THE EFFECT OF PROTEIN AND ENERGY SELF-SELECTION ON THE REPRODUCTIVE PERFORMANCE OF TURKEY HENS

by

DEREK ALAN EMMERSON

Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

Master of Science

in

Poultry Science

APPROVED:

D. M. Denbow, Chairman

R. M. Hulet

H. P. Van Krey

J. H. Wolford

May, 1988

Blacksburg, Virginia

THE EFFECT OF PROTEIN AND ENERGY SELF-SELECTION ON THE REPRODUCTIVE PERFORMANCE OF TURKEY HENS

by

DEREK ALAN EMMERSON

D. M. Denbow, Chairman

Poultry Science

(ABSTRACT)

Two experiments were conducted to determine the effect of dietary self-selection of protein and energy on the reproductive performance of Large White turkey hens. The first study examined the effect of self-selection on reproductive performance during a production cycle that started in July and ended in December. Hens were maintained on one of two dietary regimes for a 20-week production cycle. Control birds were fed a conventional diet (18% crude protein, 2700 kcal/kg) which contained nutrients at levels recommended by the National Research Council (NRC, 1984). The remaining hens were allowed to select their diet from two feed sources: one relatively high in protein and low in energy (35% crude protein, 1850 kcal/kg) and the other relatively low in protein and high in energy (8% crude protein, 3220 kcal/kg). Hens fed the split diet produced an equal number of eggs as control hens but consumed significantly less feed ($p \leq .05$). The diet that was selected contained approximately 40% less protein than the control diet ($p \leq .001$) which resulted in significantly increased efficiency of protein utilization (eggs/kg protein) for hens fed the split-diet ($p \leq .001$). In addition, the incidence of broodiness was significantly reduced in the split-diet

treatment ($p \leq .10$). Egg weight, fertility, hatchability and hatch of fertile eggs were not significantly effected by the dietary regimes. There was significantly greater body weight loss in hens fed the split-diet ($p \leq .05$). Increasing trends in feed, energy, and protein consumptions were noted over the course of production. For this reason a second experiment was conducted to determine if these trends were the result of seasonal affects, due to changing ambient temperatures, or the result of changes in nutrient requirements of the turkey hen occurring with different stages of production.

The second experiment was similar to Experiment 1 except that the production period started in March and ended in July. As in the first experiment, egg production was equal for hens in the two treatment groups. Feed intake and energy intake were not significantly different for hens fed the split and complete diets. However, as in the previous experiment, protein intake was significantly reduced in the split-diet treatment ($p \leq .001$). The incidence of broodiness was again attenuated among split-fed birds ($p \leq .10$). Average daily feed and energy intake appeared to decrease over the course of production which was presumed to be related to increasing ambient temperatures. As in the previous experiment, protein intake increased over the course of production despite increasing environmental temperatures. Therefore, the increased protein selection noted in these two experiments does not seem to be related to hot weather and may indicate an increased protein requirement in the later stages of egg production.

Based on the finding that the incidence of broodiness was reduced among hens fed the split-diet, blood sera from hens in both experiments were analyzed for luteinizing hormone (LH) and prolactin (PRL). Although the incidence of broodiness was significantly reduced among birds fed the split-diet, there was no significant difference in serum LH and PRL concentrations. Therefore, the reduction in the incidence of broodiness that was noted in these experiments was not correlated with changes in the blood concentration of these hormones.

ACKNOWLEDGEMENTS

I would like to thank Dr. D.M. Denbow for his guidance, support and enthusiasm throughout the course of my master's program. I would also like to express my gratitude to the other members of my committee. Dr. R.M. Hulet has provided important insight concerning the management of turkey breeders in the poultry industry and was always present when I was conducting experiments. Dr. Van Krey has always been very generous with his time and his willingness to serve on my committee on short notice is very much appreciated. Dr. J.H. Wolford has provided me with opportunities to interact with individuals in industry that I might not have met otherwise. In addition, his concern for my future is very much appreciated.

I would like to thank Dr. E.L. Wisman for his encouragement to continue my education and Dr. J. A. Cherry for providing the opportunity to do so. Without their help I might not have gotten the chance to enter graduate school. Dr. L.M. Potter has provided valuable assistance on the nutritional aspects of my research project and has taught me techniques which are important to applied nutritional research. I would like to thank my fellow graduate students for their friendship and patience throughout my graduate studies. Special thanks to Mike for his encouragement early in my program, to Jim for exposing me to his point of view which has given me additional perspective; to Wade who has helped me to learn that all work and no play makes Derek a dull boy; to Vernon who has helped me to develop socially; to Frosty for helping me to review statistics; to Anibal for showing me how dedication pays off; and to Nick both for his friendship and for his companionship during late night writing sessions which allowed me to finish "on time". I wish all of you success in the future. I would like to thank Trish for putting up with my shenanigans in the laboratory and for listening to my griping when things were getting me down. Without her encouragement, I might have quit long ago. Thanks to Beth for her help in verifying data. I would like to thank Suzi and Phyllis for their patience when teaching me to use script. I would also like to thank the farm crew at the turkey research center for their help in conducting experiments. Without the assistance of Leroy , Eugene , Dale , and Benny , I probably would never have gotten off the farm. I also want to express my appreciation to the students in my laboratory sections who made my teaching experience a learning experience. Special thanks to my friends in the poultry science club for providing an important social diversion from graduate life.

Finally, I want to express my gratitude to my family for their support throughout my graduate studies. The encouragement of my parents, , and my sister and brother has made all the difference.

TABLE OF CONTENTS

LIST OF TABLES

EXPERIMENT I

EXPERIMENT II

EXPERIMENT III

LIST OF FIGURES

EXPERIMENT I

INTRODUCTION

Protein requirements of turkey hens

When compared with the large body of information concerning the nutrient requirements of broilers and growing turkeys, relatively little is known about the requirements of turkey breeders. The National Research Council (NRC, 1984) has established requirements of 14% crude protein and 2900 kcal metabolizable energy/kg of diet for turkey hens during the breeding period. However, considerable disagreement exists regarding these requirements and, consequently, there remains much variation in the formulation of turkey breeder diets throughout the nation.

Diets containing crude protein (CP) levels as low as 10% CP (Jensen and McGinnis, 1961; Minear *et al.*, 1970; Minear *et al.*, 1972) and as high as 22% CP (Atkinson *et al.*, 1960) have been reported to be necessary for the maximal egg production of turkey hens. Minear *et al.* (1972) found that although the efficiency of egg production was adversely affected by a 10% CP diet, there were no differences in egg production or the fertility and hatchability of eggs produced from hens fed diets with protein levels ranging from 10 to 16% CP. Similar results were obtained by Jensen and McGinnis (1961).

