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Title: The Feeding Value of Yellow Peas (*Pisum sativum L.* var. Miranda) for Single Comb White Leghorn Laying Pullets

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Two experiments were conducted each with 768 Dekalb XL Single Comb White Leghorn (SCWL) laying pullets for nine and eight 28-day periods to evaluate the feeding value of yellow pea (YP) (*Pisum sativum L.* var. Miranda) without and with, respectively, either 1.5 or 5% meat and bone meal (MB) and 2% fish meal (FM) in Experiment 1, and 0.025% (125 mg/kg diet) choline chloride (CH), 0.05% (0.11 mg/kg diet) biotin (BN), 0.05% yeast culture (YC), 3.25% soybean oil (SO), and their combinations in Experiment 2. Each dietary treatment was replicated four times with 24 pullets per replicate. Assignment of treatments was done by lottery in a complete randomized block design with four replicates per treatment allocated in pairs of two at both sides of the house.

The mean hen-day egg production, feed conversion (based on per dozen eggs and egg mass), daily feed consumption, body weight gain, internal egg quality, and egg mass were not affected ($P > .05$) by the various dietary treatments in either experiment. Low cumulative mortality was observed for pullets on all treatments for both experiments. Pullets fed the 60% YP diets in Experiment 2 produced more ($P < .05$) large size eggs (jumbo, extra large and large) and fewer ($P < .05$)

smaller and medium eggs than pullets fed the 0, 15, 30 and 45% YP diets. Mean egg weight was markedly heavier for pullets fed 60% YP diets after they were 46 weeks of age (WOA). However, in both experiments after 38 weeks of age (WOA), thinner egg shells were observed in pullets fed the 60% YP diets when compared to the other dietary treatments. A marked decrease in yolk color was also observed with pullets fed the YP diets after 58 WOA. Supplementation of the 45% YP and CS diets with 2% FM and/or 1.5% or 5% MB meal and the supplementation of 3.25% SO, 0.05% YC, 0.025% CH, and 0.05% BN in the 60% YP diets did not affect the pullet performance. These results indicate that feeding up to 60% YP diets to SCWL laying pullets was not detrimental.

# The Feeding Value of Yellow Peas (*Pisum sativum L.* var. Miranda) for Single Comb White Leghorn Laying Pullets

by

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# Dedication

This thesis is dedicated to my parents, Pedro and Vera:

To Pedro, for his early and lasting motivation.

To Vera for her daily sacrifice and encouragement, which gave me the inspiration to continue.

# Table of Contents

# List of Tables

List of Tables (continued)

# List of Appendix Tables

List of Appendix Tables (continued)

List of Appendix Tables (continued)

THE FEEDING VALUE OF YELLOW PEAS
(*PISUM SATIVUM L.* VAR. MIRANDA) FOR
SINGLE COMB WHITE LEGHORN LAYING PULLETS

# CHAPTER I

## INTRODUCTION

The Pacific Northwest (PNW) is an area which historically has dependent on the Midwest for the supplies of corn and soybean meal for animal feeding. Approximately 146,340 tons of corn and 56,200 tons of soybean meal were imported into Oregon for manufacture of poultry feeds in 1988 (Nakaue, 1989). Importing these two major feed ingredients for poultry feeds costs Oregon poultry producers an estimated 6 million dollars annually in freight costs (Nakaue, 1989). Therefore, reducing feed cost in poultry production is of major concern to the producers in the PNW. One approach to reducing feed cost is the production and utilization of alternative feed grains in the PNW.

The basic prerequisite for the utilization of an alternative feed grain are that it is agronomically efficient and it possesses a nutrient profile compatible with the bird's requirement. Field peas, unlike soybeans, grows satisfactorily in the cooler and shorter growing season of the upper North Temperate Zone. The special combination of climate and terrain necessary to produce large quantities of top quality dry peas is found in the Pacific Northwest states of Washington, Idaho, Oregon, and Montana (USA Dry Pea and Lentil Council, 1988b). This region is responsible for approximately 95% of the total U.S. production of dry peas or

459,100,000 pounds of commercial dry peas (USA Dry Pea and Lentil Council, 1988a).

The potential of peas as a human food resource and the nutritive value of peas for animals, especially poultry, have been studied recently in the U.S. and Europe. Peas have a favorable essential amino acid balance (Moran *et al.*, 1968). The inclusion of peas in poultry rations as an alternative protein source has been limited due to the presence of unknown growth inhibitors and a low methionine content (Moran *et al.*, 1968; Savage *et al.*, 1986; McDonald *et al.*, 1988).

The feeding value of yellow peas (YP) (*Pisum sativum L.* var. Miranda) in market turkey has been reported by Savage *et al.* (1986). They found that feeding YP at levels ranging from 25% in the turkey starter to 55% in the turkey finisher diets did not cause any detrimental effects in market turkeys. Kulkarni (1987) found that feeding diets containing 25% YP and a 50% YP supplemented with methionine or choline to broilers up to seven weeks of age did not depress ($P > .05$) growth rate and feed conversion when compared to broilers fed the corn-soy (CS) diet. Moran *et al.* (1968) and Andersson (1979) found that egg production was unaffected when 30% YP was fed to laying hens.

The objective of these studies was to evaluate the feeding value of YP (*P. sativum L.* var. Miranda) in Single Comb White Leghorn laying pullets. The effects of the supplementation of 2% fish meal (FM), 1.5% or 5% meat and bone meal (MB), 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% (125 mg/kg) choline-chloride (CH) and 0.05% (0.11 mg/kg) biotin (BN), were also investigated.

# CHAPTER II

## REVIEW OF LITERATURE

### History

Dry peas were one of the first crops ever to be cultivated. Pea seeds have been a source of food for civilizations since the Stone Age and particularly since the Neolithic period, or more than 20,000 years ago (Makasheva, 1983; USA Dry Pea and Lentil Council, 1988a,b).

The primary centers of the origin of peas are the mountainous regions of Southwest Asia, particularly Afghanistan, India, and Ethiopia (Wade 1937; Makasheva, 1983). The secondary centers of diversity are in Mediterranean Europe and in Southwestern and Central Asia. Makasheva (1983) presumed that field peas were developed in northwest Asia and spread into southwest Asia, possibly moving from west Asia to central and northern Europe.

The fact that the common pea or garden pea (*P. sativum*) contains what is considered advanced traits, such as white flowers and wrinkled seeds, and because it appears more recently in archeological remains and historical records, suggests that *Pisum sativum* evolved from the field pea, which generally has more primitive traits such as colored flowers (pink, red or purple) and smooth seeds (Muehlbauer *et al.*, 1983).

The first domestication of field peas probably occurred between 9000 and 5000 B.C., when Aryans from east Europe and Asia introduced dry peas to the pre-Christian Greeks and Romans. Before the end of the 16th century, both German and British botanists developed several strains of dry peas. The Austrian monk, Gregor Mendel, used the pea as the basis for his experiments in genetics in the 1800s (USA Dry Pea and Lentil Council, 1988a,b,c).

Most of the varieties of commercial dry peas grown in the US originated in the British Isles. From these original strains, new peas were developed which were better adapted to local soil and climatic conditions (USA Dry Pea and Lentil Council, 1988b,c). Peas entered North America in the 15th century. There are reports that field peas were first sown by Columbus on Isabella Island in 1493 (Makasheva, 1983). Subsequently, field peas found wide distribution in the United States where they were cultivated by the Indians of the east coast.

Field peas were introduced in the PNW of the United States near the turn of this century. The first planting of peas in the PNW was made at the Oregon Agricultural Experiment Station in the fall of 1923 (Hyslop, 1923; Schoth, 1931). Seeds of the Austrian winter field pea variety were supplied by the Bureau of Plant Industry of the U.S. Department of Agriculture. Since these early beginnings, the PNW states of Washington, Idaho, and Oregon have led the nation in producing nearly all of the U.S. dry peas, in 1971 producing almost 500 million pounds of commercial dry peas and 46 million pounds of yellow peas (USA Dry Pea and Lentil Council, 1986). Almost all of the peas presently grown in the PNW region, with the exception of the Austrian winter variety, are the spring varieties (Karow, 1989).

The pea used in this study belongs to a relatively new variety of yellow peas, namely Miranda, which originated in the Netherlands between 1969-71, and was introduced into Oregon in 1981 (U. S. Department of Agriculture, 1981).

## Classification

Peas are known botanically as *Pisum sativum* and by the common names "Common Pea" or "Garden Pea". *Pisum sativum* belongs to the order *Fabales*, family *Leguminosae*, subfamily *Papilionoidea*, and tribe *Vicieae*. Within *Vicieae*, genus *Pisum* occupies a position along with *Vicia*, *Lathyrus*, *Lens*, and *Vavilovia* (Kupicha, 1981; Muehlbauer *et al.*, 1983).

Early taxonomists described numerous species and subspecies of *Pisum* based on phenotypic differences and distinguished between the garden and field peas (Wade, 1937). Peas are classified as follows: *P. sativum* spp. *hortense* Asch. and Graebn., the garden or common pea; *P. sativum* spp. *arvense* (*L.*), the field pea or *P. fulvum* or *P. arvense* or Austrian winter pea, and many other subspecies such as *P. sativum* spp. *macrocarpon* (*L.*), and *P. sativum* spp. *humile*, dwarf pea; and *P. sativum* spp. *elatius*, *P. sativum* spp. *syriacum*, *P. sativum* spp. *abyssinicum*, "wild" types; to name a few (Muehlbauer *et al.*, 1983; Karow, 1989).

Wade (1937), and Muehlbauer *et al.* (1983), were of the opinion that *Pisum* is monospecific based on mutual crossability and fertility and that all members of the species are self-pollinating diploids (2n = 14); the distinction seems entirely artificial, and most writers now consider both types under *P. sativum*.

The field pea, *P. sativum* spp. *arvense*, is characterized by pigmented (pink, red or purple) flowers, pods, seeds, and some stems. Seeds are usually small (less than 4 mm in diameter), brown or black speckled or mottled, smooth and round, and have a yellow cotyledon. The garden pea, *P. sativumm* spp. *hortense*, has white flowers and non-pigmented pods and seeds. Garden pea can be grouped into smooth-seeded and wrinkled-seeded classes. Within each of these classes, cotyledon can be either green or yellow (Muehlbauer *et al.*, 1983).

### Chemical Composition of Peas (*Pisum Sativum L.*)

Peas are basically similar to beans but have lower content of crude protein (26%) and crude fiber (6%). The oil content is slightly higher than that of beans but the degree of saturation is similar. Peas are regarded primarily as a source of protein. Compared to the other legumes field peas contain a higher amount of lysine (Carnovale *et al.*, 1983). Methionine is the main limiting amino acid (Boulter, 1983). The metabolizable energy content for poultry is approximately 3035 Kcal/kg (McDonald *et al.*, 1988).

Pea seeds, depending upon the varieties and growing conditions, contain (on a dry weight basis) : 9-15% water, 5-15% protein, 24-60% carbohydrate, 0.6-1.5% lipids, 2-10% cellulose, and 2-4% minerals (Makasheva, 1983).

**Protein and Amino acids:**

Among the leguminous species, field peas offer the greatest potential as an alternative to soybean for protein production. Field pea seeds have a protein content that average 23% (Monti, 1983), a good protein quality compared with other leguminous species due to the higher lysine content (6.5% of protein) and a favorable essential amino acid balance (Moran *et al.*, 1968). Disadvantages are inadequacy of methionine and a low protein content (Moran *et al* ., 1968). Peas grown in the PNW have a protein content ranging from 20.8 to 23.1% (Reddy *et al.*, 1979).

According to Boulter and Derbyshire (1971), the seed proteins of different field pea varieties contain the following percent distribution of amino acids (based on g amino acids/16 g N):

| Amino acids | % | Amino acids | % | Amino acids | % |
|---|---|---|---|---|---|
| Arginine | 7.7 | Tryptophan | 0.8 | Leucine | 6.6 |
| Cystine | 1.2 | Aspartic acid | 13.4 | Isoleucine | 5.0 |
| Histidine | 1.7 | Glycine | 3.9 | Valine | 4.6 |
| Lysine | 1.6 | Phenylalanine | 4.6 | Glutamic acid | 17.5 |
| Methionine | 1.1 | Threonine | 3.9 | Alanine | 6.6 |

Arginine, leucine, lysine, aspartic acid and glutamic acid account for 50% of the total amino acids. Histidine, methionine, threonine, tryptophan and cystine represent less than 11% of the total amino acids (Holt and Sosulski, 1979).

