AN ABSTRACT OF THE THESIS OF

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George H. Arscott

Studies were conducted with Indian River "Hybro" broiler chicks and Oregon Agricultural Experiment Station dwarf and normal White Leghorn hens to improve the utilization of white western wheat. Chick studies were primarily concerned with characterizing the growth inducing properties of an antibiotic fermentation residue (Vigofac) which had shown a greater growth response with wheat- than corn-base rations. In the adult study, evaluations were made as to the effect of feeding Vigofac and safflower oil on various performance parameters of wheat-fed hens. In both the chick and adult bird studies the feeding value of wheat was evaluated relative to corn.

The Vigofac research with chicks was divided into (1) nature of activity, (2) mode of activity, and (3) comparative growth effects.

Results of the nature of the activity confirmed that the growth inducing activity of Vigofac, which consists of an extract and a carrier

component, was found solely in the extract. No activity was found when Vigofac was ashed which indicates that it is probably organic in nature. Results suggest that the carrier, while not active, might stabilize the activity of the extract, since experiments showed the activity of the extract was destroyed by boiling for 60 minutes, while that of Vigofac (extract and carrier) was not affected by autoclaving for 30 minutes at 15 psi and 121°C.

Soaking Vigofac for 96 hours in acidic (0.1N hydrochloric acid) and basic (0.1N or 1.0N sodium hydroxide) solutions appeared to enhance its activity. Soaking it for a similar period in water or 95 percent ethanol resulted in no improvement. It was concluded that the above enhanced activity was not due to fermentation since water soaking should not have impaired fermentation. Comparatively the activity of zinc bacitracin (275 ppm) also was not adversely affected by autoclaving and was improved following soaking in the same acidic and basic solutions.

In two respects the activity of Vigofac appeared to be dissimilar from that of distillers dried solubles (DDS). As mentioned, Vigofac activity was found to be organic in nature whereas DDS has been reported to include inorganic activity as well. Also no active Vigofac fractions were found following a fractionation procedure used to isolate such fractions from DDS. It was found that phenolic acids, reported as active isolates of DDS, have inconsistent growth promoting activity when fed individually or collectively.

Research showed that Vigofac appears to promote growth primarily by inducing increased feed consumption. Energy analyses of droppings showed that it likely increases the utilization of wheat energy, but not that of corn which may account for the greater growth promotion noted when it is supplemented to wheat than when added to corn. It did not alter intestine, thyroid or pancreas weights relative to body weight. Comparatively, zinc bacitracin (275 ppm) also improved wheat energy and zinc bacitracin and five percent herring meal feeding caused a significant reduction in relative intestinal weight. Herring meal feeding also resulted in reduced relative thyroid weight.

In addition to Vigofac the fermentation products Fermacto 500, Pryferm H. B., Liquid Streptomyces Solubles, UNF-40 and Solulac as well as the antibiotic zinc bacitracin promoted growth to a greater extent when added to a wheat- than to a corn-base ration. Results showed that the variable growth response associated with fermentation products such as Vigofac may be due to the presence of antibiotics which induce a somewhat overlapping response. Growth responses, though not completely additive, were greatest when Vigofac, herring meal and zinc bacitracin were fed simultaneously rather than individually.

In view of the fact that Vigofac appears to stimulate growth primarily through increased feed consumption and because where zinc bacitracin and Vigofac were compared together they differed appreciably only in their effect on intestinal weight, the effect of Vigofac thus appears to be more closely related to that of a growth promotant, as are antibiotics, rather than as a source of unidentified nutrients.

The laying hen performance variables namely: egg production, feed consumption, feed per dozen eggs, egg weight, shell thickness, body weight, albumen height, Haugh units, yolk color, shell weight, yolk weight and albumen weight were measured at periodic intervals over a 280 day period for dwarf hens receiving either corn- or wheat-base diets as well as for their normal half sisters receiving a corn-base diet.

Where wheat was substituted for corn on a unit for unit basis, wheat-fed dwarf hens consumed significantly more feed per day, and produced eggs that were significantly smaller which contained significantly lighter colored yolks than did corn fed dwarfs. Eggs of the wheat-fed layers were found equal in size to those of the corn-fed when two percent safflower oil was substituted in the wheat base ration for animal fat. It was concluded that the increase in egg size for the wheat group was due to the additional dietary linoleic acid supplied by the safflower oil. Despite the fact that the yolk color was significantly lighter for the wheat-fed hens, it was not objectionably light due to xanthophyll contributed by alfalfa meal. The dietary addition of Vigofac did not improve laying hen performance.

Relative ranges of the dwarf treatments to the normals were as follows: egg production, 72.7 to 76.3 percent; feed consumption, 69.7 to 72.4 percent; feed per dozen eggs, 93.6 to 97.3 percent; and egg weight, 92.9 to 93.8 percent.

Improvement of White Western Wheat for Chickens Through Application of Dietary Additives

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Norman Paul Johnston

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Redacted for Privacy

Professor of Poultry Science
in charge of major

Redacted for Privacy

Head of Department of Poultry Science

Redacted for Privacy

Dean of Graduate School

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	5
Background	5
Classification	5
Distribution	6
Products of the Wheat Kernel	9
Comparative Nutritional Value of Wheats	10
Wheat for Poultry Nutrition	17
Chicks	20
Growth	20
Feed Efficiency	22
Digestibility	25
Pigmentation	26
Amino Acids	27
Vitamins	28
Laying Hens	28
Egg Production	28
Feed Per Dozen Eggs	29
Egg Size	31
Yolk Color	32
Amino Acids	33
Breeder Chickens	34
Turkeys	34
Methods of Improving Utilization of Wheat	38
Water Treatment	38
Enzyme Treatment	40
Autoclaving	41
Acid Hydrolysis	42
Pelleting	42
Other Methods of Improving Utilization	44
Fermentation Products	44
Antibiotic Residues	45
Cereal Grain Residues	46
Antibiotics	48
EXPERIMENTAL PROCEDURE	50
Chick Experiments	50
General Comments	50
Series I. Nature of Activity	53

	Page
Series II. Mode of Action	58
Series III. Comparative Growth Effects	60
Layer Experiment	62
RESULTS AND DISCUSSION	67
Chick Experiments	67
Series I. Nature of Activity	67
Results	67
Discussion	79
Series II. Mode of Action	82
Results	82
Discussion	88
Series III. Comparative Growth Effects	91
Results	91
Discussion	103
Laying Hen Experiment	109
Results	109
Discussion	113
Implications	116
SUMMARY AND CONCLUSIONS	126
Nature of Activity	126
Mode of Action	127
Comparative Growth Effects	128
Layer Experiment	129
BIBLIOGRAPHY	131

LIST OF TABLES

Table		Page
1	Major classes and subclasses of wheat produced in the United States.	9
2	Average composition of experimental wheat samples.	12
3	The metabolizable energy as determined for various types of wheat.	16
4	Indices of growth and feed conversion of chicks raised on wheat- versus corn-base diets.	21
5	Digestibility coefficients of wheat and corn.	25
6	Indices of egg production, feed per dozen eggs and egg weight for laying hens on wheat- versus corn-base diets.	30
7	Indices of turkey growth and feed conversion resulting from the feeding of wheat- versus corn-base diets.	36
8	Composition of experimental chick rations.	51
9	Growth supplements.	61
10	Composition of experimental layer rations.	64
11	Performance criteria measured in layer experiment.	65
12	Observations of Vigofac extract and carrier for growth activity (Trial 1).	68
13	Relation of Vigofac activity to ash component (Trial 2).	69
14	Fractionation of commercial Vigofac (Trial 3).	70

Table		Page
15	Fractionation of Vigofac extract (Trial 4).	70
16	Evaluation of phenolics found in DDS as growth supplements (Trial 5).	72
17	Collective and individual effect of four phenolics on growth (Trial 6).	74
18	Influence of zinc bacitracin on the phenolic growth effect (Trial 7).	75
19	Effect of heat treatment on Vigofac extract growth activity (Trial 8).	76
20	Effect of exposure of Vigofac and zinc bacitracin to various treatments on growth activity (Trial 9).	77
21	Effect of water and ethanol soaking on Vigofac growth activity (Trial 10).	78
22	Feed consumption as related to growth stimulation by Vigofac (Trial 1).	84
23	Gross energy and crude protein of droppings (Trials 2 and 3).	85
24	Effect of Vigofac, zinc bacitracin and herring meal on intestine and thyroid weights (Trial 4).	87
25	Effect of Vigofac and zinc bacitracin on intestine, thyroid and pancreas weights (Trial 5).	88
26	Effect of various fermentation products on chick growth (Trial 1).	93
27	Growth effect of fermentation products with isocaloric diets (Trial 2).	94
28	Effect of low level of zinc bacitracin on Vigofac growth stimulation (Trial 3).	96

Table		Page
29	Masking effect of zinc bacitracin on Vigofac growth response (Trial 4).	97
30	Observations of growth resulting from various levels of zinc bacitracin supplementation (Trial 5).	99
31	Growth promoting effect of various antibiotics (Trial 6).	100
32	Growth effect resulting from supplementation of Vigofac and zinc bacitracin to white winter wheat, hard red winter wheat and corn base diets (Trial 7).	102
33	Effect of Vigofac, zinc bacitracin and herring meal on growth when fed individually and collectively (Trial 8).	104
34	Summary of chick performance resulting from feeding of non-supplementary wheat- and corn-base diets.	105
35	Results of layer performance.	110
36	Internal egg quality and egg contents results.	111

LIST OF FIGURES

Figure		Page
1	Division of classes and subclasses of wheat.	7
2	Areas of wheat production by class within general boundaries.	8
3	Fractionation of fermentation products.	54

IMPROVEMENT OF WHITE WESTERN WHEAT FOR CHICKENS THROUGH APPLICATION OF DIETARY ADDITIVES

INTRODUCTION

The story of wheat represents an intriguing chapter in the book of man's history on earth (Wheat Flour Institute, 1965; Quisenberry and Reitz, 1967). The exact origin of the wheat plant is unknown. However, it was cultivated in southwestern Asia where modern man himself was first supposed to have appeared. Some speculate that as early as 10 to 15 thousand years before Christ man used wheat as food. Recent archeological findings uncovered an ancient village in Iraq which was established some 6,700 years ago and within these ruins were found two different kinds of wheat similar to those grown today.

Wheat held a position of great reverence among primitive men. Early man sought a supernatural explanation of the seasons, and of the growth, life and death cycle of plants and their rebirth the following year. Demeter, the "bread goddess," was invested by the Greeks with the rule of agriculture. Many of the early cultures have left evidences of their reliance upon wheat as a source of food. Bronze Assyrian tablets dated nine centuries before Christ depict the grinding of wheat and the making of bread. The fabled Egyptian tombs of the Nile contain murals which show the planting, harvesting and grinding of wheat. In distant China early writings describe the growing of wheat 2,700 years before Christ. From these ancient civilizations through time to today's era of highly modernized wheat production, written records and works of art depict the progressive advancement of the production of wheat.

Wheat is the most important of the cereal grains for human food. While rice is still the most common food of the Orient, wheat is basic to the diet of Europe, Africa, North and South America, Australia and large parts of Asia. As true of other cereal grains, wheat has many natural advantages as a food. It is nutritious, concentrated, readily stored and transported. Wheat products fit into many delicious recipes and consequently suit a wide continuum of varied tastes. Unlike any other plant derived food, wheat contains gluten protein which allows leavened dough to rise by forming minute gas cells that hold carbon dioxide during fermentation. This special property allows bakers to produce for tables the world over a light, appetizing bread.

Man also employes wheat as a feedstuff for the production of animal protein products. Because of wheat's intimate association with human food, its role in animal production has been greatly limited. When considering the immensity of the annual total United States' wheat crop, the amount of wheat fed to poultry and livestock represents only a relatively small portion.

Potentially, every bushel of wheat that is not used for human food could be an addition to the feed grain supply. In the United States this amount in excess is in the order of one half to one bllion bushels annually (Reitz, 1970). Whether or not a large portion of this excess moves in competition with feed grains depends on both its price and feeding value.

In recent years the price of wheat has fallen thus making it more attractive in that respect. However, for poultry wheat has most often played the role of bridesmaid to corn as a feed grain. Corn has been preferred to wheat for broilers because of its higher metabolizable energy value and its high content of xanthophyll which is necessary to produce the desired skin pigmentation. For layers corn is preferred not only for its higher metabolizable energy, but also for its apparent ability to induce larger egg size, which may be attributed to its higher level of linoleic acid.

There have been numerous attempts to improve the feeding value of wheat. These have included change in physical form such as grinding or pelleting, or exposure to the extreme heat of autoclaving or soaking in various media such as water, acid or enzymes. None of these attempts have appreciably influenced the utilization of wheat.

Arscott (1968) found that an unidentified growth factor supplement derived from an antibiotic residue and known commercially as Vigofac, when used as broiler chick dietary supplement, induced a greater growth response in chicks on a wheat-base diet than those on a corn-base diet. This research suggested the possibility of bringing the feeding value of wheat more closely in line with that of corn and consequently stimulating greater use of wheat as a poultry feed. There also exists the possibility that this product could improve the performance criteria of laying hens fed high levels of wheat.

The purpose of the research contained herein was to improve the utilization of wheat for chicks and layers through the application of dietary additives. In particular these studies were directed to improve the utilization of white western wheat, which is the wheat grown in greatest abundance in the state of Oregon.

Chick experiments were primarily conducted to characterize Vigofac as to the nature and mode of action of its growth inducing properties and to compare its effect on growth with that of other growth supplements. In layer research both Vigofac and linoleic acid were evaluated as to their effect on various performance parameters of wheat-fed dwarf White Leghorn hens relative to the performance of those fed corn.

REVIEW OF LITERATURE

Background

The following information concerning the classification and origin of wheat was extracted from a publication of the Wheat Flour Institute entitled "From Wheat to Flour" (1965).

Classification

There are many different methods of classifying wheat. Botanically, wheat belongs to the grass family, Poaceae, and the genus, Triticum. There are 14 species of wheat which are as follows:

Species	Common name
T. aegilopoides	wild einkorn
T. monococcum	einkorn
T. dicoccoides	wild emmer
T. dicoccum	emmer
T. durum	macaroni wheat
T. persicum	Persian wheat
T. turgidum	river wheat
T. polonicum	Polish wheat
T. timopheeui	--
T. aestivum	common wheat
T. shaerococcum	shot wheat
T. compactum	club wheat
T. spelta	spelt
T. macha	macha wheat

Of these, all of the common wheats (hard red winter and spring and soft red and white) belong to Triticum aestivum. Three of the species, (1) T. aestivum (common), (2) T. compactum (club), and (3) T. durum

(durum), account for 90 percent of the wheat grown in the world today.

Wheat is also classified according to the number of chromosome pairs found within the various species. Wheat species are found to have either 7, 14, or 21 chromosome pairs. Durum wheat has 14 pairs whereas the common and club wheats have 21 chromosome pairs.

Species of wheat are further subdivided into varieties. In the United States there are some 200 different varieties grown. These varieties are divided into classes according to three distinguishing features of (1) time of year of planting, (2) color and (3) degree of hardness. Figure 1 illustrates some of the divisions of wheat. From the figure it can be observed that the Gaines variety of wheat is of the subclass "soft white" and of the class "white winter."

Distribution

Because wheat grows in almost every arable soil, from sea level to elevations of 10,000 feet, wherever water is sufficient, in regions that are arid to rather humid, it may be and is produced in most sectors of the United States and many of those of the world. The predominant classes and subclasses of wheat produced are presented by approximate volume of annual production in Table 1 (Reitz, 1970) and are illustrated graphically by the approximate area of their production in Figure 2 (Quisenberry and Reitz, 1967).

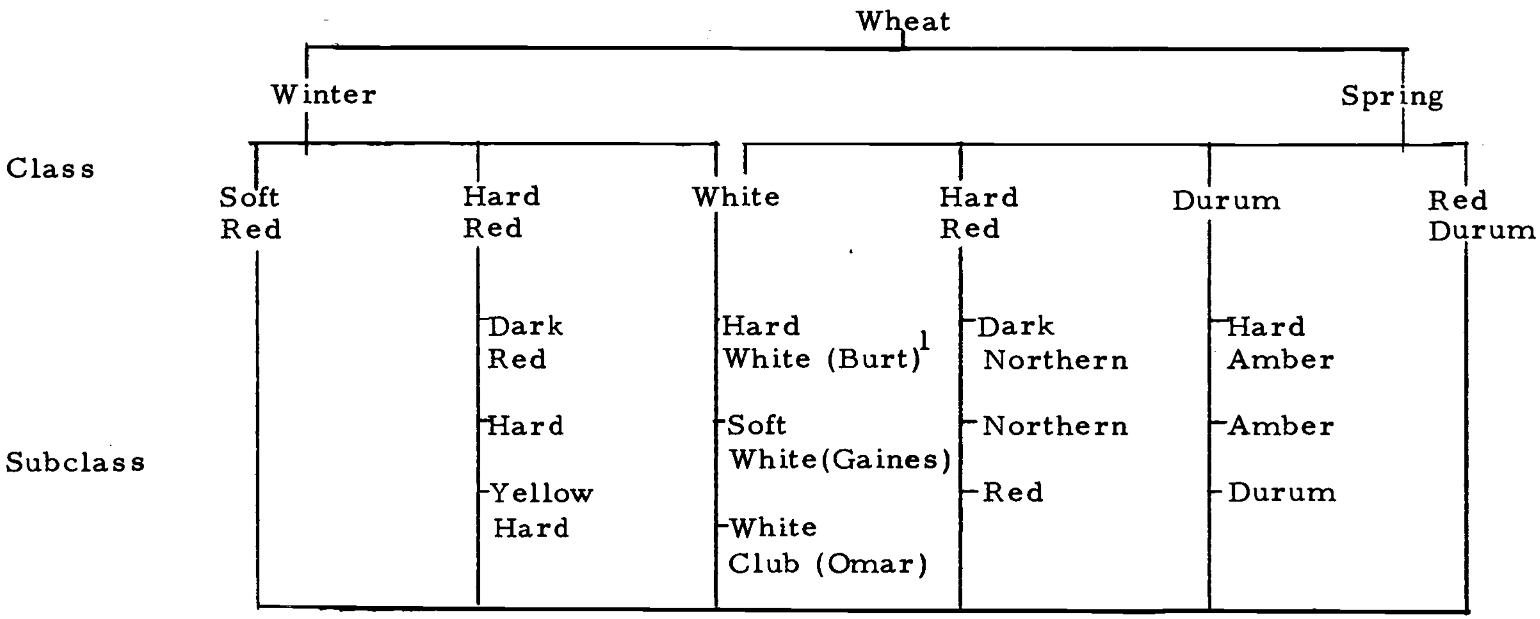
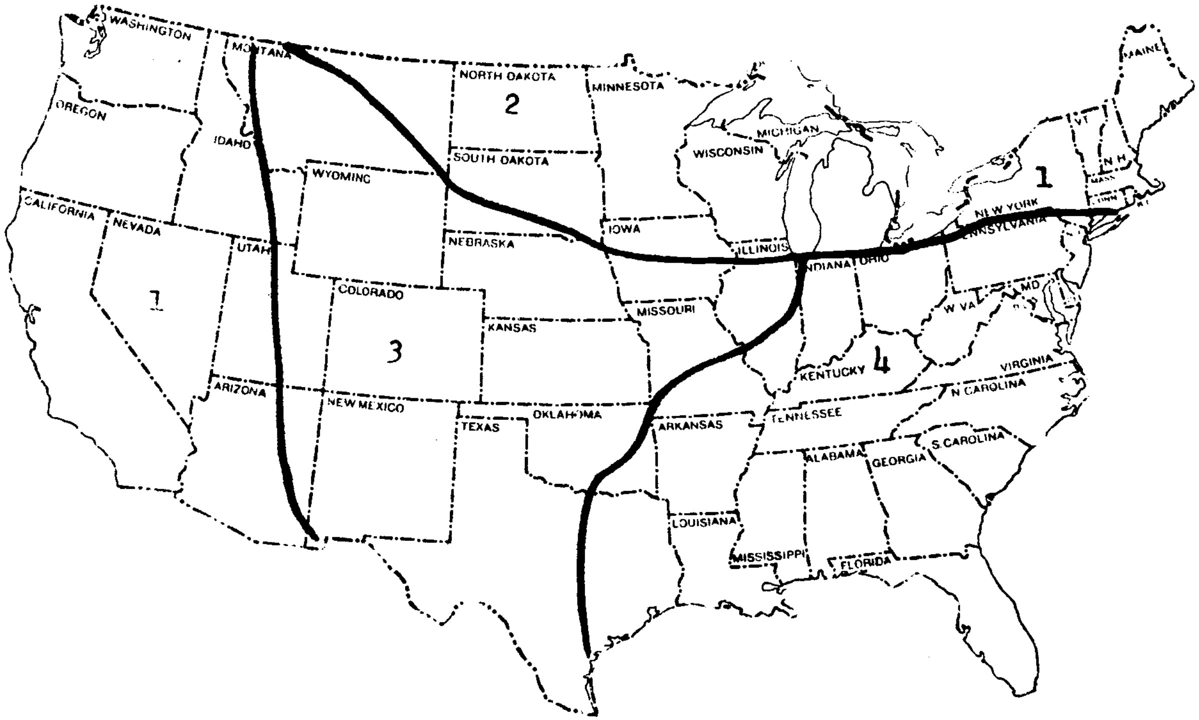


Figure 1. Division of classes and subclasses of wheat.

