



OVERDUE FINES ARE 25¢ PER DAY
PER ITEM

Return to book drop to remove
this checkout from your record.

--	--

THE FEEDING VALUE OF FLASH
DRIED BLOOD MEALS IN
SWINE DIETS

By

Matthew James Parsons

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Animal Husbandry

1979

ABSTRACT

THE FEEDING VALUE OF FLASH DRIED BLOOD MEALS IN SWINE DIETS

By

Matthew James Parsons

Blood meals contain seven to ten percent lysine, but if dried by conventional methods much of this is not available when used in swine diets. Flash drying blood, which is a faster drying process, has been shown to improve lysine availability for chicks, poults and rats. Bioavailability assays, nitrogen and energy balance trials, and feeding trials were conducted to determine the availability of lysine and the feeding value of flash dried blood meals in swine diets. Seven percent available lysine appears to be a safe value to assign to flash dried blood meals when formulating swine diets. Use of flash dried blood meals in swine diets improved biological value, net protein value and metabolizable energy density of corn-soybean meal diets with the same lysine levels. The low isoleucine levels of blood meals may limit the amount of soybean meal that can be replaced by flash dried blood meal.

ACKNOWLEDGEMENTS

For the realization of the Masters of Science degree and for the very opportunity to pursue that goal at Michigan State University I am grateful to Dr. E.R. Miller. As an educator, researcher and friend I feel immensely fortunate and proud to have been associated with this gentleman.

I am grateful to Dr. D.E. Ullrey, Dr. W.T. Magee and Dr. H. Stowe for their interest and helpfulness as graduate committee members.

I am grateful to Dr. M.G. Hogberg and Dr. P.S. Brady for their advice and interest in my education.

Finally, my wife Sharon and my family are as much responsible for this accomplishment as I am. As a source of encouragement and friendship, they have been unfaltering.

TABLE OF CONTENTS

LIST OF TABLES	v
INTRODUCTION	1
REVIEW OF LITERATURE	2
Blood Meal as a Feed Ingredient	2
Heat Damage to Proteins	7
Measuring Protein Quality by Using Animal Models	10
The Use of the Animal Model to Measure Bioavailability of Amino Acids	12
Animal Models to Determine Mineral Availability	17
The Energy Scheme	20
MATERIALS AND METHODS	22
Design of Trial 1: Lysine bioavailability assay with flash ring dried blood meal	22
Design of Trial 2: Lysine bioavailability assay with flash ring dried blood meal	22
Design of Trial 3: Nitrogen and energy balance with flash ring dried blood meal	25
Design of Trial 4: Comparison of flash ring dried cattle blood meal and flash ring dried swine blood meal	25
Design of Trial 5: Feeding trial with flash ring dried swine blood meal	26
Design of Trial 6: Lysine bioavailability assay with flash drum dried blood meal	29
Design of Trial 7: Feeding trial with flash drum dried blood meal	29
Design of Trial 8: Nitrogen, energy and mineral balance with flash drum dried blood meal	31
Design of Trial 9: Iron availability assay	32
RESULTS AND DISCUSSION	35
Trial 1: Lysine bioavailability in flash ring dried blood meal	35
Trial 2: Lysine bioavailability in flash ring dried blood meal	35
Trial 3: Nitrogen and energy balance with flash ring dried blood meal	38
Trial 4: Flash ring dried cattle blood meal vs. flash ring dried swine blood meal	39
Trial 5: Flash ring dried swine blood meal feeding trial	40

LIST OF TABLES

Table	
1. Dry Matter, protein and amino acid composition of blood meals	3
2. Availability of lysine from blood meals as determined by chick, poult and rat bioassays	6
3. Basal diet for trials 1, 2 and 3	22
4. Dietary treatments in trials 1, 2 and 3	23
5. Basal diet for trial 4	24
6. Calculated basal diet analysis (trial 4) and NCR requirements	24
7. Dietary treatments in trial 4	25
8. Dietary treatments in trial 5	26
9. Diets using flash ring dried swine blood in trial 5	27
10. Basal diet in trial 6	28
11. Calculated analysis of basal diet (trial 6) and NCR requirements	28
12. Dietary treatments in trial 6	29
13. Use of flash drum dried blood meal in swine starting growing and finishing diets (trial 7)	30
14. Diets used in trial 8	31
15. Basal diet fed in trial 9	32
16. Diets used in trial 9	33
17. Iron analysis of diets in trial 9	33
18. Cumulative performance of pigs in trials 1 and 2	36
19. Estimation of bioavailable lysine in flash ring dried cattle blood meal (trial 2, only)	36
20. Plasma lysine (trials 1 and 2)	37
21. Protein and energy balance (trial 3)	38
22. Cumulative performance in trial 4	39

23.	Average daily lysine intake vs. average daily gain (trial 4)	39
24.	Calculated lysine bioavailability values for flash ring dried cattle blood meal and flash ring dried swine blood meal in trial 4	40
25.	Performance of pigs in trial 5	41
26.	Carcass data from pigs in trial 5	42
27.	Performance on reference diets (trial 6)	43
28.	Performance of pigs on test diets and calculated available lysine (trial 6)	43
29.	Performance of pigs fed flash drum dried blood meal (trial 7)	44
30.	Nitrogen and energy balance (trial 8)	45
31.	Mineral balance (trial 8)	47
32.	Growth and feed intake data (trial 9)	48
33.	Iron intake and hemoglobin synthesis (trial 9)	48
34.	Regression equation (hemoglobin on iron intake) from trial 9	49
35.	Iron availability of blood meals	49
36.	Replacement value of flash dried blood meals in swine diets	51
37.	Value of flash dried blood meal in swine diets	51

INTRODUCTION

Corn-soybean meal diets have been widely accepted as swine diets throughout the midwestern United States. However, in these diets, lysine is the first limiting amino acid, and consequently diets are often balanced on lysine. Cereal grains tend to be low in lysine, but soybean meal has a high concentration of lysine (NRC, 1973). Yet soybean meal is generally one of the more expensive feed ingredients in swine diets. Furthermore, feed cost makes up 67% of the total cost of swine production. As a result, economical alternative lysine sources are continually being sought for use in swine diets.

Blood meal may be one such lysine source. Chemically, blood meals are rich in lysine, containing 7.0 to 10.0% lysine. Furthermore, there is a large quantity of blood that is a by-product of the packing industry. Cattle contain 6 to 7% of their body weight as blood, and sheep and hogs contain 5 to 6% of their body weight as blood. However, conventional blood meals tend to be unpalatable (Morrison, 1956) and of poor protein quality as amino acids appear to be poorly available (Kratzer, 1957). Now, faster high temperature driers are available that expose the blood to heat for only twenty-one seconds. The decreased time of heat exposure should improve lysine availability.

REVIEW OF LITERATURE

BLOOD MEAL AS A FEED INGREDIENT

Blood meal is approximately 80% protein (Morrison, 1956), and results of chemical analysis, which are shown in Table 1, show it to be rich in lysine, leucine and valine (Doty, 1973; Wahlstrom, 1977). Conventionally dried blood meal is unpalatable, poorly digestible and low in calcium and phosphorus. Consequently, it has found only limited use in animal feeds (Morrison, 1956). Optimum gains and feed efficiency resulted when two or four percent conventional blood meal was added to chick rations as a supplemental lysine source. However, 8% blood meal in the ration either did not affect performance or slightly depressed growth of chick (Squibb, 1955). Spray drying, which is a faster, cooler process (only reaching 62.8°C) was shown to improve availability of lysine in blood meal as compared with the conventional vat drying process. Using the turkey poult assay, the available lysine in vat dried blood meal was 6.2 to 6.6% and 9.0 to 12.5% available lysine in the spray dried product. Percent availability ranged from 49 to 60% for vat dried and from 71 to 76 percent for spray dried (Kratzer, 1957). Flash dried blood meal, which was dried by a process such as the ring drying process, had lysine availabilities of 86.6, 90.7 and 81.5% for the rat, chick and turkey poult assay, respectively. Values reported in the same study for conventional

TABLE 1. Dry Matter, Protein and Amino Acid Composition of Blood Meals

Dry Matter, Protein or Amino Acids in Blood Meal, %

<u>Parameter</u>	<u>Vat Dried^a</u>	<u>Spray Dried^b</u>	<u>Ring Dried^a</u>	<u>Flash Dried^c</u>
Protein	82.1		89.6	88.20
Arginine	3.6		3.8	4.28
Histidine	3.5		4.4	5.54
Lysine	7.0	8.5	8.5	8.33
Phenylalanine	5.7	6.6	6.5	7.21
Cystine				0.10
Methionine	1.0	1.4	1.2	1.58
Threonine	3.1	4.1	4.0	4.17
Leucine	10.7	11.7	12.0	12.63
Isoleucine	0.96	0.9	0.94	1.12
Valine	7.4	8.2	8.7	8.66
Glycine	4.6		4.0	
Tyrosine	2.1		2.6	
Aspartic Acid	9.1		10.0	
Serine	3.1		3.9	
Glutamic Acid	8.2		8.8	
Proline	3.8		3.7	
Alanine	6.8		7.4	
Dry Matter	93.6		91.4	90.0

^a Waibel, 1974^b Doty, 1973^c Wahlstrom, 1977

blood meal were 19.2, 0, and 14.4%, respectively (Waibel et al, 1974). Doty (1973) reported a range of lysine availabilities in ring dried blood meal of 82 to 87% as determined by turkey poult assay (Table 2). Differences in digestibility did not account for the low availability of amino acids in conventional blood meal. Vat dried blood meal had digestibilities of lysine of 49%, of methionine 40%, and of cystine 18%. Ring dried blood meal had much higher digestibility coefficients for lysine, methionine, and cystine, being 97, 96 and 87%, respectively (Waibel, 1977).

Addition of 4% of conventional vat dried blood meal in place of an equal amount of soybean meal protein resulted in slower gains when fed to growing-finishing pigs, and poorer feed conversion during the growing phase. Supplementation with 0.1% synthetic L-lysine corrected performance. When flash dried blood meal (FDBM) was used at the same level, there was no depression in performance, and addition of 0.1% synthetic L-lysine did not improve performance. Addition of 6% FDBM at the expense of an equivalent amount of soy protein resulted in performance equal to control diets in growing and finishing pigs. Incorporation of 8% FDBM by the same scheme resulted in significantly depressed gains, lower feed consumption, and poorer feed conversion in pigs from 25 to 55 kg. in bodyweight. This reduced performance was postulated to be due to the low isoleucine content and high leucine content of diets containing blood meal (Wahlstrom, 1977). Other studies have shown that additions of isoleucine to blood meal diets improved gains in chicks (Grau, 1944) and that in rat diets isoleucine is the first limiting amino acid in blood meal (Young, 1973).

