat occurs often in dairy cattle on a pure legume pasture. Legumes and grasses also contain lipids which have an antifoaming action. Antifoaming agents decrease the surface tension of the rumen fluid; they displace

saponins and proteins at the surface layer and produce an unstable foam.

Feedlot-bloat occurs when beef cattle are fed on high-concentrate rations with a restricted intake of roughages. In this case, bloat studies give reason to believe that the foaming agent is produced by bacteria of the rumen and is a polysaccharide slime. This is, therefore, quite a different type of bloat (8). Feedlot-bloat is increased by the addition of crude soybean oil in the ration, while legume bloat is prevented by vegetable oils. Detergents have not shown any positive effect as antifoaming agents in feedlot-bloat.

There is some evidence that susceptibility to legume-bloat can be inherited. Bartley (2) reported that saliva has an anti-bloating effect; saliva should release the gas from the foam. If saliva has an influence on the susceptibility of the animal towards bloat, the inheritance effect can be explained. Difference in susceptibility to bloat can be a difference in the production of saliva or a difference in the composition of the saliva. The active antifoaming agent in saliva has been found to be mucin (3). The antibloat effect of hay can be explained by the large secretion of saliva which is stimulated by the hay. This also can explain the bloat-provoking effect of damp or wet legumes which reduce the salivary flow.

Cole and Boda (4) reviewed the influence of antibiotics on bloat. They came to the conclusion that the antibiotics prevent bloat by inhibiting some of the bacterial growth and fermentation, which in turn reduces gas production in the rumen. They 'also

mentioned another possibility. Lipids in grasses and legumes, which have an antifoaming effect, are modified by the microorganisms of the rumen during the fermentation and have then lost their action. Antibiotics decrease the bacterial fermentation and also this lipid modification.

Various mineral oils, vegetable oils, and animal fats are used as antifoaming agents to control bloat. Silicone-preparations and detergents have been used, but silicones have proved to be unreliable.

There are various ways to administer the antifoaming agent to the animal. The agent can be added to the drinking water of the animal, but a disadvantage of this is that there is too large a variation of intake between animals and even from day to day for one animal. In the case of wet pastures, the animal will tend to drink less, while the conditions for the occurrence of bloat are more severe.

A second method of effective control is the spraying of fat or oil over the pasture. The pastures are not damaged when the normally low levels of fat or oil are used.

Subacute cases can be treated by administering the antifoaming agent directly into the rumen by stomach-tube, drenching, and other ways.

Perhaps the best method of preventing bloat in dairy cattle is to administer their daily dose of antifoaming agent with their feed. The intake of the agent by the cow can be controlled by this method.

The bloat preventive agent, a nonionic surfactant, is a polyoxypropylene polyoxyethylene block polymer. All properties of this new product have not been determined. The material is a liquid with a high molecular weight. The name "polyol" is used in this thesis to identify one specific compound which was supplied by Smith, Kline and French Laboratories under the code number S K and F 18667.

The purpose of this study was to find a satisfactory carrier for polyol. This product had to be palatable for cattle, have good handling properties, and be highly adsorbent. The work was done in cooperation with the Department of Dairy Science, which conducted palatability tests and experiments on the bloat-preventing effectiveness of the different mixtures.

## REVIEW OF LITERATURE

### Liquid-Solid Mixing

While much research has been done on solid-solid mixing, relatively little is known about solid-liquid mixing, where the level of liquid is so low that the mix still has the properties of a solid and is dry in appearance and behavior. If more liquid is added, the mixture can become a paste, a slurry, or a suspension.

Michaels and Puzinauskas (10) reported on experiments in which they mixed dextrose-koalinite and water in a finger-prong mixer. The torque on the mixing unit, due to the resistance met during the mixing, was recorded with a Brabander farinograph.

The influence of the amount of water on the torque was tested. (In the preliminary research for this project, this method was tried, but viscosity of the polyol was too large for the Brabander farinograph to record the torque, so this method was abandoned.)

Michaels (10) defined the several states which exist when a liquid and a solid are mixed. He differentiated among: pellet-powder state, pellet state, plastic state, sticky state, and liquid state. All these terms speak for themselves. Pellets develop when droplets of a liquid are added to a solid which is powdery. The solid then tends to form balls. This is typical for powders of very small particles; when the solid particles are larger, agglomerates are more difficult to form. Small particles can become closely packed, which makes it possible for liquid to form liquid bonds between the particles. The capillary pressure within the liquid bonds provides the forces which keep the particles together as balls (12).

After the liquid is added to and mixed with the solid, the liquid can be adsorbed by the solid and is present as a thin surface layer on the particles. The liquid also can penetrate in the particles and be adsorbed in the intraparticle voids. The liquid may be further absorbed by or react chemically with the solid (6).

The liquid should be added to the solid in small droplets to prevent lumps and to provide better mixing performance. Spray-nozzles are used which divide the liquid into small droplets. The spray-nozzles have to be situated in the mixer in such a way

that the liquid droplets never reach the wall of the mixer before they have contacted the solid particles, otherwise caking on the wall of the mixer will result.

The type of mixer to use will depend on how critical the mixing requirements are. In the mixer, liquid and solid have to be kept constantly in motion and no dead corners may be present in the mixer. For precision mixing, a tumble-blender can be used, if possible with a high-speed agitator. When a high precision is unnecessary, ribbon mixers, mullers, and planetary-paddle mixers can be used, as long as the liquid is added with a spray-nozzle. Another type of mixer, which often is used for the mixing of molasses through feed, is one which has fast-rotating blades. The blades have the form of knives, and spread the liquid through the solids by shear force. When particles are softened by the liquid or weak of structure, they will become partly ground by some of the mixers such as the muller and the rotating blade mixer, which is an undesired side effect (6).

Of importance in liquid-solid blending is the surface tension of the liquid. A liquid with a low surface tension has good wetting properties; that means that the liquid spreads itself over the whole particle and penetrates the particle if possible. The liquid tries to cover a surface as large as possible. In the case of liquids with a high-surface tension, there will be a formation of agglomerates in the form of lumps which is intensified by the fact that the droplets run together easily.

If a liquid with a low-surface tension is to be mixed with a solid, the best result is obtained when the solid particles are

coated with the liquid. When liquid with a high-surface tension is mixed with a solid, the best that can be done to secure an even distribution is to form globules of a certain size on a rotating disk or drum pelleter; the globules are dry and have good flow properties.