[1]Those names in parentheses denote varieties.



Area	Class
1	White
2	Hard red spring and Durum
3	Hard red winter
4	Soft red winter

Figure 2. Areas of wheat production by class within general boundaries.

Table 1. Major classes and subclasses of wheat produced in the United States.

Class or subclass	Approximate annual production (millions of bushels)
Hard red winter	750
Hard red spring	200
Durum	75
Eastern soft wheat	250
Soft red winter	
Eastern white	
Western white	175
Total	1450

Gaines, a common white winter wheat, is the major variety of wheat harvested in the Pacific Northwest which includes the states of Oregon, Washington and Northern Idaho (Oregon Crop and Livestock Reporting Service, 1967). Sixty-one percent of the total wheat acreage is devoted to its production. On a state basis Gaines represents 64, 55 and 97 percent of the wheat production in Oregon, Washington and Northern Idaho, respectively.

Because of the predominance of the Gaines variety in the area of this research station, most research here is performed with this variety.

Products of the Wheat Kernel

The milling of wheat for the production of flour yields appreciable quantities of by-products for animal feeds. These products include: (1) bran, almost the entire outer coatings of the wheat kernel; (2) shorts or brown shorts; (3) middlings, which consist of the fine particles of bran and germ with some Red Dog; (4) Red Dog or light shorts consists of the aleuron layer with small particles of bran, germ, and flour; (5) germ; and (6) flour. These products are listed below by the percent of the kernel that they represent (Schaible, 1970).

Wheat product	% of kernel
Flour	72 -75
Bran	12 -15
Shorts	7 - 8
Red Dog	1.5- 4.5
Germ	1

Since 1964, the average annual amount of wheat by-products fed to livestock and poultry has been about 4,500,000 tons or about 25 percent more than is fed as grain (Reitz, 1970). Though figures are not available, it is safe to assume that a considerably smaller percentage of the wheat is fed as by-products to poultry than is as grain. Bran and shorts, the major by-products fed in animal production, are less desirous as feed sources for poultry than is the grain. They contain two to four times as much fiber as the whole grain, are lower in energy and are of only mediocre protein quality.

Comparative Nutritional Value of Wheats

Thus far in the discussion of wheat, reference has been made to many different classes, subclasses and varieties of wheat. Because there are many different types of wheat, the question naturally arises, "are these various types nutritionally comparable"?

In answering the above qeustion attention is turned to a comprehensive analysis made of four different classes of wheat (Deyoe, Waggle and Ferrell, 1967). These workers analyzed blended wheat samples from different areas of the United States. Hard red winter wheats came from Oklahoma and Kansas. Hard red spring samples were obtained from Montana and North Dakota. The white wheat came from Pullman, Washington and was of the Gaines variety. The soft red winter wheat was produced in Indiana. The hard red winter and hard red spring wheat values were averages of several samples whereas only one sample each of white wheat and soft red winter wheat was analyzed. A summary of the findings of this study is given in Table 2. Mention will be made later to this study as the nutritional aspects of the various kinds of wheat are considered.

A wheat of a given class or variety may vary considerably from year to year in chemical composition depending on such factors as area, fertilization rate and moisture conditions. Crude protein is one of the more variable factors. Hard red spring wheats will vary from 12 to 19 percent, the hard red winter wheats from 10 to 15 percent and the soft wheats from 8 to 12 percent (Waldern, 1970).

Of the four wheats mentioned earlier, the protein levels ranged from a high of 12.4 percent for hard red spring wheat to a low of 9.2

Table 2. Average composition of experimental wheat samples.

	Hard red winter (%)	Hard red spring (%)	White wheat (%)	Soft red winter (%)
Moisture	12.49	12.60	13.00	14.75
Protein	11.73	12.40	9.20	11.75
Amino acids				
Lysine	0.33	0.31	0.32	0.35
Histidine	0.28	0.26	0.26	0.31
Arginine	0.57	0.52	0.55	0.63
Aspartic acid	0.62	0.62	0.57	0.65
Threonine	0.36	0.36	0.32	0.38
Serine	0.61	0.61	0.52	0.63
Glutamic acid	4.01	4.27	3.45	4.27
Proline	1.31	1.35	1.06	1.36
Glycine	0.51	0.52	0.47	0.53
Alanine	0.44	0.45	0.40	0.48
Cystine	0.33	0.32	0.29	0.35
Valine	0.52	0.53	0.48	0.56
Methionine	0.21	0.20	0.16	0.21
Isoleucine	0.43	0.44	0.38	0.44
Leucine	0.84	0.86	0.74	0.88
Tyrosine	0.38	0.38	0.32	0.38
Phenylalanine	0.59	0.59	0.49	0.62
Ash	1.59	1.58	1.20	1.61
Minerals				
Ca (%)	0.038	0.024	0.024	0.024
P (%)	0.38	0.35	0.38	0.41
K (%)	0.39	0.32	0.37	0.41
Na (%)	0.010	0.005	0.005	0.010
Mg (%)	0.11	0.11	0.09	0.10
Zn (ppm)	46.67	37	21	41
Fe (ppm)	27	20.0	30.0	22.0
Mn (ppm)	27.43	36.0	24	28
Cu (ppm)	7.1	5.2	4.2	4.2
Se (ppm)	0.28	0.50	0.04	0.04
B (ppm)	1.1	1.6	1.8	2.2
Sr (ppm)	0.72	0.69	0.48	0.48
Al (ppm)	5.0	5.0	5.0	5.0
Ba (ppm)	6.7	3.0	3.5	6.2
Co (ppm)	0.13	0.12	0.13	0.10

(Continued on next page)

Table 2. (Continued)

	Hard red winter (%)	Hard red spring (%)	White wheat (%)	Soft red winter (%)
Vitamins (mcg/g)				
Niacin	53.08	56.1	46.6	48.4
Pantothenic acid	9.79	9.2	8.4	8.6
Folic acid	0.351	0.426	0.372	0.410
Thiamine	3.70	4.26	4.11	4.11
Riboflavin	1.65	1.50	1.32	1.54
Pyridoxine	2.21	2.66	2.02	1.69
Alpha tocopherol	14.12	13.9	14.5	15.2
Betaine	587.83	1008.35	1026.5	1442.1
Choline	1080.2	1205.6	1139.6	981.2
Ether extract	1.54	1.82	1.61	1.74
Crude fiber	2.19	2.38	2.08	1.74
Starch	57.31	57.96	59.24	55.74
N.F.E.	70.33	69.22	72.91	68.41
Gross energy	4423	4427	4386	4410

Reference: Deyoe, Waggle and Farrel, 1967.

percent for the white wheat. The white western wheat was also lower in composition of many of the amino acids with more notable deviations in methionine, leucine, isoleucine, phenylalanine, valine and tyrosine. Even though the amino acid values were lower for white wheat, they usually fell just below or within the lower ranges of the hard wheats. Commonly used analysis tables (Scott, Nesheim and Young, 1969; Hubbell, 1971) list western soft wheat as lower in composition of most of the essential amino acids than the higher protein hard wheats. The degrees of difference listed by Scott, Nesheim and Young (1969) are also considerably greater than those found by the Kansas State workers with some amino acids being 50 to 75 percent lower in the western soft wheat.

The red wheats were more nearly equal in amino acid content especially the two hard wheats. Hepburn and Bradley (1965) found little difference in the quality of hard wheat protein as the quantity of protein varied. Differences in amino acid content were so small that they were considered to be of little nutritional significance. Histidine, isoleucine and tyrosine showed little variation as the nitrogen level fluctuated. The values for phenylalanine and tyrosine tend to follow the direction of the protein level. The remaining amino acids tended to follow a reverse trend in varying degrees.

Soil conditions are important determinants of the mineral status of plants. Because each of these wheats comes from different localities variation in the mineral values would be anticipated. The Se content is the most gross difference with white wheat having about one-half the content of the other wheats (Deyoe, Waggle and Ferrel, 1967).

According to the observations of the Kansas State workers, the vitamin levels of wheats also vary. It is difficult to classify this variation in regards to hardness of wheat or to the time of year of planting. One table of analysis rates the wheats comparable in all vitamins except riboflavin and folic acid (Scott, Nesheim and Young, 1969). The hard wheat of South-central United States is listed as having twice the riboflavin content of the wheat of Northern United States and the soft wheats of the East and West. Hard wheats are also listed from 14 to 28 percent higher in folic acid than the soft wheats. Hubbell (1971) rates hard wheats as a slightly better source of pantothenic acid and choline.

Research as to the metabolizable energy of wheat has resulted in a wide variation of values. Table 3 provides a summary of some of this research. The results indicated that the energy value of wheats appears to vary inversely with the protein level. In the respective studies, the low protein soft white wheats were shown to have a higher energy rating than did the higher protein red wheats. Hill et al. (1960) found all wheats tested to average 1, 490 k cal/lb whereas Sibbald and Slinger (1962) found the average to be much lower at 1, 385 k cal/lb.

Table 3. The metabolizable energy as determined for various types of wheat.

Class or subclass	Variety	% Protein	M.E. (k cal/lb)	Dry matter basis % Protein	Dry matter basis M.E. (k cal/lb)	Reference
Hard red		15.1	1449	17.2	1610	Hill *et al.* (1960)
Hard yellow		12.0	1521	13.3	1690	
Soft red winter		12.6	1485	14.0	1650	
Soft white		9.5	1539	10.5	1710	
Soft white	Avon	12.1	1385	14.1	1530	Slibbald, Slinger and Pepper (1962a, b)
Hard red spring	Northern	15.2	1221	17.4	1400	
Hard white	Burt	12.0	1267	13.1	1380	Shumaier and McGinnis (1967)
	Marfed	11.9	1315	13.1	1462	
White club	Omar	11.6	1331	12.8	1443	
Soft white	Gaines	10.5	1276	11.5	1416	
Hard red winter	Intana	13.1	1195	14.3	1307	
Durum			1413		1590	Lockhart, Bryant and Bolin (1967)

In general it may be concluded that all wheats are not similar in metabolizable energy.

Wheat for Poultry Nutrition

Wheat has been used for centuries as a source of energy and protein in animal feeds. There continued to be considerable interest for its use into the mid part of this century. However, with World War II the wheat price support began and with its inception the interest in the use of wheat dwindled. An example of the above was shown in the Pacific Northwest. From 1930 to 1941 about 24 million bushels of wheat were fed annually which represented 33 percent of the yearly production (Western Wheat Associates 1963). During the war years a further increase in use was noted; but for many years thereafter the use of wheat as a feed grain became progressively less important. Through the period of 1956 to 1960 only 3.5 million bushels or three percent of the yearly Pacific Northwest wheat production was being fed. However, in recent years the price of wheat has become more favorable relative to that of other cereal grains and with the reduced relative price the interest in its utilization has been renewed.

Of the cereal grains, corn is the most widely fed to poultry in the United States. If the use of wheat is to increase as a constituent of poultry diets, it will undoubtedly be used in lieu of or in combination with corn. Therefore in considering the use of wheat relative to other cereal grains, most comparisons need to be made with corn. Most generally the type of corn fed to poultry is dent, number 2 yellow corn. Feed analysis tables are generally in agreement as to the nutritive values of this type of corn (Scott, Nesheim and Young, 1969; Hubbell, 1971; National Research Council, 1971; and others).

The following is an abbreviated comparative analyses between wheat and corn. It is limited to those nutrients, which because of their differing levels, have been implicated as causing contrasting performances by birds fed the two grains.

	Wheat	Corn
Protein, %[1]	9.5-14	8.7
Fat, %[2]	1.5	3.8
Metabolizable energy, k cal/lb[1,2]	1360-1480	1550-1560
Xanthophyll, mg/lb[1]	0.0	11.0
Linoleic acid, %[1]	0.6	1.9

[1] Scott, Nesheim and Young, 1969
[2] Hubbell, 1971

When wheat has been substituted for corn in various types of poultry rations, some of the following effects have been noted:

1. Decreased early growth by the chick;
2. Increased amount of feed required per unit of gain for chicks and poults;
3. Decreased egg size;

4. Decreased pigmentation of egg yolk and skin.

The first two points, decreased growth and impaired feed efficiency, have generally been concluded to result from the lower level of metabolizable energy of wheat versus that of corn. As noted above wheat has been reported to have a metabolizable energy of from 87 to 96 percent that of corn. As the animal strives to meet its energy needs it must of necessity eat more of a wheat-base than a corn-base ration. But the animal apparently does not eat enough additional wheat to compensate for its lower caloric level.

The essential fatty acid, linoleic acid, has been found to be essential for maximum egg size (Shutze and Jensen, 1963). Laying birds, fed rations where wheat was the sole source of cereal grain, produce eggs of smaller size than rations where the grain portion is represented by corn (Arscott, 1965). This depression of egg size is believed to be caused by the low level of linoleic acid in wheat which is only one third that of corn.

Xanthophyll is a carotenoid contained abundantly in green and yellow plants such as alfalfa meal and corn. It is the yellow pigment deposited in the yolks of eggs and the fat and skin of broilers. Deep yellow yolks and skin of broilers have become public preferences, though of no nutritional importance. In this respect wheat fails as a substitute for corn because it contains no xanthophyll.

An asset for using wheat as opposed to corn is the greater contribution to the desired protein of the ration afforded by wheat. The protein content of corn is only 62 to 94 percent that of wheat depending on the wheat in question. The protein quality of the two grains appears to be comparable with the amino acid compositions being quite similar excepting that of lysine and cystine (Scott, Nesheim and Young, 1969). Wheat contains about 50 percent more lysine and 35 percent more cystine than corn. Some evidence indicates that as the protein content increases the energy level in turn decreases.

Chicks

The comparative work prior to 1936 involving the feeding of wheat and corn has been reviewed by Crampton (1936). He reported that wheat-fed birds gained to five percent greater weight than did the corn-fed birds, but also required four percent more feed to do so and suffered a higher rate of mortality.

Recent comparative research between wheat and corn has been performed at a number of stations with various types of wheat. Rather than trying to give wheat a flat value relative to corn based on available research, an attempt will be made to categorize the research by the type of wheat used (Table 4).

Growth. Results of the four-week chick trials showed wheat to be approximately 87 percent (Arscott, 1964) to 102 percent (McGinnis, 1970) as effective as corn in realizing chick gains. Both of these

Table 4. Indices of growth and feed conversion of chicks raised on wheat-versus corn-base diets.

Investigator(s)[1]	Class of wheat[2]	Period (days)	Wheat as % of corn	
			Gain (%)	Feed conv.
Arscott (1965)	www	28	86.6	92.5
McGinnis (1970)	www	28	101.9	98.8
Biely (1965)	hrs[3]	28	95.9	-
Naber and Touchburn (1969)	hrs[4]	28	95.8	95.6
Adams and Naber (1969a)	hrs[4]	28	99.6	98.8
Hamm et al. (1960)	srw	28	98.6	-
Biely et al. (1951)	hrs[3]	35	100.4	-
Ibid.	hrs	42	95.0	93.8
Ibid.	hrs	49	102.8	100.0
Berg (1965)	www	52	94.4	95.7
Peterson (1969)	na	53	96.8	98.7
Arscott (1957)	r[5]	56	98.9	98.1
Arscott (1964)	www	56	94.1	92.3
Arscott (1965)	www	56	94.4	84.7
Biely et al (1951)	hrs	56	97.5	89.0
Yoshida (1962)	na	na	90.0	96.0

[1] Unless otherwise indicated wheat and corn were substituted on an equiweight basis.

[2] Abbreviations are as follows: na - not available; www - western white winter; hrs - hard red spring; srw - soft red wheat; r - red wheat.

[3] Personal communication (March, 1971).

[4] Personal communication (Naber, 1971).

[5] (Arscott, 1971).

[6] Diets were made isoprotein and isocaloric.

extreme studies of the range were conducted with white western wheat. Hamm et al. (1960) and Adams and Naber (1969a) found growth resulting from the feeding of red wheats quite similar to that realized from corn.

Three papers agreed that white western wheat when fed to chicks for eight weeks was about 94 percent the value of corn in obtaining growth results (Arscott, 1964, 1965; Berg, 1965). In an earlier report Arscott (1957) found a red wheat of an unknown type (Arscott, 1971) to be essentially equal to corn. Biely et al. (1951) showed that hard red spring wheat could replace corn on a pound for pound basis in the Connecticut broiler ration without impairment of growth to five weeks of age; thereafter chick growth from the two grains was variable, but quite similar.

Feed Efficiency. Probably the major criterion in the conversion of feed to gain is metabolized energy value. For wheat the metabolizable energy is about 92 percent that of corn which was the approximate rate of conversion of white western wheat-based rations to gain found by Arscott (1964) in an eight-week trial and again in 1965 in a four-week trial. When considering the other studies there appeared to be little or no correlation between the type of wheat employed and the resulting feed conversion relative to that of corn. Four-week studies showed the relative value to range from 92.5 (Arscott, 1965) to 98.8 (Adams and Naber, 1969a; McGinnis, 1970). Ranges of studies six weeks or longer were from 84.7 (Arscott, 1965) to 100.0 (Biely *et al.*, 1951).

Arscott (1965) concluded that the complete replacement of corn with wheat in present day broiler rations resulted in a decrease in overall performance which was closely related to differences in metabolizable energy values between these two grains. In substantiation of his point he found that by making the all corn and all wheat rations isocaloric that the feeding trials resulted in equal rates of feed conversion from both grains and growth was not significantly different.

The work of Yoshida (1962) would seem to disagree with that of Arscott (1965). When feeding isocaloric and isoprotein diets to broilers, he found wheat to fall below corn in the categories of weight gain and feed efficiency by ten and four percent, respectively. Berg (1965) proposed a hypothesis to explain why birds fed corn and wheat perform differently in suggesting that wheat contains a growth depressant that is not found in corn.

Results of these feeding trials imply that identical performance cannot always be anticipated when supposedly identical types of wheat are fed. In experimenting with white winter western wheat, Berg (1965) at the Western Washington Research and Extension Center found wheat to be about 95 percent as effective as corn for achieving growth and feed conversion. However, at the cooperating research station in Pullman, Washington, McGinnis (1970) found the two grains were equal in both of the above performance categories. Results of Arscott (1964, 1965) who also used the same type wheat, are closely related to those of Berg (1965).

Some promising growth results have been obtained by mixing the grain portion of the ration. Arscott (1964) found that by raising broilers for eight weeks on a ration containing equal parts of wheat and corn, that growth gains were similar to those where corn represented all of the grain fraction. Despite the improved growth, the feed conversion still lagged three percent behind corn. In 1965 Arscott found that he could feed 11.35 percent wheat with 53.68 percent corn for eight weeks to broilers with no detrimental effects on performance. Berg (1965) found that one-half the corn in an eight-week broiler trial replaced with wheat did not significantly affect either growth rate or feed conversion. Petersen and Sauter (1967) found that substituting 25 percent or 75 percent of the corn with wheat caused depressed gains by two percent and five percent, respectively, and depressed feed conversions by two percent and four percent, respectively.