In a further study, incorporation of 4 and 5.7% FDBM resulted in depressed feed intake in the grower and finisher phases, however, there was no difference in efficiency of gain (Wahlstrom, 1977).

When poor growth rates were observed in chicks on blood meal diets, additions of cystine, threonine, tryptrophan, or arginine to diets either alone or in combination did not affect growth rate (Grau, 1944). Further studies showed no effect of added methionine (Grau, 1944; Muller, 1975). The plasma fraction of blood, as separated by the process of Tybor et al. (1973) may be first limiting in methionine or isoleucine. Blood meal has been shown to be a good source of tryptophan. When half of the protein in growing pig diets came from blood meal and the other half from meat and bone meal, pigs gained faster and were more efficient than pigs on diets in which the protein source was only meat and bone meal (Meade, 1957).

The microbial load of blood meal constituents separated by the process of Tybor et al., (1973) was very low. The total count was less than 2,000 microorganisms per gram of material. Furthermore, there were no detectable Salmonellae, Clostridia, or Escherichia coli (Doty, 1973).

TABLE 2. Availability of Lysine from Blood Meals, as Determined by Chick, Poult and Rat Bioassays.

Blood Meal and Source	Availability (% of Total Lysine)		
	Chick	Poult	Rat
<u>Conventional</u>			
Kratzer, 1957	64-66	49-60	
Doty, 1973		28-42	
Waibel <u>et al</u> , 1974	0	14.4	19.2
Waibel, 1977	0	14-43	8.0
<u>Spray Dried</u>			
Kratzer, 1957	68-85	71-76	
Doty, 1973		44-83	
<u>Flash Ring Dried</u>			
Doty, 1973		82-87	
Waibel <u>et al</u> , 1974	90.7	81.5	86.6
Waibel, 1977	93	80-87	97.0

HEAT DAMAGE TO PROTEINS

Severely heated soya flour fed to rats has been shown to result in lower portal plasma free amino acids than when properly heated soya flour was fed to rats (Goldberg, 1962). In chicks, autoclaving soybean meal above 120°C for 30 minutes has resulted in lower availability of methionine and cystine than when autoclaved at 110°C (Evans, 1946). Drastic autoclaving of soybean meal partially destroys cystine and lysine, decreases the digestibility of the lysine not destroyed, and decreases the absorption and utilization of methionine (Evans, 1948). When chicks were fed both practical and semi-synthetic starter diets, chicks fed diets containing soybean meal which was autoclaved for four hours with additional water gained faster than chicks fed diets which contained soybean meal that was autoclaved with no additional water. Both diets which contained soybean meal that had been autoclaved for four hours resulted in lower gains than diets formulated with soybean meal that had been autoclaved for 4 to 30 minutes with no additional water (Renner, 1953). Prolonged heating (4 hours under 15 pounds of steam) decreased the rate of liberation of lysine, arginine, and tryptophan from soybean meal by acid hydrolysis. Excessive heating decreased the rate of release by pancreatic hydrolysis (Riesen, 1947). Approximately 40% of the lysine in soybean meal or from crystalline D, L-lysine was destroyed by autoclaving for 4 hours at 15 pounds of pressure. Sixty percent less lysine was liberated by enzymatic digestion in vitro after autoclaving, and

20% of the added D, L-lysine was converted to a form which was not biologically active until after acid hydrolysis. Dry heat treatment did not destroy or inactivate nearly as much lysine as autoclaving did at the same temperature for the same amount of time (Evans, 1948).

Casein autoclaved for 20 hours under 15 pounds of steam had lower cystine content as determined microbially, than did casein autoclaved for 4 minutes under 15 pounds of steam (Hankes, 1948). When casein was dry-heated at 65.6°C the rate of release of lysine by pancreatic hydrolysis was too slow to allow effective supplementation of other more rapidly released amino acids (Pader, 1948). Heating casein at 65.6°C for 70 minutes did not change the total lysine content; however, lysine liberated by crystalline lysine decarboxylase was only 63 to 76% of the lysine in raw casein. Furthermore, lysine liberated by pancreatic digestion ranged from 49 to 89% of the total lysine in raw casein (Eldred, 1946).

Lysine availability is adversely affected by roasting regular dried corn above 150°C . When roasted at 160°C , available lysine was decreased by 16% and when roasted at 180°C by 44% (Costa, 1977b). When corns roasted at 82° , 104° , 127° , or 140°C were fed to growing pigs there was no difference in the performance. Finishing pigs, however, exhibited a significant linear decrease in average daily feed intake with increasing roasting temperature (Costa, 1977a). When rats were fed regular corn dried at 125°C there was a 79% reduction in gain when compared with rats fed air dried regular corn, and there was a 41% reduction in gain when opaque-2 corn was used. Rats exhibited poorer gains, lower

feed intake, and poorer feed efficiency with increasing drying temperature. Furthermore, as the drying temperature of the corn was increased the plasma tryptophan decreased. Plasma lysine levels were low in all cases. Using a growth assay it was found that as drying temperature increased the availability of amino acids, especially tryptophan and lysine, decreased. Fecal analysis showed lysine to be the amino acid most affected by drying temperature. Not only was the availability of lysine decreased, but also some lysine was either destroyed or formed a hydrolysis resistant complex with other agents (Rivers, 1978).

One proposed mechanism of heat damage on lysine is that when heated the ϵ -amino group enters easily into bonds with other compounds to render the lysine unavailable for digestion or metabolism (Eldred, 1946). ϵ -N-propionyl-L-lysine was found to give no growth response to lysine deficient rats, and more than 40% of the ingested lysine was excreted in the urine. However, ϵ -N-acetyl-L-lysine had approximately 50% as much activity as L-lysine on a mole per mole basis when fed to lysine-deficient rats, and resulted in high levels of lysine in urine. Yet, when heat damaged proteins were fed, as much as two-thirds of the lysine was recovered in the feces. Thus, it was concluded that formation of an amide linkage between the amino group of lysine and some other molecule containing a carboxyl group may cause nutritive damage, however, metabolism of acetylated and propionated amino acids and proteins is different from the metabolism of heat damaged amino acids and proteins (Bjarnason, 1969).

The loss of available lysine when protein sources are heated

can be partially explained by a condensation reaction between the ϵ -amino group of lysine and the amide groups of asparagine and glutamine, resulting in ϵ -(γ -L-glutamyl)-lysine crosslinkages (Bjarnason, 1970). Rats and chicks appear to have an enzyme in both the kidney and the stomach wall which can break the ϵ -(γ -L-glutamyl)-L-lysine crosslinkage. When present at high levels in the diet ϵ -(γ -L-glutamyl)-L-lysine appeared in the urine of the chicks; thus this cross-linkage may reduce the nutritional value of a protein source (Waibel, 1972). However, this does not account for all of the losses. Other losses may be due to a Maillard type reaction between the ϵ -amino group of lysine and the carbonyl groups of compounds formed by the destruction of cystine, which is 50% destroyed when heated to 115°C (Bjarnason, 1970). Furthermore, the presence of sugars tends to increase losses of lysine and arginine when heated to around 100°C (Bjarnason, 1970; Evans, 1948; Waibel, 1977).

When bovine plasma albumin was heated at 115°C for 27 hours, slightly less than 3% of the isoleucine was lost. It appeared as allo-isoleucine, which is a racemic product of isoleucine. Losses of isoleucine to allo-isoleucine increased to approximately 12% when bovine plasma albumin was heated to 145°C (Bjarnason, 1970).

MEASURING PROTEIN QUALITY BY USING ANIMAL MODELS

Several methods have been used to evaluate protein quality. Perhaps the simplest is the protein efficiency ratio (PER), which

is the ratio of body weight gained to the protein consumed (Church, 1974). In most species growth is a very insensitive measure of protein quality as it reflects a great deal more than just protein quality. Also, some species such as the pig are very adaptable to low protein diets and will continue to gain for several weeks (Armstrong, 1955). Apparent protein digestibility represents the difference between what is present in the feed and feces. However, this fails to correct for the metabolic fecal nitrogen (MFN). It has been proposed that a direct measurement of MFN is a better use of time and resources than extrapolating from a regression line of MFN on nitrogen intake (Mitchell, 1954). MFN in the growing pig was estimated to be 0.91 g per kg of dry matter (Armstrong, 1955). Biological value (BV) measures the utilization of absorbed protein. BV is the ratio of apparent retained nitrogen, as determined by nitrogen intake minus the fecal and urinary nitrogen, to the apparent absorbed nitrogen. However, more accurate estimates may be obtained by correcting for MFN and endogenous urinary nitrogen (Maynard, 1969). It has been noted that as the BV of proteins increase there is a decrease in the range of dietary protein levels over which the BV estimate is constant (Armstrong, 1955). Both the digestibility and the BV are accounted for by the net protein value (NPV), which is the product of the two (Church, 1974). This is the most sensitive measure of availability using a nitrogen balance. Another measure of protein quality is net protein utilization (NPU). NPU measures carcass nitrogen when a test diet is fed versus carcass nitrogen when a nitrogen free diet is fed, in relation to total nitrogen

intake (Church, 1974). This method has the advantage of a large number of values being obtained over a brief test period with a minimum of measurements (Maynard, 1969).

THE USE OF THE ANIMAL MODEL TO MEASURE BIOAVAILABILITY OF AMINO ACIDS

The fecal analysis, the growth assay, and analysis of plasma free amino acids are the three most frequently used animal assays to determine amino acid availability. A fourth, called the ileal analysis, has been described in the literature but is seldom used as it necessitates sacrificing the animal.

The fecal analysis measures the unabsorbed fecal amino acids from a feedstuff, which is dependent upon the presence of enzyme resistant peptide bonds and enzyme inhibitors in the sample (DeMuelenaere, 1967). Total or partial fecal collections are made on a test diet and on a low nitrogen or a nitrogen-free diet. Amino acid composition is determined on feed and feces. Test diet fecal amino acid levels are corrected for endogenous amino acid losses by subtracting fecal amino acid concentration of animals on nitrogen-free diet from fecal amino acid levels when test diets were fed. See formula 1 for determining amino acid availability for total collections (Bragg, 1969).