While the above studies indicate that a protein level dramatically lower than the NRC requirement is adequate for egg production, the bulk of available information has demonstrated a benefit from feeding higher protein levels. Cherms *et al.* (1978) found that hens fed 22 g of protein per day (10% CP) produced fewer and smaller eggs than hens fed 35 g of protein daily (15% CP). In addition, hens fed the lower protein diet had significantly lower body weights than hens fed the higher protein level. Cohen-Parsons *et al.* (1982) fed isocaloric methionine supplemented diets containing 10,12 and 14% CP to turkey hens and found that egg production was significantly improved by the two higher protein levels. In addition, only the 14% protein level was sufficient to maintain serum albumin concentrations at their highest level (Cohen-Parsons *et al.*, 1983). Similar results were obtained by Krueger *et al.* (1978) who found no difference in the egg production of hens fed diets containing either 14 or 18% CP. Atkinson *et al.* (1970) found that egg production, average egg weight, and body weight change were all adversely affected when birds were fed a diet containing 12% CP compared to diets containing 15, 18 or 21% CP. Similarly, Bradley and coworkers (1971) found a 15% CP diet superior to diets containing either 12 or 18% CP.

Some reports have indicated that even higher protein levels are needed to support maximal egg production. Atkinson *et al.* (1974) found that both egg production and egg weights were improved when hens were fed corn based diets containing 18% CP as compared with a protein level of 15%. This result did not hold true when the corn was replaced with milo which might be attributed to differences in the amino acid profiles of corn and milo. In an experiment comparing protein levels ranging from 12 to 21% crude protein it was determined that, although the lower protein levels were adequate during the first 11 weeks of the production period, a protein level of 18% CP was necessary to maintain egg production later in the production cycle (Bradley *et al.*, 1969). Wahid *et al.* (1967) found higher poult yields when hens were fed a 21% CP ration rather than a 19% CP diet. Similarly, Atkinson et al. (1960) found that a 22% CP diet was superior to 16 and 19% diets.

Energy requirements of turkey hens

Information concerning the energy needs of turkey hens is even more scarce than that on protein requirements. Dyzma *et al.* (1954) reported no adverse affects on egg production resulting from the reduction of dietary energy levels through the addition of fiber. Energy levels in this experiment ranged between 549 and 1944 kcal Productive Energy (PE)/kg. Only the efficiency of egg production was effected by these treatments. More recently it has been shown that increasing the energy level of the diet from 2700 to 2900 kcal ME/kg resulted in significantly improved egg production and hatchability of fertile eggs (Henau *et al.*, 1986). Embryo mortality was also significantly reduced by feeding higher metabolizable energy levels.

Most of the information on the proper energy levels of turkey breeder diets has been concerned with the effect of supplementary fat on egg production. Some experiments have shown no beneficial effect due to the addition of dietary fat. Potter *et al.* (1978) found no improvement in the egg production of hens fed diets containing 6% added fat. Similarly, Grizzle and coworkers (1982) found no significant increases in the egg production of hens fed diets containing 4% supplementary fat. However, there are many reports of improvements in the egg production of turkey hens fed diets containing up to 12.5% supplementary fat. Creger *et al.* (1970) observed increases in egg production and in the efficiency of egg production when tallow was added to an 18% CP breeder ration at levels ranging from 2.5 to 12.5%. This improvement in production efficiency was due to both an increase in egg production and a decrease in feed intake. Touchburn *et al.* (1968) found a 13% increase in egg production through the addition of 10% fat to the diet of turkey hens. These findings are supported by those of Harms *et al.* (1983) who observed an increase in egg production as the fat level of the diet was increased from 0 to 4% and from 4 to 8% of the diet. It was determined that, while feed intake was reduced as a result of increasing the fat level of the diet, daily energy consumption was actually increased through the addition of fat. In a later experiment, Harms *et al.* (1984) found that fertility was improved and body weights were increased with fat supplementation. Therefore, it appears that increasing the energy level of the diet through the addition of fat may have some beneficial effect on egg production.

Dietary self-selection by poultry

One of the reasons that information concerning the nutrient requirements of breeder turkeys is so scarce is due to the great expense and difficulty in doing such research using traditional methods. Another way to determine the nutrient needs of poultry is to allow the bird to select the proper nutrient level based on individual needs. In early management systems, poultry were routinely fed in this manner (Banta, 1932; Graham, 1932; Graham, 1934; Lee *et al.*, 1944; Vondell, 1948; Lee *et al.*, 1949; MacIntyre and Jenkins, 1955; Massey and Fuller, 1962). Under this system, referred to as a split-diet regime, birds are allowed to choose between two food sources; one an abundant source and another a scarce source of the nutrient of interest. In an extensive review of the subject, Hughes (1984) explained that fowl, through a process of learning and experience, sample potential foods and then continue to consume those which they find nutritious and palatable. The ability to self-select various nutrients with varying success has been demonstrated in chicks (Funk, 1932; Kaufman et al.,1978), growing turkeys (Massey and Fuller, 1962; Cowan and Michie, 1978; Rose and Michie, 1982), growing chickens (Graham, 1934; Kare and Maller, 1967; Cowan *et al.*, 1978; Summers and Leeson, 1978; Leeson and Summers, 1981; Brody et al., 1984; Cherry *et al.*, 1984) laying hens (Lee *et al.*, 1944; Vondell, 1948; Lee *et al.*,1949; Holcombe *et al.*, 1976; Emmans, 1977; Leeson and Summers, 1978; Leeson and Summers, 1979; Leeson and Summers, 1980; Summers and Leeson, 1981; Blake *et al*, 1984) and turkey hens (McDonald and Emmans, 1980). Specific appetites for calcium (Mongin and Sauveur, 1974; Leeson and Summers, 1979; Leeson and Summers, 1980; Blake *et al.*,1984), phosphorous (Holcombe *et al.*, 1976), zinc (Hughes and Dewar, 1971), thiamine (Hughes and Wood-Gush, 1972), protein (Graham, 1934; Holcombe *et al.* 1976; Summers and Leeson, 1978), energy (Gidlewski et al.,1982; Brody *et al.*, 1984), and energy and protein simultaneously (Kaufman et al., 1978; Leeson and Summers, 1978; Leeson and Summers, 1981; Huey *et al*, 1982; Blake *et al.*, 1984; Cherry *et al.*,1984) have been demonstrated in avian species.

The earliest self-selection experiments were observational in nature. In these experiments birds were allowed to select from a wide variety of feed ingredients. Results show that birds were able to perform equal to or better than birds on complete diets (Banta, 1932; Funk, 1932; Graham, 1932). However, our knowledge of the nutrient requirements of poultry is much greater today and contemporary birds have much greater growth rate and egg production than the birds of that time. Therefore, the success of such a system, where the bird receives a rather severe challenge, at this time is questionable.

However, more conservative approaches do have potential today. Under one such system, birds are allowed to select between a concentrated "balancer" ration and some grain source. Such a system has had variable success. Lee *et al.* (1944, 1949) observed lower egg production in White Leghorns and dual purpose laying hens when allowed to self select. More recently it was shown that the egg production and body weight of turkey hens was adversely effected by the choice feeding of balancer pellets and wheat (McDonald and Emmans, 1980). However, an increase in egg production was noted when hens were switched to choice feeding late in the production cycle. This could be due to the fact that flock requirements are more variable during this period of production. In this case the fact that birds would be able to select a diet that met their individual needs might stimulate greater egg production. Experiments with growing turkeys in a choice fed situation have shown growth rate to be equal to (Rose and Michie, 1982) or greater (Massey and Fuller, 1962; Cowan and Michie, 1978) than birds fed complete diets. A similar situation exists in growing pullets where birds consume feed and grow at a rate equal to controls (Cowan *et al.*, 1978). In laying hens it has been shown that hens are able to produce eggs satisfactorily under such a system (Vondell, 1948; Emmans, 1977).

