A review of duck nutrition research

Robert G. Elkin

World's Poultry Science Journal / Volume 43 / Issue 02 / June 1987, pp 84 - 106
DOI: 10.1079/WPS19870007, Published online:

Link to this article: http://journals.cambridge.org/abstract_S0043933987000023

How to cite this article:

Request Permissions : Click here
A review of duck nutrition research

ROBERT G. ELKIN

Department of Animal Sciences, Purdue University, West Lafayette, Indiana 47907, U.S.A.

Introduction
Despite the existence of nutrient requirement tables for ducks (Agricultural Research Council, 1975; Dean, 1978, 1986; Blair et al., 1983; Ricard et al., 1983; National Research Council, 1984; Tanner and Schmidtborn, 1984; Dumanovsky, 1985), research in the area of duck nutrition has been somewhat limited. According to Siregar and Farrell (1980b), many of the nutrient requirements of ducks are based on those of chickens. However, because of differences in growth rate, body composition, digestive physiology, and starvation heat production, it would be expected that nutrient requirements of the two species differ (Siregar and Farrell, 1980b). This review was undertaken in an attempt to summarize information on the nutrition of ducks that has appeared in the scientific literature during the past 60 years.

Three major breeds or genetic crosses of ducks predominate in the majority of studies conducted: White Pekin, Muscovy, and “mule” ducks. The latter, which are sterile, are crosses between Muscovy drakes and F1 females of White Pekin drakes and white domestic ducks (Wu et al., 1984). The United States duckling industry relies primarily on the White Pekin breed, which originated in China and was introduced to this country in the late 1870's (Ash, 1976). Because Muscovy ducks are of South American origin and are slower-growing than White Pekins, Muscovy and mule requirement data may not be directly applicable to the White Pekin. Therefore, an attempt was made to identify the specific breed or genetic cross utilized in each study cited.

Digestive system
The anatomy and physiology of the alimentary tract of ducks has been described by Koch (1973), Crompton and Nesheim (1976), and Sturkie (1976). Unlike chickens, ducks do not have a crop and their proventriculus is cylindrical, not fusiform (Das et al., 1965). The presence of a spindle-shaped widening of the esophagus, rather than a crop per se, is probably responsible for the faster rate of passage of ingesta in ducks than in chickens of similar ages fed identical rations (Pisharody and Nair, 1972). In chickens, the filling of the crop is dependent on the tonus of the esophageal-ingluvial fissura, whereas in ducks stoppage of food in the crop region is conditioned by the plenitude of the esophageal-ingluvial zone (Pastea et al., 1968). In addition, contractions of the thoracic esophagus and the glandular stomach are more active in ducks than in chickens (Pastea et al., 1968).

Atkinson and Kelsey (1984) Examined the effect of diet composition on the growth of the gut in White Pekin ducklings. Birds were fed either a corn-soybean meal control diet, a high protein diet, or a high fiber diet. All diets promoted similar 21-day weight gains and, in general, measurements of esophagus/crop, proventriculus, gizzard, small intestine, ceca, and large intestine/rectum, liver, and pancreas growth showed no effect of dietary treatment.

Kehoe and Ankney (1985) measured ceca length, small intestine length, and gizzard weight in individuals of five species of diving ducks. In contrast to the work of

1 Journal Paper No. 10,892 of the Purdue University Agricultural Experiment Station.
Atkinson and Kelsey (1984), Kehoe and Ankney (1985) concluded that morphological differences in waterfowl guts reflected dietary differences. In addition, they found that some interspecific differences in gut morphology could be explained by differences in body weight.

**Form of Feed**

In the 1930's the usual method of feeding ducklings involved providing moist mashes four or five times daily until three or four weeks of age, then three times daily until the ducks were marketed (Roberts, 1934; Heuser and Scott, 1951). Roberts (1934) reported satisfactory gains when a chick starting ration was fed *ad libitum* to White Pekin ducklings as a dry mash. When the same diet was fed as a moist mash four times daily, it produced only a slight increase in weight gains as compared to feeding the dry mash. However, when the moist mash was fed *ad libitum*, growth was significantly improved as compared with the other two methods of feeding.

Although pelleted rations were fed to ducks as early as 1932 (Tallent, 1932; McMurray, 1935), the feeding of moist mashes apparently continued into the 1950's (Heuser and Scott, 1951). It was believed that feeding pellets, as compared with wet mashes, would save time and labour; however, in the study of Tallent (1932), these predicted advantages were offset because of the higher cost associated with pelleting and the fact that pellets had to be moistened for the first five weeks of the experiment. McMurray (1935) reported greater weight gains when ducklings were fed pelleted diets in lieu of a wet mash. Heuser and Scott (1951) confirmed these results in that ducklings fed a pelleted ration exhibited greater 4- and 8-week weight gains than birds fed wet or dry mashes, alone or in combination.

In today's commercial operations, ducks are fed pelleted rations, since pelleting reduces spillage by the birds (Wilson, 1973; Ash, 1976) and growth is improved by as much as 30% when pelleted diets are used instead of crumbled mashes (Patrick and Schaible, 1980). At present, starter (0 to 2 weeks) rations for ducklings are usually made up in 1/8 inch (3.18 mm) diameter pellets while 3/16 inch (4.76 mm) diameter pellets are preferred for grower (over 2 weeks of age) and breeder diets (Ash, 1976; Patrick and Schaible, 1980). Although satisfactory results are possible with mash diets (Ash, 1976), difficulty in obtaining accurate feed intake data has been reported (Wilson, 1973; Muztar et al., 1977; Hetzel, 1983; Elkin et al., 1986).

Hegsted and Stare (1945) were the first to report the feeding of purified diets, comprised primarily of casein and sucrose, to White Pekin ducks. Although these rations supported adequate growth for 15 days, the best average daily gain attained was inferior to (approximately 80% of) that noted in ducks fed a pelleted commercial ration.

**Dietary Factors Affecting Growth and Carcass Composition**

Horton (1928) was one of the first researchers to provide a "standard" set of growth and feed consumption data for White Pekin ducklings from hatching to 12 weeks of age. Titus (1928) examined Horton's data in order to assess the relationship between live weight and feed consumption. He found that these two parameters were related by the laws of diminishing increments.

More recently, Hetzel (1983) reported growth and feed utilization data from hatching to 20 weeks of age for White Pekin, Alabio, and crosses between Muscovy or White Pekin drakes and Alabio or Tegal ducks. Alabios are an Indonesian breed and Tegals are native to Java. The twelve-week weight of Alabio ducks was increased by 40 and 48% by crossing with Muscovy and White Pekin breeds, respectively. White Pekin crosses grew faster than Muscovy crosses until 17 weeks of age, after which
there were no significant differences in weight. Muscovy crosses generally utilized feed more efficiently than White Pekin crosses at all ages. At both a given age and per unit of carcass weight, White Pekin crosses were fatter and contained a lower proportion of breast meat than Muscovy crosses.

The carcass of market-age ducks contains approximately 30% fat (60% fat on a dry matter basis) as compared to 15% fat in broiler chickens (Plavnik et al., 1982). The undesirable high carcass fat content of ducks is probably due to two factors: (1) the use of high energy diets without corresponding changes in dietary protein and (2) genetic selection for rapidly growing strains (Siregar et al., 1982b).

Numerous studies have shown that carcass composition and meat yield of ducks can be altered by breed, age, sex, weight, grade, diet, and temperature. Stadelman and Meinert (1977) determined the effects of age on carcass meat distribution of White Pekin ducklings fed a commercial pelleted ration. Total meat yield and breast meat, as a percentage of body weight without neck and giblets, increased from 4 to 9 weeks of age while concomitant reductions in skin/fat and leg/thigh meat were noted. Wilson et al. (1980) reported that high environmental temperatures suppressed growth, had no effect on feed efficiency values, and decreased the percentage of carcass skin and fat of White Pekin ducklings.

Farrell et al. (1981) provided data suggesting that heat stress or reduced feed consumption may influence the distribution of fat in the White Pekin duckling carcass.