The most limiting amino acids for human requirements are the sulfur containing amino acids: methionine and cystine. Threonine and valine are the second and third limiting amino acids, respectively (Holt and Sosulski, 1979). It is generally agreed that peas are nutritionally deficient in the sulfur-containing amino acids, cystine and methionine, and low in tryptophan concentration (Muehlbauer *et al.*, 1983). The content and quality of protein vary between different cultivars. Bajaj *et al.* (1971) reported differences in protein (21 to 28%) content among 28 pea breeding lines of peas (*Pisum sativum L.*). Holt and Sosulski, (1979) conducted a study with various lines of peas and concluded that the amino acid content in field peas were affected by environment (several locations) and genotype. It has also been shown that the total nitrogen varies within plants and year (Ali-Khan and Youngs, 1973) with maturity (Pandey and Gritton, 1975) and with applied nitrogen (McLean *et al.*, 1974; Trevino and Murray, 1975) or phosphorus (Sosulski *et al.*, 1974). The amino acids with the greatest variabilities are arginine, methionine, tryptophan and cystine.

A brief summary of a number of studies shows that the commonly used 6.25 factor has the tendency of overestimating the total protein content of peas, because not all of the nitrogen in dry pea seed is protein. From 2 to 10% of the nitrogen is in an ethanol-soluble form, largely as amino acids and small peptides, and a further 5-10% exists as non-proteinaceous, insoluble nitrogen, presumably as fiber and large peptides. For this reason, a factor of 5.25 was found more suitable for the determination of crude proteins in peas (Pate and Flinn, 1977). Other studies of protein in peas indicate a decrease of essential amino acids with increasing total nitrogen, and that the amino acid profile is a characteristic of the cultivar (Holt and Sosulski,1979). No correlation exists between protein content and protein quality (Bajaj *et al.*, 1971). However, a negative correlation was found between the sulfur amino acid content and pea seed protein (Evans and Boulter, 1980).

Pea seed protein can be divided into albumin and globulin fractions. The water soluble albumin fraction found primarily in the cytoplasm, represents a relatively minor portion of the total protein and has a considerably higher content of tryptophan than the globulin fraction (Shamanthaka and Murray, 1986). The globulin fraction which may comprise 80% or more of the total seed protein is divided into subunits: vicilin (7 S fraction, molecular weight: 186,000) and legumin (12 S fraction, molecular weight: 331,000). Vicilin is the major protein fraction in most *Pisum* genotypes and totally lacking in methionine and cysteine; whereas, legumin contains between 1.0 and 1.8 g % methionine and cysteine, respectively, depending on genotype (Pate, 1977; Pate and Flinn, 1977; Boulter, 1983; Casey, 1983; Casey and Domoney, 1985). There are considerable variations in the types and proportion of subunits in globulins of peas. Round and wrinkled peas are shown to differ in the proportion of storage proteins. Wrinkled forms on the average have less legumin than round forms (Davis and Domoney, 1983).

**Carbohydrates:**

Wrinkled and smooth pea seeds have total carbohydrate content of 60% and 67%, respectively (Cerning-Beroard and Filiatre, 1976). Carbohydrates in peas are represented mainly by starch (20-50%) and sugars (4-10%). Among the other carbohydrates present are hemicellulose, cellulose, pectin substances and pentoses (Makasheva, 1983).

The smooth-seeded pea types tend to have a higher starch content than the wrinkled types. Cerning-Beroard and Filiatre (1976) reported that smooth-seeded peas were considerably richer in starch (47.9%) than wrinkled-seeded types of peas (32.9%).

The sugar content of peas is low, representing no more than 10.2% in wrinkled peas and 8% in smooth peas (Cerning-Beroard and Filiatre, 1976). The major constituents of the ethanol soluble sugars were verbascose, stachyose, sucrose, raffinose, and arabinose, present only in wrinkled peas. Sucrose represents a minor portion (30-38%), and Alfa-galactosides are the major portion (65%) of the total sugars in wrinkled peas. Glucose appears in trace amounts in smooth peas, but in higher amounts in wrinkled peas.

Hemicellulose and cellulose contents were 6% and 6-8%, respectively, for smooth peas and 5% and 5.5% for wrinkled peas (Cerning-Beroard and Filiatre, 1976). Water-soluble hemicellulose represents 53.5% and 65% of the total hemicellulose in wrinkled and smooth peas, respectively, while the acid soluble fraction of the hemicellulose varies greatly depending on the variety. The lignin content of smooth and wrinkled peas are 1-1.2% and 0.5%, respectively, (Cerning-Beroard and Filiatre, 1976).

**Fat**

Peas have low fat content (1%) with wrinkled varieties having lower levels than smooth varieties. Triglycerides represent about 90% of total lipids and 84% of the fatty acids are unsaturated. Linoleic acid represents 50% of total fatty acids (Grosjean, 1985).

**Vitamins**

Makasheva (1983) reported that peas, based upon 1000 g fresh weight, contain 4 mg provitamin A (carotene), 3 to 5 mg vitamin B1 (thiamin), 1 to 1.5 mg of vitamin B2 (riboflavin), 300 to 500 mg of vitamin C, 1.2 mg pantothenic acid, and trace amounts of inositol. Vitamins C and E (tocopherol), which are absent in mature seed, are found in the germinating seeds of peas. A more detailed description of the vitamin content of field peas (*P. sativum*) seeds is given by the National Research Council (1984) as follows:

| **Vitamin** | **mg/kg** | **Vitamin** | **mg/kg** | **Vitamin** | **mg/kg** |
|---|---|---|---|---|---|
| Biotin | 0.18 | Niacin | 34.00 | Riboflavin(B2) | 2.30 |
| Choline | 642.00 | Pantothenic acid | 10.00 | Thiamin (B1) | 7.50 |
| Folic acid | 0.40 | Pyridoxine (B6) | 1.00 | Tocopherol (E) | 3.00 |

**Minerals**

The total ash content of dry peas was determined to be 2.8%, with phosphorus and calcium representing 79% of the total mineral content (Makasheva, 1983). The remaining 21% comprise the other elements, with iron, copper and zinc found in higher proportions (Pate and Flinn, 1977).

**Antinutritional factors**

The nutritive value of a protein is dependent upon its essential amino acids content, and the biological availability of these amino acids as well. Incomplete digestion and absorption of an essential amino acid result in altering the effective composition of a food protein (Kuiken and Lyman, 1948). Several factors in pea seeds that reduce protein digestibility include trypsin and amylase inhibitors, phytohaemagglutinin (hemagglutinins or lectins) compounds, and tannins (Muehlbauer *et al.*, 1983).

**Protease Inhibitors**

Substances inhibiting proteolytic enzymes have long been studied in the family *leguminosae*. Two of these proteolytic enzymatic inhibitors found in peas are polypeptides, with molecular weights mostly between 10,000 to 12,000. Some differences in the amino acid composition and in their isoelectric point have been reported (Liener and Kakade, 1980; Weder, 1981).

The content of trypsin inhibitor in peas is one tenth of the level found in soybeans. Wrinkled-seeded varieties have less trypsin-inhibiting activity (TIA) than smooth-seeded types and among smooth varieties, spring types (2.5-5.4 TIA mg-1) have less than winter types (7.9-10.8 TIA mg-1). The TIA of different varieties of peas (*Pisum sativum*) ranges from 7 to 13 units. The chymotrypsin inhibitory activity (CTIA) ranges between 8 to 15 units. The TIA and CTIA units were expressed as milligrams of enzymes inhibited by one gram of plant material (Weder, 1981). Trypsin inhibitors can be inactivated by heat or the addition of formaldehyde (Grosjean, 1985). Two other protease inhibitors found in peas are called plasmin and papain (Weder, 1981).

**Hemagglutinins (Lectins)**

Lectins or hemagglutinins are proteins that possess a specific affinity for certain sugar molecules (Jaffe, 1980). Many contain covalently bound sugars and so can be classed as glycoproteins (Cheeke and Shull, 1985). Phytohemagglutinins are found mainly in the *Papilionoidea* subfamily and their structural condition is that of two to four polypeptide subunits containing bivalent metal ions, capable of agglutinating a variety of cell types (Jaffe, 1980; Toms, 1981).

Two different lectins were isolated in *Pisum sativum*. They are tetramers with two binding sites (Jaffe, 1980). Their activities, measured as hemagglutinating activity of rabbit erythrocytes (H.U.), were 80 H.U. per gram of pea seeds, which is much smaller than in bean (*Phaseoulus vulgaris*: 8,000-155,000 H.U.) (de Muelenaere, 1965).

There is very little nutritional response of lectins in poultry (Grosjean, 1985). However, swine fed 5% raw beans in the ration showed growth depression due to lectin activity. Adverse effects observed with hemagglutinins are reduced growth, diarrhea, decreased nutrient absorption due to binding of the hemagglutinins to cells in the intestinal wall, and impairment of the immune system leading to greater sensitivity to bacterial infection (Cheeke and Shull, 1985). This detrimental effect is reduced in poultry by the addition of antibiotics, which controls the bacterial colonization of the gut (Cheeke and Shull, 1985). Wagh *et al.*, (1963) observed that lectin from kidney bean decreased growth in chicks, but no lethal action was detected. Lectins can only be destroyed by moist heat (Cheeke and Shull, 1985) and formaldehyde (Grosjean, 1985). Dry heat has been shown to be ineffective in destroying lectins (Cheeke and Shull, 1985).

**Polyphenolic Compounds (Tannins)**

Tannins are polyphenolic compounds which precipitate proteins from aqueous solutions. Hydrogen bonds are formed between the phenolic hydroxyls and the peptide groups to form cross-links between adjacent protein chains, reducing their digestibility (Cheeke and Shull, 1985).

There are two main groups of tannins, condensed tannins (condensed flavanols) and hydrolyzable tannins (esters of glucose). Pea contains 0.23 to 0.35% tannin, which are of the condensed type and which is restricted to the seed coat of colored-flowered varieties. White-flowered varieties of peas contain 0.06% tannin (Griffiths, 1983).

**Amylase inhibitors**

A variety of foodstuffs, including peas, wheat, oats, rye, beans, and potatoes, contain amylase inhibitors (Liener and Kakade, 1980). Amylase inhibitors appear to be of little or no significance in animal nutrition. The main effect of the amylase inhibitor is the prevention of starch digestion and the production of various digestive problems, such as diarrhea and malabsorption symptoms in animals (Cheeke and Shull, 1985).

### Saponin

Saponins are secondary plant metabolites containing a carbohydrate moiety attached to an aglycone, which may be steroidal or triterpenoid in structure. The saponin content for green and yellow peas based as a weight percentage of the defatted flour were 1.8% and 1.1%, respectively (Price *et al.*, 1986). The effect of saponin on digestibility in poultry is not clear. The bitter taste of saponins appears as the main limiting factor in monogastric consumption (Cheeke and Shull, 1985).

## Nutritional Evaluation of Peas in Poultry

### Layers

Nguen-Ngi (1964) discovered that diets fed to layers containing 30% ground raw peas resulted in 8% lower egg production than did the same diet supplemented with 0.1% methionine. The same raw pea diets fed to layers had 12-15% lower egg production than the pea diets having the peas processed by steaming or fermenting with or without added methionine.

Moran *et al.* (1968) fed raw and steam pelleted pea meal to layers at 15 and 30% of the total ration. Egg production and egg weight were unaffected by the two treatments. Differences were observed for feed utilization and consumption, with hens fed the control CS diet more efficient in egg production. Pelleting pea meal did not improve performance of laying hens.

Lindgren (1975), in an experiment with white-flowered and color-flowered pea varieties, fed to layers at 15 and 30% of a cereal based diet, found that egg production was unaffected regardless of the treatment. However, there was a negative correlation ($P < .05$) between tannin content and protein digestibility, with the white-flowered variety having the highest nutritive value of the tested peas.

Andersson (1979) observed no difference ($P > .05$) in egg production and feed conversion of laying hens fed isonitrogenous diets containing 30% peas. Increased egg deformation and decreased shell thickness were observed when a diet containing 30% peas were fed, in comparison to laying hens fed a control diet (barley-based with soybean meal, corn, wheat, oats, and 0.1% methionine supplementation).