Arscott (1964) fed all wheat as the grain for five to seven weeks and then all corn for the remaining time of an eight-week trial. Wherever wheat was fed for any period of time growth was somewhat reduced, but not significantly so as compared to when corn was fed throughout the trial. Despite the improved results in each case where some wheat was fed the birds gained less efficiently than when corn alone was fed for the entire eight weeks. Berg (1965) fed either two-thirds corn and one-third wheat or two-thirds wheat and one-third corn for two to six weeks, and found that growth was always similar to all corn rations, but the feed efficiency was slightly impaired.

In using linear programmed isocaloric rations, Arscott (1965) found that wheat would not replace corn based on nutrient specifications when the two were priced similarly. Only when wheat dropped to a price level of 80 percent that of corn did wheat then replace corn entirely in the ration. Results of feeding the linear programmed rations showed that when corn predominated in the grain component that weight gains were improved, whereas when wheat was the major grain constitutent the broilers consumed significantly less feed.

Digestibility. Digestibility coefficients of wheat and corn by chicks have been determined by Kaupp and Ivey (1922), Halnan (1928), Bolton (1955), and Titus (1961). Table 5 presents an average of these four studies.

Table 5. Digestibility coefficients of wheat and corn.

	Crude protein (%)	Ether extract (%)	Nitrogen free extract (%)	Crude fiber (%)
Wheat	78.3	48.9	88.6	4.5
Corn	80.2	84.6	90.9	8.8

The digestibility of grain components was quite similar for crude protein and nitrogen free extract, but for ether extract and crude fiber corn appeared to be the superior grain. Bolton (1955) further analyzed the carbohydrate fraction to find that 9.6 and 14.6 percent of corn cellulose and lignin were digestible where neither of these components were digestible to any extent in wheat. However, they were of questionable significance because between the digestible portion of the two components they represented less than 0.25 percent of the entire kernel.

Pigmentation. Today's American consumer associates the yellow colored fryer or broiler with "freshness." Formerly, broilers were raised out of doors on green pastures. There they had access to green grasses and alfalfa clover which contained a number of yellow and red pigments referred to as xanthophyll. These pigments were deposited in the fat and skin of broilers. The yellow skinned broiler therefore has become the accepted standard by housewives. Later as the production of broilers moved indoors, they no longer had access to rich xanthophyll sources. At home, however, the preferences for broiler color did not change, and the housewife still expected the yellow colored birds. Under today's high density indoor broiler production, corn, a good source of xanthophyll, is used to meet the desired degree of broiler pigmentation.

It therefore is to the disadvantage of a broiler producer to use wheat extensively in broiler diets unless such diets are adequately supplemented with xanthophyll. Arscott (1965) found from analyzing shank scores that as little as 1 mg/lb of feed of commercial xanthophyll would adequately pigment birds on a wheat-soybean meal diet as compared to birds on a corn-soybean meal diet. Adding five percent corn gluten meal, which supplied 2 mg/lb of additional xanthophyll, also produced the same favorable results.

Interestingly, the yellow skinned broiler is not preferred the world over. Australian broilers are white skinned (Cumming, 1969). This became so because wheat is the major grain available in Australia and secondly because the industry uses a white skinned bird that is a product of the country's egg laying industry.

Amino Acids. Wheat protein for chicks has been found deficient in some of the essential amino acids, such as lysine and methionine and possibly threonine. Many of the other essential amino acids are also present in wheat in very marginal amounts. Research has been performed to ascertain the importance of these apparent deficiencies. Jeppesen and Grau (1948) fed chicks a diet in which all the protein was contributed by a wheat protein concentrate. The diet in turn was supplemented with the amino acids lysine, methionine, arginine, tryptophan and leucine. Of the amino acids supplemented, growth depression occurred only when lysine was omitted. Later work by March, Biely and Tonzetick (1950) also showed lysine to be the most limiting amino acid of wheat. Diets were fed consisting of wheat (96 percent) supplemented with the necessary vitamins and minerals to promote growth. Chicks grew decidedly better on a ration that had been supplemented with lysine and the efficiency of feed utilization was improved up to 20 percent. The addition of methionine and tryptophan did not effect growth, but did depress feed efficiency. Other workers report that diets with high levels of wheat are improved in either growth promotion or feed efficiency by methionine supplementation (Slinger, Pepper and Hill, 1953; McDonald, 1957, 1958).

Vitamins. Though higher in content, the biotin of wheat is evidently less available than that of corn. Chicks fed rations containing 75 percent grain were more apt to show biotin deficiencies if that fraction consisted of wheat rather than corn (Wagstaff, Dobson and Anderson, 1961). McDonald (1957) noted an apparent beneficial interaction when folacin and the amino acid, methionine, were used to supplement a wheat-based diet. By supplementing with 0. 2 percent methionine an additional growth response of five percent was achieved over the unsupplemented ration. When 4. 4 ppm of folacin were added in addition to methionine a 12 percent increase in growth resulted.

Laying Hens

Egg Production. Crampton (1936) assigned relative values to cereal grains for laying hens based on research performed up to the mid 1930's. These early papers rated wheat only 94 percent as effective as corn in stimulating hen egg production.

More recent reports of hen egg production resulting from the feeding of wheat or corn as the grain portion of the ration are summarized in Table 6. It is noted that hens fed wheat diets generally produced fewer eggs than those fed corn. The decline in production was usually from one to three percent below corn fed hens. However, there were exceptions where wheat fed layers appeared superior in egg production with one report giving wheat as much as an eight percent advantage (Fox, 1966; Lockhart et al., 1967; McGinnis, 1970).

The lower production figure appeared not to be due entirely to metabolizable energy. Both Lillie and Denton (1968) and Balnave (1970) fed isocaloric corn and wheat diets and still found wheat-fed hens to be less productive than those on corn.

Two papers reported trials where the grain portion of the diet was equally divided between wheat and corn. In one instance resulting production was higher (Arscott, 1965) while in the other it was lower (McGinnis, 1965) than that realized from feeding either of the grains alone.

Feed Per Dozen Eggs. Since metabolizable energy of wheat is approximately 92 percent that of corn, and if hens were consuming precisely their energy requirements, theoretically wheat would only be 92 percent as efficiently used as is corn. With the exception of

Table 6. Indices of egg production, feed per dozen eggs and egg weight for laying hens on wheat- versus corn-base diets.

Investigator(s)[1]	Wheat class	Wheat as % of corn		
		Egg prod. (%)	Feed/ doz. (%)	Egg weight
Arscott (1965)	www	99.2	94.2	98.1
McGinnis (1965)	www	98.1	92.6	100.0
McGinnis (1970)	www	102.4	-	99.5
Fox (1966)[2]	na	101.1	-	-
Bartlett (1966)[3]	ws	97.1	98.1	97.4
Lockhart <u>et al.</u> (1967)[3,7]	d	108.0	104.5	95.5
<u>Ibid.</u>	hrs	100.9	97.8	86.3
Lillie and Denton (1968)[4,5]	na	83.6	87.5	-
<u>Ibid.</u>	na	98.5	100.0	-
<u>Ibid.</u>	na	97.9	100.0	-
Guenthner and Carlson (1970)[6]	hrs	98.8	-	-
<u>Ibid.</u>	hrs	82.3	-	-
Balnave (1970)	na	95.6	-	99.5

[1] Unless otherwise noted wheat and corn were compared on an equi-weight basis.
[2] Diets formulated at a constant ratio between energy and first limiting amino acid.
[3] Diets were isonitrogenous.
[4] Dietary protein levels were respectively 10, 12.5 and 15.0 percent.
[5] Diets were isonitrogenous and isocaloric.
[6] Dietary protein levels were respectively 15.4 and 12.0 percent.
[7] Determined the precent of large eggs produced.
[8] Abbreviations are as follows: na - not available; www - western white winter; ws - white spring; d - Durum; hrs - hard red spring.

Lockhart et al. (1967), all works summarized in Table 6, where wheat and corn were compared on an equal weight basis, found the respective types of wheat tested to be less efficiently utilized than corn in the conversion of feed to eggs. Relative to that found with corn, the efficiency of converting feed to eggs by wheat-fed hens ranged from a low of 92.6 percent (McGinnis, 1965) for western white wheat to a high of 97.1 percent (Bartlett, 1966) for white spring wheat. Since Lillie and Denton (1968) found the two grains to be utilized alike, when wheat and corn base rations were made isocaloric, the lower efficiency observed with wheat-fed hens was primarily due, as suggested above, to the lower metabolizable energy of wheat.

Where corn and wheat have been used equally in the ration the conversion of feed to eggs has been found either intermediate to corn and wheat alone (McGinnis, 1965) or equal to corn (Arscott, 1965) which in both cases was used most efficiently.

Egg Size. Of the trials reported in Table 6, in only one instance (McGinnis, 1970) did hens fed wheat base rations lay eggs equally as large as those fed corn. This difference in egg size has been linked to an essential fatty acid deficiency.

An examination of the nutrients composing the two grains (see page 18 presented earlier) shows that wheat has only one-third the linoleic acid level of corn (Scott, Nesheim and Young, 1969). Shutze and Jensen (1963) and Menge, Miller and Denton (1963) reported that dietary linoleic acid must be present in adequate amounts to produce eggs of maximal size. This requirement has now been determined as one percent of the diet (National Research Council, 1971).

The fact that linoleic acid improves egg size has led some workers to supplement wheat diets with rich sources of the acid. Corn oil, which contains 52 percent linoleic acid, when added at various levels (2.5 to 5 percent) to wheat-base diets has been reported to increase egg weight over that of unsupplemented diets (Edwards and Morris, 1967; Balnave, 1970). However, the addition of two percent safflower oil, which contains 73 percent linoleic acid, did not improve egg weight over that achieved by hens on a corn-control diet (McGinnis, 1970). Supplementation of corn diets with corn oil or safflower oil had a variable effect on egg size with one of the reports showing no increase in size (McGinnis, 1970) and another a size increase (Balnave, 1970).

Feeding half corn and half wheat has either improved egg size slightly over that of wheat-fed birds (Arscott, 1965) or to an even greater extent than when corn or wheat were fed alone (McGinnis, 1970).

Yolk Color. Arscott (1965) determined the effect of feeding all wheat, all corn or a combination of wheat and corn on yolk color. The levels of dietary xanthophyll present were 6.8, 9.9, and 12.9 mg/lb respectively. Relative to the other treatments the pigmentation of the yolks from wheat-fed layers was reduced, but not to the point of being objectionable.

Amino Acids. Wheat layer rations appear deficient in lysine (March and Biely, 1963; Sell and Hodgson, 1966), leucine (Anderson and Draper, 1956), and perhaps methionine (March and Biely, 1963). March and Biely (1963) elicited an increased egg size from hens by supplementing a 69 percent wheat diet with lysine and methionine. It was concluded that the basal wheat-soybean diet was limiting first in lysine and then in methionine. Supplementing with a third amino acid, glycine, caused a sharp drop in egg size. Glycine was believed to cause an amino acid imbalance.

Additions of methionine to a wheat-base diet have also been reported as being toxic. Sell and Hodgson (1966) found the addition of methionine or its analogue to a wheat-soybean laying ration caused decreased feed intake, reduced egg size and a lower level of egg production. When lysine was added simultaneously with methionine, the above effects were not observed. The addition of lysine alone to the basal diet improved feed conversion and egg weight.

Anderson and Draper (1956) found that a diet containing 60 percent wheat was slightly deficient in leucine. In three trials dietary supplementation of leucine yielded an increased response in egg production. Interestingly, the control diet contained 1.26 percent leucine which is similar to the 1.2 percent required for laying hens

(National Research Council, 1971).

Breeder Chickens

In regards to the performance criterion of hatching of eggs corn was rated by Crampton (1936) as being only 95 percent as effective as wheat. Recently, it was found that hard red spring wheat when supplemented with the amino acids lysine and methionine and with vitamin and mineral premixes was able to support normal hatchability, growth and livability (Biely and Goudie, 1971).

Turkeys

Prior to 1959 little research had been conducted on the feeding of wheat to turkeys. However, some interesting work was presented by Barrett, Card and Berbidge (1939, 1946) and Poley and Wilson (1939).

Barrett, Card and Berbidge (1939) found that bronze turkeys when given free access to various grains from ten weeks to maturity preferred by percent (1) 44 percent oats, (2) 33 percent wheat, (3) 20 percent corn, and (4) 3 percent barley. Further research by Barrett, Card and Berbidge (1946) found turkeys utilized wheat more efficiently than corn from hatching to 20 weeks of age. Bronze turkeys and Beltsville Small White turkeys fed wheat diets consumed 0.58 pounds and 0.59 pounds less feed per pound of gain, respectively, than corn-fed turkeys. However, during the finishing period of 20 to 26 weeks corn appeared to be the superior grain. Poley and Wilson (1939) found that wheat-fed birds grew equally as well as those fed corn, but in turn required 0.1 pound more feed per pound of gain to produce an 18 pound turkey.

In reviewing the more recent research turkey performance will be observed by periods (Table 7). First, attention will be directed toward those experiments where wheat and corn were used interchangeably on an equal weight basis. In regards to growth, wheat-fed turkeys generally have been found to perform equal to or better than corn-fed birds during the first four weeks of age (Summers, Pepper and Slinger, 1959b; Harper, 1966; McGinnis, 1970). The same observation is true for birds raised to eight weeks of age (Harper, 1959; Potter, 1963; Harper, 1966). During the first four weeks wheat is used from a low of 97.7 percent (Harper, 1966) to a high of 105.2 percent (Summers, Pepper and Slinger, 1959) of corn utilization. Efficiency of wheat utilization shows a greater decline for birds raised to eight weeks with a low of 93.6 percent (Harper, 1966) to a high of 96.9 percent (Potter, 1965) that of corn.

To 20 weeks of age the growth of turkeys fed either grain remains quite similar with wheat being about 98 to 100 percent as effective as corn (Potter, 1965; Harper, 1966; McGinnis, 1970). Potter (1965) observed that the efficiency of wheat utilization remained similar to that obtained at eight weeks (97.8 percent) while Harper

Table 7. Indices of turkey growth and feed conversion resulting from the feeding of wheat-versus corn-base diets.

Investigator(s)[1]	Class of wheat[2]	Period (days)	Wheat as % of corn	
			Growth	Feed conv.
Fry *et al.* (1958)	www	21	95.0	95.8
Ibid.	www	27	94.7	95.5
Summers *et al* (1959b)	na	28	112.2	105.2
Harper (1966)	www	28	103.4	97.7
McGinnis (1970)	www	28	101.1	98.7
March and Biely (1958)[3]	hrs	35	101.8	101.0
Ibid.	hrs	42	112.0	96.7
Waldroup *et al.* (1967)[4]	srw[5]	42	103.4	102.2
March and Biely (1958)	hrs	53	102.2	93.6
Harper (1959)	r[6]	56	105.1	99.0
Potter (1965)[5]	na	56	101.6	96.9
Waldroup *et al.* (1967)	srw	84	102.2	105.4
Ibid.	srw	126	103.8	100.0
Potter (1965)[5]	na	126	98.7	96.8
McGinnis (1970)	www	56-140	97.4	101.0
Ibid.	www	84-140	92.2	95.5
Waldroup *et al.* (1967)	srw	77-147	108.8	98.2
McGinnis (1970)	www	140	100.9	-
Harper (1966)	www	140	98.4	90.9
Waldroup *et al.* (1967)	srw	161	100.6	99.4
Harper (1966)	www	168	95.4	92.6

[1] Unless otherwise noted wheat and corn were substituted on an equi-weight basis.
[2] Abbreviations are as follows: na - not available; www - western white winter; hrs - hard red spring; srw - soft red winter.
[3] Diets were isoprotein.
[4] Diets were isoprotein and isocaloric.
[5] Personal communication (Waldroup, 1971).
[6] Arscott (1971).

(1966) noted a decline in efficiency. At 24 weeks of age, wheat-fed birds were only able to achieve 95.4 percent of the growth of those on corn and were 92.9 percent as efficient in converting feed to gain as those birds fed corn (Harper, 1966).

In summary, when comparing wheat-and corn-fed turkeys, little difference is noted in weight except during the latter stages of growth. The efficiency of wheat utilization is inversely related to age with the efficiency declining as the birds grow older. It is interesting to note that the turkey's protein requirement is also inversely related to age. The efficient utilization of wheat during early growth may be due to the fact that some wheats have a higher protein level than corn. As the requirement for protein decreases and that of energy increases wheat becomes less efficiently utilized as compared to the higher energy corn.

Some comparisons have been made of wheat- and corn-fed turkeys where the rations have been made isonitrogenous (March and Biely, 1958) or both isonitrogenous and isocaloric (Waldroup et al., 1967). March and Biely (1958) fed a 28 percent protein ration to Broad Breasted Bronze turkeys. Additional soybean meal was used to increase the corn-base rations to a protein level comparable to that of wheat. Weight gains and feed efficiencies were determined at 35, 42, and 53 days of age. The relative gains of wheat-fed turkeys to those fed corn were 103, 106, and 102 percent respectively. The respective relative feed conversions were 100, 97, and 96 percent that of corn. Comparative isocaloric trials were conducted by Waldroup *et al.* (1967) with Large White turkeys fed isocaloric and isonitrogenous diets. Growth and the amount of feed required per unit of gain were determined for 6, 12, 18, and 23 weeks of age. In each case the gains of those birds on the wheat-base diets were equal to or superior to those on corn with the respective percentages being 103, 102, 104, and 101. The feed conversions were similar at each stage of growth. These observations support the premise that metabolizable energy is primarily responsible for the less efficient performance of birds fed wheat-as opposed to corn-base rations.

Methods of Improving Utilization of Wheat

Water Treatment

A limited amount of success has been achieved in improving the nutritional value of wheat for chicks by water treatment of the grain. Fry *et al.* (1958) were able to obtain a significant imporvement in poult growth by feeding water-treated wheat. The treatment included soaking coarsely ground wheat in water on a one to one basis for eight hours at room temperature. The wheat was then dried in shallow pans in a forced air oven. Following a procedure similar to the one of Fry *et al.* (1958) others have also significantly improved wheat for chicks or poults by water soaking (Leong, Jensen and McGinnis, 1960;

Willingham et al., 1961; Naber and Touchburn, 1964; Adams and Naber, 1969a, b) while some have noted no improvement (Hamm et al., 1960). Adams and Naber (1969b) found an increased growth response with hard wheat, but not soft wheat.

Fry et al. (1958) theorized that the improved nutritional value of grains by water soaking was associated with the carbohydrate component. They suggest that the structure of the starch is changed so that the digestive enzymes of the chick or poult can hydrolyze it more readily or completely. The action appeared to them to be physical or at least not due to eyzyme action. Preliminary autoclaving did not alter the results and in theory this should have destroyed the enzymes in the wheat.

Naber and Touchburn (1964) and Adams and Naber (1969b) were also of the opinion that the water treatment effect was primarily upon the starch component of the grain. Various fractions of the wheat were treated with water and only the starch containing fraction was improved to the same extent as the entire wheat grain.

Adams and Naber (1969a) also elicited a significant increase in growth when wheat was soaked in 0. 1N hydrochloric acid. Because little or no fermentation occurred during the acid soaking process, these workers concluded that bacterial action was probably unimportant to the growth response. This conclusion was in contradiction to the findings of Thomas, Jensen and McGinnis (1961), who suggested that microorganisms were important in the nutritional improvement, in this case of barley, by water treatment because antibiotics interfered with the improvement.

Adams and Naber (1969b) examined the nitrogen retention and the feed and fecal combustible energies of chicks fed water treated or non treated wheat. Nitrogen retention was not different between the treated and untreated groups; therefore, they concluded that protein utilization was similar. They noted from the combustible energy data that the metabolizable energy value of the water treated diets was increased relative to the non treated diets. Because of this later finding the increase in growth was ascribed to an increase in metabolizable energy resulting from water treating the wheat.

A synergistic growth response was observed by Adams and Naber (1969a) when a wheat-base diet was water treated and supplemented with 6.6 ppm of procaine penicillin. Water soaking significantly improved growth, while water soaking and the addition of procaine penicillin significantly improved growth over that arrived at by water soaking alone.

