A STUDY OF DISTRIBUTION OF MICRO-INGREDIENTS IN MIXED FEEDS

by

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INTRODUCTION

Increased use of single ingredients to furnish specific nutrients and the expanding of drugs, hormones, and stimulants to increase efficiency of feed conversion in animal production, have brought formula feeds to the status of a pharmaceutical prescription. A current chick ration will commonly contain 26 ingredients, 21 of them supplying a different nutrient necessary for adequate nutrition (1). This trend has been developing since the days when cod liver oil was used to prevent rickets. The addition of synthetic riboflavin at levels of one to three grams per ton of feed, brought the manufacturer face to face with difficulties of incorporating micro-ingredients into a formula feed.

It is easy to understand the impossibility of compounding a formula and mixing it in a feed plant so that each small increment of dietary portion contains the exact proportions as added on the ton basis. Feeds which appear to be uniform and mixed may actually be un-mixed in the milling operation. Equipment which is for the purpose of distributing the various ingredients, theoretically at random, may segregate micro-ingredients, causing them to settle out, become concentrated, collect in the dust-collecting system, or migrate to dielectric material. Most feed manufacturers recognize the problems common to the use of micro-ingredients and make every effort to approach uniformity in all ingredient distribution.

The performance expected of formula feeds reflects the need for producing uniform mixing and the ability to check this in the quality control program of the product. For example, during the first two weeks of a chick's life, it consumes daily approximately 13 grams of feed. In one ton of feed there are 7×10^4 13-gram portions. The use of vital growth nutrients such as riboflavin, added at one gram per ton, or vitamin B_{12} added at 1/10 gram per ton, is past the stage of being a problem in nutrition. It is now a problem of distributing, in 7×10^4 portions of 13 grams each, sufficient riboflavin or vitamin B_{12} to balance each day's nutrient requirements.

Many micro-ingredients are frequently used in excess of recommended levels to insure an adequate amount in a day's ration. This is a needless expense, particularly if methods are known to distribute the product. However, the detection of most micro-ingredients is a biochemical problem, often time-consuming and inaccurate at the tolerances needed for cost savings. Tracers have been proposed, such as dyed minerals or cut feathers, which can be detected by a physical separation from samples in a short time. The widespread adoption of these materials attests to their need in the feed industry. The question has often been raised: "Does the distribution of a trace material denote a similar distribution of all feed ingredients, or only of the tracer?"

To study this question and relate the findings to the time element in mixing, the following experimental work was undertaken. Concurrently with collecting data on micro-ingredient

distribution, a biological answer to the importance of this subject was attempted in cooperation with the departments of poultry and chemistry. Although it has been assumed necessary to include each nutrient in the daily diet at recommended levels, is there a carry over, such as is postulated for vitamin A, permitting its effective use when present intermittently? Can inadequate mixing be followed by mixing without decreasing growth or production in domestic animals?

REVIEW OF LITERATURE

There is a fairly wide variety of subject within the field of mixing, those applying to solid particles being of particular interest in studying feeds. Literature applying directly to feeds is practically non-existent except for the recent work of Mahoney and Benson (11) on medicated feed supplements and the review on premixing micro-ingredients by Wornick (19). Mahoney and Benson stated:

> It is generally recommended that direct addition of the feed supplement (micro-ingredients) should be avoided; instead, a premix should be prepared consisting of perhaps one part of the feed supplement and ten to fifty parts of a suitable feed ingredient (carrier). This premix is then incorporated along with the major components to produce the finished feed.

In presenting statistical data on the desirable number of samples to be taken from a mix, Buslik (6) stated that if there are any differences in the ingredients, such as in density, particle size, particle shape and electrostatic properties, the materials being mixed may not achieve a random distribution, no matter how long they are mixed.

Blumberg and Moritz (3) showed that it is possible to follow the mixing process by analysis of random sampling. In discussing the number of samples necessary to determine the mixed state, they show that the taking of a small number of samples (ten) may not be sufficient to determine the degree of mixing while the mass of the mix is still unmixed, but that after the mix has approached the mixed or uniform state, there is confidence in using a small number of samples to designate the degree of mixing.

Beaudry (2), in dealing with mixer efficiency, noted the lack of information by which to measure the degree of mixing. He stated that it was impossible to prepare identical batches in the batch mixing operation.

Young and Snaddon (20) described the action of mixing dry solids in a laboratory mixer. They found that the time required for complete mixing varies with the quantity of material, particle size, and the difference in specific gravity between constituents of the sample. They described the extent of mixing as measured by visual methods of particle count. A review article on mixing techniques by Bullock (5) discussed findings by several authors and concluded that throughout the literature on the subject of mixing, there is a mass of disconnected information, most of the papers pertaining to theory and data on distribution of two ingredients.