### Adsorption

Adsorption can be defined as the condensation of gases, liquids, or dissolved substances on the surface of the solids; the molecules here are attached to sites in the solid. There is a difference in adsorption and absorption; absorption of a liquid by a solid body means that the liquid has penetrated into this solid body and is homogeneously distributed in the solid body. Often, however, it will be difficult to recognize a difference as for example, in the case that a liquid is adsorbed on the internal surface of the particles.

When a material is adsorbed, it has formed a layer on the surface of the adsorbing material. To evaluate adsorption capacity of different solids, an evaluation of the surface area will be necessary. The specific surface area of a solid material is the surface area of one gram of this material.

The specific surface area of a solid consisting of spherical particles can be calculated as follows:

There are in one gram of the material,  $N$  particles, all with the same diameter  $d$ .

The volume of a sphere is  $(1/6) \pi d^3$ .

The weight of one sphere is  $(1/6) \pi d^3 \rho$ , where  $\rho$  is the true density.

$N$  can be calculated and is  $6/(\pi d^3 \zeta)$ .

The specific surface area of the materials is  $(6\pi d^2)/(\pi d^3 \zeta) = 6/(d \zeta)$ .

The specific surface area for a material consisting of spherical particles of different diameters is:

$$S = \left( \frac{6}{\zeta \cdot 100} \right) \left( \frac{P_1}{d_1} + \frac{P_2}{d_2} + \dots + \frac{P_n}{d_n} \right)$$

Where  $P_1, P_2, P_n$  are the present weight of each group of particles with a diameter of  $d_1, d_2,$  and  $d_n,$  respectively. Spheres, as well as cubes, have a constant of 6 in the equation for their specific surface area. This constant or proportionality factor,  $P,$  is larger than six for other bodies (7).

The adsorption of a liquid by a solid material will depend on the following factors:

- a) The specific surface of the solid material.
- b) The internal surface of the solid material.
- c) The constituents of the solid material: fiber, moisture, protein, fat, inorganic material, etc.

The specific surface area of the solid material will depend, according to the formula  $S = P/(d \zeta)$  on: the proportionality factor, the diameter of the particles, and the density of the solid.

The specific surface area and the internal surface area determine the total surface area. Different methods have been developed to determine the specific surface area and the total surface area. For adsorption phenomena, we must deal with the external as well as the internal surface area. This internal surface area is formed by microcapillaries to the interior of the particles.

One method used to measure the specific surface area is based on measuring the permeability of a bulk of the material by a gas or a liquid. Gas or liquid is passed through a layer of the material in this method. The flow resistance of the gas or the liquid can be measured, and depends on the surface of the particles. The internal surface, however, is not measured with this method (7, 5).

Two other methods are directly based upon the adsorption capacity of the solid material. In the first method, the amount of gas required to cover the whole surface area by a monolayer of gas molecules is measured (5). In the other method, the solid material is placed in a dye solution. The solid material will adsorb the dye on its surface. The concentration of the dye can be measured colorimetrically before and after the solid material is placed in the dye solution (7).

Singh (13), in a study of proportioning for a concrete mixture, reported that he used the specific surface of the aggregates to determine the necessary amount of water-cement for the concrete mixture.

A method to determine the liquid-holding capacity of a solid material is described in the A.S.T.M. Standard (1). This is a standard method which is used to determine the moisture-holding capacity of soils. The moisture-holding capacity, or as named in this case, "the centrifuge moisture equivalent of a soil," is expressed as the amount of moisture as a percentage of the weight of the oven-dried soil, retained by the soil, which first has been saturated with water and then subjected to a centrifugal

force equivalent to 1000 times the force of gravity for one hour. In the earlier described methods, the amount of gas or dye that was adsorbed as a monolayer of molecules was measured. With this method there will be more than one layer. The method, therefore, gives only relative values which can be used to evaluate the adsorption capacity of various materials.

In this study, a method similar to the one described above is used to determine the adsorption capacity of the various materials.