Enzyme Treatment

Enzyme supplementation of wheat-base diets has been found to increase the nutritive value of wheat in some instances (Fry *et al.*, 1958; Leong, Jensen and McGinnis, 1960; Willingham *et al.*, 1961), whereas for others it has not (Arscott, 1965; Adams and Naber, 1959, 1969a). Fry et al. (1958) supplemented a wheat-base poult feed with Clarase 300 (1 g/ton), a commercial enzyme preparation, and found that poults on the enzyme supplemented ration attained greater four-week growth than the unsupplemented group, but not significantly so. Leong, Jensen and McGinnis (1960) found fungal enzymes significantly improved the growth of chicks when added to wheat rations. By adding enzymes to autoclaved wheat Willingham et al. (1961) were able to increase chick growth significantly to a level equal to corn-fed birds.

Arscott (1965) found that the addition of an amlolytic enzyme to wheat-base broiler rations did not improve either body weight or feed conversion. Adams and Naber (1969a) were unsuccessful in promoting improved growth of chicks from any of three alpha amylase enzymes (Alpha amylase, Agroenzyme and Daw Enzyme) used to supplement wheat diets.

Autoclaving

The autoclaving of wheat has been found to increase the chick growth response to enzymes (Willingham et al., 1961). While autoclaving gave some improvement in nutritive value, adding enzymes to the treated feeds significantly improved its nutritional value.

Acid Hydrolysis

Exposure of wheat to mild acid hydrolysis has given some improvement in growth (Adams and Naber, 1959, 1969a, b; Willingham et al., 1961). The beneficial effect is related to the concentration of the acid. With 0.05, 0.1 and 0.2N hydrochloric acid, Adams and Naber (1959) were able to improve chick growth to the same extent as water soaking. However, soaking wheat in 0.5N hydrochloric acid resulted in growth depression rather than improvement. In a later report Adams and Naber (1969a) were only able to improve chick growth when wheat was hydrolyzed in 0.1N, but not 0.2N hydrochloric acid.

Pelleting

Many papers have substantiated that pelleting of rations increases broiler and turkey performance (Patten, Buskirk and Rauls, 1937; Heywang and Morgan, 1944; Bearse et al., 1952; Lansen and Smith, 1955; Allred et al., 1957; Hamm et al., 1960; Arscott, 1964; Waldroup et al., 1967, and others).

There are two schools of thought on how pellets improve performance. Some contend that the effect is chemical in nature (Allred et al., 1957) whereas others are of the opinion that it is mechanical. If the response were chemical then birds consuming the pelleted ration, if limited to the intake of those, or mash, would show improved growth over those consuming a similar amount of mash. On the other hand if the mechanical theory is advocated, then birds fed pellets would (1) consume more feed, (2) waste less feed, (3) receive a better balanced diet due to less selection, or (4) a combination of any of the above (Hamm et al., 1960).

Allred et al. (1957) reported that when the various fractions of the diet were pelleted and incorporated into the mash, that the grain fraction showed the most improvement. These workers maintained that the observed response was both chemical and physical because not only was growth improved when birds were fed pelleted corn, but also when the pelleted corn was reground. The response from the reground corn pellet was intermediate to that observed with the pelleted and untreated corn which would indicate a loss of some of the mechanical advantages of density, but a retention of properties induced by chemical change.

Research reports have been inconsistent as to the value of pelleting wheat-base rations. Hamm et al. (1960) found the pelleting of wheat diets to improve chick growth appreciably. But the response was not tested statistically. Arscott (1964) found feed efficiency of broilers to be improved, but not significantly so, and he noted no improvement in growth. Turkeys fed wheat in the pelleted form by Waldroup et al. (1967) showed no improvement in growth over those fed ground wheat, but did convert feed to gain at a statistically improved rate.

Other Methods of Improving Utilization

Experimentation at Oregon State University with white western wheat and antibiotic residues has introduced another possible area of research concerning the improved utilization of wheat. In a four-week chick trial Arscott (1968) noted that when supplementing identical wheat and corn base diets with 0.5 percent of an unidentified growth factor supplement referred to as Vigofac II (a commercial antibiotic residue) that those birds on the supplemented wheat diet showed improved growth over the unsupplemented control by 15.4 percent whereas the growth improvement for supplemented corn groups was only 4.4 percent. Since tests were conducted with unidentified growth factors as well as antibiotics, the literature in these areas will be briefly reviewed.

Fermentation Products

The mode of action of the fermentation products as well as other sources of unidentified factors has been reviewed by Young (1969). He suggested that the response obtained from unidentified factors could be due to any or a combination of the following conditions: (1) presence of some compound, unidentified or chemically known, but recognized as a nutrient; (2) existence of a recognized metabolite not synthesized in the body at a rate sufficient to meet the metabolic demands of the particular species; (3) imbalance of nutrients that becomes increasingly critical in the more highly purified diets; or (4) underestimation of the quantitative needs of a particular nutrient due to interrelationships or specific characteristics of the purified diet used in the investigation.

Antibiotic Residues. Antibiotic fermentation residues are considered a source of unidentified growth factors for the chick (Edwards *et al.*, 1953). The growth stimulating effects of the antibiotic fermentation residues has been found to vary from experiment to experiment. A number of reports have been cited where the observed response was positive and significant (Edwards *et al.*, 1953 and others), while others have found positive, but insignificant results (Allen, 1970), while still others have witnessed a complete lack of response (Summers, Pepper and Slinger, 1959b; Allen, 1970).

Because these fermentations are by-products of the production of antibiotics, the question arises as to whether or not their activity is derived from antibiotic activity. Waldroup (1967) disproved in part this point when he supplemented a chick diet with the equivalent activity of streptomycin as found in Vigofac and observed that the resulting growth was not as great as that realized from Vigofac supplementation. The growth properties of 0.5 percent Vigofac were found equivalent to 4.5 percent fish meal (Waldroup *et al.*, 1967) and to a combination of 2.5 percent fish solubles and 2.5 percent dried whey (Summers, Pepper and Slinger, 1959a). Earlier, Edwards *et al.* (1953) established that an equivalent response existed between 6.5 percent penicillin mycelium residue and 4.5 percent fish solubles.

Cereal Grain Residues. Distillers dried solubles (DDS) are obtained after the removal of ethyl-alcohol by distillation from the yeast fermentation of a grain by condensing and drying the thin stillage fraction (Distillers Feed Research Council, 1971). They were first shown to elicit an unexplained growth response by Synold *et al.* (1943). Based on the findings of a six-week trial these workers concluded that DDS contained the unidentified growth factor present in commercial casein as well as other growth factors found in dried skim milk. Experimentation by Novak, Hauge and Carrick (1947) revealed that the DDS growth factor was not any of the B vitamins then known and was also distinct from the fat soluble vitamins A and D. The following year Novak and Hauge (1948) isolated the factor and designated it vitamin B_{13}. The factor, vitamin B_{13}, was found by Austin and Boruff (1949) to promote additional growth of chicks fed a vegetable diet which was complete in all known nutrients.

Experimentation followed to either associate the growth factor in DDS with or differentiate it from other unrecognized growth factors contained in other feedstuffs. Couch *et al.* (1951) concluded that the factor(s) in the soluble and in dried whey (Berry *et al.*, 1943) might be identical. They also suggested that the above factor(s) accentuate the growth response noted from feeding antibiotics. Scott (1951) observed that supplementing a vegetable diet with DDS, skim milk and grass alfalfa juices produced quite similar growth responses by four-week old poults as opposed to those on unsupplemented diets. The factor of DDS was noted to be dissimilar to that of fish meal (Couch et al., 1951) and fish solubles (Norris, 1954).

Half of the unidentified chick growth response has been associated with the ash portion of DDS (Norris, 1955; Couch et al., 1955). Kurnick et al. (1957) and Reid et al. (1958) concluded that molybdenum may be partly, but not entirely, responsible for the ash response. Scott and Ziegler (1960) suggested that part of the response was due to zinc or the presence of an agent that improves zinc availability.

Having identified the mineral portion of the growth response factor(s), workers turned their attention to resolving the organic portion of the response. Through fractionation procedures Stelzner et al. (1959) isolated a highly active fraction which when fed at the level of 2.5 ppm of diet produced a similar growth response to that obtained with ten percent DDS. Couch and Stelzner (1961) identified two growth promoting fractions, one fraction being isopropanol insoluble whereas the other was isopropanol-chloroform soluble. The latter fraction was also isolated from fish solubles, fish meal, and fluid egg yolk. Couch, Lozano and Creger (1969) and Dixon and Couch (1970) isolated a number of phenolic acids from DDS. From the isopropanol soluble fraction Dixon and Couch (1970) isolated and identified nine phenolic acids which stimulated chick growth.

Antibiotics

A voluminous number of papers have been published concerning the growth promoting effects of antibiotics. Rather than discussing each of these papers reference is drawn to reviews of antibiotics such as Jukes (1955), Goldberg (1959), Bird (1969), and Scott, Nesheim and Young (1969).

Scott, Nesheim and Young (1969) have concluded from published information that the growth promoting effects of antibiotics in poultry appear to be concerned with decreasing the magnitude of the environmental disease level. Diseases vary considerably as to locale and mode of inducement. Consequently, the modes of action of antibiotics may differ widely. The effect of antibiotics on growth may be one or more of the following: (1) they may favor the growth of nutrient-synthesizing and inhibit that of nutrient destroying microorganisms; (2) organisms producing excessive amounts of ammonia and other toxic nitrogenous waste products in the intestines may be inhibited; (3) antibiotics may improve the availability or absorption of various nutrients; (4) they may improve either or both feed and water consumption; or (5) antibiotics may prevent or cure actual pathological diseases which occur in the intestinal tract.

Because antibiotics indirectly improve growth through a mode or modes such as those suggested above, they are termed "growth promotants" (Briggs, 1950) and are thereby differentiated from sources of unidentified growth factors which are said to stimulate growth directly by supplying needed nutrients.

Antibiotics have also been associated with certain physiological changes in the body. Gordon (1952), and others since, noted that the addition of antibiotics to the ration caused a reduction in intestinal weight. An increase in thyroid weight has been observed by some following the dietary addition of antibiotics (Libby and Meites, 1954) while others have observed no changes of the thyroids (Mellen and Walker, 1954).

Fish meal (herring meal) was also used in this study to evaluate its effects on growth with those growth supplements previously mentioned. It has long been recognized as a source of unifentified growth factors. These growth properties have been reviewed by Bird, Steinke and Runnels (1962), Day and Dilworth (1965) and others.

EXPERIMENTAL PROCEDURE

Chick Experiments

General Comments

Unless otherwise specified the following general information applies to all chick feeding trials. The experimental animals used were Indian River "Hybro" broiler chicks equally divided by sex. With the exception of one eight-week trial all feeding trials were of four weeks duration. The four-week trials were carried out in electrically heated batteries whereas the eight-week trial was conducted in floor pens heated by infra-red heat lamps. Battery raised chicks were divided into four replicate lots per treatment of ten day-old chicks each and the eight-week broiler trial was made up of three replicate lots per treatment of 24 day-old chicks each. Feed and water were supplied *ad libitum*. Twenty-four hour lights were used and forced draft ventilation was employed. Body weight and feed conversion data were recorded at the end of four and eight weeks, respectively.

The composition of the experimental diets is given in Table 8. These diets were calculated as being adequate in all of the known nutrients. Rations 1 and 2 were used as the basal wheat and corn diets respectively. In exception to the above, Rations 3 and 4 were used in Trial 2 of Series III for isocaloric studies and Rations 5 and 6

Table 8. Composition of experimental chick rations.

Ingredient	Rations 1	2	3	4	5	6
	%	%	%	%	%	%
Wheat, ground	62.85		58.50		68.30	
Corn, ground		62.85		64.85		68.30
Animal fat	2.00	2.00	5.80			
Soybean meal (48.5%)	29.00	29.00	29.55	29.00	21.00	21.00
Fish meal, herring					5.00	5.00
Alfalfa meal	2.00	2.00	2.00	2.00	2.00	2.00
Limestone flour	1.60	1.60	1.60	1.60	1.60	1.60
Dicalcium phosphate	1.85	1.85	1.85	1.85	1.85	1.85
Salt	0.30	0.30	0.30	0.30	0.30	0.30
MHA (80%)	0.15	0.15	0.15	0.15	0.15	0.15
PM-1-65[1]	0.25	0.25	0.25	0.25	0.25	0.25
Zoamix	0.05	0.05	0.05	0.05	0.05	0.05
Calculated analysis						
Protein (%)	21.04	20.79	20.91	20.96	21.00	20.73
M.E. (k cal/kg)	2828	2973	2971	2973	2810	3042
Fiber (%)	3.25	2.62	3.13	2.66	3.18	2.49
Fat (%)	3.36	3.74	7.08	2.82	1.76	3.26

[1]The trace mineral and vitamin mix contributes per kilogram of ration the following amounts: manganese, 59.9 mg; iron, 19.8 mg; copper, 2.0 mg; cobalt, 0.1 mg; iodine, 1.2 mg; zinc, 27.5 mg; vitamin A, 3,300 I.U.; vitamin D, 1,100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 19.4 mg; choline, 190.9 mg; vitamin B_{12}, 5.5 mg; vitamin E, 1.1 I.U.; vitamin K, 0.25 mg; zinc bacitracin, 4.4 mg; BHT, 124 mg.

were used wherever fish meal was incorporated into the experimental design. For experimental purposes, zinc bacitracin was at times omitted from the basal ration and wherever this occurred it will be noted by a footnote in the table of the results for that trial. Growth supplements were added at the expense of the grain component.

Crude protein analyses of the feed and droppings were made by the Kjeldahl method using a procedure (Rachapaetayakom, 1961) designed for the Nutrition Laboratory of the Department of Poultry Science. The gross energy of the droppings was determined in a Parr Oxygen Bomb Calorimeter located in the laboratories of the Department of Animal Science of Oregon State University. The method used in operating the calorimeter was outlined in the Parr Technical Manual 130 (Parr Instrument Company, 1960).

The experimental outline consists of three major areas of investigation. Each of these major areas will be referred to as a "Series" and will consist of a number of trials conducted to resolve the problem under investigation. The experimental design of each of the trials will be provided in the respective tables on results (Tables 12 to 36).

Statistical analysis of chick experiments was performed by analysis of variance (Snedecor and Cochran, 1967). The abbreviations LSD and nsd in tables reporting results refer to least significant difference and no significant difference, respectively.

Experiments

Series I. Nature of Activity. A number of trials were conducted to determine in which fractions Vigofac activity lies and to determine its stability under various conditions. Forty percent of commercial Vigofac consists of an extract of streptomyces fermentation residues and the remaining 60 percent is a carrier upon which the residues are dried (Turk, 1969). In Trial 1 these fractions were examined to determine in which phase the activity resides (Table 12). Because both organic and inorganic activity has been identified in other fermentation products, Trial 2 was conducted to find if part or all of the Vigofac response was inorganic (Table 13). Ashing was accomplished by placing 227 grams of Vigofac in a muffle furnace for eight hours at 600°C.

In Trials 3 and 4 Vigofac and its extract were fractionated following a procedure previously employed by Dixon and Couch (1970) to isolate active fractions from DDS (Tables 14 and 15). Figure 3 illustrates an outline of the procedure used in Trials 3 and 4. Vigofac (227 grams) and Vigofac extract (227 grams) were both subjected to the fractionation procedure. Initially the above quantities were subjected to enough 6N sulfuric acid to wet them and were in turn autoclaved for 30 minutes at 15 psi and 121°C. Subsequently, each was neutralized with sodium hydroxide. In turn 95 percent ethanol was

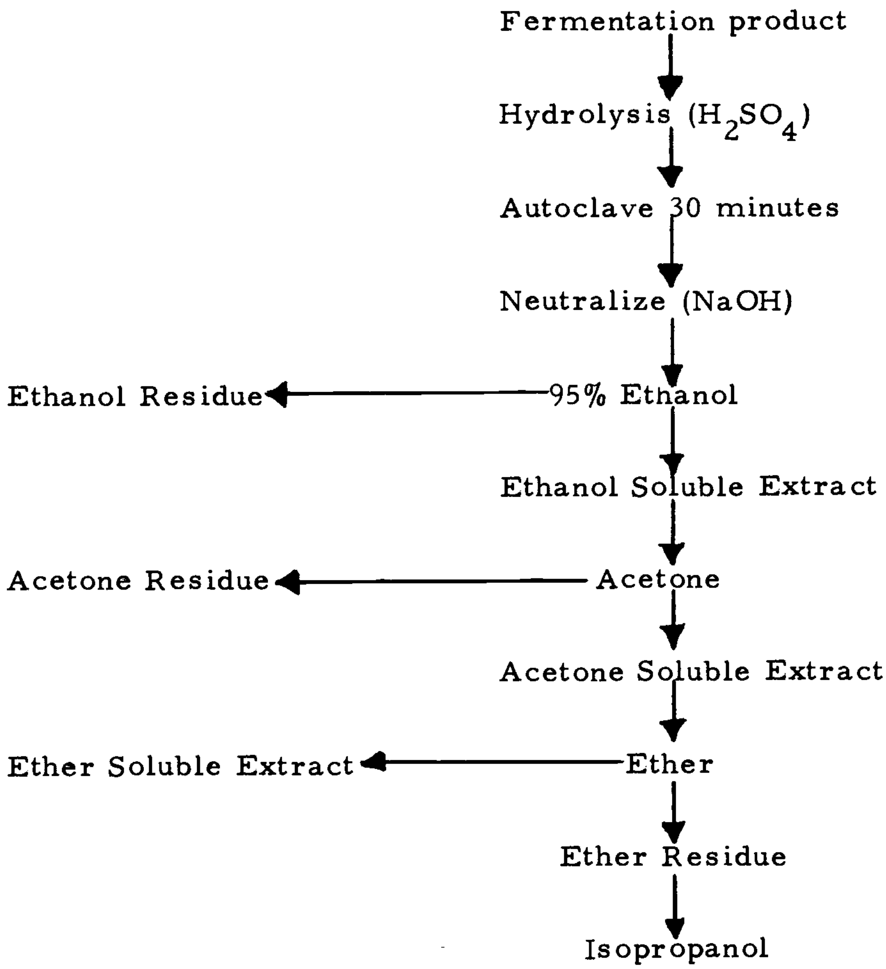


Figure 3. Fractionation of fermentation products.

added until the mixtures were liquid enough to be stirred mechanically. After stirring the mixtures overnight each was filtered in a 25.4 cm Buchner funnel. The remaining residues were extracted three times with ethanol. The filtrates were concentrated to a semisolid mass under vacuum. The above masses were then stirred with acetone after which the acetone extracts were decanted from the mass. Acetone extraction was continued until both extracts were clear. The acetone extracts were then concentrated and treated with diethyl ether. After placing the acetone ether mixtures in the refrigerator for six hours, the ethereal layer was decanted. The layer of ether was then washed three times with the aid of a separatory funnel. The ether insoluble portions were then concentrated and following the concentration were increased to twice their volume with isopropanol. The resulting mixtures were placed in a deep freeze overnight. The ethanol residues, acetone residues, ether soluble extracts and isopropanol fractions were in turn fed as supplements.

As noted earlier Dixon and Couch (1970) found that as a group, seven of nine phenolic acids isolated from the isopropanol fraction of DDS when fed collectively induced a significant ($P < 0.05$) growth response over controls. Six of the seven phenolics used by these workers and one of the two that they did not use were acquired and fed to evaluate the growth activity of fractions isolated from DDS by the preceding fractionation procedure. The compounds used and their content in DDS are listed below:

Phenolic acid	% DDS content
3, 4-dihydroxybenzoic acid	0.016
3, 4-dihydroxycinnamic acid	0.028
4-hydroxy-3-methoxybenzoic acid	0.038
n-hydroxybenzoic acid	0.054
p-hydroxycinnamic acid	0.026
4-hydroxy-3, 5-dimethoxycinnamic acid	0.009
p-hydroxybenzoic acid	0.024

In Trial 5, the seven acids were fed collectively and individually (Table 16). As a group the phenolics were fed in quantities equal to their concentration in 2.5 and 5 percent DDS. Solulac, which contains 70 percent DDS, was used as a source of the distillery by-product. Results from the first trial indicated that certain of the individual phenolics appear to have growth promoting properties. In Trial 6, those four acids which seemed most promising were fed individually at twice the concentration used previously (Table 17). Since other work had pointed to the fact that low levels of antibiotic may have an effect on growth, zinc bacitracin was removed from the basal diet to make the tests more sensitive. This point was further investigated in Trial 7 where the seven phenolics were fed with or without zinc bacitracin (Table 18).