Scott et al. (1959) noted a reduction in the carcass fat content of White Pekin ducklings, from 33 to 24%, without marked changes in growth or efficiency of feed utilization by decreasing the dietary energy:protein ratio (metabolizable energy (ME) per kg: %crude protein) from 187 to 95 in diets containing 16 to 29% protein, respectively. The reduction in carcass fat was accompanied by an increase in protein and water contents. In addition, it was found that feeding ducks diets with similar energy: protein ratios of approximately 191, but markedly different energy contents ranging from 2420 to 2970 kcal ME per kg, resulted in nearly equal carcass fat contents. The authors concluded that a single value for the protein requirement of ducklings should not be designated because the dietary level of protein needed depends upon the amount of energy present in the diet and upon the carcass fat content desired in the market ducklings.

Dean (1967) conducted a series of experiments to determine the effects of varying dietary protein concentrations during specific stages of growth on weight gain and carcass composition of White Pekin ducklings. During the first two weeks of life, 22% protein was required for maximum weight gain and feed efficiency. The requirement then decreased as the birds aged. Moisture and nitrogen contents of the carcasses varied inversely with fat content. In a subsequent experiment, Dean (1967) fed ducklings isocaloric diets containing 18, 21, or 24% protein. He found that much of the early reduction in carcass fat observed in birds fed the 24% protein diet was overcome by the time the ducklings reached market age. However, unlike the study by Scott et al. (1959), both ME consumption and the pattern of dietary amino acids were similar at all protein levels. Dean (1967) concluded that substantial reductions in carcass fat of market age ducklings may not be achieved by simply changing the protein:energy ratio under ad libitum feeding of high energy rations.

Dean (1968) fed ducklings semipurified rations which provided 16 or 24% protein at each of two energy levels (2500 or 3150 kcal ME per kg) from 0 to 8 weeks of age. Ducks fed the higher energy diet exhibited greater caloric intake and heavier body weights, but had similar levels of carcass fat at each protein level as compared to birds.
fed the low energy rations. The higher dietary protein level resulted in greater body weights during the first four weeks of the experiment and lower carcass fat throughout the entire 8-week study. In all cases, carcass protein and moisture values varied inversely with fat content.

Du Preez and Wessels (1970) reported that optimal 14-day live weights of White Pekin ducks were achieved with diets containing approximately 19% crude protein and ME:protein ratios of 130 to 139. Carcass fat content generally increased, and moisture and protein contents decreased as the energy level of the diet was increased.

Dean (1978) confirmed the findings of Scott et al. (1959) and showed that feeding White Pekin ducklings rations with widely different energy levels, but similar energy:protein ratios, resulted in similar carcass fat levels. Increasing the energy:protein ratio from 130 to 195 caused a marked increase in the amount of carcass fat. He concluded that the energy:protein balance, and not the content of energy or protein per se, was a major dietary factor affecting carcass composition.

Siregar et al. (1982b) fed White Pekin ducklings diets containing from 12 to 25% crude protein and from 2760 to 3620 kcal ME per kg in various combinations. Based on growth rate and feed conversion values, they concluded that a diet containing approximately 12.5% protein and 3330 kcal ME per kg adequately supported maximum duck growth from 3 to 8 weeks of age. Carcass fat increased and carcass protein decreased as the dietary energy:protein ratio increased. The leanest carcasses were obtained with a high protein (24%), high energy (3570 kcal ME per kg) diet.

In a subsequent study, Siregar et al. (1982c) reported that feeding White Pekin ducklings increased amounts of dietary fiber resulted in reduced carcass fat and increased carcass protein contents. However, the authors inferred that body fat is affected to a greater extent by the dietary energy:protein ratio than by dietary fiber.

Torges (1986) examined the effects of slaughter age (6 to 13 weeks) and sex of Muscovy ducklings on 20 different carcass traits. Carcass dressing percentages of males and females were nearly equal within each age. However, when compared on an equal body weight basis of 2.4 kg, the dressing percentages of 7-week old males and 11-week old females were 71 and 75%, respectively. Regardless of age or weight, females always had greater amounts of abdominal fat than males.

**Effects of Feed Restriction on Growth, Carcass Composition, and Egg Production**

Marked reductions in the body fat content of market ducklings may not be possible simply by altering the energy:protein ratio under conditions of ad libitum feeding of high energy rations (Dean, 1967). Since the duck overconsumes dietary energy during the latter part of its growing period, Dean, (1967) restricted the dietary non-protein energy intake of White Pekin ducklings from hatching to 7 weeks of age. Although the percentage of carcass fat decreased with decreased energy intake, weight gain was also reduced at each level of restriction.

Auckland (1973) fed Aylesbury-type ducklings wet mash diets which contained 19.5 or 24.7% protein, both ad libitum or to 85% of ad libitum from 1 to 21 or 24 days of age. Increasing dietary protein reduced carcass fat by 8% on a dry matter basis, whereas a 4% reduction in body fat due to restricted feed intake was observed. The 24.7% protein diets promoted significantly better growth than the 19.5% rations, whereas moderate feed restriction resulted in smaller and only slightly leaner birds.

Leclercq and de Carville (1978) reported that a slight (approximately 5%) feed restriction did not affect the growth of male Muscovy ducklings from 0 to 10 weeks of age. However, a 20% feed restriction regime reduced growth and feed efficiency values while reducing carcass lipid content.
Leclercq (1980) observed that restricting feed intake to 82% of *ad libitum* consumption during the finisher period significantly reduced Muscovy duckling live weights at both 70 and 84 days of age. Breast and leg weights and carcass fat content were also significantly reduced.

In an attempt to reduce the carcass fat content of White Pekin ducklings, Plavnik *et al.* (1982) employed various levels of feed restriction. Although weight gain may also be slightly reduced, they suggested that by careful feed restriction it was possible to limit body fat and improve feed efficiency.

Olver (1984) investigated the effects of feed restriction from 7 to 22 weeks of age (rearing period) on subsequent reproductive performance of White Pekin ducks. Three replicates of 6 male and 24 female ducks each were subjected to one of the following dietary regimes: *ad libitum*, 80% of *ad libitum*, 60% of *ad libitum*, and 40% of *ad libitum*. The diet fed during this period was a pelleted commercial ration containing 14% protein. The amount of feed required for the restricted groups was calculated from the *ad libitum* consumption during the previous 7-day period and restricted birds were fed on alternate days. From 22 to 62 weeks of age, all treatment groups were fed *ad libitum* a commercial pelleted duck breeders’ diet containing 19% protein.

As the degree of feed restriction during the rearing period increased, the number of days to sexual maturity was delayed, resulting in an increase in average egg mass. In addition, increased feed restriction was associated with increased fertility and hatchability of eggs set, decreased mortality, and increased estimated profit per duck. However, at 62 weeks of age, there were no significant differences in average body weights between the *ad libitum* and restricted groups.

Olver (1984) also reported that 22-week old drakes which had been subjected to above treatments exhibited stepwise increases in carcass moisture and stepwise decreases in carcass fat as the amount of feed restriction was increased.

Campbell *et al.* (1985) observed progressive decline in both body weight and carcass fat content as the feed intake of White Pekin ducklings was restricted from 90 to 60% of *ad libitum* in increments of 10%. They concluded that for ducks of a constant weight, carcass fat content increases curvilinearly with food intake and approaches a maximum value which is determined by sex and rate of energy intake.

Olver (1986) reported the effect of protein deficiency during various periods of growth on subsequent reproductive performance of White Pekin ducks. Although the author centered his attention on the fact that certain diets fed were lysine-deficient, the "low-lysine" diets were actually low-protein diets (10.1 and 11.3% crude protein) and were also calculated to be deficient in methionine, arginine, and tryptophan.

Sexual maturity was delayed in birds fed the protein-deficient diets; however, average egg mass was not increased. In addition, protein deficient ducks laid fewer extra large and more small eggs than birds fed higher protein diets (range 13.4 to 22.5% crude protein, depending on the age of the ducks). In addition, protein-restricted birds had a higher mortality rate than control ducks, particularly when the protein-deficient diets were fed from one day of age to either 20 or 60 weeks of age.