A Ph.D. dissertation by Weidenbaum (17) described the degree of mixing as the ratio of the theoretical standard deviation for a random distribution to that experimentally determined by spot

samples. He defined mixing, using only two ingredients, as

> Random mixing of particles A and B is that opera-
> tion in which the motion imparted to these particles
> causes them to assume arrangements such that, as mixing
> proceeds, the frequency distribution of sample compo-
> sition becomes less and less spread out and approaches
> an equilibrium distribution called the binomial distri-
> bution, provided that only a small amount of the mix-
> ture is used for sampling. If there are special
> separating tendencies, then the mixing is no longer
> purely random.

It would be difficult to apply this definition of mixing to feeds, especially where a micro-ingredient or tracer supplies a small number of particles in proportion to the total number present. If the binomial distribution is used in evaluating mixing of such feeds, the limits are so large as to be impractical.

Quillen (13), in discussing the mixing of solids, proposed that a mixing operation will eventually result in an equilibrium state in which random distribution is more or less a stable maximum. This seems feasible if there are no segregation tenden-cies as described by Weidenbaum. Quillen believes that segrega-tion is possible after long periods of mixing. He does not elaborate on a method to determine the equilibrium state of a mix containing a number of different ingredients.

Work (18) stated that after mixing is completed and the action of the mixer is continued, segregation may take place. He noted that density, particle size, and particle shape have important bearings on the distribution and segregation of par-ticles. He suggested that when small quantities of material must be mixed into a large mass, it may be desirable to first mix the small quantity with a part of the mass, then add this to the

original mass. He does not state why this step is necessary.

Perry (12) discussed mixed materials and theorized that all samples taken from a batch must contain the same components. This tends to indicate that mixing is an orderly arrangement. As was pointed out before, this is not the case. Although it is desirable to obtain a mass that has all the components present in each small part of the mix, this is not an orderly arrangement, but a random one. One must not, however, come to the conclusion that it cannot be controlled or that the action of the mixer cannot be stopped when the random nature of the apparatus has achieved a point that can be considered maximum for that mixer.

Brothman et al. (4) described mixing as, "that unit operation in which energy is applied to a mass of material for the purpose of altering the initial particle arrangement so as to effect a more desirable particle arrangement." They note that a mix can be considered mixed when each sample taken from a mixer contains at least one element of the trace material. In the mixing of feeds and other products, this concept would be very valuable indeed, but when this one element of tracer is considered mixed, the question arising is: "Is the distribution of the other materials or ingredients in the feed the same as the distribution of the tracer?"

Hixon and Tenney (10), in arriving at a mixing index, preferred the taking of a few relatively large samples to that of taking a large number of small samples. Their results checked within less than 7 per cent of theoretical values. The greater

the number of samples taken from a mixer, the greater the mass of material that will be disturbed. This may in turn lead to erroneous sampling results.

Geiger (8) showed that for optimum utilization of protein, all the essential amino acids must be present in the feed being tested and available simultaneously. These experiments were based on incomplete and complete protein rations fed to rats.

Henderson and Harris (9) reported that a delay of three hours or longer, in the feeding of lysine as a supplement in low lysine diets, interfered with metabolism. They concluded that lysine must be fed concurrently with other amino acids in the diet for most efficient utilization by the rat. The criteria they used to evaluate the effects of these rations were nitrogen retention and growth.

Rushton (14), in defining a mix, used Webster's definition, "to cause a promiscuous interpenetration of the parts of ... one substance with others." The noun, mix, is further defined by Webster (16) as "being confused or muddled." As one attempts to delve into the subject of mixing, the more one seems to approach the definition of the word itself.

STATEMENT OF THE PROBLEM

The available literature indicates that nutrients must be fed to animals in uniform amounts daily to achieve maximum efficiency from the ration. It is important then, that mixing of feeds be as complete as possible. This investigation was conducted to study distribution of a dyed mineral tracer and a drug

as related to time of mixing in various feed materials. In addition, the idea of intermittently feeding vitamin A to simulate a uniform and un-uniform distribution of this nutrient was tested on chicks.

APPARATUS USED

The mixer used in this work was a model widely used in the feed industry. It was a horizontal batch type with single shaft and double spiral ribbon agitator. It was 60 inches long, 24 inches wide at the top, and 20 inches deep, with rated capacity of 15 feet.

Facing the charged end of the mixer, the rotation was clockwise. The mixing element was mounted on a two-inch diameter steel shaft. One part of the mixing element consisted of two forward motion screws or helicles made of one and one-half inch wide steel, making one and one-half complete turns.

The distance between two corresponding points on the same ribbon was 34 inches. The other part of the mixing element consisted of two reverse motion screws or helicles. These were made of steel three inches in width. The distance between corresponding points of the same ribbon was 34 inches.

There was a hole five inches square at the discharge end of the mixer, fitted with a pneumatically-operated cover for discharging the mixer contents. The mixer turned at 80 revolutions per minute.

PROCEDURE

Feeds containing vitamin A and feeds devoid of vitamin A were fed intermittently, thus simulating the effect of unmixed feeds (Table 1). The effects of this intermittent level were compared with rations containing the required amount of vitamin A fed continuously.