Formula 1

$$\% \text{ Amino Acid Available} = \frac{\text{Total Amino Acid Consumed} - \text{Total Fecal Amino Acids} + \text{Total Non-fecal Amino Acid}}{\text{Total Amino Acid Consumed}}$$

Questions have been raised about the validity of this assay because of the possible microbial contribution of amino acids in the lower gut to the endogenous amino acids. Sizeable microbial amino acid synthesis would greatly lower the predicted availability value for a feedstuff. However, feeding of 2% sulfasuxidine to growing pigs for ten days prior to the start of the assay resulted in no significant differences in availability values obtained. Therefore, it was concluded that microbial contributions did not significantly alter predicted availability (Kuiken, 1952). Furthermore, values obtained when using gnotobiotic chicks were not significantly different than values obtained when using conventional chicks (Elwell, 1975).

True availability values for arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine for meat ranged from 99.2 to 100.7%, and were slightly lower for cereal flours with a range of 75.4 to 99.5% when determined by the fecal analysis method (Kuiken, 1948). When evaluating poor quality proteins, such as corn, this method has the advantage of using large quantities (80 to 90% of the diet) of the test protein in the diet, and still getting valid results as this assay is not dependent on a growth response which would be poor on this type of protein, or a change in plasma free amino acids which would be hard to interpret with a poor quality protein (DeMuelenaere, 1960).

In a study of the effect of feed amino acid intake on fecal amino acid level increasing the level of casein, a very highly digestible protein, did not greatly influence the output of any

amino acid in the feces. However, when soybean meal which is only moderately digested was fed as the test protein, increasing the level of soybean meal in the diet resulted in a linear increase in fecal output of each amino acid. When the regression lines were extrapolated back to a protein free diet the fecal amino acid output predicted by the casein diets was in good agreement with actual results obtained by feeding a protein free diet. However, extrapolation of results from soybean meal diets predicted a lower fecal amino acid level than actually resulted (Carlson, 1970).

When fecal collections are difficult the ileal analysis may be used. This method requires sacrificing the animal to remove the ileum. Contents are washed from the ileum and these are handled as the fecal samples described above. Results of this method compare well with results of fecal collection methods (Elwell, 1975).

The growth assay is based on the principle that simple linear regression can be used to predict bioavailability of amino acids (Harris, 1972). A basal diet is formulated to meet all the needs of the animal except the amino acid to be studied (Ousterhout, 1959). Graded levels of the limiting amino acid are added as crystalline amino acid. In rats there was a linear response in growth to the addition of lysine over a range of 0.27 to 0.77% lysine (Gupta, 1958). If the actual requirements of the animal are known the crystalline amino acid diets are the easiest to formulate to meet the needs of the animal without greatly exceeding the requirement for any amino acid. However, this practice is

quite expensive, yet it can eliminate some interactions, imbalances, and availability problems encountered with natural feedstuffs (Ousterhout, 1959; DeMuelaere, 1967).

The regression of several different response parameters on dietary amino acid level or on total amino acid consumption have been studied. Responses used include daily weight gain, feed efficiency, change in empty carcass weight or change in water, nitrogen, or amino acid content of the carcass. It appears that best results are obtained when the independent variable is total amino acid consumed (DeMuelenaere, 1967). Using feed efficiency as the dependent variable tends to give higher estimates of availability than using gain as the dependent variable (Gupta, 1957). The amount of available amino acid is determined by comparing the response criteria of animals of test diets to form the standard curve. Percent availability is calculated using the amount of available amino acid determined from the standard curve and the known amount of a given amino acid in the feed (Gupta, 1957).

Values obtained by the growth assay and by the fecal analysis method were in close agreement (Gupta, 1957). In an attempt to verify availability results from the growth assay, either a crystalline reference diet balanced to meet the needs of a growing chick or a diet balanced on the available amino acids in soybean meal or on the chemical analysis of soybean meal were fed to growing chicks. Chicks fed the reference diet or the diet balanced on available amino acids did not differ significantly in gain or feed conversion. However, chicks fed the diet balanced on chemical analysis did exhibit poorer performance. Similar results have been shown with

feathermeal (Smith, 1968).

Great care must be taken in formulation of diets when using the growth assay. An amino acid imbalance will result in lower feed intake, which will adversely affect growth rate (DeMuelenaere, 1967). Imbalance of amino acids in diets can result in inflated availability estimates (Smith, 1965). Additions of the test protein to the basal diet must not alter the protein level or energy level, as this will change the amino acid requirement (DeMuelenaere, 1967). There must be a growth response due to additions of the limiting amino acid and not to other factors, such as other amino acids, energy, or mineral levels in the diet (Elwell, 1975).

The use of plasma free amino acids to determine the bioavailability of amino acids has met with very limited success. There are three conditions needed for a valid plasma free amino acid comparison; 1) equal and concomitant feed intake of the reference diet and the test diet, 2) maximal feed intake to insure that the plasma free amino acid pattern reflects the dietary amino acid pattern, 3) diets must be fed often to establish a steady state of amino acid uptake (Smith, 1965). Using this method, plasma free amino acid levels are due to the rate of absorption from the gut and the rate of uptake by the tissue for protein synthesis (Puchal, 1962). In rat diets, adding graded levels of a single test amino acid which was deficient in the diet, resulted in a linear increase in that amino acid in the plasma free amino acid pool, if gains were not increased. However, if gains were increased by the addition of the amino acid, the changes in plasma free amino acids were quite small after the first increment. This is probably due to

an increased rate of removal of amino acids by tissue for protein synthesis (Stockland, 1970a, 1970b; Windell, 1971).

A properly balanced reference diet containing no deficient or excess amino acids is extremely important when using this assay. Reference diets containing excessive levels of amino acids can result in apparent deficiencies in test diets which can not be corrected by additions of these amino acids (Smith, 1965). Excesses of any amino acid in the reference diet will result in low predicted availability values for that amino acid in a test protein (Smith, 1966). Amino acids not limiting in the diet tended to increase as the level of protein increased, if there was no increase in gain (Windell, 1971).

ANIMAL MODELS TO DETERMINE MINERAL AVAILABILITY

The mineral most important in the evaluation of blood meal is iron, therefore most of this discussion will revolve around methods of determining bioavailable iron in feedstuffs. The most widely used method is the hemoglobin repletion method. Anemic subjects are fed a low iron basal diet with graded levels of ferrous sulfate added to obtain a standard curve (Fritz, 1974; Pla, 1970). Non-anemic chicks can be used and the iron sources will still rank the same but the availability values will be lower while and precision will be the same (Amine, 1972). In rats, depletion-repletion studies gave better estimates than prophylactic studies (Amine, 1974). Test diets are formulated with graded levels of the test ingredient added. All additions should be made at the

expense of an ingredient such as sucrose or starch (Morris, 1976).

It is desirable to have at least three levels of added test ingredient, as this will result in more accurate values which will be independent of effects of concentration of the nutrient in the diet on availability (Amine, 1972). Ten days on the diets was long enough to produce a response in rats (Morris, 1976), and fourteen days was long enough to produce a response in chicks (Pla, 1970). Either hemoglobin or hematocrit determinations will give similar results by this method (Amine, 1972). Data may be analyzed by the slope-ratio technique (Amine, 1972; Pla, 1970) or by the parallel lines method. Both will yield similar results (Fritz, 1974). It should be pointed out that the linearity of this test fails when excessive doses are tested. These points should be excluded from the analysis (Amine, 1972).

With young pigs a significant response in both hemoglobin and weight gain has been reported in an availability trial (Pickett, 1961). However, in chicks and rats using body weight gains to predict iron potency of foodstuffs gave inconsistent estimates and thus was deemed to be an unsatisfactory measure of response (Amine, 1972). Total iron retention as determined by carcass analysis gave similar results to hemoglobin repletion, although these results were not as clear cut (Nakamura, 1943). Using plasma iron concentration to estimate absorption has been shown to be unsatisfactory for quantitative determinations (Forth, 1973).

Methods have been developed to study availability of iron using labeled iron and a whole body counter (Welch, 1975). This method assumes that radioiron exactly duplicates the properties

of the stable iron source. Results obtained using $^{59}\text{FeCl}_3$ show little or no relationship to expected potency. However, when labeled hemoglobin was used the results were similar to those obtained when the hemoglobin repletion technique was used (Amine, 1972).

In three and twelve day old pigs plasma iron plateaued six days after an oral dose of ^{59}Fe labeled ferric citrate and only a small amount of the ^{59}Fe was found as non-heme iron in the liver. This indicates that the efficiency of utilization of iron for red blood cells is very high and that ^{59}Fe uptake is satisfactory for quantitative determinations in the neonatal pig. This difference from other species is most likely due to the high iron requirement of the neonatal pig. Furthermore, iron depletion prior to the start of the study did not enhance absorption in the neonatal pig (Furugouri, 1975).

Mineral balance, growth performance, and bone development have been used in some studies to determine phosphorus availability from some feedstuffs. Balance trials determine retention by difference, using intake, fecal losses and urinary losses. Parameters considered under bone development include bone ash, degree of osteoporosis, width of the distal radial epiphyseal plate, incidence of fractures, and incidence of focal enlargement of epiphyseal plates (Bayley, 1969; Miller, 1964). Other methods use pathological change as the response criteria to measure availability. Selenium availability can be measured by prevention of exudative diathesis in chicks and liver necrosis in rats fed torula yeast based diets with the test ingredient added to the basal diet (Mathias, 1965).

THE ENERGY SCHEME

Several methods have been used to evaluate the energy available in feedstuffs for productive purposes. One of the oldest is apparent digestible energy, which is determined by difference between the gross energy of the feed and fecal energy losses. True digestible energy may be calculated by correcting apparent digestible energy for endogenous fecal energy losses. Metabolizable energy can be found by correcting digestible energy for urinary energy losses (Church, 1974; Maynard, 1969). True metabolizable energy is calculated by correcting for endogenous fecal and urinary energy losses (Sibbald, 1977). Using growing pigs, metabolizable energy values for cereal grains averaged 97.4% of the digestible energy levels, and protein feeds had metabolizable energy values which were 81.9% of the digestible energy values. The digestible energy to metabolizable energy ratio is affected by the crude protein level of the feed (Morgan et al., 1975). Because of this, metabolizable energy may be corrected for nitrogen balance using the value of 6.77 kcal per gram of urinary nitrogen (Diggs et al., 1965). Morgan et al. (1975) reported an average value of 9.2 kcal per gram of urinary nitrogen, but lower protein levels were used in that study. Extrapolation of the regression line found by Morgan et al., (1975) gives a value of 7.3 kcal per gram of urinary nitrogen when the diet protein is 40% which is in close agreement with Diggs et al., (1965). Also, some have proposed adjusting metabolizable energy to a retention of 30% of the total nitrogen intake, as

it may more closely resemble the nitrogen balance of the growing pig (Morgan et al., 1975).