In the next three trials the stability of Vigofac growth activity was evaluated following exposure to various heat and soaking processes. Vigofac was subjected to two different types of heat treatments in Trials 8 and 9. In Trial 8, 227 grams of the liquid extract were boiled for 60 minutes at 112°C (Table 19). Before adding the material to the feed it was allowed to cool and air dry. In Trial 9, 227 grams of Vigofac (extract and carrier) were autoclaved for 30 minutes at 15 psi and 121°C (Table 20). A like amount of Baciferm (11.4 g/kg of zinc bacitracin) was similarly subjected to autoclaving.

Trial 9 also included an examination of the change if any in the growth promoting activity of Vigofac and zinc bacitracin (used for comparative purposes) following treatment with acid or base. This involved soaking for 96 hours in: (1) 0.1N sodium hydroxide, (2) 1.0N sodium hydroxide, and (3) 0.1N hydrochloric acid. In each instance 227 grams of Vigofac or 227 grams of Baciferm were used as starting material. Following the soaking treatment, base mixtures were neutralized with hydrochloric acid and acid mixtures with sodium hydroxide. Neutralized materials were added to the ration in the wet form.

Since the acid and base soaking treatments appeared to enhance rather than detract from the activity of Vigofac, Trial 10 was conducted to determine if the enhanced activity was due to fermentation transpiring as a result of the soaking process. To test this possibility, Vigofac was soaked in water which should not inhibit fermenetation and

95 percent ethanol which arrests fermentation (Table 21). Procedural steps were similar to those of the previous trial.

All of the soaking was done in open 1,000 milliliter beakers. The soaking solution whether acid or base was kept at a level just above the material being soaked.

Series II. Mode of Action. Five trials were conducted to ascertain the manner in which Vigofac elicits chick growth responses. Since it is possible that improved growth realized from Vigofac supplementation may be related to increased feed consumption, Trial 1 was devised to limit the consumption of Vigofac supplemented groups to that of the wheat and/or corn controls. This was accomplished by measuring consumption of the control each day for the previous 24 hours. This same amount was then allotted to the Vigofac groups for the succeeding 24 hours (Table 22). In Trials 2 and 3 energy and protein utilization of Vigofac- and zinc bacitracin-fed chicks were evaluated by means of dropping analyses. The gross energy content of the droppings was measured by means of a Parr bomb calorimeter (Table 23). In Trial 2 these measurements were made from droppings defecated at two weeks of age while in Trial 3 they were determined from droppings at three weeks. All of the droppings were collected for a 24 hour period from two pens within each treatment that was analyzed. The droppings were prepared for analysis by drying to a constant weight in an oven at 100°C. Following this, a random sample of each pen's droppings was ground to a relatively fine consistency using a mortar and pestle. From the ground material, pellets were made with a Parr pellet press and were in turn used to determine the gross energy.

The crude protein was determined for the same treatments as above by means of the Kjeldahl method (Table 23). The samples were prepared as noted previously to the point preceding pellet formation.

Trials 4 and 5 were conducted to ascertain if the action of the antibiotic fermentation residue may cause change in weight of various body organs. At four weeks of age the small intestine and the thyroids were removed and weighed from one male and one female from the four replicate groups within each treatment (Tables 24 and 25). In addition the same procedure was followed with the pancreas in Trial 5. The body weight for each of the birds was determined the preceding evening. In preparation for organ removal the birds were killed by electrical shock. Before weighing the intestines, the tissue was thoroughly cleaned to remove all the ingesta. Dry weights were also determined for the pancreas and small intestines following an oven drying period of eight hours at $100^{\circ}C$. For comparative purposes the above was employed for birds in both trials fed zinc bacitracin and those in Trial 4 fed herring meal.

Trials 2 and 4 correspond with feeding Trial 8 of Series III and Trials 3 and 5 correspond with feeding Trial 7 of Series III.

Series III. Comparative Growth Effects. In this series the growth response realized from Vigofac feeding was evaluated with that obtained from various other growth inducing supplements. Two trials were conducted to evaluate the growth promoting effect of a number of fermentation residues as supplements to wheat-and corn base diets. The products employed are presented in Table 9. In Trial 1 all the fermentation residues were evaluated (Table 26). Three of the residues which favorably improved the growth of wheat-fed chicks were again fed in Trial 2 as supplements to isocaloric diets (Table 27).

The next six trials were undertaken to examine the effects on growth realized from feeding various growth supplements individually and collectively. Two trials were conducted to evaluate the Vigofac growth response with and without a low level of antibiotics. In Trial 3 (Table 28) a level of 11 ppm of zinc bacitracin was tested whereas in Trial 4 (Table 29) the amount was increased five fold. Zinc bacitracin had proved in the previous trial to be an effective growth promotant; therefore, in Trial 5 its growth promoting properties were evaluated at various levels (Table 30). In Trial 6 the degree of growth promotion of a number of other antibiotics (see Table 9 for commercial names) was observed relative to that obtained from zinc bacitracin and the fermentation residues Vigofac and UNF-40 (Table 31). Since the fermentation residue and antibiotic response had been observed with white winter wheat, Trial 7 (Table 32) was conducted to see if similar

Table 9. Growth supplements.

Commercial name	Description
	<u>Fermentation products</u>
Fermacto 500	Streptomyces fermentation residues, condensed whey solubles, condensed fermented corn extractives and corn distillers dried solubles
Pryferm H. B.	Streptomyces fermentation residues
Solulac	Corn distillers dried solubles with grains
Streptomyces Meal and Solubles	Streptomyces meal and solubles
Liquid Streptomyces Solubles	Liquid streptomyces fermentation residues
UNF-40	Streptomyces fermentation residues, corn distillers dried solubles with grains, condensed fermented corn extractives and condensed whey solubles
Vigofac	Streptomyces fermentation residues
	<u>Antibiotics</u>
Aureomycin	Chlortetracycline
Baciferm	Zinc bacitracin
Oleandomycin	Oleandomycin
Prostrep	Procaine penicillin plus streptomycin sulfate
Terramycin	Oxytetracycline

responses would be observed with a wheat of a different class while in Trial 8 the independent and combined growth responses resulting from the feeding of three growth supplements was evaluated (Table 33).

Layer Experiment

Nine hundred-sixty Oregon Agricultural Experiment Station dwarf White Leghorn pullets and 100 normal size A. E. S. White Leghorn pullets were housed in floor pens prior to the onset of production with 60 and 50 birds per pen, respectively. The dwarfs were obtained from a mating of dwarf males to normal hens, the latter being from a criss-cross breeding program maintained at the Oregon Agricultural Experiment Station. Thus, using this type of scheme with either dwarf or normal males resulted in the two types of pullets being half sisters. During the growing period the birds were raised under the management program of the Department of Poultry Science.[1] All dwarf pullets were divided into quadruplicate lots for each treatment

[1] It should be noted that during the growing period one-half of the dwarfs received 0.033 percent of iodinated casein in their diets. During the first 20 weeks of the laying experiment one-half of the above continued to receive this treatment as did one-half of those not previously treated. For the final 20 weeks the treatment was reversed and the level lowered to 0.011 percent. Since the iodinated casein data were not a part of this investigation those results will not be presented here. All four treatments of the experiment reported here were equally affected by each change of iodinated casein.

while the normals were placed in duplicate lots. The experimental rations and the experimental outline are found in Tables 10 and 34 respectively. The ration numbers in the former table correspond with the treatment numbers in the latter table. Feed and water were supplied ad libitum. At least 14 hours of incandescent light and three square feet of floor space were provided throughout the experiment. The experiment commenced when the dwarf pullets reached 25 percent production.

The performance criteria measured during the course of the experiment and the period for which they were measured are listed in Table 11. Specific gravity, a measure of egg shell thickness, and egg weights were determined from the daily production on three successive days. Using the procedure described by Arscott and Bernier (1961), the specific gravity was measured in aqueous salt solutions scaled from 1.052 to 1.104 with intervals of 0.004. The internal egg quality and egg contents variables were measured from two eggs of each pen that were equal to the average weight of all eggs of that pen. The Roche Colour Fan[2] was used to quantitate yolk color; albumen height was measured with an Ames micrometer.[3]

Statistical analyses for the dwarfs were made by analysis of variance, whereas the comparisons between dwarfs and normals were

[2] Hoffman-La Roche Inc., Nutley, New Jersey.

[3] B. C. Ames Company, Waltham, Massachusetts.

Table 10. Composition of experimental layer rations.

Ingredient	Ration number 1	2	3	4	5
	%	%	%	%	%
Wheat, ground	67.19		67.19	66.69	
Corn, ground		67.19			67.65
Fat, animal	2.00	2.00			1.00
Fat, safflower oil			2.00	2.00	
Soybean meal, 44%	18.73	18.73	18.73	18.73	20.00
Vigofac II				0.50	
Alfalfa meal, 20%	3.00	3.00	3.00	3.00	3.00
Limestone flour	6.15	6.15	6.15	6.15	5.60
Dicalcium phosphate	2.00	2.00	2.00	2.00	2.00
Salt, iodized	0.50	0.50	0.50	0.50	0.50
DL-Methionine, 98%	0.10	0.10	0.10	0.10	
PM-2-65[1]	0.33	0.33	0.33	0.33	0.25
Calculated analysis					
Protein (%)	15.5	15.2	15.5	15.4	15.8
M. E. (k cal/kg)	2684	2911	2724	2709	2889
Fat (%)	3.39	4.87	3.39	3.38	3.90
Crude fiber (%)	3.88	3.21	3.88	3.86	3.30
Linoleic acid (%)	.54	1.41	1.95	1.95	1.40

[1]The trace mineral and vitamin mix contributes per kilogram of ration the following amounts: manganese, 59.9 mg; iron, 19.8 mg; copper, 2.0 mg; cobalt, 0.1 mg; iodine, 1.2 mg; zinc, 27.5 mg; vitamin A, 3,300 I.U.; vitamin D, 1,110 ICU; riboflavin, 2.2 mg; d-pantothenic acid 3.3 mg; niacin, 16.5 mg; choline, 95.5 mg; vitamin B_{12}, 4.4 mg; vitamin E, 1.1 I.U.; vitamin K, 0.25 mg; BHT, 124 mg.

Table 11. Performance criteria measured in layer experiment.

Parameter	Period of measurement
Egg production Feed consumption Feed per dozen eggs Egg weights Mortality	10 consecutive 28 day periods
Body weights	0, 5, 10, 20 and 40 weeks
Specific gravity	0, 10, 20, 30 and 40 weeks
Internal egg quality Albumen height Haugh units Yolk color	0, 20 and 40 weeks
Egg contents Shell weight Yolk weight Albumen weight	0, 20 and 40 weeks

made by standard error with appropriate significance determined therefrom. These tests are outlined in Snedecor and Cochran (1967).

RESULTS AND DISCUSSION

Chick Experiments

Series I. Nature of Activity

Results. The antibiotic fermentation residue (Vigofac) with which Arscott (1968) had been experimenting on wheat-base rations consisted of the residual materials from the production of antibiotics and a carrier upon which these materials were dried. Accordingly, it was felt important to identify if in fact all of the activity resided in the extract or if some originated from carrier. In Trial 1 it was found that the commercial Vigofac product (extract and carrier combined) when added at levels of 0.5, 1.0, and 2.0 percent, significantly ($P < 0.01$) improved growth at the two higher levels (Table 12). The extract also improved growth significantly when added at amounts equal to that found in one ($P < 0.05$) and two ($P < 0.01$) percent Vigofac. The carrier, however, showed no activity as all three levels failed to stimulate growth. Combining the carrier and extract improved growth significantly ($P < 0.01$) only when added at a level equivalent to two percent Vigofac. Two treatments of herring meal, which is also considered as a source of unidentified growth factors, were included for comparative growth purposes. Its addition to the wheat-base ration showed no growth improvement and had little effect when added to the corn ration.

Table 12. Observations of Vigofac extract and carrier for growth activity (Trial 1).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat	581		1.81	
2. As 1 + 0.5% Vigofac	601	3.4	1.79	1.0
3. As 1 + 1.0% Vigofac	618	6.3	1.81	0.0
4. As 1 + 2.0% Vigofac	625	7.6	1.77	2.0
5. As 1 + 0.2% Vigofac extract	580	-0.2	1.86	-2.8
6. As 1 + 0.4% Vigofac extract	613	5.5	1.79	1.0
7. As 1 + 0.8% Vigofac extract	627	7.9	1.79	1.0
8. As 1 + 0.3% Vigofac carrier	561	-3.5	1.87	-3.4
9. As 1 + 0.6% Vigofac carrier	571	-1.7	1.81	-1.7
10. As 1 + 1.2% Vigofac carrier	588	1.2	1.79	1.0
11. As 5 + 8	587	1.0	1.81	0.0
12. As 6 + 9	584	0.6	1.85	-2.2
13. As 7 + 10	626	7.7	1.82	-0.4
14. As 1 + 5.0% herring meal	577	-0.6	1.81	-1.7
15. Control - corn	591		1.80	
16. As 15 + 5.0% herring meal	610	3.2	1.78	1.8
L.S.D. ($P < 0.05$)	27		45	
L.S.D. ($P < 0.01$)	36		60	

Results of ashing Vigofac indicated that its growth promoting properties were likely organic in nature (Table 13). While there were no significant differences, Vigofac supplementation increased growth by 5.9 percent over the control while its ash fraction did so by only 1.2 percent.

Table 13. Relation of Vigofac activity to ash component (Trial 2).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control-wheat	512		1.71	
2. As 1 + 0.5% Vigofac	542	5.9	1.65	3.6
3. As 1 + 0.5% Vigofac ashed	518	1.2	1.67	2.4
	nsd		nsd	

Fractions have been isolated from distillers dried solubles (DDS) which enhance the growth of chicks and poults (Stelzner, 1961; Dixon and Couch, 1970). The latter workers identified from one of these fractions a number of phenolic compounds which, when supplemented to a basal diet at the level found in five percent DDS, significantly improved growth.

In Trials 3 and 4 both Vigofac (extract and carrier) and its extract were fractionated using the procedure described by Dixon and Couch (1970) for DDS. Table 14 shows that in fractionation of the commercial product, chicks fed the ether extract and the isopropanol

Table 14. Fractionation of commercial Vigofac (Trial 3).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat	502		1.91	
2. As 1 + 0.5% Vigofac	515	2.8	1.88	1.8
3. As 2-ethanol residue	526	4.8	1.75	9.2
4. As 2-acetone residue	487	-3.1	1.85	3.5
5. As 2-ether extract	483	-3.9	1.94	-1.4
6. As 2-isopropanol fraction	463	-8.4	1.89	1.4
L.S.D. ($P < 0.05$)	40		nsd	

Table 15. Fractionation of Vigofac extract (Trial 4).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat	502		1.91	
2. As 1 + 0.5% Vigofac extract	537	6.5	1.77	7.9
3. As 2-ethanol residue	509	1.4	1.81	5.8
4. As 2-acetone residue	520	3.5	1.78	7.4
5. As 2-ether extract	497	-1.0	1.72	11.1
6. As 2-isopropanol fraction	480	-4.4	1.80	6.5
	nsd		nsd	

fraction were significantly ($P < 0.05$) smaller than the ethanol residue groups. Thus, the activity apparently remained in the ethanol residue which would indicate that the acid hydrolysis and the subsequent ethanol extraction were unsuccessful in freeing the activity. In fractionation of the extract portion of Vigofac (Trial 4) there were no significant differences for the various fractions (Table 15). Contrary to the previous trial there was no activity retention in the ethanol residue, but possibly some in the acetone residue. Birds receiving the isopropanol fraction achieved less than 90 percent of the growth of those fed the extract intact.

Trials 5, 6, and 7 were conducted to evaluate the phenolics isolated by Dixon and Couch (1970) from DDS. The evaluation is included here becuase of its relation to the fractionation procedure used in the previous trials. Results of Trial 5 are in contrast to those of Dixon and Couch (1970). It was found that the phenolic compounds, when added collectively to wheat rations at the same level as found in five percent DDS, did not improve growth over the control groups (Table 16). On the other hand the addition of 7.2 percent Solulac, which is equivalent to 5 percent DDS, did improve growth significantly ($P < 0.05$). Fed individually at 99 ppm, five of the phenolic compounds appeared to improve growth, but only 3, 4-dihydroxy cinnamic acid did so significantly ($P < 0.05$). Solulac showed a greater growth response with wheat than with a corn-base ration. The

Table 16. Evaluation of phenolics found in DDS as growth supplements (Trial 5).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat	507		1.90	
2. As 1 + 3,4-dihydroxy-benzoic[1]	510	0.6	1.92	- 1.1
3. As 1 + 3,4-dihydroxy-cinnamic	541	6.7	2.07	- 8.9
4. As 1 + 4-hydroxy-3-methoxybenzoic	535	5.5	1.85	2.7
5. As 1 + m-hydroxybenzoic	533	5.1	2.09	-10.0
6. As 1 + p-hydroxycinnamic	505	0.4	1.86	2.2
7. As 1 + 4-hydroxy-3,5-dimethyloxycinnamic	532	4.9	2.16	-13.1
8. As 1 + p-hydroxybenzoic	536	5.7	1.78	6.7
9. As 1 + all phenolics at level of 2.5% DDS	508	0.2	2.12	-11.6
10. As 1 + all phenolics at level of 5% DDS	516	1.8	1.89	0.5
11. As 1 + 3.6% Solulac	508	1.0	1.93	- 1.6
12. As 1 + 7.2% Solulac	560	10.5	1.84	3.2
13. As 1 + 0.5% Vigofac	566	11.6	1.79	6.1
14. Control - corn	565		1.72	
15. As 14 + 7.2% Solulac	591	4.6	1.80	- 4.7
16. As 14 + all phenolics at level of 5% DDS	545	- 3.7	1.76	- 2.3
L.S.D. ($P < 0.05$)	33		nsd	
L.S.D. ($P < 0.01$)	44			

[1]Individual phenolics added at 99 ppm.

supplementation of wheat with 7.2 percent Solulac significantly improved ($P < 0.05$) growth by 10.5 percent whereas a similar supplementation of the corn ration improved growth by only 4.6 percent.

In Trial 6 four of the five phenolic compounds, which appeared in Trial 1 to have some growth promoting properties, were fed at twice the level (198 ppm) used in the previous trial (Table 17). Contrary to prior results, the four failed to improve growth. Combining them also had no effect on growth. In this connection it should be noted that in Trial 4 there was a low level of zinc bacitracin (4.4 ppm) in the ration while in this trial the antibiotic had been omitted. This introduced the possibility that an antibiotic might be related to the phenolic response. This possibility was further studied in Trial 7 where it was again found that the seven phenolics when fed in the presence of zinc bacitracin failed to improve growth, while in the absence of the antibiotic they significantly ($P < 0.05$) improved growth and appeared to have a beneficial effect on feed conversion (Table 18). It would thus appear that the presence or absence of an antibiotic was not a factor in the variable response from the phenolics.

The next four trials deal with the exposure of Vigofac or its extract to various experimental conditions and the resulting effect on its growth promoting activity. In Trials 8 and 9 the effect on activity of two different forms of heat treatment was evaluated. Results of Trial 8 show that following boiling for 60 minutes, the Vigofac extract

Table 17. Collective and individual effect of four phenolics on growth (Trial 6).

Treatment	Four-week data: Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[1]	500		1.83	
2. Control - corn[1]	533		1.79	
3. As 1 + 3,4-dihydroxy-cinnamic[2]	505	1.0	1.75	4.5
4. As 1 + vanillic acid	501	0.2	1.74	5.2
5. As 1 + n-hydroxybenzoic	493	-1.4	1.80	1.7
6. As 1 + p-hydroxybenzoic	510	2.0	1.81	1.1
7. As 1 + 3 + 4 + 5 + 6[3]	508	1.6	1.73	5.8
	nsd		nsd	

[1]No antibiotic present.

[2]Individual phenolics were added at the level of 198 ppm.

[3]In Treatment #7 each phenolic was added at 99 ppm.