A third, more specific system involves the feeding of two diets that are approximately equal in all nutrients except for one or two which are being studied. Summers and Leeson (1978) found that, although growth rate was slightly reduced, pullets and broilers fed a split diet had a more uniform growth rate and greater protein efficiency than birds fed a complete diet. In another experiment, Leeson and Summers (1981) found that, despite a reduced protein intake, growing pullets experienced no negative effects when fed a split diet. Kaufman *et al.* (1978) found that chicks were able to select a diet with a protein:energy ratio that was sufficient to maintain a growth rate equal to that of controls. In this experiment protein efficiency was also improved due to a reduced level of protein consumption. These results indicate that birds may actually be overconsuming protein when fed a complete diet.

Results in laying hens demonstrate that, despite the rather severe challenge that a split diet regime represents, egg production can be maintained under such a system. In an experiment with genetic lines selected for high and low body weights, it was determined that when birds were fed a split diet they selected a significantly lower protein level than controls (Brody *et al*., 1984). Holcombe *et al*. (1976) found that egg production could be maintained when birds were allowed to select between high and low protein diets. Similar results were obtained by Cherry *et al*. (1984) who found that, after a seven day period of adjustment, birds were able to modify their protein and energy intake to maintain egg production. Therefore, there is a great deal of information indicating that growth and egg production can be maintained on such a system.

Although self-selection experiments can provide important information concerning the nutrient needs of poultry, the level of nutrient selected cannot necessarily be regarded as the nutrient requirement. With the exception of calcium, most nutrients are not self-selected by *Aves* due to innate appetites (Hughes, 1979; 1984). Nutrients can, however, be selected through a learning process resulting from positive post-ingestional feedback For this learning process to proceed, birds must first develop a deficiency for the nutrient being selected. They then learn to increase intake of the nutrient in question because increased intake leads to a generalized improvement in metabolism. An improved feeling of well-being then serves to reinforce the individuals behavior in selecting the appropriate diet (Hughes and Wood-Gush, 1972) The length of time required for this learning process to occur varies with the class of bird being used, the nutrient being selected, and the composition of the diets being fed. In some cases the learning process may take an extremely long period to complete. Classen and Scott (1982) found that Leghorn hens reared on a self-selection regime performed better on a split-diet during the production phase than birds not reared on this system. Therefore, when conducting such research, birds must be allowed sufficient time to adapt to the self-selection regime before any meaningful results will be obtained.

Another factor that precludes interpreting the self-selection of a nutrient as the absolute requirement for that nutrient is the relative palatability of the diets that the birds are allowed to select. Although somewhat difficult to evaluate, palatability refers to factors such as diet form, texture and flavor which influence the overall acceptability of a diet (Hughes, 1984). If the palatability of one diet is low then birds will tend to select less of that diet and, consequently, less of the nutrient that predominates. Therefore the amount of a particular nutrient that is selected is the result of a balance between the requirement of the individual for the nutrient and the relative palatability of the diet that the nutrient is selected from (Hughes, 1979; 1984). This is not necessarily a bad situation. Consider the case of a nutrient that has no negative physiological effects over a wide range of intakes. If palatability did not limit the consumption of this nutrient, then birds could consume this nutrient well in excess of their requirement without any negative feedback. Individuals would not learn to limit their consumption of the nutrient to their physiological need. In this case, we would be greatly overestimating the requirement of the nutrient rather than arriving at a slight underestimate.

In addition to providing a method for looking at the nutrient needs of the bird, feeding split diets provides insight into how these needs change over time. When fed under this system, chicks have been shown to select a diet containing progressively less protein with increasing age (Kaufman *et al.*,1978). Summers and Leeson (1978) observed a similar trend in pullets, with birds selecting significantly less protein between 11 and 20 weeks of age than before 11 weeks of age. In a second experiment Leeson and Summers (1981) found that protein intake increased between 17 weeks of age and sexual maturity. It has also been shown that laying hens increase their intake of a concentrated balancer ration during peak egg production as compared to other periods in the production cycle (Emmans, 1977). These experiments all demonstrate that feeding birds on a split diet allows them to select different nutrient levels over time and, therefore, gives some insight into how the requirements for these nutrients change with changing physiological states.

Therefore, it appears that the avian species can self-select many nutrients. The amount of the nutrient selected provides an estimate of the nutrient requirement which is tempered to some degree by the relative palatability of the diets fed. In most cases self-selection occurs through a learning process which requires the development of a slight deficiency of the nutrient of interest. This learning process requires a variable length of time to occur depending on the nutrient tested and the composition of the diets selected from. Most birds are able to self-select within a fairly short time, however, a minority may require a relatively long period to adjust (Hughes, 1979). In addition, there may be a few individuals that fail to select an appropriate diet (Taylor, 1970).

Body weight and reproduction

In contrast to broiler breeders and laying hens, turkey hens characteristically lose weight over the course of the breeding season (Harper, 1950; Wolford *et al.*, 1963). This loss in body weight coincides with seasonal declines in egg production that occur late in the production cycle (Robel, 1981). Therefore, it has been suggested that diets which enable turkey hens to maintain heavier body weights might aid in preventing declines in egg production (Robel, 1984). One possible method that might allow hens to better maintain their body weight is the feeding of a split-diet. This regime might allow birds to select the proper diet to meet their individual requirements. In this case, since their individual requirements are more nearly met, turkey hens would be able to maintain heavier body weights and, hopefully, greater egg production. This possibility deserves further research.

Broodiness remains a major problem that limits the egg production of turkey hens. A precipitous decline in food intake is associated with the onset of broodiness (Wolford *et al.*, 1963; Savory, 1979; Zadworny *et al.*, 1985). It is possible that the nutritional need of the hen changes with the onset of broodiness. Through the feeding of a split-diet, it is possible to determine whether there is a change in the relative intake of protein and energy prior to the onset of broodiness. If the nutritional needs of the turkey hen do change, it may be possible to reduce the incidence of broodiness and it's detrimental effects on egg production through some dietary means.

Seasonal effects on reproduction and nutrient requirements

The negative effect of high environmental temperatures on avian reproduction has long been recognized. High environmental temperatures decrease egg production (Mitchell and Kozin, 1954; Thomason *et al.*, 1972) and increase the incidence of broodiness in turkey hens (Mitchell and Kozin, 1954; Marsden *et al.*, 1966; Thomason *et al.*, 1972) Similar decreases in egg production have been observed in laying hens (Mueller, 1961). In addition, reductions in egg weight (Bennion and Warren, 1933; Hutchinson, 1953; Meuller, 1961) and shell quality (Meuller, 1961; Harrison and Biellier, 1969) occur as temperatures increase. Reductions in reproductive performance could conceivably reduce the protein and energy need of turkey hens.