Table 1. Composition of diet used in feeding experiments.[1]

Ingredients	:	Amount
White corn		60.5 pounds
Wheat bran		4.0 "
Soybean oil meal		27.0 "
Steamed bone meal		1.0 "
$CaCO_3$		2.0 "
Mineral premix[2]		635.0 grams
Vitamin premix[3]		600.0 "
Brewers' dried yeast		3.0 pounds

[1] In feeds for lot 2, vitamin A was omitted, according to the design of the experiment.

[2] The minerals used in this feed contained the following: $CaHPO_4$, $NaCl$, $MnSO_4$, and $MgSO_4$.

[3] The vitamin premix used in this feed contained the following: B_{12}, Delsterol or D_3, Riboflavin, Niacin, Calcium pantothenate, Menadione, and Choline chloride. Shorts was added to bring the total weight of the premix up to 600 grams.

One hundred and thirty-five cockerels of broiler strains were used for the experiment. The chicks were weighed, wing-banded, and vaccinated intranasaly for Newcastle disease at one day of

age. The feeds fed intermittently contained twice the amount
of vitamin A normally fed; thereby all chicks received the same
total amount of vitamin A over the eight-week experimental per-
iod. The design of the experiment is shown in Table 2.

Table 2. Effect of simulated mixed and unmixed rations on the
growth and feed efficiency of poultry, using vitamin A
intermittently to simulate mixed and unmixed rations.

Lot No.	Source of vitamin A	Feeding schedule	Final total weight per lot g	:Total: feed :con- sumed: per lot : lbs.	Feed effi- ciency per lot
1[1]	Crystalline[2]	Control (continuous)	15,290	91.8	2.72
2[3]	Dehydrated alfalfa[4]	Control (continuous	19,770[5]	116.0	2.66
3[6]	Crystalline	Three days with vita-min A; three days without vitamin A	19,265	139.6	3.30
4	Crystalline	Three days with vita-min A; three days without vitamin A	19,983	139.0	3.16
5	Crystalline	One day with vitamin A; one day without vitamin A	16,947	105.1	2.82
6	Dehydrated alfalfa	Three days with alfal-fa; three days without alfalfa	17,746	114.8	3.16

[1] In lot 1, four birds died due to respiratory diseases.
[2] Crystalline vitamin A contained 10,000 units per gram (NAPCO).
[3] Two birds died in lot 2 due to respiratory diseases.
[4] Dehydrated alfalfa contained 453 units per gram.
[5] Statistically significant at the 0.1 level of probability, using the G test of analysis.
[6] In lot 3, two birds died due to respiratory diseases.

Chicks were weighed weekly and the feed consumption calcu-
lated. Chicks were moved from starting batteries to finishing
batteries at five weeks of age. The temperature in the batteries
was kept at 90° F. for the first week, then dropped 5° each week
until room temperature of 70° F. was reached.

Common ingredients which were used in the intermittent feed-
ing studies also were used in the mixing experiments. These
were corn, soybean oil meal, and a complete ration. Contents of
the poultry ration used are shown in Table 3.

Table 3. Experimental poultry ration used in mixing studies.[1]

Ingredients	: :	Amount (lbs.)
Corn		25.0
Milo		75.0
Oats		13.0
Shorts		112.0
Soybean oil meal		100.0
Alfalfa meal		50.0
Meat scraps		25.0
Bone meal		12.5
$CaCO_3$		6.25
NaCl		5.0
Vitamin premix		2.5

[1] Particle size determinations of this mix are shown in
Plate VIII.

The general procedure followed in making a run with the experimental mixer consisted of weighing out the required amount of each ingredient into a scale hopper located above the mixer, then discharging the contents of the hopper into the mixer located directly below. All ingredients were added while the mixer was stopped. This made better timing possible.

In each mix, dyed sodium chloride crystals of standardized particle size (Anresco, San Francisco, California) and a coccidiostat nitrophenide (The American Cyanamid Company, New York, New York were added as tracers. The nitrophenide was obtained in the form of a premix carried on citurs meal, and had a test weight of 36.8 pounds per cubic foot. The dyed sodium chloride had a test weight of 72 pounds per cubic foot. The nitrophenide premix was analyzed and the active chemical content was found to be 36 per cent.

Ingredient distribution was studied by the effect of particle size of the mix on distribution of trace materials. Also of interest was the time of mixing that was required for different trace materials to reach a random state of distribution. Particle size was arrived at by sieve separation tests using a Tyler ro-tap in particle size separations. Trace materials were weighed to the fourth decimal place and added to the center of the mixer after the mixer had been fully charged. Mixing time was taken as soon as the mixer was set into action and time recorded with a stop-watch.

Six samples were taken for analysis from different positions within the mixer. The positions and locations of these samples

appear in Plate I, Figs. 1 and 2. Each sample was divided into two equal parts; a salt particle count was made on one of the samples, while the other part was sent to the Chemistry Department for nitrophenide analysis. The method of analysis was that of Senn and Woolford (15) as modified for finished feeds and premixes. The total sample consisted of approximately 20 grams. These samples were taken from the mixer with a seed and grain sampler which consisted of a hollow tube with slots two inches apart throughout its entire length. The slots were three inches long and one inch wide. Inside the hollow tube was another tube or shell which was equipped with a round handle that could be rotated, thus closing the slots along the sides of the sampler. In some cases the feed material would not flow into the sampler; in these instances it was necessary to mark the sampling positions in the mixer and take samples by hand.