Davidson (1980) fed oat-based layer diet containing 37.5% ground raw and heat-processed peas (*Pisum sativum* var. Maro) with 1% white-fish meal to laying hens. Egg production on the raw pea diet was decreased by 47% ($P < .01$) when compared to the control receiving fish meal. The addition of methionine or heat-processed peas improved ($P < .01$) egg production by 20%. Methionine supplementation (0.2%), in addition to heat processing, further improved ($P < .05$) egg output by 25% to give the same production rate as the fish meal control diet. In a similar experiment, Davidson *et al.* (1981) observed that incorporating heat-processed peas (*Pisum arvense* var. Rosekrone) into the ration at 40% without methionine supplementation resulted in a weight loss and a reduced ($P < .05$) egg production. Addition of methionine (0.15%) improved ($P < .01$) egg production, but was not adequate to restore full egg production. It was concluded that a major heat stable anti-nutritional factor was responsible for the low performance.

Askbrant and Hakansson (1984) studied the nutrient digestibility of peas and soybean meal in laying hens. The digestibility of protein and fat was lower than soybean meal, while the digestibility of carbohydrate and organic matter was higher for peas compared to soybean meal. The high percentage of crude fiber (9.9%) is indicative for the possible cause of the low-protein digestibility of this particular pea variety.

**Broilers and Growing chickens**

For growing chicken (Single Comb White Leghorn cockerels) and broiler diets, the feeding of raw peas in moderate to large amounts is feasible provided the diets are supplemented with methionine (Moran *et al.*, 1968; Goatcher and McGinnis, 1972; Kulkarni, 1987). The limitations of incorporating YP in the diets varied, dependent upon the variety of peas used (Grosjean, 1985).

Woods *et al.* (1943) stated that Alaska field pea is a good source of essential amino acids for growth, with the exception of methionine, and that autoclaving did not increase protein digestibility. Petersen *et al.* (1944) studied the nutritional effect of Alaska field peas as the sole protein supplement in the diet of Single Comb White Leghorn (SCWL) cockerel. The results indicated that methionine is the principal growth limiting factor in feeding peas in broilers. The addition of 0.25% methionine to a 12% pea diet resulted in growth equivalent to the 12% protein (SBM) control diet. No deficiency in cystine was found as measured by growth in chicks.

Bolin *et al.* (1946) added several protein supplements (fish meal, casein, dried milk) to an 18% protein starter diet containing 54.5% Alaska field peas for SCWL cockerel chicks. An increased growth response was observed for all diets when additional methionine was added. Fish meal, casein and dried milk are good complementary sources of dietary protein to use in diets containing pea meal.

Moran *et al.* (1968) fed field peas (*Pisum sativum*) to broilers from one to three weeks of age as the sole source of protein and showed that extensive use of pea meal (65%) resulted in a substantial reduction in feed conversion and decreased ($P < .05$) growth. Decreased growth rate and feed conversion was observed when the diet containing 35% of pea meal was fed. Steam pelleting (90° C) of the peas substantially improved the performance of the broilers at either level (35 and 65%) of pea meal. These investigators concluded that only conservative quantities of field peas should be used for broiler in order for optimal performance, and the meal should at least be steam pelleted.

In a study by Goatcher and McGinnis (1972), an improvement ($P < .05$) in chick growth was obtained with methionine supplemented pea rations when compared to chicks fed a 53.5% of steam autoclaved dry peas without methionine supplementation. The addition of penicillin (50 ppm) in combination with methionine (0.35%) improved ($P < .05$) improved growth in their experiment.

Reddy *et al.* (1979) experimented with 44 lines of green peas, YP (*Pisum sativum L.*), and Austrian winter peas (*Pisum sativum L.* var. *arvense*). Supplementing the three different peas types with 0.2% dl-methionine improved ($P < .05$) both the growth and protein efficiency ratio in the three lines tested. The addition of penicillin (50 ppm) to the methionine supplemented diet provided ($P < .05$) better growth and an improved protein efficiency ratio compared to when the methionine supplemented diet without antibiotic was fed. they concluded that there was a difference in protein availability among the lines of peas tested or anti-nutritional factors that depress chick growth.

Kulkarni (1987) studied the effect of feeding diets containing 25, 50 and 65% YP (*Pisum sativum L.* var. Miranda) diet, with and without methionine supplementation, on the performance of broiler chickens. Feeding a 25% yellow pea diet did not affect broiler performance when fed from day-old to seven weeks of age. Feeding a 50% yellow pea diet depressed growth and supplementation with either threonine (0.03%) or tryptophan (0.011%) and improved ($P < .05$) growth. Body weight and feed conversion of broilers fed 50% YP diets supplemented with methionine (0.4%) or choline (0.12%) were not different (P > .05) from the control CS diet. Autoclaving of YP did not improve growth (Kulkarni, 1987).

The limitations of pea incorporation in animal diets is the result of the influence of the different trypsin-inhibitor activities of the pea varieties. Incorporation of raw peas above 50% in diets resulted in a decline in growth rate and feed conversion (Kienholz *et al.*, 1962; Moran *et al.*, 1968; Goatcher and McGinnis, 1972; Kulkarni, 1987).

**Turkeys**

The nutritive evaluation of peas with turkeys has been limited to a few studies. The determination of free plasma amino acid determination in turkey poults fed a 32% pea protein concentrate was investigated by Dunkelgod and Winkleman (1982). Methionine, arginine, proline, threonine, leucine, and taurine were found to be the limiting amino acids in pea diets.

Savage *et al.* (1986) evaluated the feeding value of ground YP (*Pisum sativum L.* var. Miranda) in market turkeys and found that when adjusted for fat and methionine content, YP diets (25% in starter and 55% in finisher diets) had no detrimental effect (P > .05) on growth rate, feed utilization or meat quality.

# CHAPTER III

# THE EFFECT OF FEEDING TO SINGLE COMB WHITE LEGHORN LAYING PULLETS DIETS CONTAINING VARYING LEVELS OF YELLOW PEAS (*PISUM SATIVUM L.* VAR. MIRANDA) WITHOUT AND WITH EITHER 2% FISH MEAL, OR 1.5% OR 5% MEAT AND BONE MEAL, OR 0.05% LIVE YEAST CULTURE, 3.25% SOYBEAN OIL, 0.025% CHOLINE, OR 0.05% BIOTIN, OR COMBINATIONS OF THESE NUTRIENTS

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**Abstract**

Two experiments were conducted, each with 768 Dekalb XL SCWL laying pullets, in two separate feeding experiments to evaluate the feeding value of YP (*Pisum sativum L.* var. Miranda), either alone or with the supplementation of nutrients for nine and eight 28-day periods, respectively, for Experiments 1 and 2. Each dietary treatment was replicated four times with 24 laying pullets per replicate. A complete randomized block design was used with an equal number of replicates per treatment at each side of the house.

In Experiment 1, the dietary treatments were corn-soy (CS) diet, and yellow pea (YP) diets with either 15%, 30%, 45%, or 60% YP. Incorporations with either 2% fish meal (FM), or 1.5% or 5% meat and bone meal (MB) alone, or a combination of the two ingredients in the 45% YP and CS diets were also examined. In Experiment 2, diets consisting of 60% YP diets were supplemented with 0.025% (125 mg/kg) choline chloride (CH), 0.05% (0.11 mg/kg) biotin (BN), 3.25% soybean oil (S0), and 0.05% yeast culture (YC), either alone or in combinations of these nutrients and ingredients.

Hen-day egg production, feed conversion (based on per dozen eggs and egg mass), body weight gain, daily feed consumption, egg mass, egg size, egg weights, egg shell thickness (shell quality), Haugh units (internal egg quality), and mortality were the parameters studied. In both experiments, the mean hen-day egg production, feed conversion, body weight gain, daily feed consumption and interior egg quality (Haugh units) were not affected ($P > .05$) by dietary treatments. Low cumulative mortality was observed for pullets for all treatments in both experiments. In Experiment 1, egg size and egg weight were not affected ($P > .05$) by feeding the various dietary treatments; however, pullets fed the 60% YP diets produced larger

and heavier eggs (P < .05) compared to pullets fed the CS diet (Experiment 2). The supplementation of the 60% YP diets with 3.25% SO, 0.025% CH, 0.05% BN, 0.05% YC alone or in combinations did not affect (P > .05) egg size, except for period 7 (Experiment 2), when supplementing the 60% yellow pea diet with choline increased (P < .05) egg weight in comparison to the remaining dietary treatments. In both experiments, 38 WOA pullets fed the 60% YP diets had thinner (P < .05) egg shells compared to the egg shells from pullets fed 0%, 15%, 30% and 45% YP diets in both experiments. A lighter (P < .05) egg yolk color resulted when the YP diets were fed compared to the yolk color from 58 WOA pullets fed the CS diet. These results indicate that feeding up to 60% YP diets to SCWL laying pullets was not detrimental.

## Introduction

Peas are alternatives to soybeans in poultry feeds of the PNW. The field pea (*Pisum sativum*), unlike the soybean, grows satisfactorily in the cooler and shorter growing season of the upper North Temperate zone. The primary nutritional advantages of pea meal are the relatively high lysine content (6.5% of total protein) and favorable essential amino acid balance. The disadvantages are inadequacy of methionine, low protein content (23%) and high fiber (9%) (Moran *et al.*, 1968; Monti, 1983).

The potential of peas as a source of protein for animals, especially poultry, has been realized for years. In chicken and broiler rations, the introduction of raw peas in large amounts is feasible provided that methionine is added (Moran *et al.*, 1968, Goatcher and McGinnis, 1972, and Kulkarni, 1987). However, the levels of incorporation of peas in diets have varied from one investigation to another because of the variety of peas used (Grosjean, 1985).

Peas have been incorporated up to 30% in laying pullets diets with methionine supplementation (Moran *et al.*, 1968; Andersson, 1979; Lindgren, 1975) without affecting egg production. However, a decline ($P < .05$) in feed conversion (Moran *et al.*, 1968) and shell quality (Andersson, 1979) was observed when laying hens were fed a diet containing peas. The incorporation of peas in the diet of more than 30%, together with methionine supplementation, resulted in a decline in the rate of lay and feed efficiency (Davidson, 1980; Davidson *et al.*, 1981).

The studies reported here were conducted because there have been no reported studies on the effect of feeding the Miranda variety of YP (*Pisum sativum L.*) in SCWL laying pullets, and because of the high variability observed in protein content and quality of the different cultivars of peas (Pate, 1977; Bajaj *et al.*, 1971; Muehlbauer, 1983; Guldager, 1983). The effects of supplementing diets containing YP with choline, biotin, fish meal, meat and bone meal, yeast culture and soybean oil were also investigated.

## Materials and Methods

Seven hundred sixty-eight Dekalb XL Single Comb White Leghorn pullets were used in each experiment in two separate feeding experiments. Each experiment was conducted separately for two consecutive years. The laying pullets were 22 and 38 WOA at the beginning of the experiment, for the first (Experiment 1) and second (Experiment 2) years, respectively. During the first (Experiment 1) and second (Experiment 2) years, the pullets were on experiment for nine and eight 28-day periods, respectively.

The pullets were housed in individual cages (20.3 cm × 45.8 cm × 40.6-48.3 cm/cage). A replicate or row contained 24 individual cages. The rows were arranged in a stair-step arrangement with four rows per bank. The birds were housed in a windowless positive pressure mechanically ventilated house. Artificial lighting was provided from 0400 to 1800 hrs daily throughout both experiments. The light intensity was approximately 5.4 lux. Feed was provided *ad libitum* throughout both experiments. Intermittent water periods were furnished daily via continuous flow water trough for each bank for 15 min every 2 hrs starting at 0415 hrs and ending at 1800 hrs.

In both experiments each dietary treatment was fed to 4 replicate rows of 24 pullets each. A complete randomized block design was used with an equal number of replicates per treatment placed at each side of the house. For both experiments, body weight and feed consumption were measured, at the end of each 28-day period. Egg weights and egg grade sizes (Egomatic)[1] were determined on eggs collected for the last three consecutive days of each period. The same eggs were used to measure egg shell quality using the specific gravity method as outlined by Arscott and Bernier (1961), internal egg quality (Haugh units) by albumen height and egg weight method (USDA Egg-Grading Manual, 1983), and yolk color determination utilizing the Roche color fan (14 = dark orange; 1 = light pale yellow). Body weight, egg shell quality, internal egg quality and yolk color measurements were measured only at the end of periods 1, 4, 7 and 9 for Experiment 1 and at the end of periods 1, 5 and 8 for Experiment 2. Body weight gain, feed conversion parameters (based on per dozen eggs and egg mass) and egg mass (number eggs × egg weights) were calculated from the data for both experiments. Mortality was recorded daily.