Table 18. Influence of zinc bacitracin on the phenolic growth effect (Trial 7).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[1]	509		1.81	
2. As 1 + 0.5% Vigofac	565		1.61	
3. As 1 + zinc bacitracin (28 ppm)	503	-1.2	1.81	
4. As 1 + all phenolics (99 ppm each)	539	5.9	1.68	7.7
5. As 3 + all phenolics (99 ppm each)	490	-3.9	1.75	3.4
L.S.D. ($P < 0.05$)	30		nsd	
L.S.D. ($P < 0.01$)	42			

[1]No antibiotic present.

appeared to lose all or most of its activity (Table 19). Although no significant differences were evident, birds on the heat treatment averaged only 2.3 percent greater weight than the controls while the birds on the non-heated extract were 5.9 percent heavier than the controls.

Table 19. Effect of heat treatment on Vigofac extract growth activity (Trial 8).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control-wheat	512		1.71	
2. As 1 + 0.5% Vigofac extract	542	5.9	1.71	0.0
3. As 2 - heat treated	523	2.1	1.67	2.4
	nsd		nsd	

Trial 9 showed that the autoclaving of Vigofac (extract and carrier) did not seem to affect its activity (Table 20). Birds receiving autoclaved as well as non-treated Vigofac were significantly ($P < 0.01$) heavier than were the control birds. Zinc bacitracin was similarly treated for comparative purposes. The non-autoclaved antibiotic improved growth significantly ($P < 0.01$) as did autoclaving, but at a lower level of probability ($P < 0.05$).

As noted above, non-treated Vigofac or zinc bacitracin significantly ($P < 0.01$) improved growth. Also in Trial 9 it was found that soaking either under basic or acidic conditions for 96 hours appeared

Table 20. Effect of exposure of Vigofac and zinc bacitracin to various treatments on growth activity (Trial 9).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[1]	486		1.96	
2. As 1 + 0.5% Vigofac	529	8.8	1.79	9.5
3. As 2 - autoclaved	529	8.8	1.72	14.0
4. As 2 - acid soaked (0.1N HCl)	545	12.1	1.72	14.0
5. As 2 - base soaked (0.1N NaOH)	567	16.7	1.74	12.6
6. As 2 - base soaked (1.0N NaOH)	573	17.9	1.80	8.9
7. As 1 - zinc bacitracin (275 ppm)	537	10.5	1.79	9.5
8. As 7 - autoclaved	526	8.2	1.76	11.4
9. As 7 - acid soaked (0.1N HCl)	559	15.0	1.79	9.5
10. As 7 - base soaked (0.1N NaOH)	565	16.3	1.81	8.3
11. As 7 - base soaked (1.0N NaOH)	567	16.7	1.74	12.6
L.S.D. ($P < 0.05$)	30		nsd	
L.S.D. ($P < 0.01$)	41			

[1]No antibiotic present.

Table 21. Effect of water and ethanol soaking on Vigofac growth activity (Trial 10).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[1]	509		1.77	
2. As 1 + 0.5% Vigofac	565	11.0	1.61	9.9
3. As 2 - water soaked	547	7.5	1.76	0.6
4. As 2 - ethanol soaked	521	2.4	1.73	2.3
L.S.D. ($P < 0.05$)	21		nsd	
L.S.D. ($P < 0.01$)	30			

[1]No antibiotic present.

to further enhance activity. Birds fed Vigofac that had been soaked in either 0.1 or 1.0N sodium hydroxide were significantly larger than those receiving the untreated Vigofac. A similar observation was made for zinc bacitracin soaked in 1.0N sodium hydroxide. Acid soaking also improved growth, but not to a point of statistical significance.

In view of this it was believed that either of two possibilities might account for the above response. First, the soaking process may have liberated additional activity that would have otherwise been unavailable to the animal, and second that increased microbial fermentation may have taken place during the soaking process which in turn improved Vigofac activity. The latter possibility was investigated further. In Trial 10, Vigofac was soaked for 96 hours in water and 95 percent ethanol. Theoretically the former would not detract from fermentation and the latter would arrest it. Results showed that the water soaked Vigofac aided birds in growing significantly ($P < 0.01$) larger than the control birds, but they were still three percent smaller than the birds receiving untreated Vigofac (Table 21). Chicks treated with ethanol soaked Vigofac were significantly smaller than those receiving water soaked ($P < 0.05$) and untreated Vigofac ($P < 0.01$).

Discussion. These results clearly indicate that the growth promoting activity of Vigofac resides in the extract (Table 12). This activity is apparently organic in nature since no activity was observed in the ash (Table 13). Since Couch et al. (1955) reported that half of the unknown growth factor of DDS was found in the ash, the last observation differentiates then in part the growth promoting properties of Vigofac from those of DDS.

The fact that the fractionation procedure of Dixon and Couch (1970) was not similarly applicable to Vigofac as it was to DDS is further evidence that the products have differing growth promoting properties. Previously, both Stelzner (1961) and Dixon and Couch (1970) had reported that the isopropanol fraction of DDS, significantly ($P < 0.01$) improved the growth of chicks and poults. Results of the fractionations used here showed that activity apparently remained in the ethanol or possibly the acetone residues (Tables 14 and 15). However, these observations do not differ entirely from those of the above workers as they also reported that at times greater growth was achieved from the ethanol and acetone residues than from isopropanol fraction which indicates they too experienced inconsistent results in their extraction procedures.

The phenolics of DDS isolated by Dixon and Couch (1970) were found to have a limited, but inconsistent influence on growth. Where the Texas workers observed a significant growth improvement when the phenolics were fed collectively at levels equivalent to five percent DDS, no improvement was seen here (Table 16). However, in Trial 7 when the compounds were fed at levels considerably higher than found in five percent DDS, one group showed improved growth ($P < 0.05$) while the other resulted in no difference (Table 18). One of the phenolics, 3, 4-dihydroxy cinnamic acid, improved growth ($P < 0.05$) in Trial 5 when fed at 99 ppm but failed to do so when the level was doubled in Trial 6. This observation was also true of three other compounds which appeared to improve growth in one trial (Table 16), but when increased in concentration showed no effects in the following trial (Table 17).

When comparing these results to those of Dixon and Couch (1970), two differences are noted which may contribute to the inconsistent phenolic effect. Nine phenolics were isolated by Dixon and Couch (1970). Of those nine, seven were fed in both studies but only six of the seven were common to both investigations. The differing seventh compound may account for the conflicting results. Another possible implicating factor is that the Texas workers' basal diet was purified in nature which could have made their test more sensitive than tests in these trials where practical diets were involved. Variation in the response of these compounds may also explain in part why the product from which they were isolated also shows a variable effect on growth. For example in the trial where Dixon and Couch (1970) observed the growth promotion of phenolics, the birds fed DDS failed to achieve the growth of the negative control. It had been observed in this series and elsewhere that Solulac, which is composed largely of DDS, improved growth at 7.2 percent in Trial 5 of Series I (Table 16), at 2.5 percent in Trial 1 of Series III (Table 26), but did not at the same level in Trial 2 of Series III (Table 27), or at 3.6 percent in Trial 5 of Series I (Table 16).

It was observed that the extract lost essentially all of its activity following boiling for 60 minutes (Table 19), whereas the extract and the carrier combined maintained its activity after autoclaving for 30 minutes at 15 psi and 121°C (Table 20). It is not known why this difference arose, however, the latter treatment is considered more severe than the former, thus it is possible that the carrier might have aided in preserving the Vigofac growth activity.

When considering the results of the soaking trials (Tables 20 and 21) it appears that acid or base soaking of Vigofac does in fact generate more growth activity. Fermentation cannot be considered to be the major factor, if at all, for the improved response, otherwise better performance should have been obtained from feeding water soaked Vigofac.

Series II. Mode of Action

Results. It has been noted at this station that in most cases chicks fed Vigofac supplemented diets consumed more feed than did birds on the control diets. To study this point, the feed consumption in Trial 1 of the Vigofac supplemented groups was restricted to that consumed by their respective wheat or corn controls the previous 24 hours (Table 22). Results show that the groups receiving Vigofac free choice were significantly ($P < 0.01$) larger than their respective controls with increased feed consumption also evident. The restricted birds on the other hand reached the same weight as did the controls. Because of the 24 hour delay in measuring feed consumption, total feed consumed was slightly lower.

In trials 2 and 3, energy and protein utilization were examined as possible modes by which Vigofac might influence growth. In Trial 2 it was found that at two weeks of age, chicks fed either 0.5 percent Vigofac or 275 ppm of zinc bacitracin excreted significantly ($P < 0.05$) less gross energy via the feces and urine than did the control birds (Table 23). On the other hand, there were no differences in the crude protein content of the droppings. Results of Trial 3 show that while at three weeks there were no significant differences in either the gross energy or crude protein content of the droppings (Table 23), there was still an actual difference of 0.12 k cal/kg between the droppings of the wheat-Vigofac supplemented birds and the control birds. All the corn groups had lower actual gross energy values than did the corresponding wheat groups.

Trials 4 and 5 were conducted to see if Vigofac might affect the weight of various body organs. The effect of two other growth supplements, antibiotics and herring meal, was also ascertained for

Table 22. Feed consumption as related to growth stimulation by Vigofac (Trial 1).

Treatment[1]	Four-week data		
	Av. body weight (g)	Feed conv.	Feed consumption (g)
1. Control - wheat	511	1.69	861
2. Control - corn	539	1.69	907
3. As 1 + 1% Vigofac	559	1.73	963
4. As 2 + 1% Vigofac	599	1.67	1000
5. As 1 + 1% Vigofac (restricted)	514	1.61	829
6. As 2 + 1% Vigofac (restricted)	541	1.63	881
7. As 1 + 5% herring meal	532	1.72	911
8. As 2 + 5% herring meal	577	1.67	961
L.S.D. ($P < 0.05$)	27	nsd	42
L.S.D. ($P < 0.01$)	37		58

[1]Treatments 5 and 6 were restricted in consumption to Treatments 1 and 2 respectively.

Table 23. Gross energy and crude protein of droppings (Trials 2 and 3).

Treatment	Two-week data[3, 4]		Three-week data[3, 5]	
	Av. gross energy[1] (k cal/g)	Av. crude protein[1] (%)	Av. gross energy[1] (k cal/g)	Av. crude protein[1] (%)
1. Control - wheat[2]	4.21	26.0	3.94	29.8
2. As 1 + 0.5% Vigofac	3.74	25.6	3.82	30.2
3. As 1 + zinc bacitracin (275 ppm)	3.72	24.8		
4. Control - corn[2]			3.77	28.7
5. As 4 + 0.5% Vigofac			3.75	28.1
L.S.D. ($P < 0.05$)	0.31	nsd	nsd	nsd

[1] Average data for 20 chicks.
[2] No antibiotic present.
[3] All calculations are on a dry weight basis.
[4] These data correspond with Trial 9 of Series III.
[5] These data correspond with Trial 8 of Series III.

comparative purposes. All weights were expressed as a percent of body weight. Results of Trial 4 (Table 24) showed no alteration as compared to the controls, in relative intestine or thyroid weights from feeding Vigofac. Intestinal weights of both males and females fed either five percent herring meal or zinc bacitracin (275 ppm) were significantly ($P < 0.01$) smaller than those of the control and 0.5 percent Vigofac-fed birds. This observation was also true where zinc bacitracin was fed in combination with other growth promotants. There were no statistically significant differences for the dry intestinal weights of the females, but for males the control group's intestinal weight remained significantly ($P < 0.05$) larger than either the fish meal or antibiotic groups.

Male thyroid weights for the herring meal treated birds were significantly ($P < 0.05$) smaller than all other groups except the control. For females receiving herring meal there were no statistically significant differences in the thyroid weights.

Results of Trial 5 (Table 25) again showed that birds fed zinc bacitracin had significantly smaller ($P < 0.01$) gross intestinal weights than did chicks of the other three groups, both in the case of males and females. The dry intestinal weights of antibiotic fed birds were also significantly lower than the other groups for the males ($P < 0.05$) and the females ($P < 0.01$). There were no significant differences for either thyroid or pancreas weights. Both the thyroid and pancreas

Table 24. Effect of Vigofac, zinc bacitracin and herring meal on intestine and thyroid weights (Trial 4).[1]

Treatment	Percent of body weight[2]							
	Males				Females			
	Body wt. (g)	Intestinal wt. gross (%)	Intestinal wt. dry (%)	Thyroid wt. (%)	Body wt. (g)	Intestinal wt. gross (%)	Intestinal wt. dry (%)	Thyroid wt. (%)
1. Control - wheat[3]	515	4.94	.97	.71[4]	456	3.92	.91	.77[4]
2. As 1 + 0.5% Vigofac	577	4.65	.84	.88	485	4.20	.93	.90
3. As 1 + zinc bacitracin (275 ppm)	610	3.00	.69	.82	480	3.00	.78	.60
4. As 1 + 5% herring meal	576	3.59	.78	.51	470	3.37	.76	.63
5. As 1 + 2 + 3	628	2.98	.69	.76				
6. As 1 + 2 + 3 + 4	623	3.19	.79	.85				
L.S.D. ($P < 0.05$)	62	.69	.17	.24	nsd	.52	nsd	nsd
L.S.D. ($P < 0.01$)		.96				.74		

[1] These data correspond with Trial 8 of Series III.
[2] Four-week data.
[3] No antibiotic present.
[4] X 0.01.

Table 25. Effect of Vigofac and zinc bacitracin on intestine, thyroid and pancreas weights (Trial 5).[1]

Treatment	Males: Body wt. (g)	Males: Intestinal wt. gross (%)	Males: Intestinal wt. dry (%)	Males: Thyroid wt. (%)	Males: Pancreas dry wt. (%)	Females: Body wt. (g)	Females: Intestinal wt. gross (%)	Females: Intestinal wt. dry (%)	Females: Thyroid wt. (%)	Females: Pancreas dry wt. (%)
		Percent of body weight[2]								
1. Control - wheat[3]	560	3.68	.84	.75[4]	.076	434	3.71	.87	.93[4]	.109
2. As 1 + 0.5% Vigofac	591	3.82	.84	.78	.080	486	3.79	.95	.92	.100
3. As 1 + zinc bacitracin (275 ppm)	603	2.66	.63	.76	.078	478	2.73	.74	.91	.092
4. Control - corn[3]	543	3.47	.82	.78	.094	466	3.64	.96	1.10	.094
L.S.D. (P 0.05)	nsd	.50	.17	nsd	nsd	nsd	.43	.09	nsd	nsd
L.S.D. (P 0.01)		.71					.62	.12		

[1]These data correspond with Trial 7 of Series III.

[2]Four-week data.

[3]No antibiotic present.

[4]X 0.01

weights of the females were as large or larger when expressed as a percent of body weight than were those of the males for each of the treatments.

Discussion. Results of this series show that Vigofac-fed birds whose feed consumption was restricted to that of the control birds attained essentially the same body weight as did the controls on slightly less feed (Table 22). Therefore, it appears as if the improved growth performance resulting from the feeding of Vigofac is primarily due to increased feed consumption rather than the presence of a specific nutrient such as a vitamin, a deficiency of which should have resulted in increased growth.

Both Vigofac and zinc bacitracin appear to aid in the more efficient utilization of dietary energy. Results of Trial 3 showed that, per unit of droppings, there was significantly ($P < 0.05$) less gross energy in the droppings of two week old birds on diets supplemented with either 0.5 percent Vigofac or zinc bacitracin (275 ppm) than in the droppings of the control birds (Table 23). Since the feed for all three of these treatments was identical, except for the added Vigofac or zinc bacitracin, the gross and metabolizable energy contents were essentially the same, as neither additive at the level used would have contributed a significant amount of energy to the diet. Thus it would appear that due to the lower fecal energy, the metabolizable energy in the feed was improved by the addition of either of the growth promotants. With the wheat-fed birds of Trial 4 this same energy relationship held with wheat control and Vigofac-fed birds, although the differences were not significant (Table 23). Arscott (1965) found through studies of isocaloric wheat-and corn-base rations that the metabolizable energy difference between the two grains was primarily responsible for the superior performance resulting from the feeding of corn. From the results presented here it appears that supplements of Vigofac might decrease the above difference by improving the metabolizable energy of wheat but not that of corn. This may also be true of zinc bacitracin which was shown to improve wheat energy utilization but was not tested with corn.

The feeding of 0.5 percent Vigofac did not alter the intestine, thyroid, or pancreas weights per unit of body weight (Tables 24 and 25). Waldroup (1967) had previously reported that the streptomycin activity in Vigofac was of insufficient quantity to achieve the weight gains realized from the feeding of Vigofac. It was shown here to also be insufficient to cause a reduction in intestinal weight. On the other hand, zinc bacitracin and herring meal did affect the weights of the intestines or the thyroids or both. The observed reduction in intestinal weight from the feeding of antibiotics agrees with the findings of Gordon (1952), Coates, Davies and Kon (1955) and others. Significantly smaller thyroid weights from the feeding of fish meal have also been observed by Kneeling _et al._ (1955). The fact that feeding antibiotics did not alter thyroid weights agrees with the findings of Maghrabi and Turner (1953), Libby and Meites (1954), Kneeling et al. (1955), and Draper and Firth (1957), but is contrary to those of Mellen and Waller (1954) and Menge and Connor (1955) who reported an increase in thyroid weight. This is the first report known to the author where herring meal feeding has resulted in significantly smaller relative intestinal weights. A search of the literature revealed no similar information on the score.

Aside from the issue of growth promotants, there were other interesting observations made from the organ weight data. For example, female thyroid weights in Trial 5 were found to be greater than those of the males. This has also been found true for White Plymouth Rocks (Schultze and Turner, 1945), White Leghorns (Latimer, 1924), and New Hempshires (Shaklee and Knox, 1956). The female pancreas weights were found to be either equal to or greater than those of the males of the corresponding treatments. This finding agrees with the work of Kumaran and Turner (1949) who found the organ larger per unit of body weight in smaller birds than in larger ones.

Series III. Comparative Growth Effects

Results. Within this series a number of feeding trials were conducted to evaluate the effects of various growth supplements on broiler chick performance. In Trial 1, seven commercially available fermentation residues were fed with both wheat-and corn-base diets as noted in Table 26. While no statistically significant differences were observed, all seven products improved growth over their respective control groups from 6.8 to 11.7 percent for wheat and 2.3 to 7.0 percent for the corn type ration. The F value in the test of significance was within 0.2 of being significant. Lack of significance notwithstanding the calculated least significant difference ($P < 0.05$) of 39 grams would have made all wheat groups and only one of the corn groups (Streptomyces-meal and solubles) significantly greater than their respective control. From the standpoint of feed efficiency, some of the residues seemed to improve feed conversion whereas others did not, but differences were small and not statistically significant.

Three of the residues (Vigofac, UNF-40 and Solulac) which had favorably improved the growth of wheat-fed chicks to the greatest extent in Trial 1 were again examined in Trial 2 as supplements to isocaloric wheat-and corn-base diets (Table 27). Results yielded no significant differences either in terms of growth or feed conversion, but actual body weights were greater where UNF-40 and Vigofac were fed. The change in growth from Vigofac supplementation of a wheat-base diet was three percentage points greater than that realized from corn supplementation. Feeding UNF-40 produced a similar response when supplemented to either wheat or corn rations.