A fiber board top was designed for the mixer to insure constant sampling positions. Round holes were cut in this top; the holes corresponded to the position of sampling shown on Plate I, Fig. 2. The sampler was slipped through these holes and adjusted to sampling positions marked on the side of the sampler. All slots in the sampler were covered with masking tape except the bottom slot. The long pointed end of the sampler was replaced with a shorter end which was one and one-half inches long. This was done in order to take samples near the bottom of the mixer.

Samples were taken at stated intervals of time. The first was obtained after one-half minute of mixing, the second sample at the end of one minute, the third at the end of one and

EXPLANATION OF PLATE I

Position of samples taken from mixer.

Fig. 1. Side view.
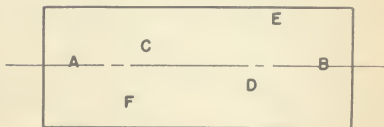Fig. 2. Top view.

PLATE I

Fig. 1

Fig. 2

one-half minutes, the fourth at the end of two minutes, the fifth at the end of three minutes, the sixth at the end of six minutes, the seventh at the end of nine minutes, the eighth at the end of 15 minutes, and the ninth sample at the end of 20 minutes of mixing time.

An inactive layer of material, about one-fourth of an inch thick, was noted on the bottom of the mixer. In some cases the analysis of samples indicated that trace substances were higher than the theoretical value. If this were the case, it appears obvious that there should be places in the mixer where the amount of trace materials would be low, indicating poor mixing.

ANALYTICAL METHODS

To all mixes, two grams of dyed sodium chloride and one-fourth pound of megasul were added to the feed ingredient or ingredients. This amount of salt should give approximately 13 particles per 10-gram sample, and the nitrophenide content should be 0.019 per cent. The determination of the amount of salt present in each sample was made as follows (Ersenberg, 7): Ten grams of each sample were weighed out and transferred to a plastic 200-milliliter test tube. Approximately 100 milliliters of reagent grade carbon tetrachloride were added to each sample, and the tube swirled to facilitate wetting of the sample. Then the tube was permitted to stand for one-half minute. The organic materials were decanted. Care was taken not to disturb the sedimentary material. The sediment was dried with the aid of a small jet of air and distributed over the surface of a No. 500,

15-centimeter filter paper. Water was sprayed gently over the
sediment, moistening it thoroughly, but avoiding excess. The
filter paper was dried, the sediment brushed off and the spots,
due to the dye left by the water soluble dyed salt, were counted.

The accuracy of this method was verified on samples of corn,
soybean oil meal, and a complete poultry ration. Ten particles
of dyed salt were added to each sample, and ten spots were found
on each filter paper in all but one sample. Eight articles were
found when the sediment was intentionally disturbed and decanted
at a rapid rate. It was important that the decantation process
be done in a gentle manner so that the sediment which contained
the dyed salt was not disturbed.

Nitrophenide was determined by the method of Senn and Wool-
ford (15) as modified for feeds and premixes. Since results
were obtained in per cent, and the theoretical level was 0.019
per cent, findings were multiplied by a factor to convert nitro-
phenide to a numerical value coinciding with particles of dyed
sodium chloride. This conversion factor was arrived at by the
ratio:

$$\frac{13 \text{ (theoretical particles of dyed mineral per sample)}}{0.019 \text{ (theoretical per cent of nitrophenide per sample)}} = 684$$

The per cent nitrophenide times 684 is equal to the distribution
of nitrophenide.

Thirteen particles of dyed mineral was assumed to be the
theoretical number that should be found in each ten-gram sample,
and the graphs used in showing the state of mixing were drawn

according to that assumption. Two grams of dyed sodium chloride,
containing approximately 288,000 particles, were added to each
mix. The deviation, while not a true statistical deviation,
shows the degree of mixing. The general formula used to deter-
mine points on the graphs was as follows: (Each point on the
graph was an average of six sample deviations)

$$D = \frac{(13-A) + (13-B) + (13-C) + (13-D) + (13-E) + (13-F)}{n}$$

Ignoring signs, this formula shows the average number of
particles of sodium chloride that were deviated from the theoret-
ical value of 13, when:

A   Number of particles found in sample A.

B   Number of particles found in sample B.

C   Number of particles found in sample C.

D   Number of particles found in sample D.

E   Number of particles found in sample E.

F   Number of particles found in sample F.

n   Number of samples analyzed

D   Average deviation.

RESULTS AND DISCUSSION

All birds in the negative control group were dead at four
weeks of age. Birds were posted upon death in order to confirm
vitamin A deficiency. Noted observations were the build-up of
urates in the ureters, mottled kidneys, ruffled appearance, and
a staggering gait. Small hemorrhagic areas around the breast

bone and near the crop were also observed.