Treatment (T) and period (P) effects were the main factors studied in both experiments. The data from both experiments were subjected to analysis of variance (repeated measures) and comparisons of significant means carried out by the use of adjacent ordered comparison. Data were summarized and presented as

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[1]Egg Candler & Grader, Otto Niederer Sons Inc., Tiyusville, NJ.

treatment average over periods for parameters where no significant interactions were observed. For parameters where significant T× P interactions were obtained, the data were presented by periods for the different dietary treatments in each experiment. All tests of significance were made at the 5% level of probability (Cochran and Cox, 1958; Rowe, 1989).

**Experiment 1**

The eight dietary treatments were 0% YP, 15% YP, 30% YP, 45% YP, 60% YP, 45% YP + 5% meat and bone meal (MB), 45% YP + 2% fish meal (FM) + 1.5% MB, and 0% YP + 2% FM + 5% MB (Table 1). The diets were formulated to be isonitrogenous and isocaloric. The nutrient composition of YP was described by Savage *et al.* (1986), and is presented in Table 2.

**Experiment 2**

The eight dietary treatments were 0% YP, 60% YP, 60% YP + soybean oil (SO), 60% YP + yeast culture (YC), 60% YP + choline (CH), 60% YP + biotin (BN), 60% YP + BN and 60% YP + CH + BN + YC. Choline chloride and biotin were supplemented as premixes at 0.025% (125 mg/kg diet) and 0.05% (0.11 mg/kg diet) of the total diets, respectively. The 60% YP diets were supplemented with 1.25% soybean oil with exception of one diet with 3.25% soybean oil. Yeast culture were incorporated at 0.05% of total diet. The diets were formulated to be isonitrogenous and isocaloric (Table 3).

**Table 1.** Composition of layer diets containing 0, 15, 30, 45 and 60% yellow peas (YP) supplemented alone with fish meal (FM), meat and bone meal (MB), or in a combination (Experiment 1).

| | Level of YP (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ingredients | 0 | 15 | 30 | 45 | 60 | 45 +MB | 45 +FM +MB | 0 +FM +MB |
| Barley, Pacific coast | 5.00 | 4.84 | 4.70 | 4.50 | 4.35 | 4.00 | 4.00 | 8.90 |
| Corn, yellow | 65.31 | 54.02 | 42.81 | 31.72 | 20.82 | 32.65 | 34.23 | 63.57 |
| Yellow peas (21.3% CP) | -- | 14.77 | 29.55 | 44.30 | 59.09 | 44.50 | 44.50 | -- |
| Soybean ml (47.5% CP) | 17.99 | 13.50 | 9.00 | 4.50 | -- | -- | -- | 9.80 |
| Fish ml, herring (72% CP) | -- | -- | -- | -- | -- | -- | 2.00 | 2.00 |
| Meat & bone ml (49.5% CP) | -- | -- | -- | -- | -- | 5.00 | 1.50 | 5.00 |
| Dehy. alfalfa ml (17.5% CP) | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| Defluo. phos. (32% Ca; 18% P) | 2.00 | 2.00 | 1.99 | 1.98 | 1.97 | 1.15 | 1.67 | .90 |
| Limestone flour | 3.65 | 3.60 | 3.52 | 3.46 | 3.39 | 3.30 | 3.35 | 3.40 |
| Oystershell, ground | 3.00 | 3.10 | 3.19 | 3.28 | 3.37 | 3.35 | 3.36 | 3.40 |
| Salt (iodized) | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix[1] | .05 | .05 | .05 | .05 | .05 | .05 | .05 | .05 |
| Vitamin premix[2] | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| d,1-methionine (98%) | .05 | .10 | .16 | .21 | .26 | .20 | .19 | .03 |
| Animal fat | -- | -- | 1.45 | 2.11 | 2.50 | 1.95 | 1.20 | -- |
| Soybean oil | -- | -- | .63 | .94 | 1.25 | 1.00 | 1.0 | -- |
| Calculated Analyses: | | | | | | | | |
| Crude protein (%) | 15.2 | 15.2 | 15.2 | 15.2 | 15.3 | 15.6 | 15.4 | 15.4 |
| Crude protein (analyzed) (%) | 15.0 | 15.1 | 15.2 | 15.3 | 15.4 | 15.1 | 15.8 | 15.6 |
| Met. energy (kcal/kg) | 2833 | 2834 | 2834 | 2834 | 2833 | 2834 | 2835 | 2834 |
| Calcium (%) | 3.28 | 3.29 | 3.28 | 3.28 | 3.28 | 3.28 | 3.29 | 3.31 |
| Avail. phos. (%) | .47 | .47 | .47 | .47 | .46 | .49 | .49 | .47 |
| Methionine (%) | .31 | .31 | .33 | .34 | .35 | .33 | .34 | .30 |
| Meth. and cystine (%) | .57 | .57 | .57 | .57 | .57 | .56 | .57 | .56 |
| Tryptophan (%) | .19 | .18 | .17 | .16 | .16 | .15 | .16 | .17 |
| Linoleic acid (%) | 1.30 | 1.33 | 1.35 | 1.37 | 1.40 | 1.41 | 1.41 | 1.28 |
| Lysine (%) | .71 | .79 | .87 | .95 | 1.02 | .98 | .98 | .76 |

[1]Mineral premix provided per kilogram of diet: Calcium, 97.5 mg; manganese, 60 mg; zinc, 27.5 mg; copper, 2 mg; iron, 20 mg; iodine, 1.2 mg; cobalt, .2 mg.

[2]Vitamin premix provided per kilogram of diet: Vitamin A, 3300 IU; vitamin D3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg; niacin, 22 mg; choline, 190.9 mg; vitamin K, .55 mg; vitamin E, 1.1 IU; vitamin B12, 5.5 mcg; folic acid, .22 mg; ethoxyquin, 60 mg.

**Table 2.** Nutrient composition of yellow peas (*Pisum sativum L.* var. Miranda).

| | |
|---|---|
| Crude protein (%) | 21.10 |
| True metabolizable energy (kcal/kg) | 2844 |
| Crude fiber, acid detergent (%) | 9.00 |
| Calcium (%) | .05 |
| Phosphorus (%) | .45 |
| Potassium (%) | .91 |
| Sodium (%) | .003 |
| Magnesium (%) | .12 |
| Iron (ppm) | 112 |
| Copper (ppm) | 6.30 |
| Zinc (ppm) | 45.00 |
| Manganese (ppm) | 15.30 |
| Arginine (%) | 1.57 |
| Glycine (%) | .54 |
| Histidine (%) | .44 |
| Isoleucine (%) | .61 |
| Leucine (%) | 1.06 |
| Lysine (%) | 1.09 |
| Methionine (%) | .08 |
| Cystine (%) | .28 |
| Phenylalanine (%) | .77 |
| Tyrosine (%) | .57 |
| Threonine (%) | .56 |
| Valine (%) | .67 |
| Tryptophan (%, estimated) | .24 |
| Linoleic acid (%) | .45 |

**Table 3.** Composition of layer diets containing 0 and 60% yellow peas (YP) supplemented with either yeast culture (YC), soybean oil (SO), choline (CH), biotin (BN) alone or in a combination (Experiment 2).

| | Level of YP (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ingredients | 0 | 60 | 60 +SO | 60 +YC | 60 +CH | 60 +BN | 60 +CH +BN | 60 +CH +BN +YC |
| Barley, Pacific coast | 5.00 | 4.35 | 11.35 | 4.35 | 4.35 | 4.30 | 4.30 | 4.30 |
| Corn, yellow | 65.31 | 20.82 | 12.00 | 20.82 | 20.79 | 20.82 | 20.79 | 20.79 |
| Yellow peas (21.3% CP) | -- | 59.09 | 60.26 | 59.04 | 59.09 | 59.09 | 59.09 | 59.04 |
| Soybean ml (47.5% CP) | 17.99 | -- | -- | -- | -- | -- | -- | -- |
| Dehy. alfalfa ml (17.5% CP) | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| Animal fat | -- | 2.50 | 1.15 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| Soybean oil | -- | 1.25 | 3.25 | 1.25 | 1.25 | 1.25 | 1.25 | 1.25 |
| Yeast culture[1] | -- | -- | -- | .05 | -- | -- | -- | .05 |
| Defluo. phos. (32% Ca; 18% P) | 2.00 | 1.97 | 2.00 | 1.97 | 1.97 | 1.97 | 1.97 | 1.97 |
| Limestone flour | 3.65 | 3.39 | 3.70 | 3.39 | 3.39 | 3.39 | 3.39 | 3.39 |
| Oystershell, ground | 3.00 | 3.37 | 3.30 | 3.37 | 3.37 | 3.37 | 3.37 | 3.37 |
| Salt (iodized) | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 |
| Trace mineral premix[2] | .05 | .05 | .05 | .05 | .05 | .05 | .05 | .05 |
| Vitamin premix[3] | .20 | .20 | .20 | .20 | .20 | .20 | .20 | .20 |
| d,1-methionine (98%) | .05 | .26 | .26 | .26 | .26 | .26 | .26 | .26 |
| Choline premix (50%) | -- | -- | -- | -- | .03 | -- | .03 | .03 |
| Biotin premix (22%)[4] | -- | -- | -- | -- | -- | .05 | .05 | .05 |
| Calculated Analyses: | | | | | | | | |
| Crude protein (%) | 15.2 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 | 15.3 |
| Crude protein (analyzed) (%) | 14.0 | 14.4 | 14.2 | 14.0 | 14.2 | 14.3 | 14.1 | 14.3 |
| Met. energy (kcal/kg) | 2833 | 2833 | 2833 | 2833 | 2833 | 2833 | 2833 | 2833 |
| Calcium (%) | 3.28 | 3.28 | 3.30 | 3.28 | 3.28 | 3.28 | 3.28 | 3.28 |
| Avail. phos. (%) | .47 | .46 | .47 | .46 | .46 | .46 | .46 | .46 |
| Methionine (%) | .31 | .35 | .34 | .35 | .35 | .35 | .35 | .35 |
| Meth. and cystine (%) | .57 | .57 | .57 | .57 | .57 | .57 | .57 | .57 |
| Tryptophan (%) | .19 | .16 | .15 | .16 | .15 | .16 | .16 | .16 |
| Linoleic acid (%) | 1.30 | 1.40 | 1.36 | 1.40 | 1.40 | 1.40 | 1.40 | 1.40 |
| Choline (mg/kg) | 1128 | 755 | 784 | 757 | 863 | 755 | 863 | 863 |
| Biotin (mg/kg) | .126 | .137 | .143 | .138 | .138 | .248 | .248 | .248 |
| Lysine (%) | .71 | 1.02 | 1.05 | 1.02 | 1.02 | 1.02 | 1.02 | 1.02 |

[1]Mineral premix provided per kilogram of diet: Calcium, 97.5 mg; manganese, 60 mg; zinc, 27.5 mg; copper, 2 mg; iron, 20 mg; iodine, 1.2 mg; cobalt, .2 mg.

[2]Vitamin premix provided per kilogram of diet: Vitamin A, 3300 IU; Vitamin D3, 1100 ICU; riboflavin, 3.3 mg; d-pantothenic acid, 5.5 mg: niacin, 22 mg; choline, 190.9 mg; vitamin K, .55 mg; vitamin E, 1.1 IU; vitamin B12, 5.5 mcg; folic acid, .22 mg; ethoxyquin, 60 mg.

[3]Gratuitously provided by Diamond V Mills, Inc., Cedar Rapids, IA.

[4]Gratuitously provided by Roche Chemical Division, Hoffmann-La Roche, Inc., Nutley, NJ.

## Results and Discussion

Treatment effects ($P < .05$) were detected for production of larger eggs and decreased shell thickness in pullets fed the 60% YP diet in Experiment 2 (Table 4). Treatment (T) × period (P) interactions ($P < .05$) were observed for the medium and small egg category, mean egg weights and egg yolk color in Experiment 2 (Tables 4 and 5) and egg shell quality in Experiment 1 (Table 6).

No T × P interactions ($P > .05$) and no treatment effects ($P > .05$) were observed on mean hen-day egg production, feed conversion (based on per dozen eggs and egg mass), daily feed consumption, and egg mass (number eggs × egg weight) for both experiments (Tables 4 and 6), and internal egg quality and mean body weight gain (Table 4) in Experiment 2. A T × P interaction ($P < .05$) were observed for internal egg quality, mean body weight, and mean egg weight in Experiment 1 (Tables 6, 7 and 8), however, no detectable differences were found between treatments across the different periods due to the large number of degrees of freedom involved in the statistical analysis. Cumulative mortality (Tables 4 and 6) was low for pullets on all the dietary treatments in both experiments; therefore, this parameter was not statistically analyzed.