Metabolizable energy can be further divided into net energy for production (NE_p), net energy for maintainance (NE_m), heat increment, and heat loss from fermentation (Church, 1974). Heat loss from fermentation is generally small and most often disregarded in monogastrics. Heat increment is the energy used for metabolism of nutrients, and when combined with NE_m is called heat production (HP). Evaluation of feedstuffs by this method to determine the net energy values requires an estimate of either HP or NE_p (Ewan, 1976).

MATERIALS AND METHODS

The feeding value of flash dried blood meals as reported here is based on nine trials. Trials 1, 2, 4 and 6 were bioassays of lysine availability and trial 9 was a bioassay of iron availability in flash dried blood meals. Trials 3 and 8 were balance studies, and Trials 5 and 7 were feeding trials.

Trials 1 and 2 had the same design and will be discussed together. In either study 40 pigs, having an average initial weight of 13 kg, were randomly allotted from litter outcome groups to five lots and placed on the basal diet shown in Table 3. This diet meets all of the known nutrient requirements of the 20 kg pig with the exception of lysine. In either trial, after initial

TABLE 3. Basal Diet for Trials 1, 2 and 3

Ingredient	Int. Ref. No.	Amount, parts
Corn starch		30.0
Ground shelled corn	4-02-931	823.0
Soybean meal 48	5-04-612	115.0
Dicalcium phosphate	6-01-080	10.0
Calcium carbonate	6-01-632	10.0
Salt		5.0
MSU VTM premix		5.0
Antibiotic premix*		2.0
		1,000.0

* Supplying 44 ppm of chlortetracycline to ration

- adjustment on the basal diet, lots were placed on one of the five treatments shown in Table 4 for a six week bioassay. All additions of lysine or blood meal were made at the expense of corn starch. The blood meal used in Trials 1 and 2 was flash ring dried cattle blood (FRDCB).

TABLE 4. Dietary Treatments in Trials 1, 2 and 3

Ration	Calculated total lysine, %
Basal (B)	0,55
Basal + 0.1% L-lysine (B+.1)*	0,65
Basal + 0.2% L-lysine (B+.2)*	0,75
Basal + 1.5% FRDCB (B+1.5)	0,69
Basal + 3.0% FRDCB (B+3.0)	0,84

* 78.4% L-lysine as L-lysine hydrochloride.

In both trials, lots of eight pigs were housed in 2.0 m by 2.4 m pens which had 7.6 cm aluminum slats as flooring and 1.9 cm slots. Feed was available ad libitum from a round metal feeder in the center of the pen. Water was continuously available from an automatic cup waterer on one side of the pen. Room temperature was maintained at about 25°C by a thermostatically regulated gas-fired furnace and two thermostatically controlled exhaust fans. Weekly pig weights and a measure of feed consumption were taken over the six week period in both trials. Blood was withdrawn from four pigs in each treatment at 3 and 6 weeks of the trial for determination of plasma lysine levels. Data were analyzed by using linear regression of diet lysine level on ADG and predicted diet lysine from the ADG. Predicted diet lysine values were adjusted for basal diet contribution of lysine and the remaining amount was considered to be from FRDCB.

TABLE 5. Basal Diet for Trial 4

Ingredient	Int. Ref. No.	Amount, parts
Corn starch		30.0
Ground shelled corn	4-02-931	781.5
DL-methionine (98%)		1.0
Soybean meal (48%)	5-04-612	150.0
Dicalcium phosphate	6-01-080	10.0
Calcium carbonate	6-01-632	10.0
Salt		5.0
MSU VTM premix		5.0
Vit. E-Se premix		5.0
Antibiotic premix		2.5
		1,000.0

TABLE 6. Calculated Basal Diet Analysis (Trial 4) and NRC Requirements

Item	Basal Diet	NRC
D.E., Kcal/kg	3450	3,300
Lysine, %	0.65	0.79
Methionine + Cystine, %	0.58	0.51
Tryptophan, %	0.15	0.12
Calcium, %	0.67	0.65
Phosphorus, %	0.50	0.50

In trial 3 nitrogen and energy balance studies were conducted on each of the five diets used in trials 1 and 2. Two lots of four pigs each which averaged about 17 kg in initial weight, were housed in elevated group metabolism cages. Three-day adjustment periods were followed by 3-day periods of collection of feces and urine. Feces were dried in a drying oven and aliquots of feces and urine were taken for nitrogen and energy determinations.

Trial 4 was a comparison of the bioavailable lysine in FRDCB and flash ring dried swine blood (FRDSB). Seven lots of 13 pigs averaging about 9 kg were randomly allotted into pens as described in Trials 1 and 2. Pigs were allowed to adjust to the basal diet shown in Table 5. The basal diet was formulated to meet all of the nutrient needs except lysine of the 9 kg pig (Table 6). After the adjustment period, lots were assigned to the treatments shown in Table 7. Synthetic lysine, FRDCB and FRDSB were added to the basal ration at the expense of corn starch. Pigs were weighed and feed intake recorded biweekly for four weeks. The regression equation of ADG and average daily lysine intake was used to predict lysine availability, in a similar manner as described for trials 1 and 2.

TABLE 7. Dietary Treatments in Trial 4

Basal	(B)
Basal + 0.1% L-lysine	(B+.1)
Basal + 0.2% L-lysine	(B+.2)
Basal + 1.5% FRDCB	(B+1.5 FRDCB)
Basal + 3.0% FRDCB	(B+3.0 FRDCB)
Basal + 1.5% FRDSB	(B+1.5 FRDSB)
Basal + 3.0% FRDSB	(B+3.0 FRDSB)

Trial 5 was conducted to study the effects of high and low levels of FRDSB in swine diets (Table 8) throughout the starting, growing and finishing periods. Bioavailable lysine values obtained from previous studies were used in balancing the rations. FRDSB was incorporated with corn into the diet to replace soybean meal (see Table 9).

TABLE 8. Dietary Treatments in Trial 5

Level of FRDSB	Starter	Grower	Finisher
Basal	0	0	0
Low	3.0%	2.0%	1.5%
High	6.0%	4.0%	3.0%

Pigs were randomly assigned to two replicates of the three levels of FRDSB incorporation at about 8.3 kg initial bodyweight. There were 14 pigs per lot during the starter phase, and they were housed in facilities described in Trials 1 and 2. At the end of a five week starter period, pigs per lots were reduced to 10 and the pigs were placed on their respective growing diets. Throughout the growing period, pigs were housed in 1.4 m by 4.3 m pens which had 15.2 cm cement slats with 1.9 cm slots as flooring. After six weeks, these pigs were placed on their respective finishing diets, and were moved to pens which were 1.8 m by 4.3 m having the same type of slotted floor as in the growing phase.

During the growing-finishing phases the temperature was maintained at about 17°C by thermostatically-controlled gas-fired furnaces and thermostatically-operated exhaust fans. Body weight and feed consumption were recorded throughout the study. Carcass data

TABLE 10. Basal Diet in Trial 6

Ingredient	Int. ref. no.	Amount, parts
Corn starch		30.0
Ground shelled corn	4-02-931	801.0
Soybean meal 48	5-04-612	130.0
Deflourinated phosphate	6-01-780	10.0
Calcium carbonate	6-01-632	8.0
Sodium chloride		5.0
MSU Vitmin-mineral premix		5.0
Vitamin E-Se premix		5.0
Antibiotic mix		2.5
DL-methionine		1.0
Tryptrophan mix (4.55 g/kg)		2.5
		1,000.0

TABLE 11. Calculated Analysis of Basal Diet (Trial 6), and NRC Requirements

Parameter	Basal diet	NRC
D.E., kcal/kg	3,432	3,500
Crude protein, %	13.3	18.0
Lysine, %	0.60	0.79
Methionine + cystine, %	0.56	0.56
Tryptophan, %	0.15	0.15
Calcium, %	0.67	0.65
Phosphorus, %	0.47	0.50

were collected on eight pigs per treatment when they reached market weight.

Another flash drying process known as flash drum drying is available for blood, so Trial 6 was conducted to determine the bioavailability of lysine in flash drum dried blood meal (FDDBM). A four week bioassay similar to those used in Trials 1, 2 and 4 was conducted. Eight four-week-old pigs averaging 9.5 kg were randomly allotted and placed on the basal diet shown in Table 10, which meets all the nutrient needs except total protein and lysine for this age pig (Table 11).

After an adjustment period, pigs were assigned to one of the five treatments in Table 12. All additions of synthetic lysine and FDDBM were made at the expense of corn starch. Feed intake and growth rates were recorded.

TABLE 12. Dietary Treatments in Trial 6

Basal	(B)
Basal + .1% L-lysine	(B+.1)
Basal + .2% L-lysine	(B+.2)
Basal + 1.5% FDDBM	(B+1.5)
Basal + 3.0% FDDBM	(B+3.0)

Trial 7: Using bioavailable lysine values obtained in Trial 6, rations similar to those in Trial 5 were formulated which had either no blood meal, a low level or a high level of blood meal incorporated into the diet with corn to replace soybean meal. Percentages of incorporated FDDBM were the same as in Trial 5. Pigs averaging about 7.8 kg were randomly allotted to two replicates

TABLE 13. Use of FDDBM in swine starting, growing and finishing diets (Trial 7)

Item	Starter			Grower			Finisher		
	corn- soy	3% FDDBM	6% FDDBM	corn- soy	2% FDDBM	4% FDDBM	corn- soy	1.5% FDDBM	3.0% FDDBM
Corn	711.5	750.5	789.5	784.5	813.5	842.5	846.0	865.0	884.0
SBM 48	250.0	180.0	110.0	180.0	130.0	80.0	120.0	85.0	50.0
Defl. phosphate	15.0	17.0	19.0	10.0	12.0	14.0	11.0	13.0	15.0
Calcium carbonate	6.0	5.0	4.0	8.0	7.0	6.0	7.0	6.0	5.0
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
MSU VTM premix	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Vit. E-Se premix	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Antibiotic	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.0	1.0
FDDBM	0.0	30.0	60.0	0.0	20.0	40.0	0.0	15.0	30.0
	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0

of the three treatments. After an adjustment period they were placed on the diets shown in Table 13. There were 13 pigs per lot in the starter phase, 10 pigs per lot in the grower phase, and 8 pigs per lot in the finisher phase. Pigs were housed in facilities described in Trial 5. Biweekly weights and feed consumption were recorded. Also, carcass data were obtained on 11 pigs per treatment at market weight.