The difference in weight gain between lots 1 and 3 was statistically significant at the 0.1 level of probability. Calculated feed efficiency was better in lot 1 than in lots 3 and 4. There were no significant differences in feed efficiency between lots 1 and 5. This may indicate that the critical level of intermittent feeding of vitamin A was greater than 24 hours. However, there were slight differences between these two groups, the differences being in favor of lot 1 (Table 2).

The chicks in lot 2 consumed more feed and gained more in proportion to the amount of feed consumed than did the chicks in lot 6. This gave group two a better feed conversion than lot 6.

Although this experiment was designed to determine the effects of simulated unmixed rations on poultry growth, another interesting aspect was brought forth; that of vitamin A storage. Conclusions were drawn from previous literature cited which indicate that vitamin A can be stored by chicks if fed in excess of growth requirements. A question arises from the data presented here concerning the length of time stored vitamin A can be used to overcome deficiencies. In lot 5, there were differences in feed efficiency when compared to lot 1. However, this difference was small, and more work is necessary before any conclusions can be drawn. The chick is undoubtedly able to store vitamin A, but perhaps the rate of availability of release should be studied in more detail.

The results obtained in the investigation of the dispersion of sodium chloride and nitrophenide in ground yellow corn, soybean

oil meal, and a complete poultry ration are summarized in Plates
II, III, IV, and V.

Plate II, showing the dispersion of sodium chloride and
nitrophenide in soybean oil meal, indicates that nitrophenide
does not follow the same distribution pattern as sodium chlo-
ride. The graph shows that nitrophenide reaches a better state
of mixing than does the sodium chloride used. This may be due
to the differences in particle density between the two tracers.
The sodium chloride was almost twice as dense (based on weight)
as the nitrophenide and seemed to segregate from the mass of the
mix. The soybean oil meal is made up of dry, relatively large,
flaky particles as shown by results of sieve separation tests in
Plate VII. This shows that the air space between individual
particles is large and the heavier sodium chloride tended to
"sift" through the soybean oil meal particles. The nitrophenide
was light in weight and seemed to cling to the soybean particles.
This action might explain the better state of mixing that nitro-
phenide obtained after three minutes of mixing. The graph shows
that sodium chloride obtained a stable maximum in a shorter
mixing time than did the nitrophenide.

The graph in Plate III shows the dispersion of nitrophenide
and sodium chloride when mixed with yellow corn, ground through
one-eighth inch screen. The graph shows that nitrophenide
reached a better state of mixing than did the sodium chloride.
Again the difference of particle size entered in, as shown by
the results of sieve separation tests in Plate VII. Here also,
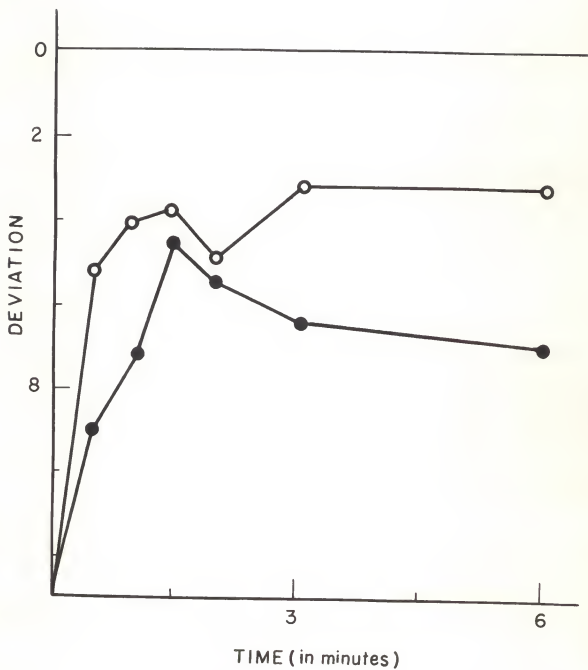sodium chloride obtained a stable maximum in shorter mixing time

EXPLANATION OF PLATE II

Distribution of sodium chloride and nitrophenide when mixed with soybean oil meal.

⊖ - Distribution of sodium chloride.

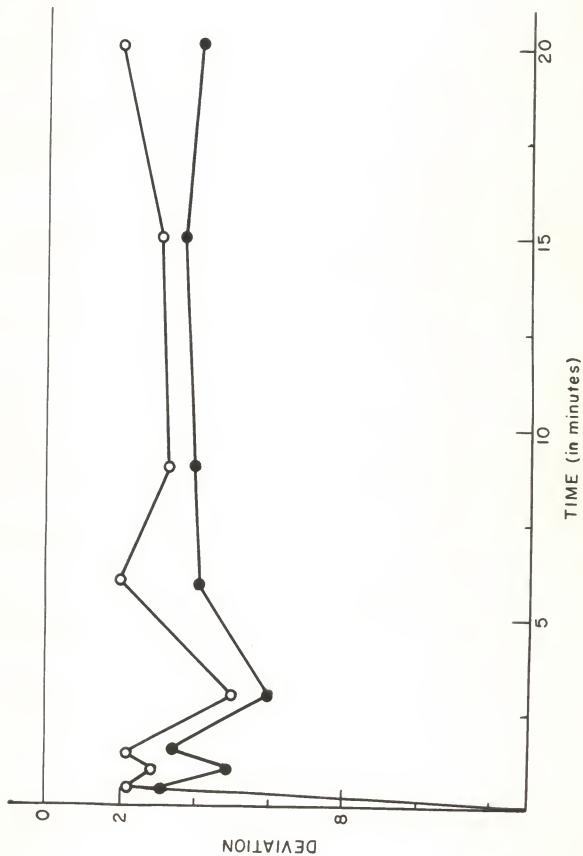O - Distribution of nitrophenide.