The results for mean hen-day egg production, feed conversion, daily feed consumption, and mean body weight gain in the present study (Tables 4, 6 and 7), are in agreement with earlier experiments where 30% white-flowered YP diets supplemented with methionine were fed to laying hens (Andersson, 1979; Askbrant and Hakansson, 1984). However, Moran *et al.* (1968) and Davidson (1980) observed that feed conversion was better ($P < .05$) for hens fed a CS (control) diet compared to that of hens fed a diet containing 30% peas.

**Table 4.** The effects of feeding diets containing 0 and 60% yellow pea (YP) and 60% YP supplemented either alone or with combinations of 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% choline-chloride (CH) or 0.05% biotin (BN) to Dekalb XL Single Comb White Leghorn laying pullets for eight 28-day periods on hen-day (H-D) egg production, feed conversion (based on per dozen eggs and egg mass), daily feed consumption, mean body weight gain, egg mass, egg shell quality (specific gravity), internal egg quality (Haugh units), egg size, egg yolk color and cumulative mortality (Experiment 2).

| Dietary Treatments (%) | | | | | | | | | | | | | Egg Size[1] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | SO | YC | CH | BN | H-D Egg Prod (%)[1] | Feed Conv (kg/dz)[1] | Feed Conv (g/Egg mass)[1] | Calc. Daily Feed Cons Bird/day)[1] | Mean Body Weight Gain (g)[1] | Egg Mass (1,2) | Egg Shell Qual. (Spec. Grav.)[1] | Intern. Egg Qual (H.U.)[1] | > Large (%)[3] | < Medium (70 WOA) (%)[4] | Egg Yolk Color (58 WOA) (1,5) | Cum. Mort.[6] (Died/Total) |
| 0 | - | - | - | - | 82 | 1.58 | 2.24 | 108 | 108 | 48.3 | 1.0795a | 81.5 | 62.4a | 27.2a | 9.4a | 1/96 |
| 60 | - | - | - | - | 80 | 1.64 | 2.26 | 109 | 106 | 48.5 | 1.0754b | 78.2 | 87.6b | 11.4b | 7.4b | 0/96 |
| 60 | 3.25 | - | - | - | 79 | 1.65 | 2.25 | 107 | 119 | 48.0 | 1.0753b | 78.8 | 89.3b | 9.2b | 6.5c | 0/96 |
| 60 | - | 0.05 | - | - | 82 | 1.61 | 2.20 | 109 | 88 | 49.8 | 1.0754b | 79.5 | 87.3b | 11.5b | 7.4b | 0/96 |
| 60 | - | - | 0.025 | - | 80 | 1.63 | 2.18 | 109 | 32 | 50.0 | 1.0745b | 80.6 | 93.6b | 4.4b | 7.6b | 1/96 |
| 60 | - | - | - | 0.05 | 81 | 1.65 | 2.23 | 111 | 79 | 49.8 | 1.0754b | 78.7 | 87.1b | 11.5b | 7.8b | 1/96 |
| 60 | - | - | 0.025 | 0.05 | 81 | 1.62 | 2.20 | 108 | 83 | 49.4 | 1.0745b | 79.1 | 89.5b | 8.9b | 7.8b | 4/96 |
| 60 | - | 0.05 | 0.025 | 0.05 | 81 | 1.66 | 2.23 | 112 | 135 | 50.3 | 1.0739b | 79.3 | 89.9b | 8.3b | 8.3b | 0/96 |
| SE[7] | | | | | 2 | 0.04 | 0.05 | 3 | 35 | 1.4 | 0.0006 | 1.5 | 3.3 | 3.4 | 0.3 | |

[1] Mean values in each column with different letters are significantly different ($P < .05$).
[2] Percentage production > average egg weight.
[3] Jumbo + extra large size eggs.
[4] Medium + small size eggs.
[5] Egg yolk color based on Roche color fan: 14 = dark orange; 1 = light pale yellow.
[6] Mortality data were not statistically analyzed.
[7] Standard error of the means.
WOA = Weeks of age.

Table 5. The effects of feeding diets containing 0 and 60% yellow pea (YP) and 60% YP supplemented either alone or with combinations of 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% choline-chloride (CH) or 0.05% biotin (BN) to Dekalb XL Single Comb White Leghorn laying pullets for eight 28-day periods on mean egg weight (Experiment 2).

| Dietary Treatments (%) | | | | | Mean Egg Weights (g)[1,2] Weeks of Age (Period) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | SO | YC | CH | BN | 42(1) | 46(2) | 50(3) | 54(4) | 58(5) | 62(6) | 66(7) | 70(8) |
| 0 | - | - | - | - | $58.8^a$ | $58.9^a$ | $59.1^a$ | $59.5^a$ | $59.0^a$ | $59.0^a$ | $58.5^a$ | $56.9^a$ |
| 60 | - | - | - | - | $60.1^a$ | $60.3^b$ | $61.0^b$ | $61.1^b$ | $61.2^b$ | $61.1^b$ | $61.0^b$ | $60.6^b$ |
| 60 | 3.25 | - | - | - | $59.7^a$ | $60.6^b$ | $61.2^b$ | $61.4^b$ | $61.5^b$ | $60.9^b$ | $62.0^b$ | $61.5^b$ |
| 60 | - | 0.05 | - | - | $60.6^a$ | $60.7^b$ | $60.6^b$ | $61.1^b$ | $60.4^b$ | $61.4^b$ | $62.1^b$ | $61.6^b$ |
| 60 | - | - | 0.025 | - | $61.2^a$ | $61.3^b$ | $62.1^b$ | $62.1^b$ | $62.0^b$ | $62.7^b$ | $64.5^b$ | $62.7^b$ |
| 60 | - | - | - | 0.05 | $61.0^a$ | $60.7^b$ | $61.2^b$ | $61.8^b$ | $62.1^b$ | $62.3^b$ | $62.7^b$ | $61.4^b$ |
| 60 | - | - | 0.025 | 0.05 | $59.8^a$ | $60.3^b$ | $61.4^b$ | $62.2^b$ | $61.8^b$ | $62.0^b$ | $61.6^b$ | $61.1^b$ |
| 60 | - | 0.05 | 0.025 | 0.05 | $60.8^a$ | $61.3^b$ | $61.6^b$ | $61.9^b$ | $62.2^b$ | $62.0^b$ | $62.9^b$ | $62.6^b$ |
| SE[3] | | | | | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |

[1]Mean values in each column with different letters are significantly different ($P < .05$).
[2]Period by treatment interaction.
[3]Standard error of the means for treatments within periods.

**Table 6.** The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets for nine 28-day periods on hen-day (H-D) egg production, feed conversion (based on per dozen eggs and egg mass), daily feed consumption, egg mass, internal egg quality (Haugh units), egg size, egg yolk color and cumulative mortality (Experiment 1).

| Dietary Treatments (%) | | | H-D Egg Prod (%)[1] | Feed Conv (kg /dz)[1] | Feed Conv Egg mass)[1] | Calc. Daily Feed Cons (g/Bird/ day)[1] | Egg Mass[1,2] | Intern. Egg Qual (H.U.)[1] | Egg Size[1] | | Egg Yolk Color (58 WOA) (1,5) | Cum. Mort. (Died/ Total)[6] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | FM | MB | | | | | | | > Large (%)[3] | < Medium (70 WOA) (%)[4] | | |
| 0 | - | - | 87.7 | 1.53 | 2.20 | 112 | 50.8 | 74.5 | 77.7 | 22.3 | 9.2[a] | 4/96 |
| 15 | - | - | 85.2 | 1.55 | 2.24 | 110 | 49.2 | 70.2 | 76.1 | 23.9 | 7.7[c] | 1/96 |
| 30 | - | - | 86.5 | 1.51 | 2.20 | 109 | 49.5 | 74.1 | 78.1 | 21.9 | 7.7[c] | 2/96 |
| 45 | - | - | 86.3 | 1.56 | 2.21 | 111 | 50.2 | 72.6 | 79.7 | 20.3 | 8.0[c] | 1/96 |
| 60 | - | - | 84.2 | 1.56 | 2.24 | 109 | 48.8 | 73.5 | 82.1 | 17.9 | 8.0[c] | 1/96 |
| 45 | - | 5 | 88.0 | 1.50 | 2.15 | 110 | 51.1 | 71.4 | 81.2 | 18.8 | 7.9[c] | 0.96 |
| 45 | 2 | 1.5 | 84.3 | 1.53 | 2.21 | 107 | 48.5 | 70.7 | 77.9 | 22.1 | 8.0[c] | 2/96 |
| 0 | 2 | 5 | 85.1 | 1.52 | 2.20 | 108 | 49.2 | 71.9 | 80.1 | 19.9 | 8.7[b] | 3/96 |
| SE[7] | | 2 | 1.6 | 0.03 | 0.03 | 2 | 1.1 | 1.5 | 2.6 | 2.6 | 0.2 | |

[1] Mean values in each column with different letters are significantly different ($P < .05$).
[2] Percentage production x average egg weight.
[3] Jumbo + extra large + large size eggs.
[4] Medium + small size eggs.
[5] Egg yolk color based on Roche color fan: 14 = dark orange; 1 = light pale yellow.
[6] Mortality data were not statistically analyzed.
[7] Standard error of the means.
WOA = Weeks of age.

**Table 7.** The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets on mean body weight gain at the end of periods 1, 4, 7 and 9 (Experiment 1).

| Dietary Treatments (%) | | | Mean Body Weight Gain (g)[1,2] Weeks of Age (Period) | | | |
|---|---|---|---|---|---|---|
| YP | FM | MB | 26(1) | 38(4) | 50(7) | 62(9) |
| 0 | - | - | 38 | 80 | 180 | 263 |
| 15 | - | - | 80 | 148 | 215 | 250 |
| 30 | - | - | 23 | 160 | 215 | 260 |
| 45 | - | - | 47 | 262 | 385 | 442 |
| 60 | - | - | 23 | 238 | 317 | 363 |
| 45 | - | 5 | 25 | 205 | 373 | 305 |
| 45 | 2 | 1.5 | 82 | 228 | 327 | 263 |
| 0 | 2 | 5 | 70 | 160 | 238 | 260 |
| SE[3] | | | 47 | 47 | 47 | 47 |

[1]Mean values in each column are not significantly different (P > .05).
[2]Period by treatment interaction.
[3]Standard error of the means for treatments within periods.

Table 8. The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets for nine 28-day periods on mean egg weight (Experiment 1).

| Dietary Treatments (%) | | | Mean Egg Weights (g)[1,2] Weeks of Age (Period) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | FM | MB | 26(1) | 30(2) | 34(3) | 38(4) | 42(5) | 46(6) | 50(7) | 54(8) | 58(9) |
| 0 | - | - | 53.3 | 55.1 | 56.7 | 57.6 | 58.4 | 59.0 | 59.5 | 59.9 | 60.9 |
| 15 | - | - | 52.8 | 54.8 | 55.9 | 56.9 | 58.2 | 59.4 | 60.2 | 60.1 | 61.5 |
| 30 | - | - | 52.8 | 54.5 | 56.1 | 57.1 | 57.6 | 58.1 | 59.1 | 59.5 | 60.6 |
| 45 | - | - | 53.4 | 55.4 | 56.6 | 57.9 | 58.6 | 59.5 | 60.0 | 60.9 | 61.5 |
| 60 | - | - | 52.9 | 54.8 | 56.1 | 57.9 | 58.6 | 59.3 | 60.5 | 60.7 | 61.2 |
| 45 | - | 5 | 52.7 | 55.1 | 56.6 | 58.1 | 58.8 | 59.5 | 60.3 | 60.4 | 60.8 |
| 45 | 2 | 1.5 | 52.2 | 54.0 | 55.9 | 57.0 | 58.6 | 59.3 | 60.1 | 60.2 | 61.0 |
| 0 | 2 | 5 | 53.1 | 54.7 | 55.9 | 57.3 | 58.7 | 59.3 | 59.9 | 59.9 | 61.0 |
| SE[3] | | | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |

[1]Mean values in each column are not significantly different (P > .05).
[2]Period by treatment interaction.
[3]Standard error of the means for treatments within periods.