**ME and Energy Metabolism**

Although duck diets are usually formulated using ME values obtained from the domestic chicken, evidence on the comparability of energy metabolism in ducks and chickens is questionable (Mohamed *et al.*, 1984). Sugden (1974) compared apparent ME values for six diets fed to Bantam chickens and Blue-Winged Teal ducks. Five of the 6 diets contained wild duck feedstuffs and ranged in protein content from 14.8 to
34.1 Yo. Although the Bantam chickens metabolized significantly more energy than Teal ducks on four of the six diets, the ducks apparently metabolized more energy relative to the chickens as the percentage of dietary protein was increased.

Muztar et al. (1977) reported true ME values of alfalfa and five freshwater plants fed to both White Pekin ducks and White Leghorn roosters. There was good agreement between species for only three of the six feedstuffs. The plants had very low true ME values and the authors suggested that true ME values obtained with roosters cannot be extrapolated to ducks.

Schubert et al. (1982) reported that 6-week old White Pekin and Muscovy ducks digested wheat organic matter, crude fiber, crude protein and nitrogen-free extract more efficiently than did 11-month old laying hens.

Shen and Dean (1982) conducted six separate true ME assays, three each for corn and soybean meal, using eight adult White Pekin drakes. They reported an average true ME value of 4.094 kcal per gm for corn and 3.235 kcal per gm for soybean meal. Both true ME values were similar to those obtained with adult White Leghorn roosters.

Ostrowski-Meissner (1984b) conducted 11 experiments in an attempt to develop an assay for the simultaneous measurement of apparent ME and true ME in corn and soybean meal using Alabio drakes. Some of the problems encountered when "standard" apparent ME and true ME techniques were used with ducks included: (1) the ducks required water in order to consume more than 30 to 40 g of feed; (2) quantitative excreta collection was difficult and led to imprecise estimates of excreta energy and high variability of apparent ME and true ME values among replicates; and (3) apparent ME and true ME estimates made with ducks frequently varied by more than 3 standard deviations from the mean. The latter situation necessitated employing 8 drakes in order to achieve similar standard errors as when 5 cockerels were used.

Based on the results of the above studies, Ostrowski-Meissner (1984b) "optimized" the bioavailable energy procedure as follows: 8 drakes which had been trained to consume daily meals within a 1 hr period were fasted for 24 hrs prior to the assay period. They were then force-fed 70 g of a test pelleted feed, given 40 ml of water upon completion of feeding, and excreta were collected quantitatively for 48 hrs and corrected for individual endogenous excreta.

Using the above procedure, the apparent ME values determined with drakes were higher than those obtained with cockerels. However, similar true ME values for corn and soybean meal were obtained using either 8 drakes or 5 cockerels. Ostrowski-Meissner (1984b) concluded that true ME values were interchangeable and could be applied in formulating rations for both ducks and chickens.

Mohamed et al. (1984) compared ME values of various feedstuffs using Muscovy ducklings and domestic chickens of similar body weights and ages. There were no significant differences between species in ME values of maize, wheat, barley, and alfalfa meal. However, the ME values obtained for soybean meal were significantly higher in ducks than in chickens, with the opposite being true for cottonseed meal. In addition, the authors observed that ducklings had no greater ability to digest fiber than did chickens. This was in agreement with the report of Muztar et al. (1977), but did not concur with the findings of Schubert et al. (1982).

Lu et al. (1985) conducted studies to determine the true ME values of corn, dehulled barley, sorghum, solvent-extracted soybean meal (44% crude protein), fish meal (65% crude protein), wheat bran, and rice hulls using adult mule drakes, male domestic (Tsaiya) ducks, and White Leghorn roosters. They found that only the corn and soybean meal true ME values obtained from mule ducks were applicable to
domestic ducks. The true ME values determined for corn, barley, sorghum, soybean meal, fish meal, wheat bran, and rich hulls were 4.164, 3.803, 3.747, 3.142, 4.025, 2.335, and 0.318 kcal per g dry matter, respectively. Only the true ME values for corn, soybean meal, and sorghum obtained from mule ducks were similar to those obtained from White Leghorn roosters.

Siregar and Farrell (1980a) compared the energy and nitrogen metabolism of male broiler chickens and male White Pekin ducklings of different ages but similar body weights. Ducklings exhibited significantly higher starvation heat production values as compared with chickens, and the authors attributed this to the former's rapid rate of growth. However, as both species aged, differences in heat production were reduced.

In a subsequent comparative study, Siregar and Farrell (1980b) reported that the rapid growth of White Pekin ducklings was due to their ability to consume large amounts of ME and to retain a higher proportion of that energy than do chickens. The increased growth rate of ducklings was associated with a higher maintenance energy requirement. The capacity of ducklings to metabolize dietary energy appeared to decrease with age.

Protein Digestion

Crompton and Nesheim (1969) observed that the dietary amino acid composition directly affected the pattern of free amino acids in the small intestine of Khaki Campbell ducks varying in age from 8 to 11 weeks. In addition, the central portion of the small intestine appeared to be the principal site of amino acid absorption into the hepatic portal system.

Mohamed et al. (1986) measured true digestibilities of amino acids from soybean meal and cottonseed meal using domestic chicks and Muscovy ducks of similar ages and body weights. Both endogenous nitrogen losses and true amino acid digestibility values were similar between species. The authors concluded that the same amino acid digestibility values could be used for ducklings and chicks.

Protein Requirements

There is considerable disagreement in the literature concerning the protein requirement of meat-type ducks (Siregar et al. 1982a). Thus, this topic will be discussed separately for the various breeds or genetic crosses.

White Pekin: The protein requirement of White Pekin ducklings was first investigated by Horton (1932). He found that ducklings fed a 19% protein chick mash exhibited greater gains and better feed efficiency values than birds fed a 12% protein mash from hatching to 15 weeks of age.

Hamlyn et al. (1934) reported that an inbred line of White Pekin ducklings required approximately 18% dietary protein for optimal performance from 0 to 10 weeks of age. Feeding a 26% protein diet produced a slight growth depression.

Scott and Heuser (1951) found that a 15% protein diet supported satisfactory growth of White Pekin ducklings from hatching to 8 weeks of age. However, based on 2-week body weights, a slight advantage in terms of early growth was associated with feeding rations containing approximately 17% protein.

Dean et al. (1965) reported that White Pekin duckling weight gains and feed:weight ratios were maximized at 22, 20, and 18% protein and 2960, 3013, and 3062 kcal ME per kg, respectively, from 0 to 7, 7 to 14, and 14 to 21 days of age. In a subsequent experiment, the authors fed ducklings 22, 20, and 18% protein during the first, second, and third weeks of age, respectively, continued on 18% protein to 31
days, and then fed graded levels of protein from 31 to 51 days. During the latter period, a diet containing 16% protein and 3112 kcal ME per kg appeared adequate.

In summarizing past work at the Cornell Duck Research Laboratory, Dean (1972) stated that the protein requirement of the White Pekin duckling for maximizing early growth was approximately 22%, but decreased substantially to no more than 16% prior to market age (7 weeks). It was apparent that the duckling has considerable ability, under favourable conditions, to be able to overcome a growth depression due to protein deficiency and to achieve normal weight at market age.

Dean (1972) confirmed these earlier findings by feeding ducklings a 28% protein diet for either the first 2 or 4 weeks of age and switching to a 16% protein diet for the remainder of the 8-week study. Two additional groups of ducks were fed either a 16 or 28% protein diet for the entire experiment. Although the birds fed the 28% protein diet for either the first 2 or 4 weeks of age had significantly greater 2 and 4 week body weights than those fed a 16% protein diet, ducklings fed the latter diet throughout the study exhibited similar final body weights and feed:weight ratios.

Wilson (1975) confirmed the work of Dean (1972) and concluded that there was no benefit in feeding diets containing greater than 18% protein to White Pekin-type ducklings for more than 14 days. Siregar et al. (1982a) fed White Pekin ducklings on eight different dietary protein regimens from hatching to 8 weeks of age and suggested that 19 and 16% protein in diets containing 3024 kcal ME per kg were adequate to meet the needs of ducklings from 0 to 2 and 3 to 8 weeks of age, respectively.