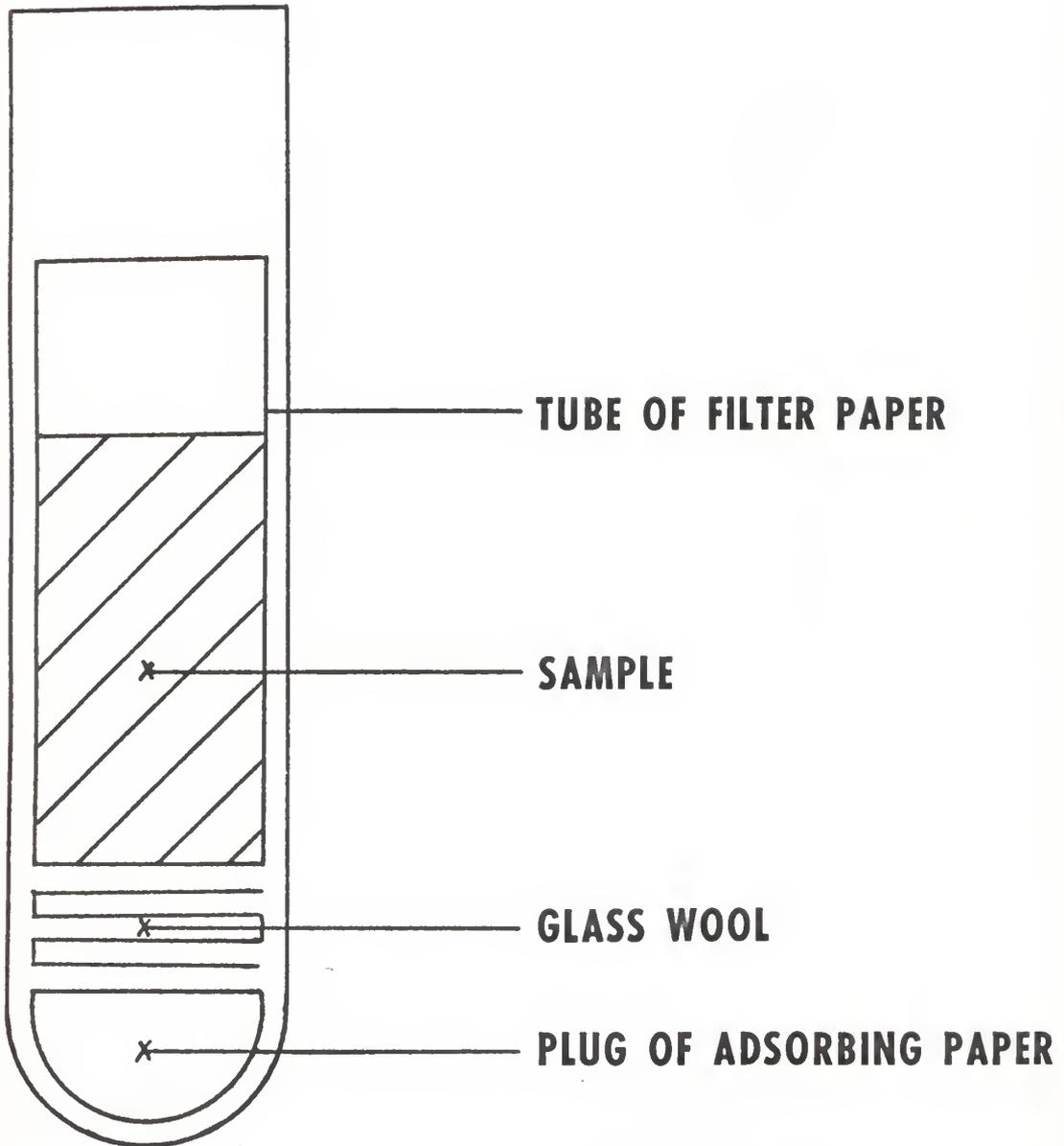
## ADSORPTION OF POLYOL BY VARIOUS MATERIALS

### Description of the Method Used

The material to be tested for its adsorption capacity was mixed with an excess of polyol in a beaker. The polyol was mixed thoroughly through the material and was given 24 hours to soak and to be adsorbed.

After 24 hours, the mixture was stirred again to insure that all particles were evenly covered with an excess of polyol. Two samples were taken from this mixture and placed in test tubes (Fig. 1).

The bottom of the test tube was filled with a plug of adsorbing paper which had to adsorb the excess polyol. Above this plug there was a layer of glass wool which separated the paper plug and the sample material and insured that no polyol would run back to the sample. The sample of two grams was placed in a tube of filter paper, which itself was placed in the test tube and rested on the glass wool.



**FIG. 1 TEST TUBE**

The test tubes with the samples were placed in a centrifuge and were centrifuged for an hour at a force of 400 times the force of gravity. The samples were weighed after they were centrifuged. The adsorbed polyol was expressed as a percentage of the weight of the original solid material.

In order to secure reproducible results, some preliminary trials might be required. When the solids and the polyol were stirred after the 24 hours, no polyol should be at the bottom of the beaker. After centrifuging, it was necessary that the plug of adsorbing paper be wetted to assure that an excess of polyol was present.

Tests were conducted with various materials, and also for different particle sizes of the materials. The materials were sieved on a Ro-Tap sieve. For calculations the arithmetic mean of the diameters of the two sieves was used; the sieve which the particles passed through, and the sieve on which the particles stayed, gave these diameters.

Solid materials selected included representative types of common feed materials. Other materials which are commonly used as liquid carriers also were tested. One material, wood fiber balls, is not available commercially, but was tested because of its rather obvious desirable characteristics.

#### The Results and the Analysis

The adsorption capacity of various materials and different particle sizes was determined (Tables 1 to 11).<sup>1</sup> The values

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<sup>1</sup> All tables appear in the Appendix.

represent the average of two determinations.

The wood fiber balls were globules and were composed of ground wood or wood fiber;<sup>1</sup> they were formed on a rotating pelleting dish. The water which was used to bind the wood fiber particles during pelleting was removed later by drying. The woodballs formed nearly perfect spheres. Figure 2 shows the amount of polyol adsorbed as a percentage of the weight of the original material (y) and the reciprocal of the diameter of the particles (x). When x and y were plotted against each other, a straight line of the equation  $y = 51.4 + 0.01026x$  could be drawn through the points.

The internal surface could be assumed constant, and was responsible for the factor 51.4. The factor  $0.01026x$  expressed the relation between the amount of polyol adsorbed on the specific external surface and the reciprocal of the diameter. The amount of polyol adsorbed on the external surface was:

$C_s = (C \cdot 6) / (d \cdot \rho) = 0.01026/d = 0.01026x$ . The wood fiber balls were spheres; the use of a proportionality factor of 6, therefore, was justified. The true density of the wood fiber balls was  $1.2 \text{ gm/cm}^3$ . C was a constant and had the value  $(1.2) (0.01026) / (6) = 0.002$ .

Most of the common feedstuffs of vegetable origin had a true density of about  $1.40 \text{ gm/cm}^3$ . They would give a coefficient for x, in the case of spheres, of  $(6/1.4) \times 0.002 = 0.0086$ . From the equations of Table 12, it could be concluded that ground corn and ground milo approached this value of 0.0086 as coefficient for x

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<sup>1</sup> An experimental product furnished by the Masonite Corp., Chicago, Illinois.