In Trial 8, twelve pigs averaging 11.3 kg were randomly assigned to one of three diets, which were either basal, 3% FDDBM or 6% FDDBM as shown in Table 14. These diets were balanced to meet the lysine, methionine-cystine, tryptophan, calcium and phosphorus requirements of this age pig. Available lysine as determined by earlier studies was used for FDDBM, and book values were used for other ingredients. Pigs were housed in individual cages and

TABLE 14. Diets Used in Trial 8

Ingredient	Int. ref. no.	Basal	3% FDDBM	6%FDDBM
Ground shelled corn	4-02-931	70.75	74.65	78.55
Soybean meal (48%)	5-04-612	25.00	18.00	11.00
Dicalcium phosphate (low iron)		1.50	1.70	1.90
Calcium carbonate	6-02-632	1.00	0.90	0.80
Salt		0.50	0.50	0.50
MSU VTM premix (low iron)		0.50	0.50	0.50
Vit E -Se premix		0.50	0.50	0.50
ASP 250		0.25	0.25	0.25
FDDBM		0.00	3.00	6.00
		100.00	100.00	100.00

were fed 400 g of feed per day in two meals. They were allowed to adjust to the diets and then a five day total collection was made. Feces were dried in a drying oven and aliquots of feces and urine were taken for energy, nitrogen, zinc, iron, calcium and phosphorus analysis.

Trial 9 was a hemoglobin depletion-repletion bioassay for iron availability in FDDBM and Flash Ring Dried Blood Meal (FRDBM). Ten three week old pigs which had received no supplemental iron since birth and were anemic at the start of the study were used. Pigs were fed the basal diet shown in Table 15 during a one week

TABLE 15 Basal Diet Fed in Trial 9

Ingredient	Int. ref. no.	Amount
Ground shelled corn	4-02-931	76.00
Soybean meal 49%	5-04-612	20.00
Calcium carbonate	6-01-069	1.00
Dicalcium phosphate (low iron)		1.00
Salt		0.50
Vitamin-mineral premix (low iron)		0.50
Vitamin E - Se premix		0.50
78% L-lysine		0.25
Aureo SP-250		0.25
		100.00

adjustment period. Two pigs were assigned to each of the following treatments no supplemental iron added (L), 30 ppm supplemental iron added (M), 60 ppm supplemental iron added (H), 2% FDDBM added (2% FDDBM) and 2% FRDBM added (2%FRDBM). Diets were formulated using the basal diet as shown in Table 16 and were fed ad libitum. Ferrous sulfate and cerelose were used to make the iron premix.

TABLE 16. Diets Used in Trial 9

Ingredient	L ^d	M ^c	H ^f	2% FDDBM ^g	2% FRDDBM ^h
Basal	98.0	98.0	98.0	98.0	98.0
Iron premix ^a	0.0	1.0	2.0	0.0	0.0
Cerelose	2.0	1.0	0.0	0.0	0.0
FDDBM ^b	0.0	0.0	0.0	2.0	0.0
FRDBM ^c	0.0	0.0	0.0	0.0	2.0
	100.0	100.0	100.0	100.0	100.0

^a Iron concentration in Iron premix was 3230 ppm.

^b Iron concentration in FDDBM was 2100 ppm

^c Iron concentration in FRDBM was 2010 ppm

^d Basal diet with no supplemental iron

^e Basal diet plus 30 ppm supplemental iron

^f Basal diet plus 60 ppm supplemental iron

^g Basal diet plus 2% Flash Drum Dried Blood Meal

^h Basal diet plus 2% Falsh Ring Dried Blood Meal

TABLE 17. Iron Analysis of Diets in Trial 9

Diet	Iron (ppm)
L ^a	45.6
M ^b	67.1
H ^c	91.8
2% FDDBM ^d	102.0
2% FRDBM ^e	87.4

^a Basal diet with no supplemental iron

^b Basal diet plus 30 ppm supplemental iron

^c Basal diet plus 60 ppm supplemental iron

^d Basal diet plus 2% Flash Drum Dried Blood Meal

^e Basal diet plus 2% Flash Ring Dried Blood Meal

Iron analysis of the diets is shown in Table 17.

Blood samples were withdrawn for hemoglobin analysis and body weights were recorded at the time pigs were placed on treatments and weekly thereafter for three weeks.

RESULTS AND DISCUSSION

In Trial 1, FRDCB additions gave higher than expected growth rates as based on observed growth responses of pigs on reference diets. On the other hand, data from Trial 2 more nearly matched expectations (Table 18). Feed consumption data in either trial did not indicate any palatability problems from using up to 3% FRDCB in the rations. Thus, it appears that the growth response observed in Trial 1 may be due to some nutrient other than lysine supplied by the blood meal. The calculated methionine-cystine content of the basal ration may have been marginally inadequate, being between 0.46 and 0.49 percent depending on the source of values (Pond and Manner, 1974; NRC, unpublished) and the requirement for 10-20 kg is 0.51% (NRC, unpublished). When data from Trials 1 and 2 are combined, the availability values calculated are unbelievably high, as they range from 98% to 117% of the total lysine. This is due to the poor response to added synthetic L-lysine as compared to the response of added FRDCB in the first trial. Amino acid imbalances in the reference diets will result in inflated availability estimates (Smith, 1965).

In Trial 2 there appears to have been some problems in collecting accurate feed intake data, especially on the B + 1.5 diet. Consequently, availability values ranged from less than zero, which of course is impossible, to as high as 155%. However, the availability values obtained when calculated using the regression average daily gain on diet lysine concentration appeared to be more realistic. The regression equations, total diet lysine as determined by the

TABLE 18. Cumulative Performance of Pigs in Trials 1 and 2

	B	B+.1	B+.2	B+1.5	B+3
<u>Trial 1</u>					
Ave. init. wt., kg	13.0	12.4	12.7	12.8	12.8
ADG, g	431	454	558	572	645
ADF, g	1270	1172	1395	1373	1343
F/G	2.95	2.58	2.50	2.40	2.08
<u>Trial 2</u>					
Ave. init. wt., kg.	13.0	12.9	13.8	13.8	13.6
ADG, g	445	522	636	518	636
ADF, g	1138	1370	1482	1390	1400
F/G	2.56	2.64	2.33	2.70	2.19

TABLE 19. Estimation of Bioavailable Lysine in FRDCB (Trial 2 data only)

Period	Equation	r	Total bioavail- able lysine %		Bioavailable lysine in FRDCB, %			% Bio- avail- able ^a
			b+1.5	B+3	B+1.5	B+3	X	
1 week	$y^b = -128 + 725 x^c$	.989	.69	.75	9.3	6.7	8.0	82
2 weeks	$y = -94 + 725 x$	.982	.62	.76	4.7	7.0	5.8	60
3 weeks	$y = -119 + 840 x$	.999	.65	.77	6.7	7.3	7.0	72
4 weeks	$y = -138 + 930 x$	.999	.65	.76	6.7	7.0	6.8	70
5 weeks	$y = -141 + 995 x$	.999	.65	.76	6.7	7.0	6.8	70
6 weeks	$y = -86 + 995 x$	.994	.64	.76	6.0	7.0	6.5	67

^a Based on 9.7% total lysine analysis.

^b Average daily gain, g.

^c Diet lysine level, %.

growth response, available lysine, and percent availability are shown for cumulative data for six weeks (Table 19). The percent availability values obtained tended to stabilize by three weeks on test. Seventy percent of the total lysine in FRDCB appeared to be bioavailable, thus a range of 6.5 to 7.0% bioavailable lysine appeared to be very safe as values to use in ration formulation.

The free plasma lysine values for Trials 1 and 2 are shown in Table 20. Using the values obtained the average of the two availability values calculated at 3 and 6 weeks is only 30% of

TABLE 20. Plasma lysine ($\mu\text{M}/100\text{ ml}$) (Trials 1 and 2)

Treatment	Time of sampling	
	3 weeks	6 weeks
B	7.0 ± 0.7	7.4 ± 0.6
B + .1	9.2 ± 1.1	13.8 ± 1.4
B + .2	14.8 ± 2.2	19.3 ± 1.7
B + 1.5	8.3 ± 0.3	10.9 ± 0.6
B + 3	9.3 ± 0.6	12.0 ± 1.0

the total lysine in FRDCB, or only 2.8% available lysine in FRDCB. This is a much lower value than obtained by the growth assay. The difference in values may be due to a deficiency of another amino acid in the reference diet. As pointed out earlier, methionine-cystine levels were only marginally adequate in the reference diet. Additions of FRDCB to the basal diet resulted in increased lysine as well as increases in other amino acids in the diet. Increasing the level of the second limiting amino acid in the reference diet, which appears to be methionine-cystine in this case by the addition of FRDCB may have resulted in a better amino

acid balance in the diet. Assuming 70% availability of methionine-cystine in FRDCB, the addition of 1.5% FRDCB could raise the available methionine-cystine to .47 to .50% and addition of 3.0% FRDCB would result in available methionine-cystine values of .49 to .53%.

With a better amino acid balance in the test diets, the clearance rates of the first limiting amino acid is increased (Stockland, 1970a, 1970b; Windell, 1971). Thus, plasma free lysine values of pigs on test diets would appear low when compared to reference diets.

Results of the nitrogen and energy balance study (Trial 3) on the diets used in the availability studies are shown in Table 21. Biological value of the diet protein was improved by additions of FRDCB or synthetic L-lysine.

TABLE 21 Protein and Energy Balance (Trial 3)

Treatment	B.V. ^a	N.P.V. ^b	D.E. ^c	M.E. ^d	N. cor M.E. ^e
B	84	62	3366	3332	3321
B + .1	88	74	3521	3482	3470
B + .2	87	55	3118	3077	3067
B + 1.5	91	73	3426	3399	3385
B + 3.0	87	67	3444	3412	3400

^a Biological Value

^b Net Protein Value

^c Digestible Energy

^d Metabolizable Energy

^e Nitrogen Corrected Metabolizable Energy

With the exception of B + .2 treatment, FRDCB and synthetic L-lysine additions improved N.P.V., D.E., M.E., and N cor M.E.