Chin and Hutagalung (1984) conducted 3 experiments to determine the protein and energy requirements of White Pekin ducks under the tropical conditions of Malaysia. Based on maximal growth and feed efficiency, they concluded that the birds' energy requirement was between 3500 and 3850 kcal ME per kg while 22 to 24% and 20 to 22% protein was required from 0 to 6 weeks and 7 to 10 weeks of age, respectively. ME contents of the rations were determined by a duck bioassay prior to the feeding trials. As compared to diets fed in more temperate countries, the higher nutrient density diets required by ducks in the present study was attributed to the birds' reduced feed intake under tropical conditions.

**Muscovy:** Leclercq and de Carville (1975) reported that the protein requirements of female Muscovy ducklings was 15% between 4 and 6 weeks, 14.5% between 6 and 8 weeks, and lower than 13% thereafter. In a subsequent study, Leclercq and de Carville (1976a) fed male Muscovy ducklings isonitrogenous (3000 kcal ME per kg) corn-soybean meal diets containing 10.6, 12.0, 13.4, 14.9, or 16.3% protein from 4 to 12 weeks of age. They concluded that the protein requirement of male ducklings did not differ from that of females (Leclercq and de Carville, 1975), and was not greater than 15% between 4 and 8 weeks of age and 12% between 8 and 10 weeks.

Further work by Leclercq and de Carville (1976b) focussed on the young Muscovy duckling. Based on the results of two experiments, the 0 to 4 week protein requirements of males and females fed isonitrogenous, isocaloric (2950 kcal ME per kg) corn-soybean meal diets did not exceed 19.3 and 17.7%, respectively.

Leclercq and de Carville (1977b) investigated the effects of reducing dietary protein during the finishing period (6 to 10 weeks of age). Male Muscovy ducklings were fed isoenergetic diets (approximately 2970 kcal ME per kg) containing from 10.4 to 14.2% protein in Trial 1 and isoenergetic diets (approximately 2940 kcal ME per kg) containing from 12.2 to 15.3% protein in Trial 2. The authors reported that an absolute protein intake of 800 g was necessary to obtain a weight gain of 1400 g during the finisher period. By expressing protein requirement on an absolute rather than a
percentage basis, the authors sought to avoid imprecision due to variations in feed consumption caused primarily by environmental temperature fluctuations.

When lysine-HCl and DL-methionine were added to corn-soybean meal diets, it was possible to reduce the amount of protein required by male Muscovy ducklings by approximately 19% during both the grower (3 to 6 weeks) and finisher (6 to 10 weeks) periods (Leclercq and de Carville, 1981a). This agreed with earlier work by Jeroch and Hennig (1965) who found that the amount of dietary protein could be reduced by 22 to 30% without reductions in 8-week weight gains when "fattening" ducks were fed rations containing 11 to 12% protein supplemented with lysine, lysine and methionine, or lysine and B-complex vitamins as compared to control birds fed an unsupplemented 14.4% protein diet. Jeroch et al. (1969) subsequently reported that the amount of dietary protein could be reduced by 5 to 7% when fattening ducks were fed rations containing 11.7 or 13.2% protein with supplemental methionine and lysine, as compared to control birds fed an unsupplemented 14.4% protein diet from 3 to 8 weeks of age.

Schubert et al. (1981) tested five feeding regimens for male Muscovy ducks in which the amount of dietary protein was varied at different growth stages. They recommended a two-phase feeding programme in which 21 and 18% protein diets were fed from 0 to 3 and 4 to 11 weeks, respectively. They indicated that one-phase feeding of an 18% protein diet from day-old to 11 weeks could be applied since the Muscovy, like the White Pekin, exhibited compensatory growth when fed a slightly protein-deficient diet during the first weeks of life.

**Mule Ducks:** Shen (1977) conducted studies to establish the protein and energy requirements of mule ducklings fed corn-soybean meal diets. Based on weight gain and feed efficiency from 0 to 3 weeks, he suggested that the optimal dietary protein level was 17% with 2750 kcal ME per kg. When the dietary ME content was increased from 2600 to 3000 kcal per kg, and protein content was held constant at 18%, feed efficiency was improved approximately 5% for each 150 kcal ME per kg increment.

In a later study, Shen (1979) investigated the protein and energy requirements of mule ducks from 4 to 10 weeks of age. He observed that ducks fed isoenergetic (2750 kcal ME per kg) corn-soybean meal diets had protein requirements of 13.2 and 13.7% for optimal growth and feed efficiency, respectively. The ducks could maintain adequate weight gain by adjusting their intake of 14% protein rations as dietary ME was varied between 2600 and 3050 kcal per kg. However, a dietary ME value of at least 2900 kcal per kg was required for maximal efficiency of feed utilization.

**Khaki Campbell:** Reddy et al. (1981) fed diets containing 15, 17, or 19% protein in a factorial arrangement with 2400 or 2700 kcal ME per kg for 34 weeks to 18-week old Khaki Campbell ducks. Based on egg production and the efficiency of feed utilization, it was concluded that the ducks required 19% protein and 2400 kcal ME per kg for optimal performance.

In a subsequent study, Gowd et al. (1983) estimated the protein and energy requirements of Khaki Campbell grower ducks. From 9 to 20 weeks of age, birds were fed diets containing 14, 16, or 18% protein in a factorial arrangement with 2400, 2600, or 2800 kcal ME per kg. Based on weight gain, feed consumption, feed efficiency, age at sexual maturity, hematological profiles, and carcass composition, 16% protein with 2800 kcal ME per kg appeared optimal.

**Unspecified Breeds:** Oluyemi and Fetuga (1978) determined the protein and energy requirements of local (Nigerian) and an imported commercial strain of ducklings. They concluded that, under tropical conditions, a corn-groundnut meal diet containing 24% protein, 0.9% methionine plus cystine, and 3088 kcal ME per kg...
was required for maximal 0 to 8 week growth and feed conversion for either strain of ducklings. However, the imported birds were superior to the local ducklings with regard to the above performance parameters.

**Amino Acid Requirements**

**Methionine and Cystine:** With regard to the amino acid nutriture of ducks, the sulfur amino acids should merit the greatest attention since they are generally considered to be first-limiting for poultry (Scott *et al.*, 1982).

On the basis of one experiment, Demers and Bernard (1950) indicated that, in the absence of cystine, the methionine requirement of White Pekin ducklings fed 24% protein diets from hatching to 22 days of age was approximately 0.8%. In the presence of 0.4% cystine, a level of 0.5% methionine was deemed adequate for growth.

Dean (1967; 1968) reported that 10-day body weights of White Pekin ducklings were maximized at 0.6% total dietary sulfur amino acids (estimated 0.45% methionine plus 0.15% cystine). However, Demers and Bernard (1950) and Dean (1967; 1968) neither analyzed their experimental diets for sulfur amino acids nor did they employ any type of regression model to estimate dietary methionine and cystine requirements.

Elkin *et al.* (1986) conducted two experiments to determine the methionine requirement of male White Pekin ducklings. In each study, day-old ducklings were fed a corn-peanut meal basal diet supplemented with either 0, 0.06, 0.12, 0.18, 0.24 or 0.30% L-methionine. Based on the analysis of the corn and peanut meal, the basal diet contained 22% protein, 0.268% methionine and 0.284% cystine. The dietary energy content was calculated to be 2914 kcal ME per kg. Twelve-day weight gain data were analyzed by both a regression model and the broken-line method. The former predicted a methionine requirement of 0.422% ($r^2 = 0.49$) while the latter yielded a requirement estimate of 0.382% ($r^2 = 0.50$). It was concluded that the White Pekin duckling’s methionine requirement was between 0.382 and 0.422% (0.666 and 0.706% total sulfur amino acids, respectively).

Leclercq and de Carville (1977a) reported that male Muscovy ducklings required 0.60 and 0.55% total sulfur amino acids for maximal growth from 3 to 6 and 6 to 10 weeks, respectively. The respective corn-soybean meal basal diets fed during these two periods were supplemented with graded levels of DL-methionine and contained 15.5% protein, 0.25% methionine, 0.30% cystine, and 2986 kcal ME per kg and 13% protein, 0.20% methionine, 0.25% cystine, and 3090 kcal ME per kg. The authors did not state what proportion of the total sulfur amino acid requirement could be supplied by cystine.