The effect of environmental temperatures on energy requirements (Kurick *et al.*, 1961; Daghir, 1973) and feed intake (Bray and Gesell, 1961; Kurnick *et al.*, 1961; Leeson and Shrimpton, 1973) is well established. As ambient temperature increases there is a consequential decrease in feed intake. This decrease is related to the decreasing energy needs of the hen during hot weather and may result in a reduction in feed intake of as much as 25% compared to cooler periods of the year. Although energy requirements are being met in this situation, deficiencies of other nutrients may occur if their supply in the diet is marginal (Thornton and Whittet, 1960). Therefore, nutrient requirements must be evaluated not only on an absolute basis but also relative to energy intake.

The importance of the relationship between the energy and protein content of the diet has been well established in many classes of poultry (Hill and Dnasky, 1950; Donaldson *et al.*, 1955; Lockhart and Thayer, 1955; Matterson *et al.*,1955). This relationship becomes particularly important considering the effect of environmental temperature on food intake. The importance of this consideration is demonstrated by the existence of a protein by fat or protein by energy interaction in some factorially designed experiments. Bray and Gesel (1961) found that when the protein content of the diet was suboptimal, negative effects on the egg production of leghorn pullets were first noted among hens maintained at high environmental temperatures. Anderson *et al.* (1964) observed an increase in egg production when fat was added to a 14.5% CP diet at a rate of 4% of the diet. However, a similar increase in production was not noted when the same fat level was added to 16.5 or 18.5% CP diets. Similar results were obtained by Menge *et al.* (1979). In this experiment a significant protein by energy interaction was observed with the highest level of egg production occurring when birds were fed a diet containing 18% CP and 2.3 Mcal ME/kg.

Despite the importance of this relationship, few experiments have been conducted looking directly at the proper ratio of energy to protein in the diets of turkey hens. In one experiment no difference was found in the egg production of hens fed diets with ratios of productive energy (therms) to protein ranging between 41 and 59:1 (Robblee and Clandinin, 1959). However, more research is needed in this area to determine the proper relationship between energy and protein in the diet of turkey breeder hens.

Self-selection of protein allows the bird to maintain protein intake independent of energy intake. This eliminates the confounding effects of seasonality on protein requirements and consequently allows investigation of the effect of stage of production on protein requirements. Therefore, this type of study can provide an important method for evaluating changes in the seasonal and physiological requirements for protein.

The primary objective of the following experiments was to determine the effect of protein and energy self-selection on the reproductive performance of turkey hens. An additional objective was to determine the effect of seasonality on patterns of protein and energy selection.

REFERENCES

Anderson, D.L., 1964. Effect of body size and dietary energy on the protein requirement of turkey breeders. Poultry Sci. 43:59-64.

Atkinson, R.L., J.W. Bradley, J.R. Couch, and J.H. Quisenberry, 1960. Effect of protein level and electric shock on reproductive performance and incidence of broodiness. Poultry Sci. 39:1231.

Atkinson, R.L., J.W. Bradley, T.M. Ferguson, J.R. Couch, and J.H. Quisenberry, 1970. Protein level and reproductive performance of turkey hens. Nutr. Rep. Int. 1:353-366.

Atkinson, R.L., K.K. Krueger, J.W. Bradley, J.R. Couch, and W.F. Krueger, 1974. Relation of protein level and grain source to turkey reproduction. Nutr. Rep. Int. 4:259-266.

Banta, L., 1932. What judgement does a hen use in selecting her food? Poultry Sci. 11:364.

Bennion, N.L. and D.C. Warren, 1933. Temperature and its effect on egg size in the domestic fowl. Poultry Sci. 12:69-82.

Blake, A.G., F.B. Mather, and E.W. Gleaves, 1984. Self-selection of laying hens inadequate to overcome the effects of high environmental temperature. Poultry Sci. 63:1346-1349.

Bradley, J.W., R.L. Atkinson, J.R. Couch, and J.H. Quisenberry, 1969. Protein requirement of breeder turkeys. Poultry Sci. 48:1788.

Bradley, J.W., R.L. Atkinson, J.R. Couch, and J.H. Quisenberry, 1971. Relation of protein level and grain type to egg production of turkeys. Poultry Sci. 50:1555.

Bray, D.J., and J.A. Gesell, 1961. Studies with corn-soya laying diets 4. environmental temperature-a factor affecting performance of pullets fed diets suboptimal in protein. Poultry Sci. 40:1328-1335.

Brody, T.B., J.A. Cherry, and P.B. Siegel, 1984. Responses to dietary self selection and calories in liquid form by weight selected lines of chickens. Poultry Sci. 63:1626-1633.

Cherms, F.L., M.G. Stoller, and J.J. MccIlraith, 1978. A comparison of 22 and 35 grams of daily protein intake and the effects on reproduction of turkey hens. Poultry Sci. 57:1126.

Cherry, J.A., K.S. Young, and D.E. Jones, 1984. Feed intake response to the dilution of high-protein and high-energy diets under self-selection feeding. Poultry Sci. 63:744-749.

Classen, H.L., and Scott, 1982. Self-selection of calcium during the rearing and early laying periods of white leghorn pullets. Poultry Sci. 61:2065-2074.

Cohen-Parsons, M., A.T. Leighton, and G.B. Meyer, 1982. Reproductive performance of female breeder turkeys fed on maize-soyabean diets supplemented with methionine. Br. Poult. Sci. 23:135-143.

Cohen-Parsons, M., A.T. Leighton, and K.E. Webb, 1983. Blood proteins and amino acids of female breeder turkeys fed on maize-soyabean diets supplemented with methionine. Br. Poult. Sci. 24:287-293.

Cowan, P.J., and W. Michie, 1978. The use of barley in choice feeding of the turkey. Br. Poult. Sci. 19:1-6.

Cowan, P.J., W. Michie, and D.J. Roele, 1978. Choice feeding of the egg-type pullet. Br. Poult. Sci. 19:153-157.

Creger, C.R., R.L. Atkinson, and J.R. Couch, 1970. Fat levels in the diet of turkey breeders. Nutr. Rep. Int. 2:1-8.

Daghir, N.J., 1973. Energy requirements of laying hens in a semi-arid continental climate. Br. Poult. Sci. 14:451-461.

Donaldson, W.E., G.F. Combs, G.L. Romoser, and W.C. Supplee, 1955. Body composition, energy intake, feed efficiency, growth rate, and feather condition of growing chickens as influenced by calorie-protein ratio of the ration. Poultry Sci. 34:1190.

Dyzma, H., R.V. Boucher, and M.G. McCartney, 1954. Influence of dietary fiber and energy level on reproductive performance of turkey pullets. Poultry Sci. 33:1159-1163.

Emmans, G.C., 1977. The nutrient intake of laying hens given a choice of diets, in relation to their production requirements. Br. Poult. Sci. 18:227-236.

Funk, E.M., 1932. Can the chick balance its ration? Poultry Sci. 11:94-97.

Gidlewski, T., J.A. Cherry, P.B. Siegel, and H.P. Van Krey, 1982. Feed intake response of four populations of chickens to calories in liquid form. Arch. Geflugelk. 46:136-142.

Graham, W.R., 1932. Can we learn anything from a free choice of feeds as expressed by chickens? Poultry Sci. 11:365-366.

Graham, W.R., 1934. Individuality of pullets in balancing the ration. Poultry Sci. 13:34-39.