Cumulative four week performance of pigs in Trial 4 is shown in Table 22. Performance of pigs on test diets when compared to performance of pigs fed reference diets was closer to expected results than performance on test diets in Trial 1. The largest response was exhibited when 0.1% synthetic lysine, 1.5% FRDCB and 1.5% FRDSB were added to the basal diet. Higher levels of

TABLE 22. Cumulative Performance (4 weeks) in Trial 4

Diet	ADG (g)	ADF (g)	F/G
Basal	300	826	2.78
B + 0.1% L-lysine	472	1062	2.27
B + 0.2% L-lysine	477	962	2.00
B + 1.5% FRDCB	422	972	2.33
B + 3.0% FRDCB	281	972	2.00
B + 1.5% FRDSB	236	981	2.25
B + 3.0% FRDSB	463	917	2.00

TABLE 23. Average Daily Lysine Intake (x) vs. Average Daily Gain (y) (Trial 4)

Diet	x (g/day)	y (g/day)
Basal	5.4	300
B + .1% L-lysine	8.0	472
B + .2% L-lysine	8.2	477

$$y = 64.5x - 48$$

$$r = .99$$

TABLE 24. Calculated Lysine Bioavailability Values for FRDCB and FRDSB in Trial 4

	Average daily lysine intake, (g/day)	Total bioavailable lysine (%)	Blood Meal	
			Bioavailable lysine (%)	Bioavailable %
B + 1.5% FRDCB	7.3	.76	7.25	74.9
B + 3.0% FRDCB	8.2	.84	6.47	66.7
B + 1.5% FRDSB	7.5	.77	7.67	79.1
B + 3.0% FRDSB	7.9	.86	7.07	72.9

incorporation (B+.2% L-lysine, B+3.0% FRDCB and B+3.0% FRDSB) appear to have exceeded the lysine requirement of this size pig, therefore a smaller response than expected was shown. The average daily lysine intake (ADL), average daily gain (ADG) and the regression equation of ADL on ADG is shown in Table 23. The calculated ADL, diet lysine concentration, and percent availability of lysine is shown in Table 24. These data indicate that FRDSB and FRDCB have similar available lysine values and that 6.5 to 7.0% available lysine appears to be a safe range of available lysine to use in balancing rations.

The results of the feeding trial (Trial 5), in which rations were balanced using a value of 7% available lysine in FRDSB, are in Table 25. Pigs fed diets containing FRDSB performed as well as pigs fed the corn-soy basal diet throughout the starter, grower and finisher phases. Furthermore, there were no significant differences in carcass data gathered from pigs fed the respective diets (Table 26). It can be concluded that 7% available lysine in FRDSB is a safe value to use in ration formulation. Also, FRDSB may be

TABLE 25. Performance of pigs in Trial 5

Parameter	Replicate	Basal	Low FRDSB	High FRDSB
<u>Starter Phase (5 weeks)</u>				
Initial weight, kg	1	6.4	6.3	6.1
	2	<u>10.2</u>	<u>9.7</u>	<u>10.2</u>
	Average	8.3	8.0	8.2
ADG, g	1	427	436	413
	2	<u>463</u>	<u>531</u>	<u>506</u>
	Average	445	484	460
F/G	1	2.26	2.19	2.35
	2	<u>2.44</u>	<u>2.42</u>	<u>2.36</u>
	Average	2.35	2.30	2.35
<u>Grower Phase (6 weeks)</u>				
Initial weight, kg	1	22.5	22.9	21.8
	2	<u>28.9</u>	<u>31.1</u>	<u>30.0</u>
	Average	25.7	27.0	25.9
ADG, g	1	640	622	672
	2	<u>790</u>	<u>736</u>	<u>763</u>
	Average	715	684	717
F/G	1	3.03	3.14	3.01
	2	<u>3.01</u>	<u>2.97</u>	<u>2.99</u>
	Average	3.02	3.05	3.00
<u>Finisher Phase (8 weeks)</u>				
Initial weight, kg	1	51.1	50.9	52.1
	2	<u>64.5</u>	<u>62.9</u>	<u>64.7</u>
	Average	57.8	56.9	58.4
ADG, g	1	663	663	645
	2	<u>736</u>	<u>708</u>	<u>745</u>
	Average	700	685	695
F/G	1	4.03	3.85	3.88
	2	<u>3.95</u>	<u>3.34</u>	<u>3.85</u>
	Average	3.98	3.58	3.86

TABLE 26. Carcass Data from Pigs in Trial 5

Measure	B	Low FRDSB	High FRDSB
Live weight, kg	93.8	93.1	94.8
Carcass weight, kg	69.1	67.6	70.5
Dressing Percent, %	73.7	72.7	74.5
Carcass Length, cm	77.2	77.2	77.7
Backfat, cm	2.52	2.56	2.42
Ham + Loin %	42.3	43.3	41.2

incorporated in swine diets up to 6% in the starter, 4% in the grower and 3% in the finisher diets without affecting performance or carcass characteristics.

Using this information, the value of FRDSB can be calculated as follows. Nutritionally, 100 kg of soybean meal (49) plus 2 kg of calcium carbonate is equal to 40 kg of FRDSB plus 58 kg of corn plus 4 kg defluorinated phosphate. If current market prices are assigned to soybean meal (49), calcium carbonate, corn and deflourinated phosphate, then the value of FRDSB for swine diets can be calculated by substitution into the above equality.

In Trial 6 the availability of lysine in FDDBM, a product dried by a different method known as drum drying, was evaluated. Performance of pigs on reference diets and the regression equation of ADG on ADL are shown in Table 27. Available lysine estimates in FDDBM range from 6.0% to 7.3% (Table 28). This indicates that FDDBM is similar to FRDCB and FRDSB, and thus a value of 7% available lysine seems appropriate for use in balancing rations.

TABLE 27. Performance on Reference Diets (Trial 6)

Diet	ADG (g)	F/G	ADF (g)	ADL (g)
Basal	204	2.57	526	3.16
B + .1% L-lysine	272	2.33	636	4.45
B + .2% L-lysine	282	2.21	622	4.98

$$y = 44.7 x + 65$$

$$r = .98$$

y = Average daily gain, g

x = Average daily lysine intake, g

TABLE 28 Performance of Pigs on Test Diets and Calculated Available Lysine (Trial 6)

Diet	ADG, g	F/G	ADF, g	Available lysine (%)
B + 1.5% FDDBM	232	2.35	545	6.0
B + 3.0% FDDBM	277	2.10	581	7.3

TABLE 29. Performance of Pigs Fed FDDBM (Trial 7)

Parameter	Replicate	Basal	Low FDDBM	High FDDBM
<u>Starter Phase</u>				
Initial weight, kg	1	7.81	7.63	7.95
	2	<u>7.49</u>	<u>7.81</u>	<u>7.99</u>
	Average	7.67	7.72	7.97
ADG, kg	1	0.31	0.32	0.22 ^a
	2	<u>0.30</u>	<u>0.34</u>	<u>0.25^a</u>
	Average	0.31	0.33	0.24 ^a
Feed/Gain	1	2.34	2.20	2.39
	2	<u>1.94</u>	<u>2.20</u>	<u>2.39</u>
	Average	2.14	2.20	2.39
<u>Grower Phase</u>				
Initial weight, kg	1	28.1	27.0	28.1
	2	<u>28.5</u>	<u>29.5</u>	<u>26.9</u>
	Average	28.3	28.2	27.5
ADG, kg	1	0.66	0.67	0.67
	2	<u>0.67</u>	<u>0.64</u>	<u>0.63</u>
	Average	0.66	0.66	0.63
Feed/Gain	1	3.11	2.66	2.89
	2	<u>2.66</u>	<u>2.91</u>	<u>2.71</u>
	Average	2.90	2.79	2.80
<u>Finisher Phase</u>				
Initial weight, kg	1	55.7	54.5	56.0
	2	<u>60.0</u>	<u>57.2</u>	<u>55.3</u>
	Average	57.8	55.8	55.7
ADG, kg	1	0.56	0.65	0.70
	2	<u>0.66</u>	<u>0.68</u>	<u>0.73</u>
	Average	0.60 ^b	0.66	0.72 ^c
Feed/Gain	1	4.11	3.59	4.09
	2	<u>3.93</u>	<u>3.88</u>	<u>3.69</u>
	Average	4.03	3.74	3.88

^a Significantly less than other means in that phase (P<.05)^{b,c} Significant difference between two means (P<.01)

TABLE 30. Nitrogen and Energy Balance (Trial 8)

	B.V. (%)	N.P.V. (%)	D.E. (Kcal/kg)	M.E. (Kcal/kg)	N-corrected M.E. (Kcal/kg)
Basal	62.2 ^A	55.2 ^A	3599	3492 ^{a,c}	3389 ^a
3% FDDBM	78.1 ^B	71.1 ^B	3651	3607 ^b	3467
6% FDDBM	75.2 ^B	67.1 ^B	3669	3593 ^d	3474 ^b

A,B Means with different superscripts are significantly different (P<.01).

a,b Means with different superscripts are significantly different (P<.05).

c,d Means with different superscripts are significantly different (P<.10).

The performance of pigs fed diets which were formulated using a value of 7% available lysine in FDDBM is reported in Table 29. During the starter phase, pigs on the high FDDBM diet gained more slowly than those on the low FDDBM or corn-soy basal diets. This may be due to the high leucine to isoleucine ratio (2.84) which could cause the level of isoleucine (.64%) to become deficient. Addition of 2.0% L-leucine to rat diets has been shown to increase the isoleucine requirement by 0.2 to 0.3% (Harper, 1955).

Trial 8 was a balance trial in which 3 or 6% FDDBM was incorporated into starter diets, primarily as a lysine source, as well as a source of other amino acids and energy. Incorporation of 3 and 6% FDDBM significantly improved B.V. and N.P.V. (P< .01). Three percent FDDBM in the diet had no effect on D.E. or N corrected M.E., but did improve M.E. (P< .05). M.E. was increased (P<.10)

and N corrected M.E. was improved ($P < .05$) by incorporation of 6% FDDBM, but D.E. was not changed (Table 30). Mineral balance data showed no significant differences in absorbed iron, zinc, calcium, or phosphorus. Furthermore there was no significant difference in retained iron, zinc or calcium. However, pigs on the 3% FDDBM diet retained more phosphorus than pigs on the basal diet ($P = .10$), and pigs on the 6% FDDBM diet were intermediate (Table 31).