Leclercq and de Carville (1981b) conducted three follow-up experiments in which male Muscovy ducklings were fed corn-soybean meal diets supplemented with DL-methionine. They confirmed their previous work (Leclercq and de Carville, 1977a) in that the duck’s sulfur amino acid requirement apparently did not exceed 0.50% when the diet contained 2875 kcal ME per kg.

Hsieh *et al.* (1980) fed straight-run mule ducklings a starter diet for one week and then fed corn-soybean meal diets containing 17.8% protein and 2890 kcal ME per kg supplemented with graded levels of L-methionine. It was concluded that 0.59% total sulfur amino acids were required for maximal growth and feed conversion. However, the authors did not state what proportion of the total sulfur amino acid requirement could be supplied by cystine.

**Lysine:** Lysine is generally considered to be the second-limiting amino acid for ducks (Tanner and Schmidtborn, 1984). Jeroch and Hennig (1965) reported that 0.6% dietary lysine was required by fattening ducks.
Leclercq and de Carville (1979b) investigated the lysine requirement of male Muscovy ducklings from 3 to 6 and 6 to 10 weeks of age. Four experiments were conducted in which corn-sunflower meal diets were supplemented with graded levels of L-lysine-HCl. Depending on the experiment, the basal diets contained 13.5 to 15.0% protein, 0.44 to 0.52% lysine, 0.58 to 0.71% total sulfur amino acids, and 2667 to 2962 kcal ME per kg. The 3 to 6 week lysine requirement was estimated to be 0.60%, which equated to 2.2 g lysine per 1000 kcal ME, or an absolute intake of 21 g lysine over the 3-week period. The 6 to 10 week lysine requirement was estimated to be 0.56% in one experiment and 0.68% in another. Because basal diets with different energy contents were fed in these two experiments, the authors chose to express the bird's lysine requirement in terms of dietary energy. They concluded that between 6 and 10 weeks of age, the ducks required 1.96 g lysine per 1000 kcal ME, which equated to an absolute intake of 30 to 35 g lysine over the 4-week period.

With regard to mule ducklings, Chen and Shen (1979) reported that for maximal 9 to 21-day weight gain and feed efficiency, the minimal dietary requirements for total lysine and available lysine were 1.06 and 0.97%, respectively. The basal diets used in this study contained 2828 kcal ME per kg.

Adams et al. (1983) conducted four experiments to determine the effect of supplemental dietary lysine on performance and yield of different carcass components of male and female White Pekin ducklings. A starter diet containing approximately 21% protein was fed to all ducks from 0 to 10 days of age. Corn-soybean meal diets calculated to contain approximately 14.6% protein, 0.70% lysine, and 0.62% methionine plus cystine were supplemented with graded levels of L-lysine-HCl and fed from 10 to 49 days of age. Dietary lysine had no significant effect on body weight or feed efficiency at market age (48 or 49 days) suggesting that the bird's lysine requirement was not greater than 0.70%.

Arginine: Chen and Shen (1979) reported mule ducklings fed a basal diet containing 18% protein and 2810 kcal ME per kg required 1.08% dietary arginine for maximal 9 to 21-day growth and feed conversion values.

Tryptophan: Wu et al. (1984) fed mule ducklings graded levels of dietary tryptophan from 8 to 20 days of age. The basal diet used contained 18% protein and 3013 kcal ME per kg. The minimal dietary tryptophan level required for maximal growth and feed efficiency was 0.23%. Although excess dietary tryptophan could spare the duckling's requirement for niacin, excess niacin failed to compensate for a dietary deficiency of tryptophan.

Leucine, Isoleucine, and Valine: Yu and Shen (1984) reported that branched-chain amino acid supplementation of corn-soybean meal wheat bran diets containing 18% protein and 2800 kcal ME per kg did not improve 8 to 20-day weight gain or feed conversion values of mule ducklings. In later experiments, graded levels of isoleucine, leucine, and valine were supplemented to basal diets deficient in these amino acids. As determined by regression analyses of weight gain and feed efficiency data, the minimal dietary requirements for leucine, isoleucine, and valine were 1.26, 0.63, and 0.78%, respectively.

Vitamin and Mineral Requirements and Interrelationships

Calcium, Phosphorus, and Vitamin D: Dean et al. (1967) reported that when White Pekin ducklings were fed practical-type rations containing 0.7 to 0.9% total phosphorus and supplemented with 1498 to 1652 ICU of vitamin D, per kg of diet, maximal weight gain and feed conversion values were observed with a dietary calcium level of 0.56%. Subsequent studies by Dean (1972) showed that when White Pekin
Ducklings were fed corn-soybean meal diets containing 0.60% calcium and supplemented with 1650 ICU of vitamin D₃ per kg, weight gain and bone ash content were maximized when the total level of dietary phosphorus was 0.60% (0.35% available phosphorus). Raising the level of dietary calcium to 0.80, 1.00, or 1.50% resulted in progressive declines in weight gain, although the percentage of bone ash tended to increase.

Lin and Shen (1979) determined that the minimal calcium level required by mule ducks for maximal growth and optimal tibia ash content were 0.48 and 0.58%, respectively. The minimal available phosphorus requirements were 0.26 and 0.34%, respectively, for maximal weight gain and tibia ash. All diets were supplemented with 800 ICU of vitamin D₃ per kg of diet.

Su (1977) reported that growing Taiwan ducks required a minimum dietary level of 1.0% calcium and 0.6% phosphorus for optimal growth. For laying ducks, diets containing 3.75% calcium and 1.25% phosphorus were required for adequate egg production.

Leclercq and de Carville (1979) estimated that Muscovy ducklings required 0.40, 0.22, and 0.18% available phosphorus from 0 to 3, 3 to 6, and 6 to 10 weeks of age, respectively. These diets were supplemented with various calcium levels (estimated 0.79 to 0.95%) and 1000 ICU vitamin D₃ per kg.

The duckling's requirement for vitamin D was first reported by Fritz et al. (1941). White Pekin ducklings were fed either a corn-wheat bran-flour diet in one experiment or a basal rachitic diet prescribed for the AOAC chick assay for vitamin D in a second experiment. The duckling's vitamin D requirement was determined based on the percentage of ash in dry, fat-free tibias at 3 weeks of age. In each experiment, ducklings needed 30 AOAC chick units of vitamin D per 100 g of feed for optimal bone calcification.

Motzok et al. (1946) also used White Pekin ducklings fed the AOAC basal diet and found, based on bone ash and plasma phosphatase values, that the bird's vitamin D requirement exceeded 30 units per 100 g of feed. In a subsequent study, Motzok and Branion (1948) fed the AOAC basal diet to both White Pekin and India Runner ducklings for 3 weeks. Based on bone ash values, they concluded that the ducklings required between 30 and 40 AOAC units of vitamin D per 100 gm diet. Using plasma phosphatase activity as a criterion of vitamin D adequacy, the requirement was apparently higher, but the exact level was not determined.

Black and Coates (1948) conducted three experiments to determine the vitamin D requirement of Khaki Campbell ducklings. Satisfactory growth and bone calcification were observed in birds fed a ration which contained 1.25% calcium, 0.78% phosphorus, and 0.25% cod liver oil. This equated to approximately 0.7 μg of vitamin D₃ per 100 g of diet. The authors cautioned that this amount might be marginal and that a slightly higher level of cod liver oil might be needed for maximal calcification.

**Selenium and Vitamin E:** It is interesting to note that there have been as many reports dealing with the selenium (Se) and vitamin E nutrition of ducks as have been published for all other vitamins and minerals combined. This is probably due to the fact that relative to other species, the duck is quite sensitive to a deficiency of these nutrients and serves as an excellent model for studies dealing with vitamin E-Se deficiency (Yarrington et al., 1973).

Although nutritional myopathy was first observed in White Pekin ducklings by Pappenheimer and Goettsch (1934), several years elapsed before it was conclusively
shown that this disease was attributable to a lack of vitamin E and was completely prevented by the daily administration of 4 mg \( \alpha \)-tocopherol (Pappenheimer, 1940).