Table 26. Effect of various fermentation products on chick growth (Trial 1).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat	523		1.78	
2. As 1 + 0.25% Fermacto 500	568	8.6	1.74	2.4
3. As 1 + 0.25% Pryferm H. B.	564	7.3	1.80	-1.1
4. As 1 + 0.20% Streptomyces M. and S.	559	6.8	1.77	0.6
5. As 1 + 0.625% Liquid Strep. Sol.	566	8.2	1.70	4.5
6. As 1 + 0.25% UNF-40	582	11.3	1.72	3.5
7. As 1 + 0.50% Vigofac	568	8.6	1.74	2.4
8. As 1 + 2.50% Solulac	584	11.7	1.77	0.6
9. Control - corn	557		1.71	
10. As 9 + 0.25% Fermacto 500	594	6.6	1.70	0.6
11. As 9 + 0.25% Pryferm H. B.	571	2.5	1.72	-0.3
12. As 9 + 0.20% Streptomyces M. and S.	596	7.0	1.71	0.2
13. As 9 + 0.625% Liquid Strep. Sol.	578	3.7	1.70	0.6
14. As 9 + 0.25% UNF-40	586	5.2	1.70	0.6
15. As 9 + 0.50% Vigofac	582	4.4	1.75	-2.1
16. As 9 + 2.50% Solulac	570	2.3	1.73	-0.8
	nsd		nsd	

Table 27. Growth effect of fermentation products with isocaloric diets (Trial 2).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat	512		1.71	
2. As 1 + 0.5% Vigofac	542	5.8	1.65	3.6
3. As 1 + 0.25% UNF-40	535	4.5	1.62	5.7
4. As 1 + 2.50% Solulac	505	-1.3	1.69	1.4
5. Control - corn	533		1.72	
6. As 5 + 0.5% Vigofac	548	2.8	1.80	-4.2
7. As 5 + 0.25% UNF-40	554	4.0	1.66	3.9
8. As 5 + 2.50% Solulac	542	1.6	1.70	1.3
	nsd		nsd	

Antibiotic residues such as Vigofac have not consistently yielded positive growth responses (Summers, Pepper and Slinger, 1959b; Allen, 1970). Morrison (1970) attributed a great deal of this inconsistency to the presence of other growth inducing substances in the rations from which antibiotic residues were being evaluated. He argued that the stimulatory effect on growth by these substances may be similar but not complementary. When expected growth responses do not occur they may be masked by those resulting from other growth promotants. For example, antibiotics have growth stimulatory properties (Scott, Nesheim and Young, 1969) and most chick rations contain some type of antibiotic as did the broiler rations used here which contained zinc bacitracin (4.4 ppm). In view of this, trials were initiated to study the relationship of antibiotics to this growth effect. The Feed Additive Compendium (Tietz, 1971) recommends 4 to 55 ppm of zinc bacitracin for growth promotion. For purposes of this research levels within the growth promotion range were considered as low levels and those in excess, high levels.

In Trial 3, groups of broilers were fed diets with or without zinc bacitracin (11 ppm). Other groups were fed similar diets to the above supplemented with 0.5 percent Vigofac (Table 28). Results showed no significant differences, however actual differences in body weight were evident. Without antibiotics in the diet the growth response from adding Vigofac was 12.3 percent, but with the addition of the low level

Table 28. Effect of low level of zinc bacitracin on Vigofac growth stimulation (Trial 3).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[1]	472		1.82	
2. As 1 + zn bacitracin (11 ppm)	502	6.4	1.91	-4.9
3. As 1 + 0.5% Vigofac	530	12.3	1.76	3.4
4. As 2 + 0.5% Vigofac	516	9.3	1.88	-3.3
	nsd	(2.8)[2]	nsd	(1.6)[2]

[1]No antibiotic present
[2]Figures in parentheses represent response over treatment number 2.

of zinc bacitracin the Vigofac response was only 2.8 percent.

For Trial 4 the antibiotic level was increased to 55 ppm. This level was chosen for comparative purposes. McGinnis (1970) had employed a similar level (Arscott, 1970) in his work where he found the feeding values of wheat and corn to be comparable. The masking of the Vigofac growth response was again observed in this trial. Without zinc bacitracin in the diet the Vigofac response was 5.9 and 3.5 percent at four and eight weeks, respectively, and in both cases proved significantly ($P < 0.01$) greater than the control groups (Table 29). With the antibiotic present in both the control and Vigofac supplemented diets, the Vigofac response was only 1.1 percent at four weeks and 1.5 percent at eight weeks and was not significantly different in either case.

Table 29. Masking effect of zinc bacitracin on Vigofac growth response (Trial 4).

Treatment	Four-week data				Eight-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[2]	538		1.75		1,628		2.38	
2. As 1 + zinc bacitracin (55 ppm)	573	6.2	1.78	-2.1	1,689	3.7	2.33	2.2
3. As 1 + 0.5% Vigofac	570	5.9	1.77	-1.6	1,685	3.5	2.36	1.0
4. As 2 + 0.5% Vigofac	579	7.6 (1.0)[1]	1.70	2.70 (4.7)	1,715	5.3 (1.5)	2.33	2.2 (0.0)
5. Control - corn[2]	585		1.69		1,700		2.29	
6. As 5 + zinc bacitracin (55 ppm)	598	2.2	1.69	0.0	1,748	2.8	2.26	1.7
L.S.D. ($P < 0.05$)	23		0.18		40		0.09	
L.S.D. ($P < 0.01$)	32				55		0.12	

[1] Figures in parentheses represent responses over treatment number 2.
[2] No antibiotic present.

The growth response afforded by antibiotics was more pronounced for birds fed the wheat than those fed the corn rations. Adding zinc bacitracin to the wheat diet significantly ($P < 0.01$) improved growth both at four the eight weeks. Its addition to the corn diet caused a slight but nonsignificant improvement at four weeks and a somewhat greater response at eight weeks at the 0.05 level of probability. There was a slight, but nonsignificant additive effect from feeding zinc bacitracin and Vigofac together over feeding either alone.

Since zinc bacitracin had proved to be an effective growth promotant, it was decided, therefore, to observe in Trial 5 the degree of growth promotion achieved by feeding it at various levels (Table 30). The lower level (33 ppm) did not promote additional growth. However, significantly greater growth resulted from feeding the 275 ppm ($P < 0.05$) and the 550 ppm ($P < 0.01$) levels.

Because the zinc bacitracin appeared, as did Vigofac, to stimulate growth of birds on wheat-base diets to a greater extent than those on corn diets, it was decided in Trial 6 to observe the degree of response of other antibiotics such as oxytetracycline, penicillin, streptomycin, oleandomycin and chlortetracyline on wheat rations as compared to zinc bacitracin, Vigofac and UNF-40 supplementation (Table 31). While there were no statistically significant differences among the various treatments in body weight or feed conversion, at the higher treatment levels both zinc bacitracin (275 ppm) and oleandomycin (22

Table 30. Observations of growth resulting from various levels of zinc bacitracin supplementation (Trial 5).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[1]	509		1.77	
2. As 1 + zinc bacitracin (33 ppm)	503	-1.1	1.81	-2.3
3. As 1 + zinc bacitracin (275 ppm)	555	8.3	1.70	4.1
4. As 1 + zinc bacitracin (550 ppm)	563	10.6	1.70	4.1
5. As 1 + 0.5% Vigofac	565	11.1	1.61	9.9
L.S.D. ($P < 0.05$)	38		nsd	
L.S.D. ($P < 0.01$)	54			

[1]No antibiotic present.

Table 31. Growth promoting effect of various antibiotics (Trial 6).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[1]	521		1.80	
2. Control - corn[1]	556		1.77	
3. As 1 + zinc bacitracin (28 ppm)	538	3.3	1.77	1.6
4. As 1 + zinc bacitracin (280 ppm)	570	9.5	1.75	2.6
5. As 1 + oxytetracycline (6 ppm)	547	4.9	1.80	0.0
6. As 1 + oxytetracycline (60 ppm)	523	0.4	1.79	0.6
7. As 1 + penicillin (3.3 ppm) streptomycin (16.5 ppm)	555	6.5	1.79	0.6
8. As 1 + penicillin (33 ppm) streptomycin (165 ppm)	542	3.9	1.73	3.9
9. As 1 + oleandomycin (2.2 ppm)	552	6.0	1.78	1.1
10. As 1 + oleandomycin (22 ppm)	571	9.6	1.89	-5.2
11. As 1 + chlortetracycline (110 ppm)	525	0.8	1.77	1.6
12. As 1 + 0.5% Vigofac	564	8.3	1.80	0.0
13. As 1 + 0.25% UNF-40	560	7.5	1.80	0.0
	nsd		nsd	

[1]No antibiotic present.

ppm) appeared superior to the other antibiotics and equivalent to Vigofac and UNF-40 for purposes of growth.

In all prior research at this station Vigofac had been added to a white winter wheat originating in the Pacific Northwest. The question arose as to whether or not the growth response from Vigofac was peculiar to white western wheat. To shed further light on this question, in Trial 7 Vigofac supplementation was compared for white winter wheat, hard red winter wheat and corn (Table 32).

The addition of Vigofac to the feed significantly ($P < 0.01$) improved growth for groups fed the various grains. The degree of improved growth was most pronounced for white winter wheat followed in order by hard red winter wheat and corn. Adding Vigofac to white winter wheat also significantly ($P < 0.05$) improved feed conversion.

While in Trial 4 an "antibiotic effect" was observed where supplementation of the antibiotic to wheat and corn diets had improved growth relatively greater with wheat than corn diets, feeding zinc bacitracin (275 ppm) in Trial 7 significantly improved growth when it was added to white wheat ($P < 0.05$), red wheat ($P < 0.01$) and corn ($P < 0.01$). Of the three treatments, the degree of improvement over its respective control was greatest for the red wheat and least for the white wheat. No significant growth differences were evident for the three control rations. In terms of feed conversion the red wheat-fed chicks were more efficient ($P < 0.05$) than those fed white

Table 32. Growth effect resulting from supplementation of Vigofac and zinc bacitracin to white winter wheat, hard red winter wheat and corn base diets (Trial 7).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - white winter wheat[1]	509		1.77	
2. As 1 + 0.5% Vigofac	565	11.0	1.61	9.9
3. As 1 + zinc bacitracin (275 ppm)	547	7.5	1.76	0.6
4. Control - hard red winter wheat[1]	520		1.68	
5. As 4 + 0.5% Vigofac	571	9.8	1.63	3.0
6. As 4 + zinc bacitracin (275 ppm)	588	13.1	1.61	4.3
7. Control - corn[1]	526		1.71	
8. As 7 + 0.5% Vigofac	573	9.2	1.63	4.9
9. As 7 + zinc bacitracin (275 ppm)	582	10.6	1.58	8.2
L.S.D. ($P < 0.05$)	30		0.12	
L.S.D. ($P < 0.01$)	40			

[1]No antibiotic present.

winter wheat and comparable to those fed corn.

In Trial 8 three feed supplements (Vigofac, zinc bacitracin and herring meal) each considered to possess growth inducing properties, were compared individually and in combination to observe similarities or differences in the growth responses that they might elicit (Table 33). Each of the three improved growth, but only Vigofac ($P < 0.05$) and zinc bacitracin ($P < 0.01$) did so significantly. Combinations of two of the supplements also improved growth significantly ($P < 0.01$) with an apparent additive effect. Herring meal supplementation of the ration with either zinc bacitracin or Vigofac not only gave a significant ($P < 0.01$) growth response over the control group, but also significantly improved growth over the herring meal addition alone. Combining the three supplements elicited an improved response over herring meal ($P < 0.01$), Vigofac ($P < 0.05$) or zinc bacitracin ($P < 0.05$) alone. In every instance supplementing the ration with growth additives individually or in combinations resulted in a consistent, but nonsignificant, improvement in feed conversion.

Table 34 presents a summary of the trials in the three series where wheat and corn were compared on an equal weight basis. No growth supplements were present in the ration other than zinc bacitracin which if present did not exceed 4 ppm. Results of this table will be discussed in the section entitled "Implications."

<u>Discussion.</u> In addition to Vigofac there are available a number

Table 33. Effect of Vigofac, zinc bacitracin and herring meal on growth when fed individually and collectively (Trial 8).

Treatment	Four-week data			
	Av. body weight (g)	Response over control (%)	Feed conv.	Response over control (%)
1. Control - wheat[1]	486		1.96	
2. As 1 + 0.5% Vigofac	529	8.8	1.79	9.6
3. As 1 + zinc bacitracin (275 ppm)	537	11.0	1.72	13.6
4. As 1 + 5% herring meal	510	4.9	1.80	7.8
5. As 1 + 2 + 3	559	15.0	1.72	13.8
6. As 1 + 2 + 4	559	15.0	1.75	11.9
7. As 1 + 3 + 4	558	14.8	1.69	16.1
8. As 1 + 2 + 3 + 4	576	18.5	1.67	17.4
L.S.D. ($P < 0.05$)	36		nsd	
L.S.D. ($P < 0.01$)	49			

[1]No antibiotic present.

Table 34. Summary of chick performance resulting from feeding of non-supplemented wheat-and corn-base diets. (grams)

Series	Trial	Body weight		Wheat as a % of corn
		Wheat	Corn	
		Body weight		
Four weeks				
I	1	581	591	98.3
I	5	507	565	89.7**
I	6	500	533	93.8
II	1	511	539	94.8*
III	1	523	557	93.9
III	4	538	585	91.9**
III	6	521	556	93.7
III	7	509	526	96.8
Average		524	557	94.1
Eight weeks				
III	4	1,628	1,700	95.8
		Feed conversion		
Four weeks				
I	1	1.81	1.80	99.5
I	5	1.90	1.72	90.5
I	6	1.83	1.79	97.8
II	1	1.69	1.69	100.0
III	1	1.78	1.71	96.1
III	4	1.75	1.69	96.6
III	6	1.80	1.77	98.3
III	7	1.77	1.71	96.6
Average		1.79	1.74	97.2
Eight weeks				
III	4	2.38	2.26	95.0**

*($P < 0.05$)

**($P < 0.01$)

of commercial fermentation products (Fermacto 500, Pryferm H. B., Liquid Streptomyces Solubles and UNF-40) that were shown to stimulate growth relatively more when added to a wheat- than a corn-base ration (Table 26). In Trials 3 and 8 Vigofac was also shown to be more beneficial as a supplement to a wheat rather than a corn type diet. In Trial 2 it was shown that even when using isocaloric diets the added response to wheat was greater than with corn (Table 27).

In Trials 3 and 4 Morrison's (1970) suggestion of an antibiotic masking effect was confirmed. In Trial 3 the exclusion of the antibiotic from the control ration resulted in a 12.3 percent growth response from Vigofac supplementation (Table 28). By including the antibiotic the Vigofac response was reduced to 2.8 percent. In Trial 4 a similar situation was observed at both four and eight weeks (Table 29). At both intervals where the antibiotic was withheld from the ration a significant ($P < 0.01$) growth response resulted from Vigofac supplementation, but with the antibiotic present the response was small and not significant.

Comparative growth response from the addition of zinc bacitracin to wheat and corn rations were observed in Trials 4 and 7. Wheat-fed broilers of Trial 4 that received a zinc bacitracin (55 ppm) supplement were significantly ($P < 0.01$) heavier than the controls at both four and eight weeks (Table 29). Unlike the wheat groups, broilers receiving a corn ration supplemented with the antibiotic were not different from their controls at four weeks although they were different at eight weeks at the 0.05 level of probability. In Trial 7 involving considerably higher levels of antibiotics (275 ppm vs 55 ppm) the hard red winter wheat groups had a greater percentage growth response from zinc bacitracin than did the corn groups (Table 32). Perhaps some of the conflicting reports pertaining to comparative broiler studies with wheat- and corn-base rations may be traced to the use of antibiotics. For example, Arscott (1964, 1965) and Berg (1965) found white western wheat to be inferior to corn on a unit for unit basis for broiler chick performance both in terms of growth and feed efficiency while McGinnis (1970) found the grains of comparable worth. McGinnis (1970) did not specify the antibiotic level used in his rations. However, from personal communication (Arscott, 1970) it was learned that he generally uses the level of 55 ppm, which is the upper level recommended for growth promotion and is 11 times the level routinely used at this station. The inclusion of this relatively higher level of an antibiotic into his comparative wheat and corn rations may be in part responsible for McGinnis (1970) having found the two grains equal on a per unit basis since the antibiotic may have provided a response to wheat sufficient to make resulting growth equal to that realized from corn.

The response with wheat may be also related to its lower level of dietary metabolizable energy rather than to special properties it may have that corn does not. In support of this premise Carlson et al. (1956) and Chang and Waibel (1970) reported a greater growth response for turkey poults due to antibiotic supplementation of a low rather than a high energy diet.

The response from antibiotics, Vigofac and herring meal in part overlap one another. Trial 8 showed that combining the supplements by twos provided an additive, but not necessarily significant response, over that noted from feeding the one independent of the other (Table 33). Feeding the three together also provided a greater degree of response over that noted for the various combinations of two and significantly greater than realized from single supplementation. The growth realized from herring meal was not significantly better than that of the control, but in the presence of either zinc bacitracin or Vigofac it became significant. These results concur with those of Chang and Waibel (1970) who also found that poult growth was improved to the greatest extent with herring meal, an antibiotic fermentation residue and zinc bacitracin present in the diet simultaneously than when any of the three were fed independent of the other and also that the herring meal response was more evident in the presence of either an antibiotic or a fermentation product.

Laying Hen Experiment

Results

Since wheat fed laying hens have been found to lay a smaller egg than those on a corn type ration (Arscott, 1965 and others) and since linoleic acid, a nutrient in which wheat is notably deficient, has been shown to improve egg size (Shutze and Jensen, 1963), a layer experiment involving White Leghorn layers was initiated to further study this problem. Safflower oil which consists primarily of linoleic acid was used in lieu of animal fat in the wheat type ration to observe its effect on egg size as well as the other experimental variables. Vigofac, which affects chick performance, was used as a dietary variable to see if it might also improve layer performance. A dwarf strain of layer was used as the experimental bird in place of the normal size hen because the size of their egg seemed to be more sensitive to dietary alterations than did that of the normal. Arscott and Bernier (1970) have found the dwarf egg size was quite sensitive to a wide range of protein levels where the normal's egg was not. For reference purposes normal size controls fed a corn type layer diet were also included.

The results and experimental outline are given in Tables 35 and 36. Among the dwarf treatments there were significant differences in feed consumption and egg weight (Table 35). The corn-fed dwarfs

Table 35. Results of layer performance.

Treatment	Egg prod. (%)	Feed cons./day (g)	Feed/doz eggs (kg/doz)	Egg weight (g)	Specific gravity	Body weight (kg)
1. Control - wheat	55.8**[2]	84.9**	1.86	55.6**	1.0774	1.5**
2. Control - corn	54.2**	82.2**	1.84	56.2**	1.0763	1.4**
3. As 1 + 2.0% safflower oil	53.9**	84.4**	1.85	56.2**	1.0773	1.4**
4. As 3 + 0.5% Vigofac	56.5**	85.4**	1.87	56.1**	1.0780	1.4**
L.S.D. ($P < 0.05$)[1]	nsd	1.4	nsd	0.6	nsd	nsd
L.S.D. ($P < 0.01$)						
5. Normals - corn	74.13	118.0	1.92	59.9	1.0766	1.8**

[1] Least significant differences apply only to the dwarf treatments.
[2] The asterisks refer to significant differences between the normal hens and the dwarfs.
* = $P < 0.05$; ** = $P < 0.01$

Table 36. Internal egg quality and egg contents results.

Treatment	Albumen height (mm)	Haugh units	Yolk color	Shell weight (g)	Yolk weight (g)	Albumen weight (g)
1. Control - wheat	6.1	77.3	5.8**[2]	8.2	17.6*	32.5**
2. Control - corn	6.8	83.2	10.0	8.0	17.7*	33.0*
3. As 1 + 2.0% safflower oil	6.5	79.7	5.3**	8.3	18.1	33.6
4. As 1 + 0.5% Vigofac	6.6	79.8	5.8**	8.0	17.8	33.3*
[1]L.S.D. ($P < 0.05$)	nsd	nsd	0.6	nsd	nsd	nsd
L.S.D. ($P < 0.01$)			0.8			
5. Normals - corn	6.7	80.2	9.2	8.8	19.3	35.2

[1]Least significant differences apply only to dwarf treatments.

[2]The asterisks refer to significant differences between the normal hens and the dwarfs.
* = $P < 0.05$; ** = $P < 0.01$

consumed significantly ($P < 0.05$) less feed per day than did any of the wheat-fed birds. Though not significant, the birds on the wheat diets produced slightly more eggs than did those fed on corn and consequently there were no significant differences in the amount of feed required per dozen eggs. The wheat controls laid significantly ($P < 0.05$) smaller eggs than the corn-fed dwarfs and the layers receiving wheat plus safflower oil. Looking at the Vigofac-safflower oil diet a difference in egg size approaching significance was noted. There were no significant differences among the dwarf layers for egg shell thickness (specific gravity) and body weights.

When compared to the normal White Leghorns all dwarf treatments produced significantly ($P < 0.01$) fewer and smaller eggs, consumed significantly ($P < 0.01$) less feed and also weighed significantly ($P < 0.01$) less. Even though the normal hens produced more eggs they required more feed to do so; consequently, they were still not as efficient as the dwarfs in the feed required per dozen eggs. There were no differences between the dwarfs and the normals in egg shell thickness.