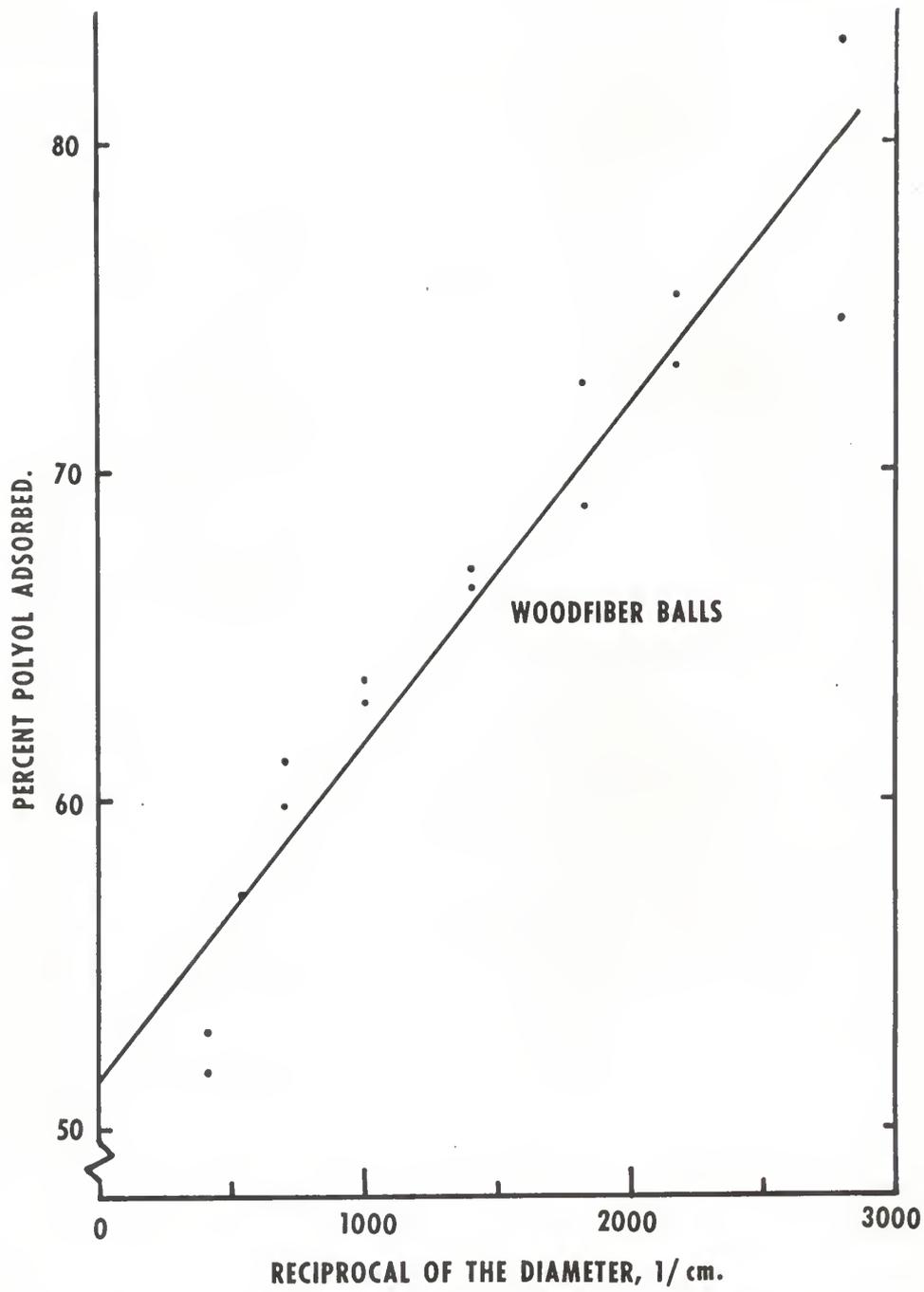


FIG. 2. Relationship between particle diameter and adsorption capacity.

(Fig. 3). Products such as soybean meal and wheat bran, both consisting of flake-like particles, were far from this value. This was still in accordance with the formula  $S = P/(d^2)$ ; there was here, however, a change in specific surface because of the change in particle diameter and because of the change of the proportionality factor. The relationship was linear, however (Fig. 4).

By sieving, the largest diameter was measured or in this case because the particles had the form of flakes, the side with the largest surface. During the grinding process, the length and width tended to become reduced before the thickness, which could be assumed constant until length and width were of the same size. When the particles were ground so far that the three diameters were about equal, the line would arrive at an equation  $y = a + 0.086x$ . This moment arrived when the proportionality factor was reduced to 6. A change in equation would result in a deflection of the curve. This was never found, however, presumably because this happened when the diameter was very small--less than  $300\mu$ . At this size, the particles were packed close together and the liquid was held between them by capillary forces, which made the results in this range unreliable.

When the flakes had the shape of circular disks, the equation became:

$$CS = C (2 + 4 d_2/d_1) 1/d_2$$

The amount of polyol adsorbed by these flakes was:

$$y = a + 0.002 (2 + 4 d_2/d_1) 1/d_2$$

Here was  $d_1$  the large diameter and  $d_2$  the small one. The diameter

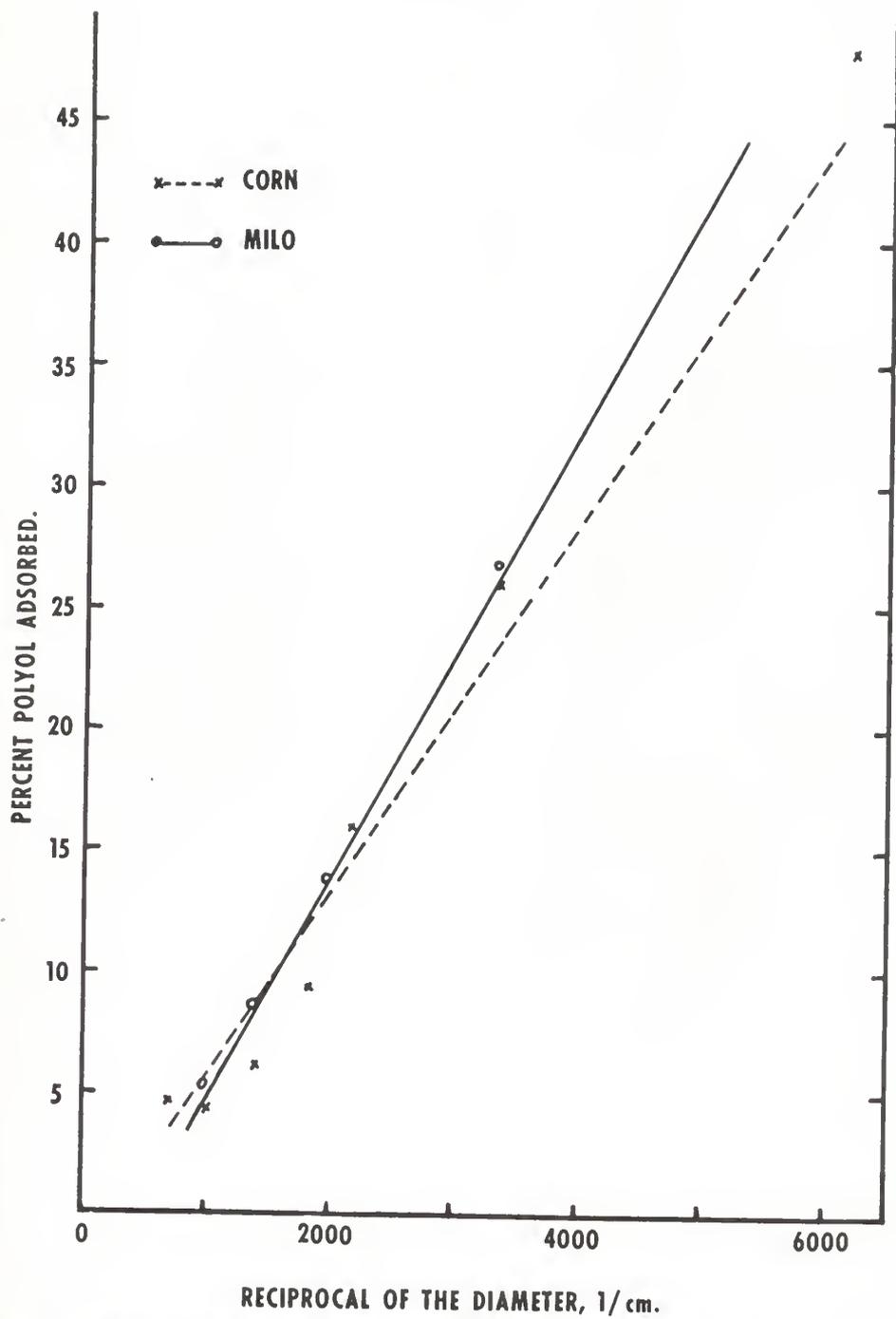


FIG. 3. Relationship between particle diameter and adsorption capacity.

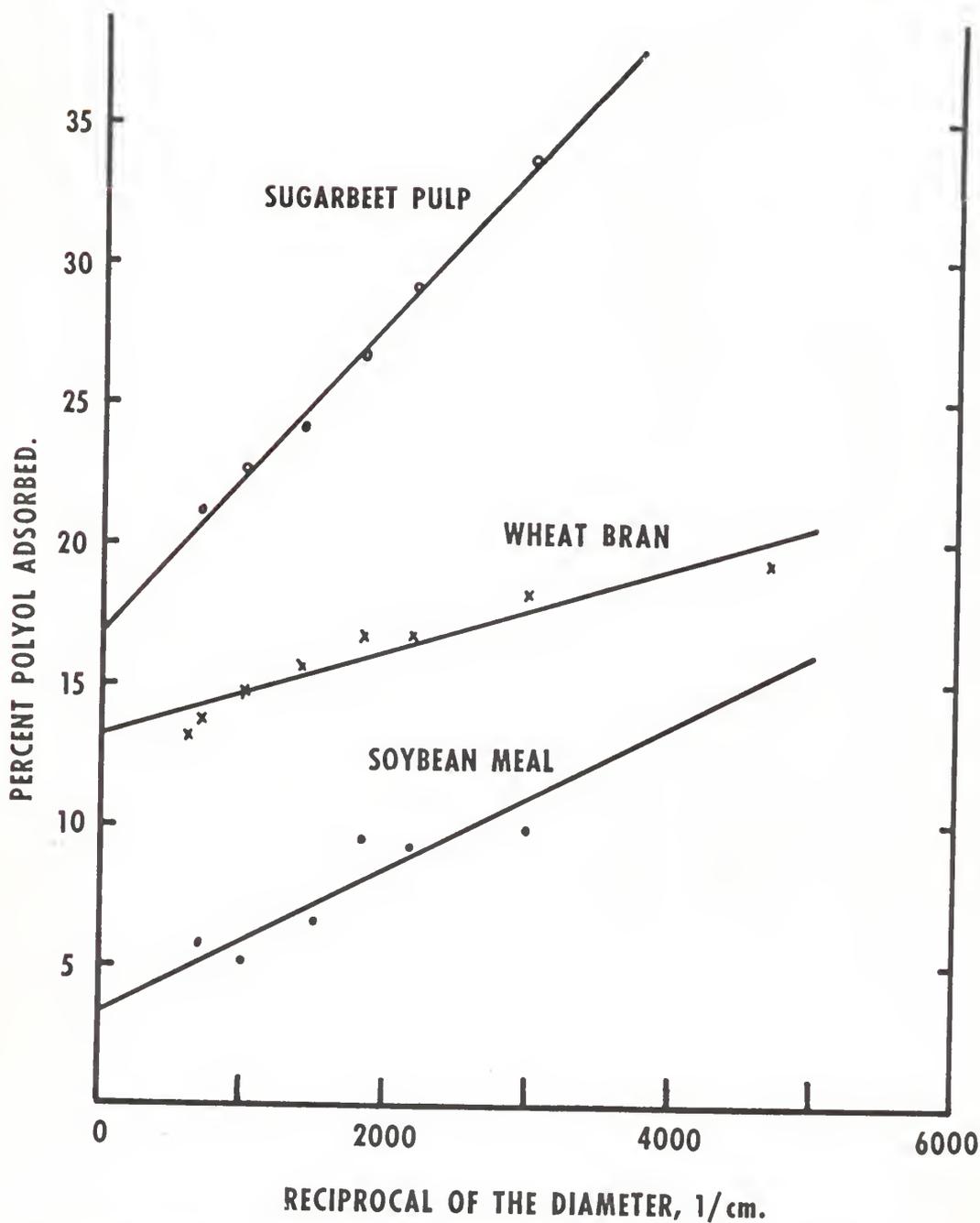


FIG. 4. Relationship between particle diameter and adsorption capacity.

$d_2$  was assumed constant. This equation for disks was linear. This equation changed to  $y = a + 0.0086x$  when  $d_1 = d_2$  and  $\rho = 1.4 \text{ gm/cm}^3$ .

Rice hulls and corn germ meal did not show a linear relationship because particles of various sizes differed in the content of fiber and other constituents.

Table 12 shows a positive correlation between the adsorption of polyol by the internal surface and the fiber content of materials of plant origin or, in other words, a high fiber content indicates a larger internal surface.

Table 11 gives the adsorption capacities of different materials without regard to their particle size. The values give approximate values of the relative adsorption capacities.

Vermiculite was supplied by W. R. Grace and Company, Chicago, Illinois, and was marketed under the name of Verxite. Verxite was defined in the 1962 Official Publication of the Association of American Feed Control Officials, Inc., as an "exfoliated magnesium-aluminum-iron silicate containing not less than 98 per cent exfoliated hydrobiotite." The physical properties of this material made it an interesting carrier for liquids. The bulk density of the vermiculite was low and was in the range of 5 to 7 pounds per cubic foot; the true density was approximately 0.23 (Table 13), and could be compared there with the values of the other materials. The organic materials had a density in the range of 1.20 to 1.50  $\text{gr/cm}^3$ , while minerals had a density above 2  $\text{gr/cm}^3$ . An exception was the vermiculite with a density of 0.23  $\text{gr/cm}^3$ , which made it a good liquid carrier, while the other

minerals had only small liquid adsorbing capacities. The density was determined with an air pycnometer.