PLATE II

EXPLANATION OF PLATE III

Distribution of sodium chloride and nitrophenide when mixed with yellow corn,
ground through a one-eighth-inch screen.

0 - Distribution of sodium chloride.

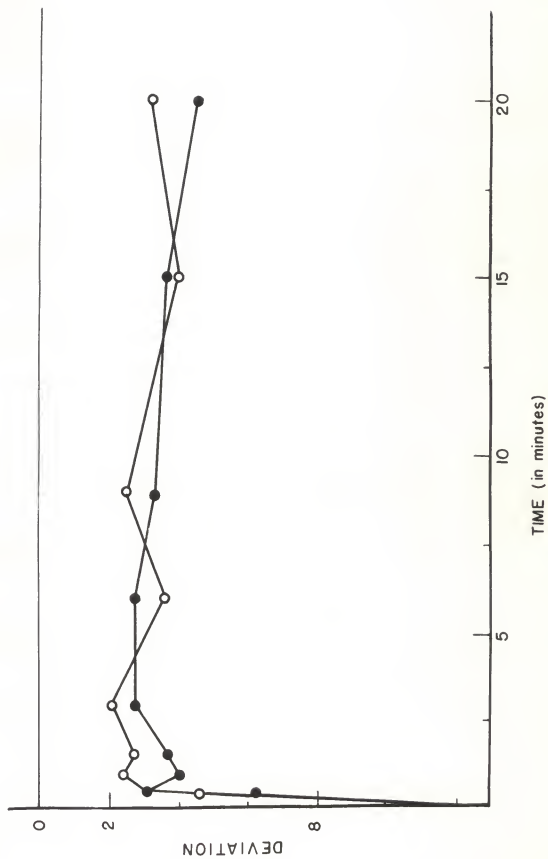0 - Distribution of nitrophenide.

PLATE III

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EXPLANATION OF PLATE IV

Distribution of sodium chloride and nitrophenide when mixed with yellow corn, ground through a six sixty-fourths-inch screen.

⊖ - Distribution of sodium chloride.

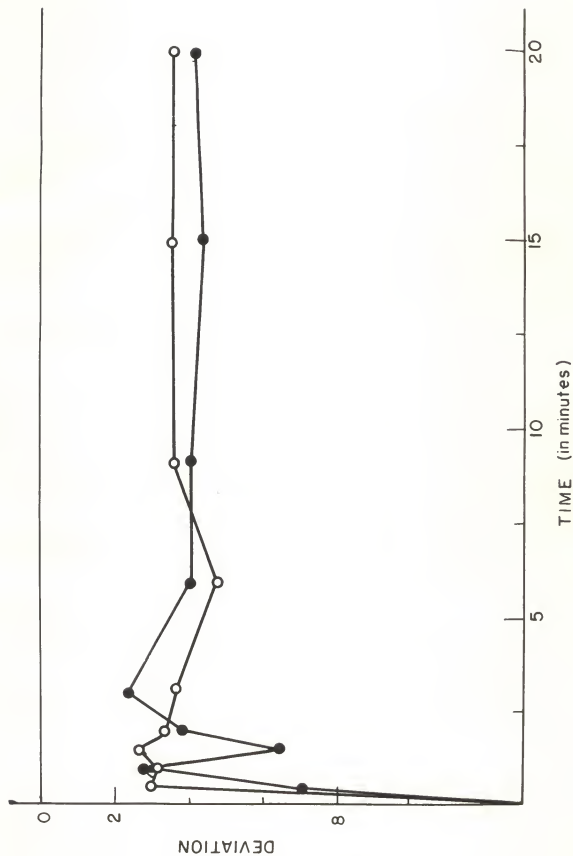○ - Distribution of nitrophenide.

PLATE VI

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EXPLANATION OF PLATE V

Distribution of sodium chloride and nitrophenide when mixed with a complete poultry ration.

Θ - Distribution of sodium chloride.

Ο - Distribution of nitrophenide.

PLATE V

TIME (in minutes)

DEVIATION

than did the nitrophenide. This possibly can be explained from
the fact that nitrophenide, being light in weight and made up of
small particles, tended to localize and was not evenly dis-
tributed throughout the mix at short mixing times.

Nitrophenide tended to follow the dispersion of sodium chlo-
ride when the fineness of grind of the corn was changed to 6/64.
This substantiates the supposition of particle size of the mass
of the mix affecting the dispersion of the heavier sodium chlo-
ride. The difference between these two lines of the graph
shown in Plate IV are small, and some of the variation may be
due to sampling techniques.