Grizzle, J.M., R.A. Voitle, and R.H. Harms, 1982. Evaluation of distillers dried grains with solubles in diets of turkey hens. Poultry Sci. 1982:1363-1366.

Harms, R.H. and H.R. Wilson, 1983. Improved performance of turkey hens from the addition of dietary fat. Poultry Sci. 62:2283-2284.

Harms, R.H., R.E. Buresh, and H.R. Wilson, 1984. The influence of the grower diet and fat in the layer diet on performance of turkey hens. Poultry Sci. 63:1634-1637.

Harper, J.A., 1950. Changes in body weight and conformation of broad breasted bronze turkeys during the breeding season. Poultry Sci. 29:98-103.

Harrison, P.C., and H.V. Biellier, 1969. Physiological response of domestic fowl to abrupt changes of ambient air temperature. Poultry Sci. 48:1034-1045.

Henau, P.D., C.W. Chan, and S.P. Touchburn, 1986. Effects of dietary energy, protein, and fat levels on the reproductive performance of turkey hens. pages 34-37 *in* Research reports, Department of Animal Science, McGill University. Montreal, Canada.

Hill, F.W., and L.M. Dansky, 1950. Studies of the protein requirements of chicks and its relation to dietary energy level. Poultry Sci. 29:763.

Holcombe, D.J., D.A. Roland Sr., and R.H. Harms, 1976. The ability of hens to regulate protein intake when offered a choice of diets containing different levels of protein. Poultry Sci. 55:1731-1737.

Huey, D.F., J.A. Cherry, D.M. Denbow, and H.P. Van Krey, 1982. Self-selection of dietary protein and energy by diverse populations of chickens. Nutr. Behav. 1:55-64.

Hughes, B.O., and W.A. Dewar, 1971. A specific appetite for zinc in zinc-depleted domestic fowls. Br. Poult. Sci. 12:255.

Hughes, B. O., 1979. Appetites for specific nutrients. Pages 141-169 in Food Intake Regulation in Poultry. K.N. Boorman and B.M. Freeman, ed. Br. Poult. Sci. Ltd., Edinburgh.

Hughes, B.O., 1984. The principles underlying choice feeding behavior in fowls-with special reference to production experiments. World Poultry Sci. 40:144-150.

Hughes, B.O., and D.G.M. Wood-Gush, 1972. Hypothetical mechanisms underlying calcium appetite in fowls. Rev. Comp. Anim. 26:135-156.

Hutchinson, J.C.D., 1953. Effect of hot climates on egg weight. Poultry Sci. 32:692-696.

Jensen, L.S. and J. McGinnis, 1961. Nutritional investigation with turkey hens 1. quantitative requirement for protein. Poultry Sci. 40:288-290.

Kare, M.R., and O. Maller, 1967. Taste and food intake in domesticated and jungle fowl. J. Nutr. 92:191-196.

Kaufman, L.W., G. Collier, and R.L. Squibb, 1978. Selection of an adequate protein-carbohydrate ratio by the domestic chick. Physiol. Behav. 20:339-344.

Krueger, K.K., J.A. Owen, C.E. Krueger, and T.M. Freguson, 1978. Effect of feed and light regimes during the growing period on subsequent reproductive performance of broad breasted white turkeys fed two protein levels. Poultry Sci. 57:27-37.

Kurnick, A.A., H.B. Hinds, M.W. Pasvogel and B.L. Reid, 1961. Dietary energy levels for laying hens as related to age and environmental temperatures. 1. effect on egg production, body weight and feed conversion. Poultry Sci. 40:1483-1491.

Lee, C.E., J.C. Scholes, and C.L. Henry, 1944. The effect of "free choice" grain feeding on egg production, feed consumption, body weight and egg quality. Poultry Sci. 23:360-370.

Lee, C.E., J.C. Scholes, and C.L. Henry, 1949. The effect of "free choice" grain feeding on egg production and feed consumption. Poultry Sci. 28:10-13.

Leeson, S., D. Lewis, and D.H. Shrimpton, 1973. Multiple linear regression equations for the prediction of food intake in the laying fowl. Br. Poult. Sci. 14:595-608.

Leeson, S., and J.D. Summers, 1979. Dietary self-selection by layers. Poultry Sci. 58:646-651.

Leeson, S., and J.D. Summers, 1978. Voluntary food restriction by laying hens mediated through dietary self-selection. Br. Poult. Sci. 19:417-424.

Leeson, S., and J.D. Summers, 1980. Effect of early light treatment and diet self-selection on laying performance. Poultry Sci. 59:11-15.

Leeson, S., and J.D. Summers, 1981. Dietary self-selection and use of reverse-protein diets for developing broiler breeder pullets. Poultry Sci. 60:168-171.

Lockhart, W.C., and R.H. Thayer, 1955. Energy-protein relationships in turkey poult starters. Poultry Sci. 34:1955.

Luther, B., 1932. What judgement does a hen use in selecting her food? Poultry Sci. 11:364.

Marsden, S.J., L.M. Lucas, and S.P. Wilson, 1966. The influence of daylength and environment on reproduction, broodiness, and mortality of turkeys. Poultry Sci. 45:668-675.

Matterson, L.D., L.M. Potter, L.D. Stinson, and E.P. Singsen, 1955. Studies on the effect of varying protein and energy levels in poultry rations on growth and feed efficiency. Poultry Sci. 34:1955.

MacIntyre, T.M., and M.H. Jenkins, 1955. Effect of different feeding methods on the efficiency of egg production. Poultry Sci. 34:376-383.

Massey, J.H., and H.L. Fuller, 1962. Methods of feeding turkeys. Poultry Sci. 41:145-150.

McDonald, R., and G.C. Emmans, 1980. Choice feeding of turkey breeder hens in single cages. World Poultry Sci. 36:68-73.

Menge, H., L.T. Frobish, B.T. Weinland, and E.G. Geis, 1979. Effect of dietary protein and energy on reproductive performance of turkey hens. Poultry Sci. 58:419-426.

Minear, L.R., D.L. Miller and S.L. Balloun, 1970. Protein requirement of turkey breeder hens. Poultry Sci. 49:1415-1416.

Minear, L.R., D.L. Miller and S.L. Balloun, 1972. Protein requirements of turkey breeder hens. Poultry Sci. 60:2709-2712.

Mitchell, M.S., and I.L. Kosin, 1954. The effect of controlled ambient temperature on some factors associated with egg laying in turkeys. Poultry Sci. 33:186-191.

Mongin, P., and B. Sauveur, 1974. Voluntary food and calcium intake by the laying hen. Br. Poult. Sci. 15:349-359.

Mueller, W.J., 1961. The effect of constant and fluctuating environmental temperatures on the biological performance of laying pullets. Poultry Sci. 40:1562-1571.

National Research Council, 1984. Nutrient requirements of poultry. 8th ed. Nat. Acad. Sci., Washington, DC.

Potter, L.M., J.R. Shelton, and G.B. Meyer, 1978. Added fat, ipropan, and rofenaid in diets of breeder turkeys. Poultry Sci. 57:485-488.