The adsorption capacity of vermiculite was determined under a centrifugal force of 400g during one hour. The values are presented in Table 9 and plotted in Fig. 5. In this case, the results were different from those obtained for other materials. The adsorption capacity of the vermiculite decreased with a decrease in particle diameter. This might be explained by the fact that most of the polyol, which was adsorbed, was present in the capillaries of the particles. When the particles became smaller, the volume of the capillaries became smaller in relation to the surface area, and the adsorption capacity decreased. Vermiculite had the highest adsorption capacity found.

The most satisfactory carrier for liquid was found to be vermiculite. Vermiculite had a high adsorption capacity, especially for the coarser particles.

If a material other than vermiculite is used, then we need to look for a light material; if from vegetable origin, for a high fiber content, and if possible, divided into small particles. Materials consisting of very small particles cannot be used satisfactorily because of caking and poor flowability.

#### DEVELOPMENT AND TESTING OF PRACTICAL PREMIXES

All rations were mixed in the feed mill of the Department of Flour and Feed Milling Industries. Mixers used included a small ribbon mixer with a mixing capacity of 3 to 4 cubic feet and a larger ribbon mixer with a mixing capacity of around 12.5 cubic

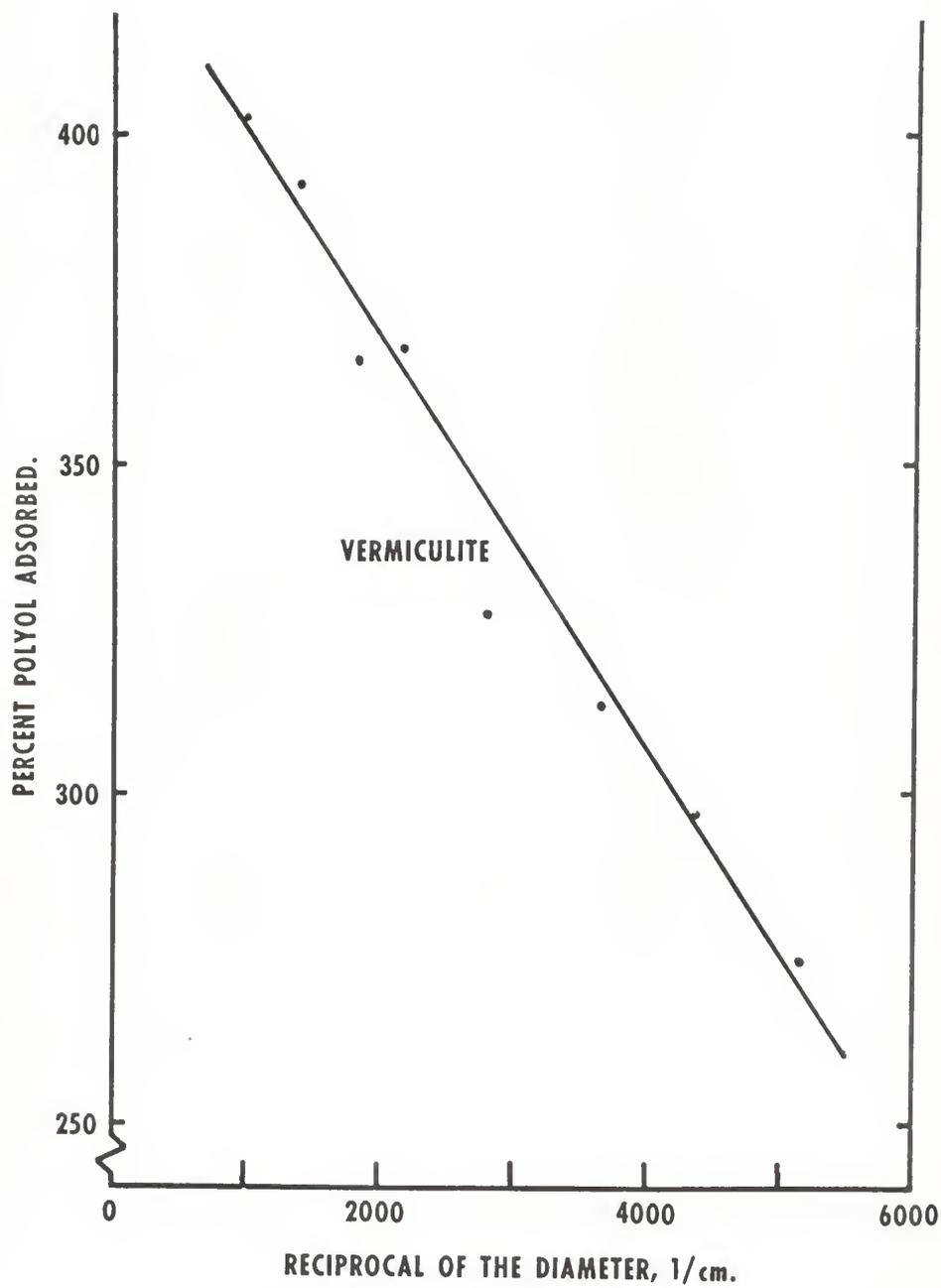


FIG. 5. Relationship between particle diameter and adsorption capacity.

feet. The small ribbon mixer was used as much as possible to avoid contamination of the complete mill system.

Polyol and liquid fat were added in the mixer to the carrier via a drum with holes of 1/8-inch diameter in the bottom. The drum was situated above the mixer and simulated the function of a spray nozzle. This insured an even distribution and better mixing; there was only a slight formation of lumps.

Fat was added to the polyol-carrier mixture to coat the particles and to mask the taste of the polyol. Different fats and oils were tested; they were all heated to 70-80°C to melt them before they were mixed with the polyol and its carrier.

Vermiculite was chosen as a carrier because it was highly adsorbent. Vermiculite could adsorb 200-250 percent polyol without losing its dry appearance.

#### Mixing Test

Two mixing experiments were done to determine the mixing properties of different premixes. The formulations tested are shown in Table 13. Specifications of the ingredients used are shown in Appendix B.