Some studies have shown that anti-nutritional factors depress ($P < .05$) egg production in laying pullets (Nguen-Ngi, 1964; Davidson 1980, Davidson *et al.*, 1981). However, in the current study, feeding diets containing 15, 30, 45, and 60% YP had no detrimental effect ($P > .05$) on hen-day egg production (Tables 4 and 6). The difference in egg production with the various studies may be due to the variety of peas used in these experiments (Miranda variety: spring type, white-flowered smooth seeded pea) compared to colored-flowered peas used in the earlier experiments of Davidson *et al.* (1981). A high variability in the nutritional value for poultry exist for the different varieties of peas Bajaj *et al.* (1971). The tannin content is lower for white-flowered peas than for colored-flowered peas (Griffiths, 1983; Muehlbauer, 1989). Lindgren (1975) observed a negative correlation ($P < .05$) between the tannin content and protein digestibility, with the white-flowered variety having the highest nutritive value of the peas tested. Davidson *et al.* (1981) observed a marked decrease ($P < .01$) in egg production and feed conversion when colored-flowered peas were fed to laying hens. Spring varieties of smooth seed type peas have lower trypsin-inhibiting activity than winter type peas (Grosjean, 1985) and a higher content of sulfur amino acids than the wrinkled seed peas (Pate, 1977; Pate and Flinn, 1977; Boulter, 1983; Casey, 1983; Casey and Domoney, 1985). More recently, Savage *et al.* (1986) and Kulkarni (1987), working with growing turkeys and broilers, respectively, did not find antinutritional effects by feeding the Miranda variety of peas.

Marked reductions in egg production (8 and 47%) were observed when 30 and 38% raw pea diets (respectively, Nguen-Ngi, 1964; Davidson, 1980) were fed without methionine supplementation. Normal egg production (79%) was attained with 0.2% methionine supplementation to a 38% raw pea diet (Davidson, 1980). Methionine and total sulfur amino acid levels for all treatments in the present study

(Tables 1 and 3) were in accordance with the minimum requirement levels for Leghorn-type pullets (NRC, 1984).

The incorporation of 2% FM and either 1.5% or 5% MB to the 45% YP and CS diets (Experiment 1) and 0.05% yeast culture to the 60% YP diet (Experiment 2) did not affect ($P > .05$) body weight gain or daily feed consumption (Tables 4, 6 and 7). Davidson (1980) and Davidson *et al.* (1981) found marked increases ($P < .05$) in feed intake and body weight gain by hens fed a 10% fish meal supplemented diet compared to pullets fed a pea diet. The differences in body weight of birds fed the different diets were probably due to the antinutritional factors in peas.

From period 2 (46 WOA) to period 8 (end of the experiment, 70 WOA) in Experiment 2 (Table 5), pullets fed the CS diet produced more ($P < .05$) smaller eggs than the pullets fed the 60% YP diets. A marked increase ($P < .05$) in larger eggs (jumbo, extra large and large eggs) was obtained in Experiment 2 for pullets fed the 60% YP diets (Table 4). Egg size was not affected ($P > .05$) by dietary treatments (Experiment 1, Table 6). However, when the 60% YP diet was fed the production of large eggs approached significance ($P < .06$) compared to diets of pullets fed the other diets.

The increases in egg size in these studies are corroborated by a decrease ($P < .05$) in egg shell quality in both experiments (Tables 4 and 9). Thinner ($P < .05$) egg shells (shell quality) were observed in pullets fed a 60% YP diet when compared to diets containing 0, 15, and 45% YP diets. In Experiment 1, a significant $T \times P$ interaction was observed for the shell quality (Table 9), with pullets fed the 60% YP diet at the end of periods 4 (38 WOA), 7 (50 WOA) and 9 (58 WOA) having significantly thinner shells. However, this interaction was not observed in Experiment 2 due to the difference in age at the start of the experiment (38 WOA for Experiment 2 versus 22 WOA in Experiment 1). As the laying hen ages, egg size

**Table 9.** The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets on mean egg shell quality at the end of periods 1, 4, 7 and 9 (Experiment 1).

| Dietary Treatments (%) | | | Mean Egg Shell Quality (specific gravity)[1,2] Weeks of Age (Period) | | | |
|---|---|---|---|---|---|---|
| YP | FM | MB | 26(1) | 38(4) | 50(7) | 62(9) |
| 0 | - | - | 1.0855[a] | 1.0822[a] | 1.0789[a] | 1.0728[a] |
| 15 | - | - | 1.0851[a] | 1.0808[a] | 1.0782[a] | 1.0721[a] |
| 30 | - | - | 1.0850[a] | 1.0817[a] | 1.0791[a] | 1.0733[a] |
| 45 | - | - | 1.0855[a] | 1.0806[a] | 1.0771[a] | 1.0718[a] |
| 60 | - | - | 1.0843[a] | 1.0789[b] | 1.0748[b] | 1.0679[b] |
| 45 | - | 5 | 1.0856[a] | 1.0804[a] | 1.0768[a] | 1.0709[a] |
| 45 | 2 | 1.5 | 1.0850[a] | 1.0807[a] | 1.0768[a] | 1.0704[a] |
| 0 | 2 | 5 | 1.0853[a] | 1.0811[a] | 1.0780[a] | 1.0728[a] |
| SE[3] | | | 0.0007 | 0.0007 | 0.0007 | 0.0007 |

[1]Mean values in each column with different letters are significantly different ($P < .05$).
[2]Period by treatment interaction.
[3]Standard error of the means for treatments within periods.

increases while shell thickness decreases because calcium absorption and retention decreases with age, yet a constant amount of calcium is deposited in the egg shell throughout the hen's laying cycle (Roland *et al*., 1975; Washburn, 1982).

A further increase ($P < .05$) in egg weight was observed for the pullets fed the 60% YP diet supplemented with 125 mg/kg choline (period 7, Table 5) compared with the other dietary treatments in Experiment 2. However, the increase in egg weight due to dietary choline was an isolated case and not a recurring effect from the dietary treatment. Most likely it was a chance effect. Furthermore, the effect of choline on size and weight of eggs has been controversial. Earlier research has demonstrated that choline supplementation in practical laying rations deficient in methionine and total sulfur amino acids resulted in an increase ($P < .05$) in egg size, egg weight, egg production, daily feed consumption, body weight gain and improved feed conversion (Griffith *et al*., 1969; Nesheim *et al*., 1971; Tsiagbe *et al*., 1982; Brooks and Creger, 1983; Parsons and Leeper, 1984). Moreover, Keshavarz and Austic (1985), and Miles *et al*. (1986) observed that in laying rations deficient in total sulfur amino acids, choline supplementation may improve the rate of egg production, but not increase the size and weight of eggs, and that only methionine supplementation can increase the weights of eggs under these conditions. Scott *et al*. (1982) reported that purified diets essentially devoid of choline failed to produce a marked choline deficiency, and concluded that the laying hen is capable of synthesizing considerable amounts of choline.

Also, an age factor should be noted as influencing the need for choline by poultry. Christmas and Harms (1987) found that methionine and/or choline may be reduced without detrimental effect to the final body weight of growing pullets, especially in the later stages of growth. In Experiment 2, the calculated choline concentration in all diets ranged from 750 to 1128 mg/kg. These levels are all minimum requirement (500 mg/kg) for Leghorn-type laying pullets at the onset of egg production (NRC, 1984).

The inclusion of vegetable oils rich in linoleic acid in the diet of laying hens has proven to be an effective way of increasing egg size (Jensen *et al.*, 1958; Shutze and Jensen, 1963; Menge *et al.*, 1965; Balnave and Brown, 1968; Whitehead, 1981; Balnave, 1982, 1987). Menge *et al.* (1965) observed a proportional increase ($P < .05$) in egg weight with increasing levels of dietary linoleic acid from 10 to 250 mg/day in SCWL laying pullets fed linoleic depleted diets. However, no effect ($P > .05$) on the size of eggs from hens fed diets containing 60% YP and supplemented with 3.25% soybean oil (rich source of linoleic acid) was observed (Experiment 2, Table 5). Research has indicated that increases in egg weight caused by supplementation of diets with linoleic acid were most pronounced during early egg production when pullets were less than 38 WOA (Shutze *et al.*, 1962; Sell *et al.*, 1987). In Experiment 2, the starting age of the pullets was 38 WOA.

Other factors such as protein intake or metabolizable energy (ME) are the next limiting factors which determine egg size (Harms and Waldroup 1963; Menge *et al.*, 1965; Balnave, 1970) after the requirement for linoleic acid (1% of diet; Balnave, 1970) has been met. The lower protein content in YP used in the present experiment (21.1%) compared to soybean meal (47.5%) and the low level of crude protein determined for the 60% YP diets (14%, or one unit less than the control diet, Experiment 2, Table 3) suggest that protein is not an important factor in determining egg size. On the other hand, the increase in the energy intake in the present study cannot be ruled out. The metabolizable energy of the various diets in the present experiments were based on calculated values obtained from published ME values of the various feedstuffs. Probably the actual ME levels of the 60% YP diets were greater than the CS diets and proportionally higher than the 15, 30 and 45% YP diets in Experiment 1.

The selective consumption by the SCWL laying pullets of the more energy rich part of the grain (oats) has also been mentioned as a mean by which birds may increase their energy intake in isocaloric diets (Shutze *et al.*, 1962). Blamberg *et al.* (1964) fed diets containing 1.4% of linoleic acid (approximately the same level used in the present study, Table 3) and obtained a greater effect on egg weight with increased levels of ME than with linoleic acid intake. Summers *et al.* (1988) observed a reduction in egg size due to reduced energy intake with canola-meal-supplemented laying diets.

Albumen consistency and Haugh units (internal egg quality) were affected by the tryptophan level in the diet (Butts and Cunningham, 1972). Although peas are generally low in tryptophan (Muehlbauer *et al.*, 1983), the Haugh unit values in the present study were not affected by the different levels of YP in the diets. These findings are corroborated by Andersson (1979), who reported no significant difference in Haugh units from eggs with pullets fed 30% raw pea diets. The calculated values of tryptophan on all treatments (Tables 1 and 3) were above the minimum (0.14% of diet) requirement for laying Leghorn-type pullets (NRC, 1984).

The low biotin requirement (30 mcg available biotin/kg diet) for Leghorn-type pullets (Whitehead, 1977, 1984), and the lower female requirements for biotin (10 mcg lower than male chicks, Frigg, 1984) can be the reason that no differences ($P > .05$) were observed for biotin supplementation (0.05%, or 0.11 mg/kg) in the various dietary treatments in Experiment 2. The biotin level of all diets (Experiment 2, Table 3) were above the minimum requirement (0.10 mg/kg diet) for Leghorn-type laying pullets (NRC, 1984).

Pullets fed YP diets produced egg yolks which had a lighter ($P < .05$) yellow color than in egg yolks from pullets fed the CS diet from 58 WOA (Tables 4 and 6). The lighter yolk color observed in the YP diets (Tables 4 and 6) strictly depends on the amount of corn in the ration and, therefore, the level of xanthophyll in the YP diets. This finding is corroborated by a further decrease ($P < .05$) in yolk color observed in the soybean oil supplemented 60% YP diet (Table 4), which had the lowest percentage of corn among the various diets in this study (Tables 1 and 3).

White-flowered yellow peas can be incorporated in laying diets up to 60% and fed to laying pullets without affecting their performance. The eggs were larger with thinner egg shell and lighter yolk color than eggs obtained from pullets fed the corn-soy diet.

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# CHAPTER IV

# CONCLUSIONS

Feeding a diet containing 45% yellow pea to Dekalb XL SC White-Leghorn laying pullets did not affect hen-day egg production, daily feed consumption, feed conversion, body weight gain, egg shell quality and internal egg quality in either of the experiments conducted for this study. Pullets, 46 WOA and older, fed 60% YP diets produced significantly heavier and larger eggs with marked thinner shells than pullets fed a CS diet.

The supplementation of choline, biotin and soybean oil (linoleic acid) in laying diets (Experiment 2) was ineffective in improving egg production and the size of eggs when the minimum requirement for these nutrients were met. Supplementing a 45% YP and CS diets with 2% FM and/or 1.5 or 5% MB (Experiment 1) and supplementing a 60% YP diet with 0.05% yeast culture (Experiment 2), had no effects ($P > .05$) upon production and egg parameters. Pullets fed corn-soy diets produced eggs with a darker yolk ($P < .05$) color than eggs from pullets fed YP diets.

These studies indicate that YP (*Pisum sativum L.* var. Miranda, white-flowered, smooth-seed-coat peas) can replace all the soybean meal protein (60% YP in diet) in practical laying diets without affecting production performance of SCWL laying pullets. Egg produced from laying pullets fed 60% YP diets were markedly larger than those from pullets fed diets with 0%, 15%, 30% and 45% of YP. This provides an economic advantage for egg producers.