Robblee, A.R., and Clandinin, 1959. The relationship of energy and protein to reproductive performance in turkey breeders. Poultry Sci. 38:141-145.

Robel, E.J., 1981. Relationships of age and body weight to reproductive traits in turkey hens. Poultry Sci. 60:2709-2712.

Robel, E.J., 1984. Weight loss as related to body composition in aging white turkey hens. Poultry Sci. 63:1281-1283.

Rose, S.P., and W. Michie, 1982. The food intakes and growth of choice-fed turkeys offered balancer mixtures of different compositions. Br. Poult. Sci. 23:547-554.

Savory, C. J., 1979. Changes in food intake and body weight of bantam hens during breeding. Appl. An. Ethol. 5: 283-288.

Summers, J.D., and S. Leeson, 1978. Dietary selection of protein and energy by pullets and broilers. Br. Poult. Sci. 19:425-430.

Summers, J.D., and S. Leeson, 1981. Diet self-selection by laying hens of feeds separated by texture. Nutr. Rep. Int. 23:525-529.

Taylor, T.G., 1970. The provision of calcium and carbonate for laying hens. *in*: Fourth Nutrition Conference for Feed Manufacturers. H. Swan, and D. Lewis, ed. Churchhill, London.

Thomason, D.M., A.T. Leighton, and J.P. Mason Jr., 1972. A study of certain environmental factors on the reproductive performance of Large White turkeys. Poultry Sci. 51:1438-1449.

Thornton, P.A., and W.A. Whittet, 1960. Protein requirement for egg production as influenced by management, genetic background and dietary energy level. Poultry Sci. 39:916-921.

Touchburn, S.P., E.C. Naber, and V.D. Chamberlin, 1968. Effect of growth restriction on reproductive performance of turkeys. Poultry Sci. 47:547-556.

Vondell, J.H., 1948. Methods of feeding layers and breeders. Poultry Sci. 27:531-535.

Wahid, M.A., W.F. Krueger, C.B. Ryan, and R.L. Atkinson, 1967. Optimum protein levels for off-season turkey hatching egg production. Poultry Sci. 46:1334.

Wolford, J.H., R.K. Ringer, T.H. Coleman and H.C. Zindel, 1963. Individual feed consumption of turkey breeder hens and the correlation of feed intake, body weight and egg production. Poultry Sci. 42:599-604.

Zadworny, B.J., J.S. Walton and R.J. Etches, 1985. The relationship between plasma concentrations of prolactin and the consumption of feed and water during the reproductive cycle of the domestic turkey. Poultry Sci. 64:401-410.

CHAPTER 1

THE EFFECT OF PROTEIN AND ENERGY SELF-SELECTION ON THE REPRODUCTIVE PERFORMANCE OF TURKEY BREEDER HENS

INTRODUCTION

In contrast to broilers and growing turkeys, relatively little is known about the nutritional requirements of the turkey breeder hen. While the National Research Council (NRC, 1984) has established requirements of 14% crude protein (CP) and 2900 kcal metabolizable energy/kg of diet, there is considerable disagreement regarding the proper protein and energy needs of turkey hens.

The literature contains reports of protein requirements ranging from 10% CP (Jensen and McGinnis, 1961; Minear *et al.*, 1970) to 22% CP (Atkinson *et al.*, 1960). Jensen and McGinnis (1961) found no significant differences in the reproductive performance of hens fed diets containing 10, 12, 14 or 16% CP. Similarly, Minear *et al.* (1970, 1972) found no significant improvement in reproductive performance of turkey hens fed 10, 14, 16 and 18% CP diets. Cherms *et al.* (1978) found that egg production and egg weight were adversely affected when turkey hens were fed a 10% CP diet rather than a 15% CP diet. Other reports have indicated that an intermediate protein level produces some benefits on egg production. Cohen-Parsons *et al.* (1982) found 12 and 14% CP diets superior to a 10% CP diet in supporting egg production. Bradley *et al*. (1971) determined that both Broad Breasted White and Beltsville Small White hens benefited from a 15% CP diet as compared to a diet containing 12% CP. Similar results were obtained by Atkinson *et al*. (1970). In the latter experiment it was found that egg production was maximized when hens were fed 15% CP as compared with 12, 18 and 21% CP. Even higher levels of protein have been recommended in some cases. Atkinson *et al*. (1974) found a 18% CP diet supported greater egg production and maintained higher body and egg weights than a 15% CP diet. Bradley *et al*. (1969) found that Broad Breasted Bronze hens had greater reproductive efficiency when fed an 18% CP diet rather than a 15% CP diet. Atkinson *et al*.(1960) found that egg production was maximized when hens were fed a diet containing 22% CP as compared to 16, 19 and 25% CP diets. Therefore, much disagreement remains as to the proper protein level needed in the diets of turkey hens.

Little work has been conducted looking at the proper energy level in the diet of turkey hens. Much of the work has been concerned with the effect of supplemental dietary fat on egg production. Although Potter *et al*. (1978) found no improvement in egg production from the addition of 6% fat to breeder diets, most reports have indicated some benefit from the inclusion of fat in the diet. Harms and Wilson (1983) and Harms *et al*. (1984) found an improvement in egg production when dietary fat levels were increased from 0 to 4 and from 4 to 8% of the diet. Similarly, Creger *et al*. (1970) found that egg production and feed efficiency were improved with increasing fat levels ranging from 2.5 to 12.5% of the diet.

Information concerning the nutrient requirements of turkey hens is relatively scarce due to the great expense and labor intensity of conducting experiments using traditional methods. An unconventional method that can be used to study nutrient requirements is to allow the bird to select the proper level of a nutrient based on individual needs. This system, referred to as a split-diet regime, has been used with some success in broiler chicks (Funk, 1932; Wharton *et al*., 1960; Kaufman *et al*., 1978), growing turkeys (Massey and Fuller, 1962; Cowan and Michie, 1978; Rose and Michie, 1982), growing chickens (Leeson and Summers, 1981; Brody *et al*.,1984; Cherry *et al*., 1984) and laying chickens (Emmans, 1977; Summers and Leeson, 1981; Blake *et al*., 1984). Little such work has been done with turkey hens.

The primary purpose of the present study was to determine the effect of dietary self-selection of protein and energy by turkey breeder hens on egg production, feed, protein, and energy intake, body weight, and the incidence of broodiness. A second objective was to determine if the protein and energy requirement of the turkey hen changes over the course of the breeding season.

MATERIALS AND METHODS

Animals and Husbandry- Seventy Large White turkey females were started and reared to 9 weeks of age under continuous lighting. The photoperiod was then restricted to 12 hours per day. At 20 weeks of age the photoperiod was further reduced to 6 hours of light per day at an intensity of 43 lux. The birds were fed a standard turkey ration *ad libitum* throughout the growout period. At 28 weeks of age 48 hens were transferred to individual cages located in two identical rooms each containing 24 cages. Cages measured 43.2 cm wide, 61.0 cm long and 64.8 cm high. Light was restricted to 6 hours of light per day at an intensity of 10.8 lux for a period of two weeks. The production season for this experiment started in July and ended in December.