The mixing procedure for both rations was the same. First, the premix was prepared; polyol was added to vermiculite and mixed for five minutes. The polyol had about another ten minutes time to soak in. Heated Lecithin N at 80°C was added to the vermiculite-polyol mixture and was mixed for five to seven minutes. The proper amount of premix was mixed with ground corn in the large ribbon mixer for three or five minutes.

To evaluate the mixing performance, samples were taken at the discharge of the mixer. To test how much segregation had taken place, samples were taken at the sack off. The results are presented in Table 15. (The polyol content of the samples which were taken, was determined in the Department of Dairy Science, using the procedure of Meyer et al. [9]).

The coefficient of variation, C. V., is a value which can be used to evaluate a mixture (11). The coefficient of variation was large for samples of one gram; the sample size was changed to 5 grams and a small change in the assay procedure was made. The difference in the C. V. between a mixing time of three and five minutes was negligible. The No. 4 Verxite gave better mixing results than the No. 5. The samples from the sackoff showed there had been some segregation.

The coefficients of variation for a sample size of 5 grams were small enough to evaluate this mixture as satisfactory, keeping in mind that the animals eat one pound of this ration every day.

#### Bag Test

When polyol-vermiculite-lecithin mixtures are manufactured on a large scale, the storage of the material may present some problems such as:

- a) Does the pressure upon a sack have a caking effect upon the mix?
- b) Does polyol or lecithin leak out the particles when the bags are under pressure, and discolor the sacks?

For the storage experiment, the following premix formula was used:

36% polyol  
17% Lecithin N  
47% vermiculite

First, polyol and vermiculite were mixed for five minutes in the small ribbon mixer, then Lecithin N was added and the materials were mixed for another five minutes. A sample was taken from this mixture and sieved (Table 16).

In this experiment, six sacks (three duplicated treatments) were subjected to storage tests. All were stored during four weeks. Each sack was subjected to a force of 300 pounds during that time. This force was divided over an average surface of 190 square inches, which gave a pressure of about 1.5 pounds per square inch.

The three different treatments were:

- a) The mix was stored first a week without a pressure upon it and was held in ordinary three-ply kraft-paper bags.
- b) The mix was stored under pressure directly after the mixing process and also was held in ordinary three-ply kraft-paper bags.
- c) The mix was stored under pressure directly after the mixing process and was held in kraft bags with a 1-mil. poly-propylene liner inside.

After the storage period of four weeks, the bags were opened and judged by sight on their lumpiness. In all cases, there were lumps present, which broke up easily. Lumpiness was least in the case of treatment "a." Storing the bags for a couple of days

without any pressure upon them, in order to allow the polyol and lecithin to be adsorbed, therefore, is desirable.

To arrive at a more objective judgment, a sample from each sack was sieved. The samples weighed 300 grams and were sieved on a Ro-Tap sieve for seven minutes. The results given in Table 16 represent the average of the duplications. During the sieving process, the lumps broke, and the results did not show too much difference between the particle-size distributions before and after the treatments. Only the amount of smaller particles was diminished.

No leaking of polyol or lecithin through any of the bags occurred during this experiment. Therefore, ordinary kraft bags can be used satisfactorily for holding this mixture.

#### CONCLUSIONS

The "centrifugal force method" to determine the liquid adsorption capacity of materials has proven itself useful.

A large selection of materials, which included representative types of common feed materials, was tested, out of which vermiculite was found to be the best liquid adsorber. The particle size of the vermiculite influenced the adsorption capacity. The larger particles had a higher adsorption capacity and a better flowability. Vermiculite of the same coarseness as ground grains for cattle had an appearance with which the farmer is familiar, and gave good results. Vermiculite can have many more applications than as a polyol carrier.

Vermiculite-polyol mixtures can be used as a premix because of the high concentration of polyol. This premix mixes very well with grains.

Bag tests with one of the premixes showed there was no excessive lump formation; and the lumps which were formed, broke easily. Further, no leakage and discoloration of the paper bags were found.

Vermiculite and polyol, and possibly lecithin, can form a mixture with good handling properties and appearance, while the vermiculite can carry sizeable amounts of polyol.

## ACKNOWLEDGMENTS

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## APPENDICES

## APPENDIX A

Table 1. Adsorption capacity of wood fiber balls.

Reciprocal of the particle diameter in cm (x)	:	Adsorption of polyol in percentage weight (y)*	
417	:	52.9	51.7
548	:	57.1	57.0
709	:	61.3	59.7
1000	:	63.7	62.9
1404	:	66.9	66.3
1835	:	72.6	68.6
2174	:	75.3	73.2
2793	:	74.3	83.0

$$* y = 51.4 + 0.01026x$$

Table 2. Adsorption capacity of wheat bran.

Reciprocal of the particle diameter in cm (x)	:	Adsorption of polyol in percentage weight (y)*
537	:	13.2
709	:	13.7
1000	:	14.7
1404	:	15.6
1835	:	17.1
2174	:	17.1
2985	:	18.2
4673	:	19.3

$$* y = 13.27 + 0.00148x$$

Table 3. Adsorption capacity of sugar beet pulp.

Reciprocal of the particle diameter in cm (x)	Adsorption of polyol in percentage weight (y)*
709	21.2
1000	22.6
1404	24.2
1835	26.8
2174	29.2
2985	31.2
4673	49.4

$$* y = 18.1 + 0.0046x$$

Table 4. Adsorption capacity of ground corn.

Reciprocal of the particle diameter in cm (x)	Adsorption of polyol in percentage weight (y)*
709	4.89
1000	4.62
1409	6.21
1835	9.46
2174	16.00
3344	26.30
6173	48.00

$$* y = -2.3 + 0.00768x$$

Table 5. Adsorption capacity of soybean meal.

Reciprocal of the particle diameter in cm (x)	Adsorption of polyol in percentage weight (y)*
709	5.70
1000	5.04
1404	6.57
1835	9.49
2174	9.17
3344	9.74
6173	16.70

$$* y = 4.38 + 0.00185x$$

Table 6. Adsorption capacity of corn germ meal.

Reciprocal of the particle diameter in cm (x)	Adsorption of polyol in percentage weight (y)
709	22.8
1000	20.1
1404	19.6
1835	17.6
2174	17.7
3344	16.4
6173	19.7

Table 7. Adsorption capacity of ground milo.

Reciprocal of the particle diameter in cm (x)	Adsorption of polyol in percentage weight (y)*
1000	5.3
1404	8.4
1980	13.9
3344	26.8
6173	27.4

$$* y = -4.2 + 0.00916x$$

Table 8. Adsorption capacity of rice hulls.