Plate V shows the dispersion of sodium chloride and nitro-
phenide when mixed with a complete poultry ration. Sieve separa-
tion data for the mix are shown in Plate VIII. The sodium chlo-
ride reached the point of being mixed before the nitrophenide
did, indicating that different ingredients do not reach a stable
maximum at the same time. This also shows that ingredients of
different density and particle size have a definite sequence in
which they must be added.

The irregularity of the first part of the graphs indicates
that it is difficult to determine the degree of mixing when a
small number of samples are analyzed from the mix. At moderate
mixing time, the graph tended to level off or become stable.
This shows that although the degree of mixing is difficult to
arrive at when a small number of samples are analyzed, the state
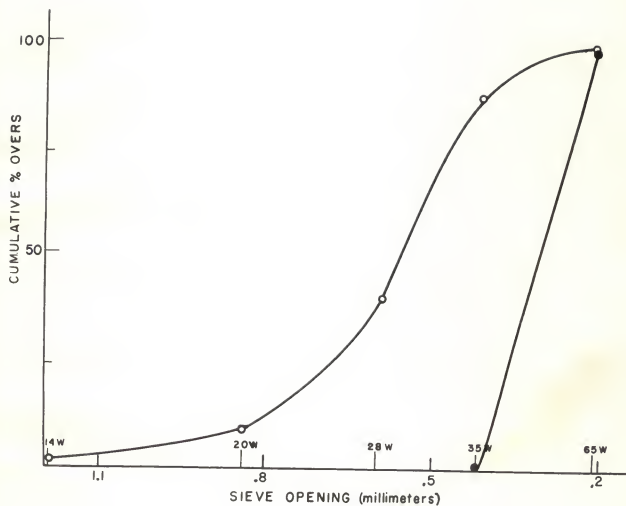of being mixed can be ascertained at by this method.

EXPLANATION OF PLATE VI

Particle size distribution of megasul, the nitro-
phenide carrier, and sodium chloride, as shown by sieve
separation tests.

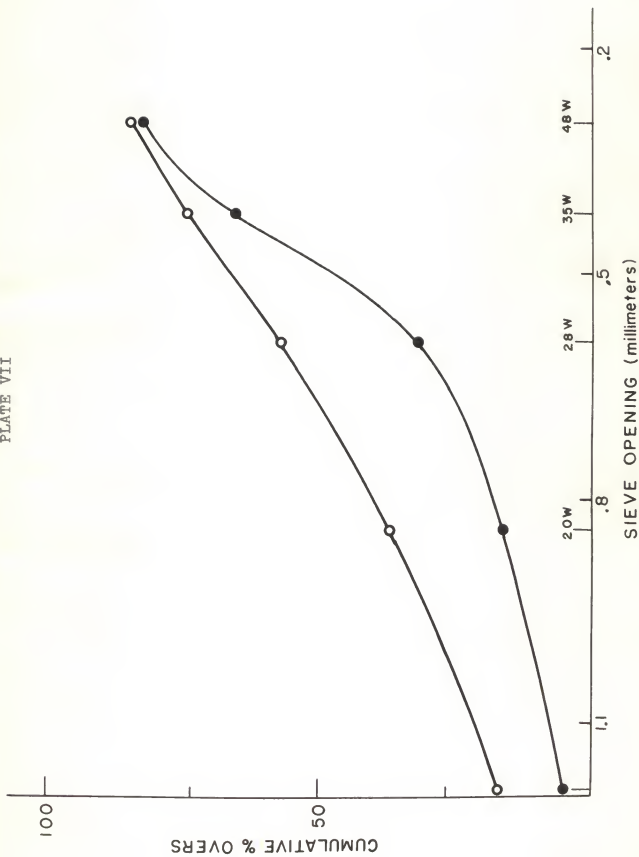⊘ - Sodium chloride.

O - Megasul.

PLATE VI

EXPLANATION OF PLATE VII

Particle size distribution of ground yellow corn, ground through a one-eighth-inch screen, and the particle size distribution of soybean oil meal as shown by sieve separation tests.