Growth and feed intake data from Trial 9, the iron availability study, are summarized in Table 32. Feed intake was low for pigs on the M diet and this is reflected in their low final weight. Also hemoglobin (HB) synthesis was low for pigs on the M diet (Table 33). The correlation between Hb synthesis and daily supplemental iron intake as ferrous sulfate was 0.84. The regression equation of Hb synthesis on daily iron intake for reference diets is reported in Table 34. In this study the availability of iron in FDDBM and FRDBM was expressed as a percent of the reference standard ferrous sulfate. The availability of iron in FDDBM was calculated to be 65.03% and in FRDBM was calculated to be 42.15% (Table 35). From these data it can be concluded that a conservative estimate of iron availability in flash dried blood meals is 45% of that of the availability of iron from ferrous sulfate ($\text{FeSO}_4 \cdot 7 \text{H}_2\text{O}$). Thus, flash dried blood meal containing approximately 2000 ppm of iron and incorporated into the diet at a level of 5% will supply 100 ppm of iron to the diet providing an amount of available iron equivalent to 45 ppm of iron from ferrous sulfate.

TABLE 31 Mineral Balance (Trial 8)

	Parameter									
	Apparent absorb FE (%)	Apparent retain FE (%)	Apparent absorb ZN (%)	Apparent retain ZN (%)	Apparent absorb Ca (%)	Apparent retain CA (%)	Apparent absorb P (%)	Apparent retain P (%)		
Basal	42.1	39.9	26.0	19.4	52.9	52.2	48.6	46.9 ^a		
3% FDDBM	48.6	47.8	19.3	10.7	51.7	51.1	60.1	59.7 ^b		
6% FDDBM	41.6	41.0	29.1	18.7	50.4	49.7	54.8	51.7		

a, b Means with different superscripts are significantly different (P<.10).

TABLE 32. Growth and Feed Intake Data (Trial 9)

Parameter	Diet				
	L	M	H	2% FDDBM	2% FRDBM
Initial weight (kg)	6.73	5.24	5.88	7.19	6.14
Final weight (kg)	10.62	6.71	11.10	13.21	11.55
Average daily feed intake (g)	357.1	216.4	377.7	444.2	435.8

TABLE 33. Iron Intake and Hemoglobin Synthesis (Trial 9)

Parameter	Diet				
	L	M	H	2% FDDBM	2% FRDBM
Daily Supplemental Fe. mg (X)	0.0	4.65	17.45	25.05	18.22
Initial Hb. conc. g/dl	7.01	6.32	7.23	5.90	6.62
Initial Total Hb, g*	39.01	27.44	35.23	35.21	33.68
Final Hb. conc., g/dl	7.08	5.63	9.85	7.68	6.58
Final Total Hb, g*	46.37	31.30	81.97	76.06	56.94
Hb Synthesized, g, (Y)	17.27	3.87	46.74	40.85	23.26

* Total Hb = Hb concentration x blood volume.

Values for blood volume from Ramirez et al. (1963).

TABLE 34. Regression Equation (Hb on Fe intake) from Trial 9

$$Y = 2.04 X + 7.58$$

Y = Hb synthesized (g)

X = Daily supplemental iron intake (mg)

$$r = .84$$

TABLE 35. Iron Availability of Blood Meals

Diet	Hb Synthesized (g)	Equivalent FeSO ₄ intake (mg/day)	Supplemental FE intake (mg/day)	Supplemental FE availability* (%)
2% FDDBM	40.85	12.29	25.05	65.0
2% FRDBM	23.26	7.68	18.22	42.2

* Reference standard of Ferrous Sulfate as 100%.

DETERMINING THE VALUE OF FLASH DRIED

BLOOD MEALS

Using a figure of seven percent bioavailable lysine in flash dried blood meals, a nutritional equality can be developed (Table 36). The relationship has been corrected for changes in calcium and phosphorus levels in the diet resulting from changes in soybean meal and corn levels in the diet. The value of flash dried blood meals can be calculated by using this equation and current prices of soybean meal (48), corn, calcium carbonate and deflourinated phosphate (Table 37).

TABLE 36. Replacement Value of Flash Dried Blood Meals in Swine Diets

$$100 \text{ kg S} + 2 \text{ kg L} = 40 \text{ kg F} + 58 \text{ kg C} + 4 \text{ kg P}$$

S = Soybean meal (49)

L = Calcium carbonate

F = Flash dried blood meal

C = Corn

P = Deflourinated phosphate

TABLE 37. Value of Flash Dried Blood Meal in Swine Diets

$$F' = \frac{100 \text{ kg (S')} + 2 \text{ kg (L')} - 58 \text{ kg (C')} - 4 \text{ kg (P')}}{40 \text{ kg}}$$

F' = Value per kg of flash dried blood meal

S' = Value per kg of soybean meal (48)

L' = Value per kg of calcium carbonate

C' = Value per kg of corn

P' = Value per kg of deflourinated phosphate

CONCLUSIONS

1) Bioassays and feeding trails indicate that Flash Ring Dried Cattle Blood Meal (FRDCB), Flash Ring Dried Swine Blood Meal (FRDSB), and Flash Drum Dried Blood Meal (FDDBM) have similar available lysine levels.

2) Seven percent available lysine appears to be a safe value to assign to these ingredients when formulating swine diets.

3) Additions of up to 3.0% FRDCB and incorporation of up to 6.0% FDDBM in swine diets improved the biological value and net protein value of corn-soybean meal diets with the same lysine levels.

4) Incorporation of 3% FDDBM into a corn-soybean meal diet improved metabolizable energy density. Use of 6% FDDBM in diets improved metabolizable energy density and nitrogen corrected metabolizable energy density.

5) Iron in FDDBM and FRDSB, respectively, is 65 and 42% as available as iron from ferrous sulfate ($\text{Fe SO}_4 \cdot 7\text{H}_2\text{O}$).

6) It appears that isoleucine levels in flash dried blood meals may limit the amount of soybean meal that can be replaced by flash dried blood meal in corn-soybean meal based swine diets. The low level of isoleucine in flash dried blood meals is compounded with high leucine levels in flash dried blood meals, thus raising the dietary requirement for isoleucine.

7) The replacement value of flash dried blood meals for soybean meal is:

$$100 \text{ kg S} + 2 \text{ kg L} = 40 \text{ kg F} + 58 \text{ kg C} + 4 \text{ kg P}$$

S = Soybean meal (48)

L = Calcium carbonate

F = Flash ring dried blood

C = Corn

P = Deflourinated phosphate

The current value of flash dried blood meals can be calculated from this relationship.

$$F' = \frac{100 \text{ kg (S')} + 2 \text{ kg (L')} - 58 \text{ kg (C')} - 4 \text{ kg (P')}}{40 \text{ kg}}$$

F' = Value per kg of flash dried blood meal

S' = Value per kg of soybean meal (48)

L' = Value per kg of calcium carbonate

C' = Value per kg of corn

P' = Value per kg of deflourinated phosphate

BIBLIOGRAPHY

- Amine, E.D., R. Neff and D.M. Hegsted. 1972. Biological estimation of available iron using chicks or rats. *J. Agr. Food Chem.* 20:246.
- Amine, E.K. and D.M. Hegsted. 1974. Biological assessment of available iron in food products. *J. Agr. Food Chem.* 22:470.
- Armstrong, D.G. and H.H. Mitchell. 1955. Protein utilization and the utilization of dietary protein at different levels of intake by growing swine. *J. Anim. Sci.* 14:49.
- Bayley, H.S. and R.G. Thompson. 1969. Phosphorus requirements of growing pigs and effect of steam pelleting on phosphorus availability. *J. Anim. Sci.* 28:484.
- Bjarnason, J. and K.J. Carpenter. 1969. Mechanisms of heat damage in proteins: 1. Models with acylated lysine units. *Brit. J. Nutr.* 23:859.
- Bjarnason, J. and K.J. Carpenter. 1970. Mechanisms of heat damage in preteins: 2. Chemical changes in pure proteins. *Brit. J. Nutr.* 24:313.
- Bragg, D.B., C.A. Ivy and E.L. Stephenson. 1969. Methods for determining amino acid availability of feeds. *Poul. Sci.* 48:2135.
- Carlson, K.H. and H.S. Bayley. 1970. Nitrogen and amino acid in the feces of young pigs receiving a protein-free diet and diets containing graded levels of soybean oil meal or casein. *J. Nutr.* 100:1353.
- Church, D.C. and W.G. Pond. 1974. *Basic Animal Nutrition and Feeding* (1st Ed.). O and B Books, Corvallis, Oregon.
- Costa, P.M.A., A.H. Jensen, B.G. Harmon and H.W. Norton. 1977a. Effects of roasting and roasting temperature on the nutritive value of high-moisture corn for swine. *J. Anim. Sci.* 44:234.
- Costa, P.M.A., A.H. Jensen, D.H. Baker and H.W. Norton. 1977b. Lysine availability of roasted dried and high-moisture corns as determined by the chick growth assay. *J. Anim. Sci.* 45:457.
- DeMuelenaere, H. and R. Feldman. 1960. Availability of amino acids in maize. *J. Nutr.* 72:447.
- DeMuelenaere, H., M.L. Chen, and A.E. Harper. 1967a. Assessment of factors influencing estimation of lysine availability in cereal products. *J. Agr. Food Chem.* 15:310.