Three decades later, Jager and Vles (1970) reported that histologically-assessed scores of skeletal muscle myopathy as well as serum lactic dehydrogenase activity (Jager and Verbeek-Raad, 1970) were sensitive criteria for determining the vitamin E requirement of White Pekin ducklings. Both parameters showed on inverse linear log-dose response relationship, and 20 mg \( D-\alpha \)-tocopheryl acetate per kg of diet was required to prevent myopathy.

Two years later, Jager (1972b) reported that the White Pekin duckling’s vitamin E requirement was influenced by the level of dietary linoleic acid. Subsequent studies established that Se deficiency was also involved in the production of nutritional myopathy (Jager, 1972a; George et al., 1973; Yarrington et al., 1973; Brown et al., 1974; Yarrington and Whitehair, 1975; Moran et al., 1975; Hulstaert et al., 1976; Van Vleet, 1977). Dean and Combs (1981) briefly reviewed investigations demonstrating the duckling’s nutritional need for Se.

The most studied conditions in poultry which are due to Se or vitamin E deficiency, or both, are encaphalomalacia, exudative diathesis, and muscular dystrophy (Lannek and Lindberg, 1975). Electron microscopic studies by Molenaar et al. (1970) showed that jejunal epithelial cells from vitamin E-deficient White Pekin ducklings failed to reveal the positive contrast normally observed after fixation with osmium tetraoxide. In follow-up studies, Vos et al. (1972, 1973) isolated inner and outer mitochondrial membrane fractions from livers of vitamin E-adequate or deficient White Pekin ducklings. Both inner and outer mitochondrial membranes from vitamin E-deficient birds had reduced levels of linoleic and arachadonic acids. The authors concluded that the reduced positive membrane contrast observed after osmium tetraoxide fixation in tissues from vitamin E-deficient animals was caused by a critical loss of specific polyunsaturated membrane-bound fatty acids. Additional work from their laboratory indicated that increased mitochondrial and microsomal enzyme activities associated with vitamin E deficiency were the result of the influence of free radicals on membranes with electron transport functions (Hulstaert et al., 1975; Hulstaert and Molenaar, 1976).

In addition to experimentally-produced lesions, vitamin E-Se deficiency disease has occurred in commercial poultry production units where birds were fed diets containing feedstuffs grown in soils low in Se (Kubota et al., 1967; Lannek and Lindberg, 1975; MacDonald et al., 1976; Dean and Combs, 1981). Furthermore, tocopherols are apparently destroyed by microbial or chemical (propionic acid) treatment of high moisture grains; however, the situation can be completely corrected by Se supplementation (Moran et al., 1971, 1974).

Dean and Combs (1981) produced an acute Se deficiency in progeny of Se-depleted White Pekin ducks fed corn-soybean meal-based diets containing ingredients low in Se. As assessed by survival and weight gain, they concluded that the duckling’s Se requirement appeared to be no more than 0.14 ppm, which was originally suggested by Dean (1978). However, plasma glutathione peroxidase activity, a highly sensitive indicator of the Se status of the duckling, continued to increase as Se supplementation increased to 0.2 ppm (0.24 ppm total dietary Se). Dean and Combs (1981) suggested that the optimal level of Se for certain biological functions may be different from the requirement indicated by the whole animal response.

In accordance with the work of Van Vleet (1977), Dean and Combs (1981) found that highest concentrations of Se in kidney and liver and the lowest in muscle.
However, they failed to confirm the findings of Brown et al. (1974) who observed reduced plasma ascorbic acid levels due to decreased dietary Se.

**Other Minerals:** Although administering saltwater can reduce body weight and impair bone (femur) growth and development (Wink et al., 1983), the duckling requires approximately 0.14% sodium and 0.12% chloride for maximal weight gain (Dean, 1972).

Van Reen and Pearson (1953) reported that feeding White Pekin ducklings magnesium-deficient diets resulted in reduced growth, incoordination, convulsions, and death. They determined that 0.05% dietary magnesium was required by the duckling for maximal growth during the first 16 days post-hatching.

Wu and Shen (1978) reported that dietary zinc and manganese levels of 68 and 50 ppm, respectively, promoted optimal mule duckling growth. Growth rate was depressed by the addition of 0.5% phytic acid.

**Other Vitamins:** Dean (1972) investigated the vitamin K requirement of White Pekin ducklings fed diets based either on glucose and isolated soy protein or corn and soybean meal. The effects of adding sulfaquinoxaline, a drug used to treat certain bacterial diseases in ducks, was also determined. Ducks fed sulfaquinoxaline had previously been observed to bleed excessively following debilling. Vitamin K was added in the diet in the form of both vitamin K₃ and menadione dimethylpyrimidinol bisulfite (MPB), and prothrombin times were measured. In the absence of sulfaquinoxaline, 0.4 to 0.5 mg of vitamin K₃ or MPB per kg of diet appeared to minimize prothrombin time in birds fed the glucose-isolated soy protein and corn-soybean meal diets, respectively. The addition of sulfaquinoxaline increased mortality and prothrombin times; however, this effect could be almost completely overcome by dietary supplementation of 5 to 8 mg MPB per kg of diet.

**Niacin:** Hegsted (1946) conducted the initial studies on the niacin nutrition of ducks and reported that they required a minimum dietary level of 25 mg per kg.

Scott and Heuser (1952) showed that a niacin deficiency was responsible for a bowed-leg disorder in White Pekin ducklings raised on wire-mesh floors. The deficiency was ameliorated by 7.5% supplemental dried brewer’s yeast or by the addition of 22 mg of niacin per kg of diet. In a subsequent report, Heuser and Scott (1953) confirmed their earlier work and found that the effect of supplemental yeast was entirely due to its high niacin content. Synthetic niacin, when fed at equivalent levels, was as effective as yeast in preventing the bowed-leg condition and promoting growth. Since the basal diet used in their studies contained approximately 30 mg of niacin per kg, the authors concluded that the ducklings either had a relatively higher niacin requirement (approximately 52 mg per kg) than the chick, or that much of the niacin in the basal diet was unavailable.

In experiments with mule ducklings, Wu et al. (1984) confirmed the duck’s high niacin requirement (45 mg per kg diet minimum) and showed that excess tryptophan could spare the bird’s need for niacin. However, niacin could not compensate for a deficiency of tryptophan.

Fritz et al. (1939) reported that the minimal dietary amount of riboflavin required for optimal growth of White Pekin ducklings was 3 mg per kg. Hegsted and Perry (1948) concluded that approximately 4 mg of riboflavin and 11 mg of pantothenic acid per kg of diet were needed for optimal growth of White Pekin ducklings. Hegsted and Rao (1945) found that White Pekin ducks required approximately 2.5 mg of pyridoxine per kg of diet.

Bernard and Demers (1949) reported that dietary choline promoted growth, prevented hepatic fatty infiltration, and reduced the incidence of perosis in White
Pekin ducklings. Dean and Shen (1982) observed that ducklings fed a low-choline diet based on isolated soy protein and corn required supplemental choline and methionine in order to prevent perosis and support maximal growth, respectively. When ducklings were fed a practical corn-soybean meal diet, methionine supplementation improved growth either in the absence or presence of added choline. Choline supplementation improved growth in the absence, but not in the presence, of added methionine. This indicated that methionine supplementation can eliminate the need for supplemental dietary choline, but that the reverse was not true.

Trager (1943) produced a biotin deficiency in White Pekin ducks by feeding a diet containing a large proportion of dried egg white. He then infected the birds with *Plasmodium lophurae*, a malaria-producing parasite. Biotin-deficient ducks developed more severe infections than did control animals. However, pantothenic acid-deficient ducks did not develop any more severe infections with *Plasmodium lophurae* than did control birds.

Roos et al. (1946) studied the effect of deficiencies of choline, vitamin A, niacin, and thiamine on the course of infection of White Pekin ducks with avian malaria. None of the deficiencies influenced the degree of infection. The authors concluded that the *Plasmodium lophurae* probably reproduced at near maximum rate in normal ducks and that an increase in susceptibility to infection would probably have been difficult to detect.