Experimental Treatments- At 29 weeks of age birds were randomly assigned to one of two treatment groups with the restriction that each room contained 12 females from each dietary treatment. Control birds were fed a standard breeder diet while birds in the split-diet treatment were allowed to select between two diets, one relatively high in energy and one relatively high in protein. The birds were then allowed one week to adapt to the diets before they were exposed to stimulatory lighting of 14 hr light per day. Feed and water were available *ad libitum*.

The composition of the experimental diets are presented in Table 1. The formulation of the control diet was based on diets commonly fed to breeder hens in the poultry industry. This diet was adequate in all essential nutrients as recommended by the National Research Council (NRC, 1984). The split diets were then formulated such that ingredients in the control diet that are relatively high in energy were included in the high energy (HE) diet while those which are relatively high in protein were placed in the high protein (HP) diet. The mineral supplements and the vitamin premix were evenly distributed between the two diets based on the assumption that the bird would consume 5 parts of the HE diet for every 3 parts of the HP diet consumed. This 5:3 ratio of consumption was based on the relative distribution of high energy and high protein feed ingredients in the control diet.

When the birds reached 30 weeks of age, the photoperiod was increased to 14 hours of light per day. Individual feed consumption and evidence of either molting or broody behavior were observed on a daily basis throughout the 20-week production cycle. Body weights were recorded bi-weekly and blood samples were taken monthly via the brachial vein. Egg weights were recorded once a month for all eggs collected over a one week period.

Broody birds were detected based on three criteria: reduced feed intake, behavioral changes, and lack of egg production. Only birds which met all three criteria were considered broody. Since the effect of the dietary treatments on the incidence of broodiness was of interest, no attempt was made to prevent birds from going broody or to break up broodiness once it had occurred.

Hens were artificially inseminated twice in the first week of lighting and on a weekly basis thereafter with 0.05 cc of diluted semen. Semen was collected from 16 Large White Nicholas toms maintained in floor pens. These males were reared similar to the females except that they were placed on photostimulatory light two weeks prior to the females. Semen was collected with the aid of an aspirator and semen samples were mixed to form a pooled sample. This sample was then diluted with an equal volume of Beltsville Poultry Semen Extender.

Eggs were collected twice daily and stored at 12.8 C and 75% relative humidity. Eggs were allowed to accumulate for a one week period and were then set in a forced air incubator. After 24 days of incubation, the eggs were transferred to a forced draft hatcher. At 28 days, all eggs were removed from the hatcher and those which had not hatched were broken out and examined to determine fertility.

Statistical Analysis- Egg production, feed intake, energy intake, protein intake and feed, energy and protein efficiencies were analyzed by one-way analysis of variance. Due to the effect of broodiness in reducing feed intake, data from broody and non-broody birds were analyzed separately. Percentage data were transformed to arcsine square roots prior to analysis. Chi-square analysis was used to determine if there was a difference in the incidence of broodiness of the two dietary treatment groups. Significance implies $p \leq .05$ unless otherwise stated.

RESULTS AND DISCUSSION

While there were no significant differences between the total number of eggs produced by hens in the two treatment groups (Table 2), there was a difference in the pattern of egg production. Although the production of birds on the control diet was significantly greater during the first half of the breeding season (Figure 1), this level of production could not be maintained late in the production cycle. This difference in the later part of the cycle is largely due to differences in the incidence of broody birds in the two treatment groups. The incidence of broodiness was significantly higher in birds fed the conventional diet ($p \leq .10$) than among self-selecting hens. When broody birds were included in the analysis, the mean egg production of hens fed the split-diet is slightly, but not significantly, greater (55 vs. 53) than that of hens fed the conventional diet. Fertility, hatchability, and hatch of fertile eggs were not significantly affected by the dietary treatments (Table 3).

A relationship between body weight and egg production has been reported in the literature (Wolford *et al.*, 1963; Robel, 1981; Robel, 1984). Turkey hens characteristically experience a rather large weight loss over the course of the production cycle. There has been some suggestion that this weight loss may be partially responsible for poor late season egg production (Robel, 1981; Robel, 1984). The results of this self-selection experiment do not support this theory since hens fed a split-diet displayed significantly greater weight loss over the course of the production cycle (Figure 2). In addition, the period during which the relative weight loss was the greatest corresponds with the period when hens on the split diet displayed the greatest advantage over control birds with regard to egg production. Therefore, loss of body weight does not seem to be entirely responsible for poor late season egg production in turkey hens.

The effect of the dietary treatments on the cumulative feed intake of broody and non-broody birds is displayed in Table 4. Among birds that did not go broody there was a significant reduction in total feed intake of hens fed a split diet when compared to control birds (Figure 3). This difference may have been partially the result of a trend toward lower egg production in this group. However, feed intake was reduced by over 15% while the egg production of this group was only 8% lower than that of control hens. In addition, there was a significant improvement in the feed efficiency (eggs/kg feed) of this group (Table 5). Therefore, it appears that some of this reduction in food intake can be attributed to the fact that birds fed a split-diet had the opportunity to consume a diet based more nearly on their individual needs.

Total energy intake for the production cycle was not significantly affected by dietary treatment (Table 4). Although the adjustment of food intake in response to changes in dietary energy content is in many cases imperfect (Hill and Dansky, 1954;

Morris, 1968; Booth, 1979; Reid and Mairino, 1980), the energy content of the diet is a major factor determining the level of food intake (Hill and Dansky, 1954; Morris, 1968; Powell *et al.*, 1972; Booth, 1979; Cherry, 1979). Therefore, one would expect the energy consumption of control birds and birds fed a split-diet to be similar. Stage of production did not appear to alter the daily energy intake (Figure 4).

In contrast to energy intake, the protein intake of birds fed the split-diet was significantly reduced compared to hens fed the control diet (Table 4). This reduction represents nearly 50% of the total protein consumption of control birds and results in a significant improvement in the efficiency of protein utilization by birds fed the split-diet (Table 5). Although these data indicate that turkey hens do not require as much protein as was present in the control diet, the protein level selected in this experiment cannot necessarily be regarded as the true protein requirement for turkey breeder hens. Most of the available research suggests that birds do not have an innate appetite for protein (Hughes, 1979; 1984). They can, however, select protein through a learning process resulting from positive post-ingestional feedback (Hughes and Wood-Gush, 1972). For this learning process to proceed, birds must first develop a deficiency for the nutrient being selected. In the present experiment hens were allowed one week to adapt to the experimental diets before they were exposed to stimulatory lighting. Many hens, however, did not consume significant amounts of the high protein diet until the third week after the photoperiod was increased (Figure 5). It is possible that the hens did not even start the learning process that is necessary for proper self-selection until they were already in egg production. Therefore, the protein deficient state that is necessary for self-selection to occur may be partly responsible for the lower early season production of hens in the split-diet group.

Turkey hens are generally fed a single diet throughout their egg production cycle. This is in sharp contrast to other classes of poultry which are usually fed a series of diets through the growing or production cycle. In the present experiment protein intake increased over the course of production which may indicate that the protein needs of turkey hens are changing over the egg production cycle (Figure 6). The protein content (g protein/ 100 g diet) of the diet selected increased sharply 8 to 10 weeks into the production period (Figure 7). During the first half of the experiment the diet that was selected contained between 10 and 11% crude protein while in the second half of the experiment the protein content increased to approximately 12% of the diet. When regression lines are fitted through the protein level selected in the first ten weeks of production and the second ten weeks of production, these lines have equal slopes but significantly different intercepts. This indicates that the protein levels selected during these two periods were significantly different. This change may be a reflection of a change in the protein requirement of the turkey breeder hen.