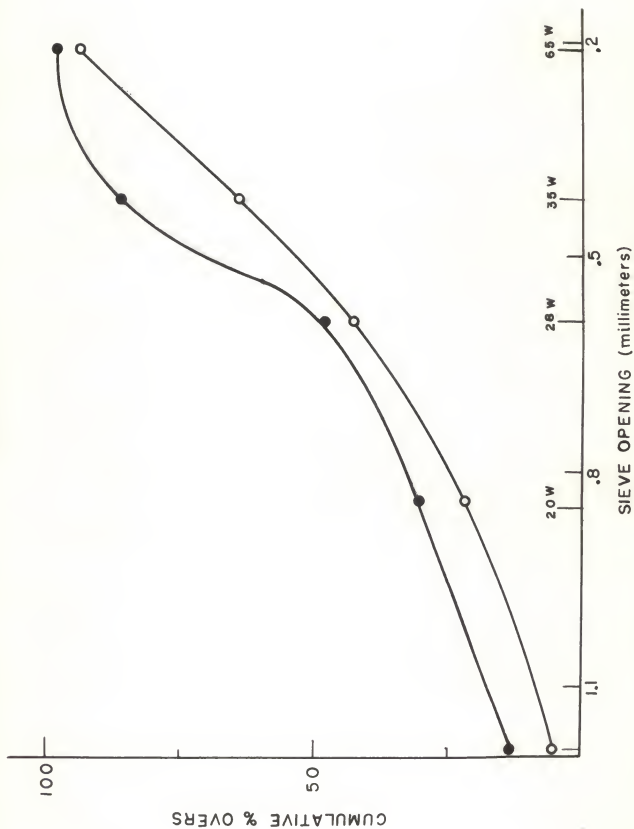O - Soybean oil meal.

⊕ - Ground yellow corn.

PLATE VII

EXPLANATION OF PLATE VIII

Particle size distribution of ground yellow corn, ground through a six sixty-fourths-inch screen, and the particle size distribution of the complete poultry rations, as shown by sieve separation tests.

O - Complete poultry ration.

◉ - Ground yellow corn.

PLATE VIII

CONCLUSIONS

Two experiments were conducted with a total of 135 sexed cockerels of broiler breeds.

Evidence was presented using vitamin A to simulate mixed and unmixed rations. This evidence showed a marked influence as to the degree of mixing on growth of poultry. The data presented showed that simulated unmixed rations did not promote so good a growth as did the rations that were considered mixed.

The difference in net gain shown between lots 1 and 2 was significant at the 1 per cent level. Although it was impossible to present a great deal of statistical data, due to the design of the experiment, greater confidence can be placed in the results because experiments were duplicated.

Perhaps the time and rate of release of this vitamin should be studied in more detail in order to further substantiate results obtained herein.

Experimental evidence was obtained in mixing trials which indicate that:

1. Sodium chloride tends to segregate when mixed with a mass of material that has many particles of relatively large size present, such as soybean oil meal or coarsely ground corn.

2. Ingredients of light weight have less tendency to segregate from the mass of the mix, once they have become mixed, than do heavy materials.

3. When granular materials are being mixed with relatively large particles, the effects of over mixing may be as deleterious as undermixing.

4. While the mass of the mix is still in the unmixed state, the taking of a small number of samples from a mix cannot be used satisfactorily to determine the degree of mixing.

5. The taking of a small number of samples from a mix can be used to determine when the mixed state is reached.

6. A trend was noticed which indicated that different ingredients reach a maximum point of being mixed at different time intervals. This suggests that there is a definite sequence in the addition of ingredients if a desirable mix is to be obtained.

7. Sodium chloride can be used with some confidence as a tracer in mixed feeds. However, this will give only a crude estimate for determining the mixed state. More research must be done on sequence of adding ingredients before definite and decisive conclusions can be arrived at on mixing time for various rations.

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APPENDIX

SUGGESTIONS FOR FURTHER STUDY

The relationship between mixing time and ingredient distribution in mixed feeds cannot be understood fully until further investigations are made. Studies relating ingredient distribution to particle size, particle shape, and particle density are necessary. Further, the effects of particle attraction or cohesion for one another must be studied, and these small forces overcome, if they cannot be made to work in favor of mixing.

The sequence in which the ingredients should be added to obtain a mixed ration is another problem that should be investigated. Sampling techniques and tracers used in determining the degree of mixing and the mixed state should be studied in more detail.

A STUDY OF DISTRIBUTION OF MICRO-INGREDIENTS IN MIXED FEEDS

by

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To approach more closely a balanced ration, the effects of improper mixing must be stressed as more supplements are added to formula feeds in trace quantities.

Rations were fed which simulated an unmixed diet. The ration was determined, mixed or unmixed, by the presence or absence of vitamin A. The results obtained showed that better growth and feed efficiency were promoted when a chick receives these trace materials in the desired quantity each day. Unmixed rations tended to decrease growth of chickens when measured by weight gains and feed efficiency.

Since the effect of unmixed rations on poultry growth has been shown, emphasis must be placed on the distribution of micro-ingredients in mixed feeds. Sodium chloride and nitrophenide were added to different feed ingredients and to complete rations in order to study distribution as affected by particle size of the mass of the mix. The distribution of sodium chloride was also studied as a possible tracer in determining when the mixed state was approached.

In general, as particle size of the mass of the mix became larger, the distribution of the sodium chloride became more critical and tended to segregate from the mass of the mix. Also, sodium chloride did not obtain a mixed state at the same time as other ingredients present in the mix, namely nitrophenide. This then, suggests a definite sequence of adding ingredients in order to more closely approach the mixed state. From this experiment it can be concluded that sodium chloride is not considered a

suitable material to use as a tracer in determining the mixed
state in feeds. When a point is reached where the sodium chlo-
ride distribution tends to be constant throughout the mass of
the mix, it can give some indication of mixing.