**Mycotoxins**

Ducklings are more susceptible to aflatoxin than chickens, turkeys, or pheasants, and this sensitivity makes them the bird of choice when testing feed for toxicity (Peckham, 1984). Asplin and Carnaghan (1961) were among the first researchers to describe gross and microscopic aflatoxicosis lesions in ducklings and chickens. They observed that the lesions varied according to the toxicity of the sample. Liver degeneration and hemorrhaging appeared to predominate (Asplin and Carnaghan, 1961; Muller et al., 1970) and survival time was related to the age of the birds. An historical account of the incidence of aflatoxicosis, as well as detailed descriptions of symptoms and lesions in poultry, have been summarized by Peckham (1984).

Based on both his earlier work and reports of others, Ostrowski-Meissner (1983a) suggested that the detrimental effects of aflatoxins on growth and nutrient utilization by ducks were dependent on the dietary protein source. For example, the use of low quality protein sources or a lack of dietary protein exacerbated the deleterious effects of aflatoxins on growth and gross histological appearance of the liver of Alabio and Tegal ducks (Ostrowski-Meissner, 1983a). In addition, when Alabio ducks were fed a diet containing fishmeal, a protein source of high biological value, aflatoxin did not affect the growth and efficiency of protein utilization to the same extent as when ducks were fed lower quality protein sources such as soybean meal and peanut meal (Ostrowski-Meissner, 1983b). Ostrowski-Meissner (1984a) later reported that, irrespective of the dietary protein source, feeding Alabio ducks sublethal doses of aflatoxin inhibited both the absorption of amino nitrogen from the small intestine and muscle protein synthesis. This probably reflected the interference of aflatoxin in the digestive process.

Mehdi et al. (1984) described the effects of feeding citrinin, a secondary fungal metabolite, to White Pekin ducklings. In addition to exhibiting reduced body weights and decreased feed consumption, ducklings fed citrinin had liquid fecal droppings, increased water intakes, and developed nephropathy characterized by degeneration, necrosis, mineralization, and regeneration of tubular epithelial cells of both the cortical and medullary regions of the kidney.
Alternative Feedstuffs

Heuer et al. (1951) reported that live or dressed weights of 9-week old White Pekin ducks were unaffected when 20% dietary potato meal was substituted for 20% corn meal, 20% wheat standard middlings, or 10% corn meal plus 10% wheat standard middlings. In addition, there were no differences in live or dressed weights of birds fed dehydrated potato meal or sun-dried potato meal.

Scott and Heuer (1951) observed that growth and feed efficiency of White Pekin ducklings fed corn-wheat standard middlings based diets were improved by the addition of fish meal, dried skim milk, or dried brewer's yeast. Subsequent work from Scott's lab showed that the growth promoting effects of dried brewer's yeast were due to its niacin content (Scott and Heuer, 1952; Heuer and Scott, 1953). In a follow-up study, Scott et al. (1957) reported that supplementation of niacin-adequate corn-soybean meal diets with fish meal, dried distiller's solubles, dried whey, or dried fish solubles resulted in little, if any, improvement in growth and feed efficiency. However, 4 to 5-week old White Pekin ducks receiving an unsupplemented 16% protein ration had a greater incidence of leg weakness and feather picking as compared to birds fed the "unidentified growth factor" supplements.

Dean (1972) observed that on an equal weight basis, substitution of dried bakery product for up to 40% corn in corn-soybean meal diets had no effect on duckling weight gains but improved feed:weight ratios. This was attributed to the higher energy content of the dried bakery product as compared with corn. Other work failed to show any effect of dietary alfalfa meal on duck performance (Dean, 1972). The addition of more than 8% dietary meat and bone meal was shown to depress the growth of ducklings fed corn-soybean meal rations (Dean, 1972).

Bolton et al. (1972) reported that maize germ meal, a byproduct of the whisky manufacturing process, could be used to replace wheat meal in the diet of White Pekin ducklings at levels up to 30%. However, more fat was found in the drip from cooked carcasses of maize germ meal-fed birds as compared with control ducks. This was attributed to the higher ME content of maize germ meal as opposed to wheat meal.

Wilson (1972) concluded that up to 30% field beans (Vicia Faba L.) may be included in place of soybean meal and wheat meal in diets of White Pekin ducklings, provided that the diets are supplemented with methionine, pelleted, and free of "fines" and adequate water is available.

Effects of Ingestion of Crude Oil

Hartung and Hunt (1966) reported that several industrial oils caused lipid pneumonia, gastrointestinal irritation, fatty livers, and adrenal cortical hyperplasia when wild-trapped and domesticated ducks received single doses of oil via a stomach tube.

Crocker et al. (1974) observed that ingested crude oil diminished intestinal absorptive functions in seawater-adapted White Pekin ducklings. They postulated that dehydoration, resulting from impairment of mucosal transfer mechanisms, may be an important factor contributing to the deaths of oil-contaminated seabirds.

Holmes et al. (1978) reported that the dietary addition of southern Louisiana crude oil tended to decrease feed consumption of White Pekin ducks for 5 to 10 days, after which intake increased and plateaued at a level which was higher than that of control birds.

Harvey et al. (1981) administered, via a stomach tube, a small dose (5 ml per kg body weight) of North Sea crude oil to both freshwater and saltwater-reared Aylesbury ducklings. The oil treatment had no significant effect on body and organ weights, hematocrits, or plasma glucose, electrolytes, and hormones.
Rattner (1981) fed adult male mallards either an untreated mash diet or mash supplemented with 1.5% Prudhoe Bay crude oil ad libitum for 7 days. Although initial 24-hour intakes were significantly reduced and birds lost approximately 3.5% of their initial body weight, neither feed intakes nor body weights differed between crude oil-fed and control ducks on days 2 to 7. Plasma concentrations of corticosterone, thyroxine, glucose, total protein, uric acid, and the activities of aspartate aminotransferase, alanine aminotransferase, and butyrylcholinesterase were not affected by dietary crude oil. Rattner (1981) concluded that adult mallards may be able to ingest up to 25 ml of crude oil over a 7-day period without mortality, overt signs of distress, or biochemical dysfunctions.

Discrepancies in the results of the above studies might be attributed to the mode of administration or differences in the composition of the oils used (Rattner, 1981) or the ages of species of duck involved.

Effects of Ingestion of Heavy Metals

White and Finley (1978) fed 0, 2, 20, or 200 ppm cadmium chloride to adult mallard ducks for 30, 60, or 90 days. They found that approximately 97% of the birds' tissue cadmium was in the liver and kidney. In addition, dietary cadmium did not significantly affect body weight, feed consumption, hematocrit, or hemoglobin concentrations. Interestingly, birds fed 2 or 20 ppm cadmium laid more eggs than did unsupplemented control ducks. However, little cadmium was transferred to the eggs of cadmium-supplemented ducks.

DiGiulio and Scanlon (1985) reported that cadmium ingestion alone had no effect on mallard body or tissue weights, liver glycogen, plasma concentrations of glucose, urea, uric acid, nonesterified fatty acids, thyroxine, triiodothyronine, or plasma or adrenal concentrations of corticosterone. However, cadmium enhanced food restriction-induced alterations in energy metabolism at levels of dietary cadmium that were by themselves without apparent effect. DiGiulio and Scanlon (1985) also observed increased cadmium and zinc concentrations in liver and kidney as well as increased kidney copper levels with increased dietary cadmium. Although these authors did not measure levels of metallothionein, a protein which can bind heavy metals, the effect of cadmium ingestion on copper and zinc concentrations suggested that metallothionein had been induced. Brown and Chatel (1978) inferred that metallothionein induction may provide protection against excessive levels of cadmium in ducks.

Hall and Fisher (1985) reported that concentrations of several heavy metals in tissues of six species of wild ducks which had ingested spent shot. The bones of three species which were known to have a high incidence of shot ingestion ("indicator species") contained 28.8 ppm lead as compared to 9.5 ppm lead in the bones of three species not known to have a high incidence of shot consumption ("non-indicator species"). Similarly, feathers of indicator species contained 15.9 ppm lead while non-indicator species averaged 1.6 ppm lead. Feather and bone arsenic concentrations were not different between species groups. None of the other heavy metals analyzed were present in duck tissues at toxic levels.