Reciprocal of the particle diameter in cm (x)	Adsorption of polyol in percentage weight (y)
1404	15.9
1835	25.5
2174	26.5
3344	29.3
6173	38.0

Table 9. Adsorption capacity of vermiculite.

Reciprocal of the particle diameter in cm (x)	: :	Adsorption of polyol in percentage weight (y)*
1000		402
1404		392
1835		365
2174		367
2793		327
3663		313
4348		297
5155		275
6173		269

$$* y = 420 - 0.0272x$$

Table 10. Adsorption capacity of alfalfa.

Reciprocal of the particle diameter in cm (x)	: :	Adsorption of polyol in percentage weight (y)*
419		13.4
780		13.4
1000		15.1
1404		16.5
1980		17.3
6173		23.2

$$* y = 11.9 + 0.00285x$$

Table 11. The adsorption capacity of various ungraded materials.

Material	: Adsorption of polyol in : percentage weight
Corn cobs (not ground)	22.4
Whole corn flakes	3.2
Regular corn flakes	3.7
Expanded corn pellets	5.0
Cottonseed hulls	10.5
Citrus pulp	10.8
Tomato pomace	22.4
Soybean meal granules	6.1
Dicalcium phosphate	19.9
Meat and bonemeal	11.9
Dried whey	16.8
Distiller's solubles	12.3
Salt	Too small to determine
Limestone	Small particles gave unreliable results

Table 12. The effect of fiber content on the regression equation.

Material	: Regression equation	: Percentage fiber : of the material
Ground corn	$y = -2.3 + 0.00768 x$	2.0
Ground milo	$y = -4.2 + 0.00916 x$	2.3
Wheat bran	$y = 13.3 + 0.00148 x$	10.0
Sugar beet pulp	$y = 18.1 + 0.00460 x$	19.6
Alfalfa meal	$y = 11.9 + 0.00285 x$	24.0
Soybean meal	$y = 4.4 + 0.00185 x$	5.9
Wood fiber balls	$y = 51.4 + 0.01026 x$	61.2

Table 13. The true density of various materials which were tested on their adsorption capacity.

Material	:	Density (g/cm <sup>3</sup> )
Ground milo		1.41
Soybean meal		1.22
Alfalfa		1.47
Sugarbeet pulp		1.41
Woodballs		1.20
Rice hulls		1.42
Distiller's solubles		1.29
Dicalcium phosphate		2.02
Limestone		2.64
Vermiculite		0.23

Table 14. Formulations used for mixing test.

Ingredient	: Ration D-35 (T) :		Ration W
	:		lbs.
Polyol	11.00		16.75
Lecithin N*	5.50		8.31
Vermiculite No. 5*	8.25		
Vermiculite No. 4*			16.75
Ground corn (1/8" hammer mill screen)	475.00		459.00

\* Specifications for these products are shown in Appendix B.

Table 15. Mixing performance of two types of premixes.

Sample set	: Ration	: Sample size (gm)	: Mixing time (min)	: Sampling location	: No. of samples	: $\bar{x}$	: $\sigma$	: c.v.
A	T	1	3	Mixer	12	6.74	2.27	33.70
B	T	1	5	Mixer	13	6.17	1.22	19.80
C	T	1	-	Sack off	12	7.15	0.66	9.25
D	T	5	3	Mixer	12	8.98	0.46	5.09
E	T	5	5	Mixer	13	9.62	0.67	6.91
F	T	5	-	Sack off	12	9.44	1.40	14.83
G	W	5	3	Mixer	10	17.87	0.72	4.06
H	W	5	3	Mixer	11	18.19	0.57	3.16
I	W	5	-	Sack off	9	18.77	1.56	8.31

Table 16. Particle size distribution of the mixture before and after storage treatments.

U. S. sieve numbers	: Before treatment	: Treatment		
		: a	: b	: c
6	0.7	0.7	0.7	1.3
6-14	1.7	0.3	0.3	0.7
14-20	6.6	10.3	8.0	17.3
20-30	25.7	35.7	30.7	34.0
30-40	34.7	47.3	36.0	33.7
40-50	22.9	6.0	18.3	12.3
50	7.6	0.3	6.0	0.7

## APPENDIX B

Vermiculites No. 4 and 5, from Grace and Company, were used as carriers. They had a particle distribution as shown in Table 17.

Table 17. Distribution of the particle size of Verxites No. 4 and 5.

Verxite No. 4		:	Verxite No. 5	
Tyler sieves mesh	: Cumulative : percentage : weight	:	Tyler sieves mesh	: Cumulative : percentage : weight
28	45	:	28	0
35	70	:	35	10
48	85	:	48	42
65	92	:	65	76

Bulk density (lb./cu.ft.) = 6.5      Bulk density (lb./cu.ft.) = 7.6

Lecithin N is a product of Cargill, Inc. and is a purified soybean oil, consisting largely of lecithin.

PREPARATION OF FEED ADDITIVES CONTAINING LIQUIDS

by

ROBERT JAN NIJWEIDE

L. I., State Agricultural University  
of the Netherlands, 1963

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

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The purpose of this research was to find a way to incorporate polyol into feed. Polyol is a liquid compound with an antifoaming action and is used to prevent bloat. To incorporate polyol into feed, a liquid carrier was needed. A method was developed to evaluate different feed materials as liquid carriers. The research was extended to arrive at a practical feasible premix.

To evaluate the adsorption capacity of the various materials, the solid material was mixed with an excess of polyol. This mixture was subjected to a centrifugal force of 400 times the gravitational force. The values of the adsorption capacity were relative, but they made it possible to compare the various materials.

It was found that vermiculite had by far the highest adsorption capacity and had the additional advantage that its adsorption capacity increased with an increase in particle diameter; for the other materials, the opposite was true.

Experimental rations were mixed during the research, and experience showed that vermiculite could carry 150-250 percent of its weight in polyol. Mixing tests showed that a premix consisting of vermiculite, polyol, and lecithin, could be mixed satisfactorily with grains, and an even distribution could be obtained. Segregation was not a problem with this particular premix.

It was found that during storage, vermiculite retained the polyol, and pressure upon the bag in which the premix was stored did not cause leakage. The bags did not discolor or show spots on the outside from the fat or the polyol.

This research proved that vermiculite was an excellent adsorber of polyol, and that it was possible to mix polyol and vermiculites to a satisfactory product.