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# APPENDIX

## APPENDIX

The following data provide more information regarding the experiments. Enclosed are mean square summaries for treatment, period and treatment by period interactions for all parameters studied in both experiments, along with the statistical analyses for egg grade size (jumbo, extra large, large, medium and small eggs), mean body weight and egg yolk color for Experiment 1 and Experiment 2. Data on internal egg quality for Experiment 1 are also included.

**Table A1.** Mean square summary for treatment (T), period (P) and T× P interaction of the hen-day (H-D) egg production, daily feed consumption, food conversion (based on per dozen eggs and egg mass), egg mass, egg size, and mean egg weight (Experiment 1).

| Source of Variation | Deg. of Free. | H-D Egg Prod | Daily Feed Cons | Food Conv | Food Conv | Egg Mass | Egg Size ≥ Large[1] | Egg Size ≤ Medium | Egg Weight | Mean Jumbo Eggs | Large Eggs | Extra Large Eggs | Medium Eggs | Small Eggs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (%) | g/bird /day | kg /doz | g/egg mass | % Prod× Egg Wt | (%) | (%) | (%) | (%) | (%) | (%) | (%) | (%) |
| Treatment (T) | 7 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Period (P) | 8 | * | * | * | * | * | * | * | * | * | * | * | * | * |
| P > T | 56 | NS | NS | NS | NS | NS | NS | NS | * | NS | NS | NS | NS | * |
| Error (a) | 21 | $.47\times10^2$ | $.59\times10^2$ | $.13\times10^{-1}$ | $.20\times10^{-1}$ | $.20\times10^2$ | $.12\times10^3$ | $.12\times10^3$ | $.38\times10$ | $.16\times10^2$ | $.13\times10^3$ | $.21\times10^3$ | $.88\times10^2$ | $.99\times10$ |
| Error (b) | 192 | $.93\times10$ | $.65\times10$ | $.33\times10^{-2}$ | $.56\times10^{-2}$ | $.33\times10$ | $.28\times10^2$ | $.28\times10^2$ | $.24\times10$ | $.42\times10$ | $.30\times10^2$ | $.55\times10$ | $.27\times10^2$ | $.30\times10$ |

[1]Jumbo + extra large + large size eggs.

[2]Medium + small size eggs.

NS = not significant.

* = significant to 5% level.

**Table A2.** Mean square summary for treatment (T), period (P), and T > P interaction of egg shell quality, egg yolk color, internal egg quality, mean body weight gain, and mean body weight (Experiment 1).

| Source of Variation | Degrees of Freedom | | Egg Shell Qlty. | Egg Yolk Color[1] | Int. Egg Qlty. | Mean Body Weight Gain | Mean Body Weight |
|---|---|---|---|---|---|---|---|
| | DF[2] | DF[3] | Grav. | | H.U. | g | g |
| Treatment (T) | 7 | 7 | * | * | NS | NS | NS |
| Period (P) | 3 | 4 | * | * | * | * | * |
| P× T | 21 | 28 | * | * | * | * | * |
| Error (a) | 21 | 21 | $.34\times10^{-5}$ | .11 | $.86\times10$ | $.19\times10^{5}$ | $.32\times10^{-1}$ |
| Error (b) | 72 | 96 | $.60\times10^{-6}$ | $.90\times10^{-1}$ | $.44\times10$ | $.26\times10^{4}$ | $.29\times10^{-2}$ |

[1]Eggs yolk color based on Roche color fan: 14 = dark orange; 1 = light pale yellow.
[2]Degrees of freedom for egg shell quality, egg yolk color, internal egg quality, and mean body weight gain.
[3]Degrees of freedom for mean body weight.
NS = not significant.
* = significant to 5% level.
H.U. = Haugh units.

**Table A3.** Mean square summary for treatment (T), period (P), and T > P interaction of hen-day (H-D) egg production, daily feed consumption, feed conversion (based on per dozen eggs and egg mass), egg mass, and mean egg weight (Experiment 2).

| Source of Variation | Degrees of Free. | H-D Egg Prod. | Daily Feed Cons. | Feed Conv. | Feed Conv. | Egg Mass | Mean Egg Weight |
|---|---|---|---|---|---|---|---|
| | | % | g/bird /day | kg /doz. | g/egg mass | % prod. x egg wt. | % |
| Treatment (T) | 7 | NS | NS | NS | NS | NS | * |
| Period (P) | 7 | * | * | * | * | * | * |
| P× T | 49 | NS | NS | NS | NS | NS | * |
| Error (a) | 21 | $.63\times10^{2}$ | $.99\times10^{2}$ | $.30\times10^{-1}$ | $.39\times10^{-1}$ | $.29\times10^{2}$ | $.77\times10$ |
| Error (b) | 168 | $.11\times10^{2}$ | $.67\times10$ | $.49\times10^{-2}$ | $.87\times10^{-2}$ | $.41\times10$ | .48 |

NS = not significant.
* significant to 5% level.

**Table A4.** Mean square summary for treatment (T), period (P), and T × P interaction of egg size, egg shell quality, egg yolk color, internal egg quality, mean body weight gain and mean body weight (Experiment 2).

| Source of Variation | Degrees of Freedom | | | > Large[1] | < Medium[2] | Egg Size Jumbo | Extra Large | Large | Medium | Small | Egg Shell Qlty. | Egg Yolk Color[6] | Int. Egg Qlty. | Mean Body Weight Gain | Mean Body Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DF[3] | DF[4] | DF[5] | (%) | (%) | (%) | (%) | (%) | (%) | (%) | Spec. Grav. | | H.U. | g | g |
| Treatment (T) | 7 | 7 | 7 | • | • | NS | NS | NS | • | • | • | • | NS | NS | NS |
| Period (P) | 6 | 2 | 3 | • | • | • | NS | • | • | NS | • | NS | • | • | • |
| P × T | 42 | 14 | 21 | NS | • | • | NS | NS | • | NS | NS | • | NS | NS | NS |
| Error (a) | 21 | 21 | 21 | $.15\times10^3$ | $.16\times10^3$ | $.73\times10^2$ | $.48\times10^3$ | $.40\times10^3$ | $.10\times10^3$ | $.15\times10^2$ | $.23\times10^{-5}$ | .17 | $.14\times10^2$ | $.74\times10^4$ | $.16\times10^{-1}$ |
| Error (b) | 144 | 48 | 72 | $.21\times10^2$ | $.16\times10^2$ | $.77\times10$ | $.43\times10^2$ | $.44\times10^2$ | $.16\times10^2$ | $.19\times10$ | $.90\times10^{-6}$ | .17 | $.83\times10$ | $.20\times10^4$ | $.21\times10^{-1}$ |

[1]Jumbo + extra large + large size eggs.
[2]Medium + small size eggs.
[3]Degrees of freedom for grade size eggs.
[4]Degrees of freedom for egg shell quality, egg yolk color, internal egg quality, and mean body weight gain.
[5]Degrees of freedom for mean body weight.
[6]Eggs yolk color based on Roche color fan: 14 = dark orange; 1 = light pale yellow.
NS = not significant.
• = significant to 5% level.
H.U. = Haugh units.

**Table A5.** The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets for nine 28-day periods on jumbo, extra large, large and medium size eggs (Experiment 1).

| Dietary Treatments (%) | | | Egg Size (percent)[1] | | | |
|---|---|---|---|---|---|---|
| YP | FM | MB | Jumbo | Ex. Large | Large | Medium |
| 0 | - | - | 1.9 | 18.0 | 57.9 | 21.0 |
| 15 | - | - | 2.1 | 20.0 | 54.1 | 22.7 |
| 30 | - | - | 1.3 | 15.8 | 61.0 | 19.8 |
| 45 | - | - | 2.8 | 20.1 | 56.9 | 19.3 |
| 60 | - | - | 2.1 | 15.5 | 64.5 | 17.3 |
| 45 | - | 5 | 2.1 | 18.4 | 60.7 | 16.5 |
| 45 | 2 | 1.5 | 1.0 | 18.0 | 58.9 | 20.0 |
| 0 | 2 | 5 | 1.6 | 17.4 | 61.2 | 19.1 |
| SE[2] | | | 1.0 | 2.7 | 3.4 | 2.2 |

[1]Mean values in each column are not significantly different (P > .05).
[2]Standard error of the means.

**Table A6.** The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets for nine 28-day periods on small eggs (Experiment 1).

| Dietary Treatments (%) | | | Small Eggs (%)[1,2] Weeks of Age (Period) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | FM | MB | 26(1) | 30(2) | 34(3) | 38(4) | 42(5) | 46(6) | 50(7) | 54(8) | 58(9) |
| 0 | - | - | 5.2 | 3.4 | 2.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.4 |
| 15 | - | - | 4.9 | 0.8 | 2.4 | 0.0 | 0.9 | 0.4 | 0.0 | 0.5 | 1.2 |
| 30 | - | - | 4.7 | 3.0 | 4.5 | 0.8 | 1.9 | 1.6 | 1.6 | 0.0 | 0.0 |
| 45 | - | - | 4.5 | 2.2 | 0.8 | 0.8 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 |
| 60 | - | - | 2.8 | 1.1 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 45 | - | 5 | 7.7 | 3.8 | 2.3 | 1.5 | 1.6 | 2.0 | 0.0 | 0.8 | 1.2 |
| 45 | 2 | 1.5 | 12.1 | 2.7 | 2.4 | 0.9 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 |
| 0 | 2 | 5 | 4.3 | 1.1 | 0.8 | 0.0 | 0.4 | 0.0 | 0.0 | 0.4 | 0.0 |
| SE[3] | | | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |

[1]Mean values in each column are not significantly different (P > .05).
[2]Treatments by period interaction.
[3]Standard error of the means for treatments within periods.

**Table A7.** The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets on mean body weight at the beginning of the experiment and at the end of periods 1, 4, 7 and 9 (Experiment 1).

| Dietary Treatments (%) | | | Mean Body Weight (kg)[1,2] Weeks of Age (Period) | | | | |
|---|---|---|---|---|---|---|---|
| YP | FM | MB | 22(0) | 26(1) | 38(4) | 50(7) | 62(9) |
| 0 | - | - | 1.51 | 1.54 | 1.59 | 1.69 | 1.77 |
| 15 | - | - | 1.56 | 1.63 | 1.70 | 1.77 | 1.81 |
| 30 | - | - | 1.48 | 1.50 | 1.63 | 1.69 | 1.74 |
| 45 | - | - | 1.54 | 1.59 | 1.80 | 1.93 | 1.99 |
| 60 | - | - | 1.52 | 1.54 | 1.76 | 1.84 | 1.88 |
| 45 | - | 5 | 1.52 | 1.54 | 1.72 | 1.79 | 1.83 |
| 45 | 2 | 1.5 | 1.48 | 1.56 | 1.70 | 1.80 | 1.84 |
| 0 | 2 | 5 | 1.50 | 1.57 | 1.66 | 1.74 | 1.76 |
| SE[3] | | | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |

[1]Mean values in each column are not significantly different ($P > .05$).
[2]Period by treatment interaction.
[3]Standard error of the means for treatments within periods.

**Table A8.** The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets on internal egg quality at the end of periods 1, 4, 7 and 9 (Experiment 1).

| Dietary Treatments (%) | | | Internal Egg Quality (Haugh units)[1,2] Weeks of Age (Period) | | | |
|---|---|---|---|---|---|---|
| YP | FM | MB | 26(1) | 38(4) | 50(7) | 58(9) |
| 0 | - | - | 89.0 | 88.1 | 80.1 | 64.5 |
| 15 | - | - | 90.2 | 88.3 | 78.6 | 70.2 |
| 30 | - | - | 90.6 | 87.6 | 79.2 | 74.1 |
| 45 | - | - | 90.5 | 87.6 | 79.7 | 72.6 |
| 60 | - | - | 89.8 | 87.1 | 82.1 | 73.5 |
| 45 | - | 5 | 91.9 | 87.4 | 83.0 | 71.4 |
| 45 | 2 | 1.5 | 92.0 | 84.4 | 79.3 | 70.7 |
| 0 | 2 | 5 | 91.6 | 88.5 | 79.1 | 71.9 |
| SE[3] | | | 1.5 | 1.5 | 1.5 | 1.5 |

[1]Mean values in each column are not significantly different (P > .05).
[2]Period by treatment interaction.
[3]Standard error of the means for treatments within periods.