- DeMuelenaere, H.J.H., M.L. Chen and A.E. Harper. 1967b. Assessment of factors influencing estimation of availability of threonine, isoleucine and valine in cereal products. *J. Agr. Food Chem.* 15:318.
- Diggs, B.G., D.E. Becker, A.H. Jensen and H.W. Norton. 1965. Energy values of various feeds for young pigs. *J. Anim. Sci.* 24:555.
- Doty, D.M. 1973. Developments in processing meat and blood by-products. In *Alternative Sources of Protein for Animal Production*. National Academy of Sciences, Washington, D.C.
- Eldred, N.L. and G. Rodney. 1946. The effect of proteolytic enzymes on raw and heated casein. *J. Biol. Chem.* 162:261.
- Elwell, D. and J.H. Soares Jr. 1975. Amino acid bioavailability: A comparative evaluation of several assay techniques. *Poul. Sci.* 54:78.
- Evans, R.J. and J. McGinnis. 1946. The influence of autoclaving soybean oil meal on the availability of cystine and methionine for the chick. *J. Nutr.* 31:449.
- Evans, R.J. and J. McGinnis. 1948. Cystine and methionine metabolism by chicks receiving raw or autoclaved soybean oil meal. *J. Nutr.* 35:477.
- Evans, R.J. and H.A. Butts. 1948. Studies on the heat inactivation of lysing in soybean oil meal. *J. Biol. Chem.* 175:15.
- Ewan, R.C. 1976. Utilization of energy of feed ingredients by young pigs. *Distillers Feed Research Council Proceedings.* 31:16.
- Forth, W. and W. Rummel. 1973. Iron absorption. *Physiol. Rev.* 53:724.
- Fritz, J.C., G.W. Pla, B.N. Harrison and G.A. Clark. 1974. Collaborative study of rat hemoglobin repletion test for bioavailability of iron. *J. Assoc. Official Anal. Chem.* 57:513.
- Furugouri, K. and A. Kawabata. 1975. Iron absorption in nursing piglets. *J. Anim. Sci.* 41:1348.
- Goldberg, A. and K. Guggenheim. 1962. The digestive release of amino acids and their concentrations in the portal plasma of rats after protein feeding. *Biochem. J.* 83:129.
- Grau, C.R. and H.J. Almquist. 1944. Beef blood proteins in chick diets. *Poul. Sci.* 23:48.
- Gupta, J.D. and C.A. Elvehjem. 1957. Biological availability of tryptophan. *J. Nutr.* 62:313.

- Gupta, J.D., A.M. Dakroury, A.E. Harper and C.A. Elvehjem. 1958. Biological availability of lysine. J. Nutr. 64:259.
- Hankes, L.V., W.H. Riesen, L.M. Henderson and C.A. Elvehjem. 1948. Liberation of amino acids from raw and heated casein by acid and enzyme hydrolysis. J. Biol. Chem. 176:467.
- Harper, A.E., D.A. Benton and C.A. Elvehjem. 1955. L-leucine, an isoleucine antagonist in the rat. Arch. Biochem. Biophys. 57:1.
- Harris, L.E., L.C. Kearl and P.V. Fonnesbeck. 1972. Use of regression equations in predicting availability of energy and protein. J. Anim. Sci. 35:658.
- Kratzer, F.H. and N. Green. 1957. The availability of lysine in blood meal for chicks and poults. Poul. Sci. 36:562.
- Kuiken, K.A. and C.M. Lyman. 1948. Availability of amino acids in some foold. J. Nutr. 36:359.
- Kuiken, K.A. 1952. Availability of the essential amino acids in cottonseed meal. J. Nutr. 46:13.
- Mathias, M.M., W.H. Allaway, D.E. Hogue, M.V. Marion and R.W. Gardner. 1965. Value of selenium in alfalfa for the prevention of selenium deficiencies in chicks and rats. J. Nutr. 86:213.
- Maynard, L.A. and J.K. Loosli. 1969. Animal Nutrition (6th Ed.). McGraw Hill Book Co., New York.
- Meade, R.J. and W.S. Teter. 1957. The influence of calcium pantothenate, tryptophan, and methionine supplementation and source of protein upon performance of growing swine fed corn-meat and bone scraps rations. J. Anim. Sci. 16:892.
- Meade, R.J. 1972. Biological availability of amino acids. J. Anim. Sci. 35:713.
- Miller, E.R., D.E. Ullrey, C.L. Zutaut, B.V. Baltzer, D.A. Schmidt, J.A. Hoefer and R.W. Luecke. 1964. Phosphorus requirement of the baby pig. J. Nutr. 82:34.
- Mitchell, H.H. and M.H. Bert. 1954. The determination of metabolic fecal nitrogen. J. Nutr. 52:483.
- Morgan, D.J., D.J.A. Cole and D. Lewis. 1975. Energy values in pig nutrition: 1. The relationship between digestable energy, metabolizable energy and total digestable nutrient values of a range of feed stuffs. J. Agr. Sci. (Camb.) 84:7.
- Morris, E.R. and R. Ellis. 1976. Isolation of monoferric phytate from wheat bran and its biological value as an iron source to the rat. J. Nutr. 106:753.

- Morrison, F.B. 1956. Feeds and Feeding (22nd Ed.). The Morrison Publishing Company, Ithaca, New York.
- Muller, R. and S. Ojun. 1975. The use of feather meal in poultry feeding. Nut. Abstr. and Rev. 45:360 (Abstr.).
- NRC 1973. Nutrient requirements of domestic animals. Nutrient requirements for swine. National Academy of Sciences. National Research Council, Washington, D.C.
- Nakamura, F.I. and H.H. Mitchell. 1943. The utilization for hemoglobin regeneration of the iron in salts used in the enrichment of flour and bread. J. Nutr. 25:39.
- Ousterhout, L.E., C.R. Grau and B.D. Lundholm. 1959. Biological availability of amino acids in fish meals and other protein sources. J. Nutr. 69:65.
- Pader, M., D. Melnick and B.L. Oser. 1948. Factors affecting the availability of lysine in heat-processed casein. J. Biol. Chem. 172:763.
- Pickett, R.A., M.P. Plumlee and W.M. Beeson. 1961. Availability of dietary iron in different compounds for young pigs. J. Anim. Sci. 20:946.
- Pla, G.W. and J.C. Fritz. 1970. Availability of iron. J. Assoc. Official Anal. Chem. 53:791.
- Puchal, F., V.W. Hays, V.C. Speer, J.D. Jones and D.V. Catron. 1962. The free blood plasma amino acids of swine as related to the source of dietary proteins. J. Nutr. 76:11.
- Ramirez, C.G., E.R. Miller, D.E. Ullrey and J.A. Hoefer. 1963. Swine hematology from birth to maturity: III. Blood volume of the nursing pig. J. Anim. Sci. 22:1068.
- Renner, R., D.R. Clandinin and A.R. Robblee. 1953. Action of moisture on damage done during over-heating of soybean oil meal. Poul. Sci. 32:582.
- Riesen, W.H., D.R. Clandin, C.A. Elvenjem and W.W. Cravens. 1947. Liberation of essential amino acids from raw, properly heated and overheated soybean oil meal. J. Biol. Chem. 167:143.
- Rivera, P.H., E.R. Peo, Jr., B.D. Moser, T. Crenshaw and P.J. Cunningham. 1978. Effect of drying temperature on nutritional quality and availability of amino acids in normal and opaque-2 corn for rats. J. Anim. Sci. 46:1275.
- Sibbald, I.R. 1977. The true metabolizable energy system: 1. Advantages of T.M.E. in poultry feed formulation. Feedstuffs. 49:42:21.

- Smith, R.E. and H.M. Scott. 1965a. Use of free amino acid concentrations in blood plasma in evaluating the amino acid adequacy of intact proteins for chick growth: I. Free amino acid patterns of blood plasma of chicks fed unheated fishmeal proteins. J. Nutr. 86:37.
- Smith, R.E. and H.M. Scott. 1965b. Use of free amino acid concentrations in blood plasma in evaluating the amino acid adequacy of intact proteins for chick growth: II Free amino acid patterns of blood plasma of chicks fed sesame and faw, heated and overheated soybean meals. J. Nutr. 86:45.
- Smith, R.E. and H.M. Scott. 1965c. Measurement of the amino acid content of fish meal proteins by chick growth assay. Poul. Sci. 44:401.
- Smith, R.E. and H.M. Scott. 1965d. Measurement of the amino acid content of fish meal proteins by chick growth assay. 2. The effects of amino acid imbalances upon estimations of amino acid availability by chick growth assay. Poul. Sci. 44:408.
- Smith, R.E. 1966. Importance of an accurate reference diet in the evaluation of protein for chick growth using plasma amino acid titers. J. Nutr. 89:271.
- Smith, R.E. 1968. Assessment of the availability of amino acids in fish meal and feather meal by chick growth assay. Poul. Sci. 47:1624.
- Stockland, W.L., R.J. Meade and J.W. Nordstrom. 1970a. Meat and bone meal as sources of amino acids for growing swine: Use of a reference diet to predict amino acid adequacy by plasma levels. J. Anim. Sci. 31:1142.
- Stockland, W.L. and R.J. Meade. 1970b. Meat and bone meals as sources of amino acids for the growing rat: Use of a reference diet to predict amino acid adequacy by levels of plasma free amino acids. J. Anim. Sci. 31:1156.
- Squibb, R.L. and J.E. Braham. 1955. Blood meal as a lysine supplement to all vegetable protein rations for chicks. Poul. Sci. 34:1050.
- Tybor, P.T., C.W. Dill and W.A. Landmann. 1973. Effect of decolorization and lactose incorporation on the emulsification capacity of spray-dried blood protein concentrates. J. Food Sci. 38:4.
- Wahlstrom, R.C. and G.W. Libal. 1977. Dried blood meal as a protein source in diets for growing-finishing swine. J. Anim. Sci. 44:778.
- Waibel, P.E. and K.J. Carpenter. 1972. Mechanisms of heat damage in proteins: 3. Studies with ϵ -(λ -L-glutamyl)-L-lysine. Brit. J. Nutr. 27:509.

- Waibel, P.E., K.J. Carpenter and B.R. Behrends. 1974. Nutritional availability of lysine in blood meal. Fed. Proc. 33:657 (Abstr.).
- Waibel, P.E. 1974. Protein quality of blood meal. National Provisioner 1971:64.
- Waibel, P.E., M. Cuperlovic, R.F. Hurrell and K.J. Carpenter. 1977. Processing damage to lysine and other amino acids in the manufacture of blood meal. J. Agr. Food Chem. 25:171.
- Welch, R.M. and D.R. VanCampen. 1975. Iron availability to rats from soybeans. J. Nutr. 105:253.
- Windel, H.F., R.J. Meade, J.W. Nordstrom and W.L. Stuckland. 1971. Influence of source and level of dietary protein on plasma free amino acid concentrations in growing swine. J. Anim. Sci. 32:268.
- Young, C.R., R.W. Lewis, W.A. Landmann and C.W. Dill. 1973. Nutritive value of globin and plasma protein fractions from bovine blood. Nutr. Rep. Internat'l. 8:211.

MICHIGAN STATE UNIVERSITY LIBRARIES



3 1293 03142 7721