As for the variables on internal egg quality and egg contents, there were no significant differences among the dwarfs in albumen height, Haugh units, shell weight, yolk weight of albumen weight (Table 36). Of these parameters the only difference arose in yolk color where the corn controls were found to lay eggs with significantly

($P < 0.01$) darker colored yolks than did the birds of the wheat treatments.

Significant differences were evident between the dwarfs and the normals in yolk color, shell weight and albumen weight. The yolk color of normal eggs was significantly ($P < 0.01$) darker than that of eggs produced by the three dwarf wheat treatments, but not for dwarfs fed corn. Normal egg yolk weights were significantly ($P < 0.05$) heavier than the yolks from either of the wheat or corn controls, but not from the two wheat safflower oil treatments. The normals' albumen weight was significantly heavier than that of the wheat control ($P < 0.01$), the corn control ($P < 0.05$), and the Vigofac-safflower oil ($P < 0.05$) treated birds, but was not statistically different from the weight of the group treated with safflower oil alone.

Discussion

Results of the laying experiment showed that using wheat in lieu of corn as the grain component of the laying ration produced significantly different results only in terms of (1) feed consumption, (2) egg weight, and (3) yolk color (Tables 23 and 24). The increased feed consumption would be anticipated because the wheat type rations contained approximately 200 k cal/kg less energy than did the corn type ration.

The observation that smaller eggs result from the feeding of wheat instead of corn has been previously reported by a number of workers (Arscott, 1965; Bartlett, 1966; Edwards and Morris, 1967; Balnave, 1970). It was found that supplementing the wheat ration with two percent safflower oil, which contains about 73 percent linoleic acid, resulted in the production of eggs that were equal in size to those of the corn group and significantly ($P < 0.05$) larger than those of the wheat group. The observation that linoleic acid improves egg size is not unique to this experiment. Its required presence for optimum egg size was reported by Shutze and Jensen (1963) and Menge, Miller and Denton (1963) using synthetic diets. Despite the fact that wheat base rations are usually deficient in linoleic acid, its addition to this type of ration by means of safflower oil (73 percent linoleic acid) or corn oil (52 percent linoleic acid) has not always resulted in improved egg weight. Those reporting a positive effect include Shutze, Jensen and McGinnis (1962), Edwards and Morris (1967) and Balnave (1970) while no effect was shown by McGinnis (1965, 1970). Of the above observations, only McGinnis (1970) used safflower oil. To the writer's knowledge this is one of the first published reports of successfully improving egg size by adding safflower oil to a wheat-base diet. The reliability of this observation is further enhanced by the fact that the presence of safflower oil resulted in actual increases in egg weight in both treatments 3 and 4. The observed increase in egg size from safflower oil supplementation was apparently due to the heavier yolk and albumen weights of the eggs of the supplemented hens (Table 36).

There is some question as to whether or not the smaller eggs produced by the wheat fed hens would be of great concern to the commercial poultryman in his decision to feed wheat or corn. For example, in this experiment the average egg weight varied by only 0.6 of a gram. The average egg weight for the dwarf treatments was in excess of the 54.5 gram minimum weight required for large eggs.

The yolk color of corn fed birds, being significantly ($P < 0.01$) darker, occurs because corn contains xanthophyll (25 ppm) whereas wheat contains none. Despite the significant difference, the yolk color of the wheat fed birds did not appear objectionable. This confirms a previous observation by Arscott (1965).

In the past a number of workers have shown that the egg production of wheat fed layers was depressed from one to five percent below that of the production of corn fed birds (Arscott, 1965; McGinnis, 1966; Bartlett, 1966; Lillie and Denton, 1967; Geunther and Carlson, 1970; Balnave, 1970). However, in this study egg production was slightly greater for wheat-than corn-fed hens which is similar to the observations of Fox (1966), Lockhart _et_ _al_. (1967), and McGinnis (1970).

Where wheat and corn have been compared on a nonisocaloric basis, the feed required per dozen eggs by wheat fed birds as a percent of that required for corn ranged from a high of 7.4 percent more (McGinnis, 1966) to a low of 4.0 percent less (Lockhart et al., 1967). In the dwarf study reported here all three of the wheat groups were within 1.5 percent of the efficiency of the corn-fed birds.

The addition of Vigofac to the safflower oil-wheat treatment did not result in a significant change from the supplementation of safflower oil alone in any of the variables tested. The greatest actual difference was in the area of egg production where the Vigofac supplemented hens had over two percent greater production than the corn group. Whether this production improvement arose strictly by chance or by some change brought about by the presence of Vigofac is difficult to say without additional tests including the antibiotic residue. Based on the results of this study Vigofac does not appear to improve the performance of wheat-fed birds and consequently would not improve the utilization of wheat by layers.

The dwarfs when compared to their normal size half sisters produced 72.7 to 76.3 percent as many eggs, consumed 69.7 to 72.4 percent as much feed per day, required 2.7 to 4.4 percent less feed per dozen eggs, laid eggs that were 92.9 to 93.8 percent as large and attained 77.8 to 83.3 percent the body weight of the normals.

Implications

The feeding value of wheat with respect to that of corn is not a clearly defined issue. Where in general one type of corn is used in poultry feeding, there are many types of wheat employed (see Figure 1). Among the classes of wheat there is variation in nutrient content with considerable variation for some nutrients. For example the protein level of white western wheat is 9.2 percent whereas that of some of the red wheats may be in excess of 14 percent. Despite the wide differences that exist in some of the nutritive aspects of wheats, many investigators seemingly consider all wheats as being nutritionally homogenous. Several have considered the feeding value of wheat with that of corn without specifying the type of wheat used (Biely et al., 1951; Yoshida, 1962; Fox, 1966; Lillie and Denton, 1967; Balnave, 1970 and others). Consequently, there exists considerable variance of opinion as to the relative feeding value of wheat to that of corn.

One of these wheats, white western, was used quite extensively in the research reported here. Comparative observations were made between it and corn on a unit for unit basis both for chick and layer studies. Table 34 summarizes the chick trial results where wheat and corn were compared where no more growth supplement then 4.4 ppm of zinc bacitracin was present. It was observed that chicks receiving the wheat ration weighed 94 percent as much as those fed corn and their feed conversion was 97 percent as efficient as the corn-fed birds. Compared to other four-week trials where white western has been evaluated the average growth relative to corn was eight percent higher here than reported by Arscott (1965) and seven percent lower than observed by McGinnis (1970). Feed conversion was four percent more efficient than found by Arscott (1965) and two percent less efficient than McGinnis (1970). The single eight-week observation was similar in relative growth to observations of Arscott (1964, 1965) while the feed conversion was three percent and ten percent better relative to that observed by Arscott in 1964 and 1965, respectively. It should be noted that some of the above four-week variation in performance may be due to the fact that the results reported here represent the average of several trials whereas the studies cited above are but single experiments. Based on the findings reported here it would appear that the finding of McGinnis (1970) that wheat and corn yield comparable feeding results is likely related in part to the antibiotic levels in the rations routinely used by McGinnis. His studies are customarily conducted with 55 ppm zinc bacitracin, which is 11 times the level used at this station. When utilizing this level of zinc bacitracin it was found that growth was increased over using no antibiotics by 6.5 percent for wheat-fed birds and only 2.2 percent for corn-fed birds (Table 29).

In addition to zinc bacitracin a number of fermentation products which include Vigofac, Fermacto 500, Pryferm H. B., Streptomyces, UNF-40 and Solulac were all shown to improve growth to a greater extent on a wheat- than a corn-base ration. Others have previously shown that dietary antibiotic supplementation provided a greater response with a low rather than high energy diet (Carlson et al., 1956; Chang and Waibel, 1970). This may explain why in this report that zinc bacitracin (55 ppm) provided a greater response to white wheat and at 275 ppm to supplemented to red wheat. The metabolizable energy of the corn-base ration was 140 k cal/kg higher than that of the wheat ration. The greater observed growth response from wheat feeding with fermentation type products might also be related to the energy level. In one trial the fermentation products were compared under isocaloric conditions and there it was observed that only one of three products improved wheat greater than corn (Table 27). Further investigations need to be performed to evaluate the growth response from zinc bacitracin and fermentation products under isocaloric conditions.

The mode of action of Vigofac on growth is not a simple item. Data have been presented which show that the growth response appears to be primarily due to increased feed consumption. The finding that feed energy is better utilized when Vigofac is added to the diet suggests better nutrient utilization. A small but consistent improvement in feed conversion resulting from Vigofac supplementation also implies improved utilization of nutrients. There is also the possibility that it is due in part to one of the modes postulated by Young (1969) for unidentified factors, namely: (1) presence of some compound that is either unidentified or chemically known but not recognized as a nutrient; (2) provision of a metabolite that is not synthesized at a sufficient rate to meet metabolic demands; or (3) under estimation of the quantitative need of a nutrient. All of these theories postulated by Young suggest that the source of unidentified factors such as Vigofac improve growth by supplying nutrients. If a nutrient deficiency were involved a significant improvement in growth would be anticipated for the Vigofac-fed birds when receiving the same amount of feed as the controls; however, this was shown not to be the case here. Also a closer observation of improved nutrient utilization shows that of the nutrients only energy and protein were evaluated and only the former was utilized to a greater extent. Furthermore, improved energy utilization was identified only with Vigofac supplementation of wheat and not of a corn ration. The improvement of chick growth from Vigofac supplementation of corn-base rations may simply be due to increased feed consumption while its addition to the wheat-base ration not only stimulates increased feed consumption, but also induces better utilization of feed energy. This selective improvement of the wheat energy, but not of corn, may explain why the growth response supplied by the fermentation products and zinc bacitracin is more pronounced with wheat than corn feeding. An examination of the wheat and corn digestibility data presented previously (see page 25) shows that over 60 percent more of the ether extract portion of corn than of wheat is digestible by the chick. Perhaps this portion of wheat may be rendered more digestible by the actions of the fermentation residues or zinc bacitracin and as a result bring the metabolizable energy of wheat to a level closer to that of corn.

From this discussion the question arises as to how feed consumption is stimulated or how feed energy is improved. Because Vigofac is a derivative of antibiotic production and it does contain antibiotic activity, it is difficult to completely separate its mode of inducing growth from that of the antibiotic. Research here has shown some relationship between zinc bacitracin and Vigofac in that both promote growth to about the same extent (Tables 29, 30, 31, and 32); a large part of the growth response realized when the two are combined is overlapping (Tables 28, 29, and 32); both of them appear to improve the utilization of feed energy (Table 23); neither of the two supplements loses its activity from autoclaving (Table 20); prolonged soaking in basic or acidic solutions enhances rather than detracts from the activity of either (Table 20); and both show a greater response when supplemented to a wheat- than a corn-base ration.

Waldroup (1967) has previously shown that the streptomycin (antibiotic) activity of Vigofac is insufficient to promote growth to the extent that Vigofac does. However, streptomycin activity may serve to provide a more favorable environment for the Vigofac effect by helping to prevent or alleviate low levels of disease. The degree of prevention or alleviation would of course not be as great as from a higher level of antibiotics. This action against disease organisms by antibiotics is thought to increase the ease of absorption of nutrients because of the decreased effort necessary for the intestinal wall to defend itself (Goldberg, 1959). In the presence of a sufficient level of dietary antibiotics this specialization of the intestinal mucosa leads to a decreased amount of connective tissue in the intestinal wall and a consequent decreased weight or thickness of the intestinal wall as was also observed here (Tables 24 and 25). Though to a much lesser extent the increased mucosal specialization for absorption might also occur from the feeding of Vigofac. With increased rate of nutrient absorption the contents of the digestive tract would be emptied more quickly and would initiate feed consumption at an earlier moment. As digestibility efficiency improves, wheat components such as ether extract may be digested to a greater extent than they would otherwise have been.

Vigofac feeding might also result in the establishment of an intestinal microflora that is more favorable to the nutritive needs of the host. Through the aid of its antibiotic activity some harmful organisms, such as producers of growth depressing toxins or users of essential nutrients, might be removed from the population in preference to those of a more beneficial nature. The fermentation residues might also supply nutrients which are supportive of a favorable microflora. With the establishment of a favorable intestinal flora more utilizable nutrients would be made available to the host.

Results here have shown that Vigofac and possibly certain antibiotics improve the feeding value of white western wheat chick rations relative to those of corn base. The added growth response associated with wheat and the growth supplements brings the feeding value of wheat, if not equal to that of corn, to a point much closer to corn than realized without supplementation. It is a far more practical method of wheat improvement than some of those attempted in the past such as water soaking or autoclaving. With the knowledge of these findings made available to the commercial poultryman and feed manufacturer, it is anticipated that a more favorable outlook might result toward the increased utilization of wheat.

From the performance variables observed in the layer experiment, the two major nutritional drawbacks to the feeding of wheat as opposed to corn appeared to be lower metabolizable energy and linoleic levels. The metabolizable energy of the wheat rations was approximately 200 k cal/kg less than that of the corn rations. As a result of this difference, the wheat-fed groups in this experiment consumed significantly more feed than the corn group. However, the increased feed consumption was not a disadvantage in this instance because the wheat-fed birds actually produced more eggs than the corn-fed-birds and consequently required no more feed per dozen eggs.

The linoleic acid content of the wheat ration calculated to 0.54 percent as compared to 1.41 percent for the corn ration while 1.0 percent is recommended for optimum performance (National Research

Council, 1971). Both decreased production and smaller egg size are said to result from a linoleic acid deficiency (Menge, Calvert and Denton, 1965). Only the latter symptom was observed here. A small but significant difference was found between the egg size of the wheat and corn controls. By substituting safflower oil in place of animal fat the linoleic acid level of the wheat ration calculated at 1.95 percent and the birds fed this ration produced eggs equal in size to those of the corn controls and which were significantly larger than the wheat controls.

While safflower oil improved the egg size resulting from wheat-fed rations, Vigofac added to a wheat safflower oil diet did not improve egg size or, further, any of the other variables over that resulting from safflower oil supplementation alone. Based on these results Vigofac appears of questionable value as a layer feed supplement.

Of the egg quality and egg contents parameters measured, the only difference occurred for yolk color and this was due to the lack of xanthophyll in wheat. Despite this significant difference in color, the yolks of the wheat-fed birds were sufficiently dark due to the xanthophyll provided by the dehydrated alfalfa meal.

Because the difference in egg size is not great, and dietary xanthophyll can be obtained from other sources, the major deterrent from feeding white western wheat to layers would be metabolizable energy. When grain prices are such that wheat can be purchased at a price sufficiently below corn, that a source of energy can be purchased to compensate for the difference in metabolizable energy, there appears to be no substantial reason why wheat cannot be used in lieu of corn.

SUMMARY AND CONCLUSIONS

The objective of this research was to increase the utilization of white western wheat for chickens through the application of various dietary additives. Both chick and layer studies were conducted in pursuing this goal. Chick studies were primarily concerned with characterizing a streptomyces fermentation product (Vigofac), while in the layer study, evaluations were made as to the effect of feeding Vigofac and safflower oil on various performance parameters.

Vigofac research with chicks was divided into (1) nature of activity, (2) mode of activity, and (3) comparisons with other growth supplements. The results and conclusions of these studies are summarized below.

Nature of Activity

From feeding various levels of Vigofac extract and/or carrier equivalent to that found in commercial Vigofac, it was confirmed that the growth activity of Vigofac is found solely in the extract. No activity was found when Vigofac was ashed which indicated that it was not inorganic but probably organic in nature. Results suggest that the carrier, while not active, might stabilize the activity of the extract, since experiments showed the activity of the extract was destroyed by boiling for 60 minutes, while that of Vigofac (extract and carrier) was not affected by autoclaving for 30 minutes at 15 psi and 121°C.

Soaking Vigofac for 96 hours in acidic (0.1N hydrochloric acid) and basic (0.1N or 1.0N sodium hydroxide) solutions appeared to enhance its activity. Soaking it for a similar period in water or 95 percent ethanol resulted in no improvement. It was concluded that the above enhanced activity was not due to further fermentation since water soaking should not have impaired fermentation. Similarly, the activity of zinc bacitracin (275 ppm) also was not adversely affected by autoclaving and was improved following soaking in the same acidic and basic solutions.

In two respects the activity of Vigofac appeared to be dissimilar from that of distillers dried solubles (DDS). As mentioned Vigofac activity was found to be organic in nature whereas DDS has been reported to include inorganic activity as well. Also no active Vigofac fractions were found following a fractionation procedure used to isolate such fractions from DDS. It was found that phenolic acids, reported as active isolates of DDS, have inconsistent growth promoting activity when fed individually or collectively.

Mode of Action

It appeared that Vigofac primarily influences growth by inducing increased feed consumption; as noted Vigofac-fed birds, with feed restricted to that of unsupplemented controls, gained no better than the controls. Because Vigofac-fed birds were found to excrete significantly less gross energy per unit of droppings on feeds containing the same gross and/or metabolizable energy contents, it was concluded that improvement of feed energy utilization was involved. Improved energy utilization appeared to be specific to wheat and not corn-type diets. It was postulated that specificity of energy improvement from the wheat-type diet may account for the greater growth response noted when Vigofac was added to wheat than to corn diets. Vigofac feeding did not alter intestine, thyroid or pancreas weights relative to body weight. Zinc bacitracin (275 ppm) also improved wheat ration energy utilization. Both zinc bacitracin (275 ppm) and five percent herring meal feeding caused a significant reduction in relative intestinal weight. Herring meal feeding also resulted in reduced relative thyroid weight.

Comparative Growth Effects

In addition to Vigofac the fermentation products Fermacto 500, Pryferm H. B., Liquid Streptomyces Solubles, UNF-40 and Solulac as well as the antibiotic zinc bacitracin promoted growth to a greater extent when added to a wheat than to a corn base ration. This observation was found true of Vigofac when supplemented either white western or hard red winter wheats. Results showed that the variable growth response associated with fermentation products such as Vigofac may be due to the presence of antibiotics which induce a somewhat overlapping growth response. Of a series of antibiotics (zinc bacitracin, oxytetracycline, penicillin-streptomycin, oleandomycin and chlortetracycline) supplemented to a wheat-base ration, chick growth was affected to the greatest extent by zinc bacitracin (275 ppm) and oleandomycin (22 ppm). Growth responses, though not completely additive, were greatest when 0.5 percent Vigofac, 5.0 percent herring meal and 275 ppm zinc bacitracin were fed simultaneously rather than individually.

In view of the fact that Vigofac appears to stimulate growth primarily through increased feed consumption and because where Vigofac and zinc bacitracin were compared together they differed appreciably only in their effect on intestinal weight, the effect of Vigofac thus appears to be more closely related to that of a growth promotant, as are antibiotics, rather than as a source of unidentified nutrients.

Layer Experiment

Results of the study with dwarf White Leghorn layers showed that where wheat was substituted for corn on a unit for unit basis, wheat fed hens consumed significantly more feed, produced eggs that were significantly smaller which contained significantly lighter yolks than did corn fed dwarfs. There were no significant differences in egg production, feed per dozen eggs, egg shell thickness, body weight, albumen height, Haugh units, yolk color, shell weight, yolk weight or albumen weight.

Where two percent safflower oil was added to the wheat base ration in place of animal fat, the wheat-fed hens laid eggs significantly larger than those of the wheat control hens and equal in size to those of the corn-fed dwarf hens. It was concluded that the improvement in egg size was due to the additional dietary linoleic acid contributed by the safflower oil. While the yolk color of wheat fed hens was significantly lighter than those fed corn, the yolks were still sufficiently dark to not be objectionable. The addition of 0.5 percent Vigofac to the feed did not improve any of the performance variables; and therefore, it would appear to be of limited if any value in layer feeds.

Normals differed significantly from the dwarfs in producing more and larger eggs, consuming more feed, and attained a higher body weight. They also laid eggs with significantly higher yolk and albumen weights than all dwarf treatments except those receiving safflower oil. The relative ranges of the dwarf treatments to normals were as follows: egg production, 72.7 to 76.3 percent; feed consumption, 69.7 to 72.4 percent; feed per dozen eggs, 93.6 to 97.3 percent; and egg weight, 92.9 to 93.8 percent.

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