**Table A9.** The effects of feeding diets containing 0, 15, 30, 45 and 60% yellow pea (YP) and 0 and 45% YP supplemented with either fish meal (FM) or meat and bone meal (MB) or a combination of both to Dekalb XL Single Comb White Leghorn laying pullets on egg yolk color at the end of periods 1, 4, 7 and 9 (Experiment 1).

| Dietary Treatments (%) | | | Egg Yolk Color[1,2,3] Weeks of Age (Period) | | | |
|---|---|---|---|---|---|---|
| YP | FM | MB | 26(1) | 38(40) | 50(7) | 58(9) |
| 0 | - | - | 7.7[a] | 7.7[a] | 8.9[a] | 9.2[a] |
| 15 | - | - | 7.6[a] | 7.4[a] | 8.4[a] | 7.7[c] |
| 30 | - | - | 7.4[a] | 7.3[a] | 8.4[a] | 7.7[c] |
| 45 | - | - | 7.1[a] | 7.3[a] | 8.3[a] | 8.0[c] |
| 60 | - | - | 7.3[a] | 7.2[a] | 8.2[a] | 8.0[c] |
| 45 | - | 5 | 7.4[a] | 7.5[a] | 8.2[a] | 7.9[c] |
| 45 | 2 | 1.5 | 7.0[a] | 7.8[a] | 8.3[a] | 8.0[c] |
| 0 | 2 | 5 | 8.2[b] | 8.0[a] | 8.8[a] | 8.7[b] |
| SE[4] | | | 0.2 | 0.2 | 0.2 | 0.2 |

[1]Mean values in each column with different letters are significantly different ($P < .05$).
[2]Period by treatment interaction.
[3]Egg yolk color based on Roche color fan: 14 = dark orange; 1 = light pale yellow.
[4]Standard error of the means for treatments within periods.

**Table A10.** The effects of feeding diets containing 0 and 60% yellow pea (YP) and 60% YP supplemented either alone or with combinations of 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% choline-chloride (CH) or 0.05% biotin (BN) to Dekalb XL Single Comb White Leghorn laying pullets for eight 28-day periods on jumbo size eggs (Experiment 2).

| Dietary Treatments (%) | | | | | Jumbo size eggs (%)[1] Weeks of Age (Period) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | SO | YC | CH | BN | 46(2) | 50(3) | 54(4) | 58(5) | 62(6) | 66(7) | 70(8) |
| 0 | - | - | - | - | 0.8 | 2.0 | 0.9 | 1.4 | 4.5 | 0.9 | 3.1 |
| 60 | - | - | - | - | 1.6 | 3.7 | 4.4 | 3.8 | 2.9 | 5.7 | 7.1 |
| 60 | 3.25 | - | - | - | 2.5 | 3.3 | 2.2 | 3.7 | 4.0 | 6.0 | 10.8 |
| 60 | - | 0.05 | - | - | 4.1 | 4.4 | 5.3 | 5.4 | 4.9 | 9.0 | 8.1 |
| 60 | - | - | 0.025 | - | 1.9 | 3.8 | 5.4 | 3.6 | 4.5 | 10.1 | 14.4 |
| 60 | - | - | - | 0.05 | 3.5 | 4.7 | 5.4 | 8.4 | 8.5 | 11.7 | 9.7 |
| 60 | - | - | 0.025 | 0.05 | 1.6 | 2.9 | 6.9 | 3.8 | 4.6 | 10.8 | 11.5 |
| 60 | - | 0.05 | 0.025 | 0.05 | 4.3 | 3.9 | 7.5 | 4.9 | 5.3 | 10.0 | 12.3 |
| SE[3] | | | | | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |

[1]Mean values in each column are not significantly different (P > .05).
[2]Standard error of the means for treatments within periods.

**Table A11.** The effects of feeding diets containing 0 and 60% yellow pea (YP) and 60% YP supplemented either alone or with combinations of 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% choline-chloride (CH) and 0.05% biotin (BN) to Dekalb XL Single Comb White Leghorn laying pullets for eight 28-day periods on extra large, large and small size eggs (Experiment 2).

| Dietary Treatments (%) | | | | | Egg Size (%)[1] | | |
|---|---|---|---|---|---|---|---|
| YP | SO | YC | CH | BN | Extra Large | Large | Small |
| 0 | - | - | - | - | 26.2 | 44.7 | 3.9[a] |
| 60 | - | - | - | - | 36.6 | 47.9 | 0.3[b] |
| 60 | 3.25 | - | - | - | 41.7 | 44.5 | 0.1[b] |
| 60 | - | 0.05 | - | - | 39.1 | 43.5 | 0.3[b] |
| 60 | - | - | 0.025 | - | 47.0 | 42.4 | 0.0[b] |
| 60 | - | - | - | 0.05 | 42.7 | 38.4 | 0.3[b] |
| 60 | - | - | 0.025 | 0.05 | 38.3 | 46.9 | 0.3[b] |
| 60 | - | 0.05 | 0.025 | 0.05 | 43.8 | 41.0 | 0.3[b] |
| SE[2] | | | | | 5.8 | 5.4 | 1.0 |

[1]Mean values in each column with different letters are significantly different (P < .05).
[2]Standard error of the means.

**Table A12.** The effects of feeding diets containing 0 and 60% yellow pea (YP) and 60% YP supplemented either alone or with combinations of 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% choline-chloride (CH) or 0.05% biotin (BN) to Dekalb XL Single Comb White Leghorn laying pullets for eight 28-day periods on medium size eggs (Experiment 2).

| Dietary Treatments (%) | | | | | Medium Size Eggs (%)[1] Weeks of Age (Period) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | SO | YC | CH | BN | 46(2) | 50(3) | 54(4) | 58(5) | 62(6) | 66(7) | 70(8) |
| 0 | - | - | - | - | 20.2$^{a}$ | 19.7$^{a}$ | 20.1$^{a}$ | 19.6$^{a}$ | 23.8$^{a}$ | 26.6$^{a}$ | 33.1$^{a}$ |
| 60 | - | - | - | - | 9.3$^{b}$ | 10.8$^{b}$ | 8.1$^{b}$ | 11.5$^{b}$ | 12.8$^{b}$ | 11.9$^{b}$ | 12.9$^{b}$ |
| 60 | 3.25 | - | - | - | 10.6$^{b}$ | 7.3$^{b}$ | 10.6$^{b}$ | 7.7$^{b}$ | 12.4$^{b}$ | 7.8$^{b}$ | 7.5$^{b}$ |
| 60 | - | 0.05 | - | - | 8.8$^{b}$ | 11.3$^{b}$ | 9.7$^{b}$ | 16.0$^{b}$ | 13.6$^{b}$ | 6.4$^{b}$ | 12.9$^{b}$ |
| 60 | - | - | 0.025 | - | 5.1$^{b}$ | 2.0$^{b}$ | 5.3$^{b}$ | 5.0$^{b}$ | 4.0$^{b}$ | 4.3$^{b}$ | 4.8$^{b}$ |
| 60 | - | - | - | 0.05 | 10.4$^{b}$ | 11.4$^{b}$ | 10.5$^{b}$ | 10.5$^{b}$ | 13.1$^{b}$ | 9.7$^{b}$ | 12.9$^{b}$ |
| 60 | - | 0.05 | 0.025 | 0.05 | 7.2$^{b}$ | 7.6$^{b}$ | 8.3$^{b}$ | 5.6$^{b}$ | 11.9$^{b}$ | 11.0$^{b}$ | 6.7$^{b}$ |
| SE[3] | | | | | 3.2$^{b}$ | 3.2$^{b}$ | 3.2$^{b}$ | 3.2$^{b}$ | 3.2$^{b}$ | 3.2$^{b}$ | 3.2$^{b}$ |

[1]Mean values in each column with different letters are significantly different ($P < .05$).
[2]Standard error of the means for treatments within periods.

**Table A13.** The effects of feeding diets containing 0 and 60% yellow pea (YP) and 60% YP supplemented either alone or with combinations of 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% choline-chloride (CH) or 0.05% biotin (BN) to Dekalb XL Single Comb White Leghorn laying pullets for eight 28-day periods on medium + small size eggs (Experiment 2).

| Dietary Treatments (%) | | | | | Medium + Small Size Eggs (%)[1] Weeks of Age (Period) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| YP | SO | YC | CH | BN | 46(2) | 50(3) | 54(4) | 58(5) | 62(6) | 66(7) | 70(8) |
| 0 | - | - | - | - | 22.2 | 23.6 | 21.7 | 23.4 | 29.2 | 32.3 | 38.1 |
| 60 | - | - | - | - | 9.3 | 11.2 | 9.0 | 11.5 | 12.8 | 12.4 | 13.4 |
| 60 | 3.25 | - | - | - | 10.6 | 7.7 | 10.6 | 7.7 | 12.4 | 7.8 | 7.5 |
| 60 | - | 0.05 | - | - | 8.8 | 11.3 | 9.7 | 16.5 | 14.1 | 6.9 | 13.3 |
| 60 | - | - | 0.025 | - | 5.1 | 2.0 | 5.3 | 5.0 | 4.0 | 4.3 | 4.8 |
| 60 | - | - | - | 0.05 | 10.4 | 11.4 | 10.5 | 10.5 | 13.5 | 9.7 | 14.6 |
| 60 | - | - | 0.025 | 0.05 | 11.6 | 8.5 | 6.9 | 9.5 | 6.9 | 6.7 | 12.0 |
| 60 | - | 0.05 | 0.025 | 0.05 | 7.2 | 7.6 | 8.3 | 5.6 | 11.9 | 11.0 | 6.7 |
| SE[3] | | | | | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 |

[1]Mean values in each column with different letters are significantly different ($P < .05$).
[2]Standard error of the means for treatments within periods.

**Table A14.** The effects of feeding diets containing 0 and 60% yellow pea (YP) and 60% YP supplemented either alone or with combinations of 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% choline-chloride (CH) and 0.05% biotin (BN) to Dekalb XL Single Comb White Leghorn laying pullets for eight 28-day periods on mean body weight (Experiment 2).

| Dietary Treatments (%) | | | | | |
|---|---|---|---|---|---|
| YP | SO | YC | CH | BN | Mean Body Weight (kg)[1] |
| 0 | - | - | - | - | 1.67 |
| 60 | - | - | - | - | 1.66 |
| 60 | 3.25 | - | - | - | 1.68 |
| 60 | - | 0.05 | - | - | 1.65 |
| 60 | - | - | 0.025 | - | 1.58 |
| 60 | - | - | - | 0.05 | 1.69 |
| 60 | - | - | 0.025 | 0.05 | 1.62 |
| 60 | - | 0.05 | 0.025 | 0.05 | 1.69 |
| SE[2] | | | | | 0.04 |

[1]Mean values within column are not significantly different ($P > .05$).
[2]Standard error of the means.

**Table A15.** The effects of feeding diets containing 0 and 60% yellow pea (YP) and 60% YP supplemented either alone or with combinations of 3.25% soybean oil (SO), 0.05% yeast culture (YC), 0.025% choline-chloride (CH) and 0.05% biotin (BN) to Dekalb XL Single Comb White Leghorn laying pullets on egg yolk color at the ends of periods 2, 5 and 8 (Experiment 2).

| Dietary Treatments (%) | | | | | Egg Yolk Color[1,2] Weeks of Age (Period) | | |
|---|---|---|---|---|---|---|---|
| YP | SO | YC | CH | BN | 46(2) | 58(5) | 70(8) |
| 0 | - | - | - | - | 8.5[a] | 9.4[a] | 9.7[a] |
| 60 | - | - | - | - | 8.0[a] | 7.4[b] | 7.5[b] |
| 60 | 3.25 | - | - | - | 7.3 | 6.5[c] | 6.4[c] |
| 60 | - | 0.05 | - | - | 8.0[a] | 7.4[b] | 7.9[b] |
| 60 | - | - | 0.025 | - | 8.0[a] | 7.6[b] | 8.1[b] |
| 60 | - | - | - | 0.05 | 8.1[a] | 7.8[b] | 8.0[b] |
| 60 | - | - | 0.025 | 0.05 | 8.1[a] | 7.8[b] | 7.3[b] |
| 60 | - | 0.05 | 0.025 | 0.05 | 8.0[a] | 8.3[b] | 8.3[b] |
| SE[3] | | | | | 0.3 | 0.3 | 0.3 |

[1]Mean values in each column with different letters are significantly different ($P < .05$).
[2]Egg yolk color based on Roche color fan: 14 = dark orange; 1 = light pale yellow.
[3]Standard error of the means for treatments within periods.