Water

There is very little information available on the water intake of ducklings. Siregar and Farrell (1980b) reported that the ratio of water:feed consumption (corn-wheat diets) was 4.25:1: (870.0 g/kg weight/day:204.6 g/kg weight/day) for White Pekin ducklings from 5 to 22 days of age. Over the same time period, chickens consumed approximately 2.29 parts of water to 1 part food (258.0 g/kg weight/day:112.8 g/kg
weight/day). Siregar and Farrell (1980b) suggested that the duckling’s high requirement for water was related to the rate of passage of food and the need to propel food along the digestive tract.

Veltmann and Sharlin (1981) allowed 2-week old White Pekin ducks access to water for either 4, 6, 8, 16, or 24 hr per day for 4 weeks. Compared to all other treatment groups, ducks allowed access to water for 4 hr per day had significantly lower water and feed intakes and reduced body weights. There were no significant differences in 6-week body weights among ducks allowed access to water for 6, 8, 16, or 24 hr per day. Although feed conversion values were not significantly affected by treatment, feed consumption tended to increase with increasing access to water. Carcass fat and meat (leg and breast) contents were generally not altered by treatment.

The authors concluded that, under laboratory conditions, allowing ducks access to water for 8 hr per day, 4 hr each in the morning and evening, provided an alternative to ad libitum water consumption. The practical implications of water restriction were that duck producers using confinement-rearing systems may possibly be able to reduce water usage, without compromising growth or feed conversion, while benefitting from drier litter. However, Veltmann and Sharlin (1981) stated that an 8 hr water restriction regimen may not be applicable to commercial duck operations in which birds are either exposed to extreme environmental conditions or fed diets containing salt-rich ingredients. Furthermore, adequate waterer space was required so that all ducks could drink simultaneously in order to prevent smothering when the water supply was turned on.

Although 4- and 8-week old broiler chickens can survive between one and three weeks without food or water (Bierer et al., 1966), 7- or 8-week old Aylesbury ducks that were deprived of water for 36 hours exhibited significant weight loss and increased hematocrit levels, plasma sodium concentrations, and sodium: potassium ratios as compared with control birds (Harvey et al., 1981).

Miscellaneous

Nutrition and Hepatic Malic Enzyme: Goodridge et al. (1984) reported that feeding a low fat, high carbohydrate commercial mash diet caused 25-fold and 5 to 10-fold increases in hepatic malic enzyme and fatty acid synthase activities, respectively, in White Pekin ducklings. In contrast, food deprivation significantly depressed the hepatic activities of these enzyme in newly-hatched and 11-day old ducklings. Decreased sequence abundance of hepatic malic enzyme and fatty acid synthase messenger ribonucleic acids were observed in starved 4-day old ducklings.

In a subsequent report, Goldman et al. (1985) concluded that feeding regulates the levels of malic enzyme messenger ribonucleic acid in White Pekin ducklings by both increasing transcription of the malic enzyme and decreasing the degradation of malic enzyme messenger ribonucleic acid.

Efficiency of Feed Utilization: Avens et al. (1980) reported that housing Khaki Campbell laying ducks in cages did not reduce egg production or feed efficiency in comparison to birds raised in floor pens. However, egg production and egg size were adversely affected by restricting feed intake to approximately 67% of controls fed ad libitum.

Hester et al. (1981) recorded daily feed:gain ratios of male and female White Pekin ducks during the latter stage of growth in order to determine the age at which poor feed efficiency occurred. They concluded that ducks reared under normal environmental conditions should be marketed between 48 and 51 days of age.

Storey and Maurer (1986) fed White Pekin ducklings isocaloric and isonitrogenous diets containing either graded levels of corn oil (0 to 10% in increments
of 2%) or 4% each of corn oil, peanut oil, vegetable shortening, lard, or tallow. Body weights at 49 days of age were not significantly affected by dietary treatment; however, feed efficiency (feed:gain) values decreased linearly as the amount of dietary corn oil was increased. Although ducklings fed tallow consumed significantly less feed than ducklings fed no fat, 4% corn oil, peanut oil, vegetable shortening, and lard, feed efficiency values were not significantly different. Unlike the chick, which shows decreased metabolizability and absorbability of tallow between 2 and 8 weeks of age, Storey and Maurer (1986) suggested that tallow is utilized as well as other fats and oils by young ducklings during all phases of growth (0 to 7 weeks of age).

Anticoccidial Drugs: Ducks and geese are generally considered to exhibit greater resistance to most diseases and parasites than do domestic land fowl, making the routine usage of medicated feeds for waterfowl much less common than with chickens and turkeys (Holderread et al., 1983). In addition, there is an extreme lack of information on this subject.

Holderread et al. (1983) individually incorporated 3 different anticoccidial drugs, zoalene, sulfadiazine, and amprolium, into corn-soybean meal mash diets at the manufacturers’ recommended use levels for chickens and turkeys. Khaki Campbell male ducklings were fed the above diets as well as commercial pelleted turkey starter or chick starter rations, each containing amprolium, from day-old to 4 weeks of age. The authors reported that feeding the various anticoccidial drugs at recommended levels for chickens and turkeys did not cause any leg or anatomical problems in ducklings.

Summary
A review of the literature on the nutrition of ducks revealed that although several areas have been intensively researched (protein requirements, dietary effects on carcass composition, and vitamin E-selenium interactions), others have been almost totally neglected (certain vitamins, trace elements, and amino acids).

Three major breeds or genetic crosses of ducks predominate in the majority of studies conducted: White Pekin, Muscovy, and "Mule" ducks. The latter, which are sterile, are crosses between Muscovy drakes and F1 females of White Pekin drakes and white domestic ducks. Because Muscovy ducks are slower-growing than White Pekins, Muscovy and mule requirement data may not be directly applicable to the White Pekin. Therefore, an attempt was made to identify the specific breed or genetic cross utilized in each study cited.

Résumé
UNE REVUE DE LA RECHERCHE SUR LA NUTRITION DU CANARD
(R. G. Elkin)

Une revue de la recherche sur la nutrition du canard révèle que, quoique plusieurs domaines aient fait l'objet de recherches intensives (besoins en protéines, effets de la ration sur la composition des carcasses, interactions vitamine E—sélénium), d'autres ont été presque totalement négligés (certaines vitamines, oligoéléments, acides aminés).

Trois races principales ou croisements de carnards prédominent dans la majorité des études: Pékin blanc, Barbarie, et Mulards. Ces derniers, qui sont stériles, sont des croisements entre des mâles Barbarie et des femelles F1 entre des mâles Pékin blancs et des canes domestiques blanches. Du fait que les canards de Barbarie ont une croissance plus lente que les Pékin, les données sur les besoins des Barbarie et des Mulards peuvent ne pas être directement applicables au Pékin blanc. Par suite, un essai a été fait d'identifier la race ou croisement spécifique utilisé dans chacune des études citées.

Zusammenfassung
EINE OBERSICHT DIE ERNÄHRUNG VON ENTEN
(R. G. Elkin)

Das Studium der vorhandenen Veröffentlichungen über die Ernährung von Enten ließ erkennen, daß einige Gebiete zwar sehr intensiv erforscht sind (Eiweißbedarf, Einfluß der Fütterung auf die
Schlachtkörperrzusammensetzung und Wechselbeziehungen zwischen Vitamin E und Selen), wurden andere fast vollkommen vernachlässigt (bestimmte Vitamine, Spurenelemente und Aminosäuren).


Resumen

UNE REVISTA SOBRE LA INVESTIGACIÓN DE LA NUTRICIÓN DEL PATO

(R. G. Elkin)

Una revista de la literatura acerca de la nutrición del pato descubrió que aunque varias zonas han ido intensivamente investigadas (requisitos para la proteína, efectos del régimen sobre la composición corporal, y las interacciones de la vitamina E-selenio), otras han sido casi completamente descuidadas.

Tres razas o cruces genéticas del pato predominan en la mayor parte de los estudios: White Pekin, Muscovy, y patos "Mule". Estos últimos, que son esteriles, son cruces entre machos Muscovy y hembras F1 de machos White Pekin y patos domésticos blancos. A la razón que patos Muscovy crecen más lentamente que patos White Pekin, los datos sobre Muscovy y "Mule" pondrán no ser directamente aplicables al pato White Pekin. Entonces, se intentó identificar la raza específica o la cruce genética usada en cada estudio citado.

Referencias