The net result of birds on a split diet consuming less protein and equal energy as compared to controls is an increase in the energy:protein ratio of the diet that is consumed. In fact, the energy:protein ratio of the diet consumed by self-selecting birds is nearly double that of the complete diet.

In summary, two major differences were observed between birds fed a complete diet and those allowed to self-select. First, there was a significant difference in the incidence of broodiness. Secondly, there was a significant difference in energy:protein ratio of the diet that was selected. The question that arises is whether the difference in the diet consumed was responsible for the lower incidence of broodiness. One could speculate that a lower energy:protein ratio was partially responsible for the higher incidence of broodiness in control birds. Clearly, there is a need for more research into the proper relationship between energy and protein in the diet of turkey breeder hens so that the impact of diets with differing energy:protein ratios on reproductive performance of breeder hens can be determined.

SUMMARY

An experiment was conducted to determine the influence of the self-selection of protein and energy on the reproductive performance of Large White turkey hens. Forty-eight hens were individually caged and provided 14 hr of light per day for a 20-week production cycle. Half the birds were provided a choice between a high protein-low energy diet (34.8% protein, 1850 kcal ME/kg) and a high energy-low protein diet (8.1% protein, 3200 kcal ME/kg). The control group was fed a diet prepared by blending the high protein (HP) and high energy (HE) diets to produce a feed intermediate in protein and energy (18.5% CP, 2700 kcal ME/kg). Feed consumption, egg production, egg weight, body weight and the incidence of broodiness were measured throughout the period.

Birds fed the split-diet produced an equal number of egg as control birds but consumed approximately 10% less feed. While energy intake was equal for the two groups, protein consumption was significantly lower for birds in the split-diet treatment ($p \leq .001$). Therefore, birds on the split-diet regime selected a diet with a higher energy:protein ratio. Feed efficiency ($p \leq .05$) and protein efficiency ($p \leq .001$) were both significantly improved among birds allowed to self-select their diet. The self-selection of protein and energy also resulted in a significant reduction in the incidence of broodiness ($p \leq .10$). There were no significant differences in the average egg or body weight of the two treatment

groups. Fertility and hatchability were also not significantly affected by the dietary treatments.

Table 1. Composition of Experiment Diets

Ingredients	Control (%)	High Energy[1]	High Protein[2]
Ground yellow corn	57.76	57.60	0.16
Stabilized fat	1.0	1.0	-
Dehulled soybean meal	12.00	-	12.00
Menhaden fish meal	5.00	-	5.00
Meat and bone meal	5.00	-	5.00
Dehydrated alfalfa meal	12.00	-	12.0
Dried whey	1.00	-	1.00
Deflourinated phosphate	0.80	0.50	0.30
Ground limestone	4.80	3.00	1.80
Iodized salt	0.32	0.20	0.12
Trace mineral mix[3]	0.80	0.05	0.03
Vitamin and additive premix[4]	0.24	0.15	0.09
Total	100.0	62.5	37.5
% Crude protein[5]	18.0	8.1	34.8
Metabolizable energy (Kcal)[5]	2700	3200	1850

[1]Expressed as parts per 62.5 parts.

[2]Expressed as parts per 37.5 parts.

[3]A trace mineral mix guaranteed to contain: 15% manganese, 10% zinc, 7% iron, 1.0% copper, and 0.22% iodine from manganese oxide, zinc oxide, ferrous sulfate, copper oxide and calcium carbonate as a diluent.

[4]The vitamin and feed additive premix supplied in milligrams per kilogram diet unless otherwise stated: 16,500 IU vitamin A, 5,500 ICU vitamin D_3, 40 IU vitamin, 6.6 menadione dimethyl-pryimidinol bisulfite, 2.2 thiamine HCl, 18 riboflavin, 25 calcium pantothenate (D), 66 niacin, 600 choline chloride, 0.013 vitamin B_{12}, 2.2 folic acid, 0.11 biotin, 2.2 pyridoxine HCl, 62 ethoxyquin, 0.2 selenium from sodium selenite, 55 bacitracin from zinc bacitracin.

[5]Calculated values.

Table 2. Total egg production, days to first egg and egg weight for turkey breeder hens for turkey breeder hens fed complete and split diets during a 20-week production cycle.[1] [2]

Group	Egg production (eggs/hen)	Days to first egg produced	Average egg weight (g)
Non-Broody			
Control diet	61.82±4.69	15.59±0.61	89.27±0.48
Split diet	56.86±5.23	17.67±0.66	88.63±0.49
Broody			
Control diet	29.17±3.00	16.83±0.70	83.13±1.07
Split diet	35.00±7.00	14.50±1.50	81.65±1.24

[1] Values represent mean ± standard error.

[2] There are no significant differences

Table 3. Percent fertility, hatchability and hatchability of fertile eggs of eggs laid by turkey breeder hens fed complete and split diets over a 20-week production cycle.[1 2]

	Control Diet	Split Diet
% Fertility	94.87± 0.96	92.07± 1.82
% Hatchability	72.34± 2.25	67.49± 3.13
% Hatch of Fertile Eggs	76.14± 2.06	72.80± 2.72

1 Values represent mean ± standard error.

2 There are no significant differences

Table 4. Cumulative feed, protein, and energy consumption of turkey breeder hens fed complete and split diets during a 20-week production cycle.[1]

Group	n	Feed Intake (kg feed)	Protein Intake (kg crude protein)	Energy Intake (Mcal)
Non-Broody				
Control diet	17	34.71 ± 1.12 a	6.28 ± 0.20 a	93.92 ± 3.00
Split diet	21	28.96 ± 1.02 b	3.47 ± 0.21 b	86.72 ± 2.89
Broody				
Control diet	6	23.14 ± 1.74	4.19 ± 0.31 a	62.62 ± 4.70
Split diet	2	20.03 ± .03	2.08 ± 0.24 b	61.76 ± 1.42

[1] Values represent mean ± standard error.

a, b Means within same broody class and column with different superscripts are significantly different ($P \leq .05$).

Table 5. Cumulative feed, protein, and energy efficiencies of turkey breeder hens fed complete and split diets during a 20-week production cycle.[1]

Group	Feed Efficiency (eggs/kg feed)	Protein Efficiency (eggs/kg protein)	Energy Efficiency (eggs/megcal energy)
Non-Broody			
Control diet	1.86 ± 0.15	10.28 ± 0.81 a	0.69 ± 0.05
Split diet	1.98 ± 0.15	16.97 ± 1.21 b	0.66 ± 0.05
Broody			
Control diet	1.30 ± 0.13	7.19 ± 0.74 a	0.48 ± 0.05
Split diet	1.74 ± 0.35	17.40 ± 5.34 b	0.56 ± 0.10

1 Values represent mean ± standard error.

a, b Means within same broody class and column with different superscripts are significantly different ($P \leq .05$).

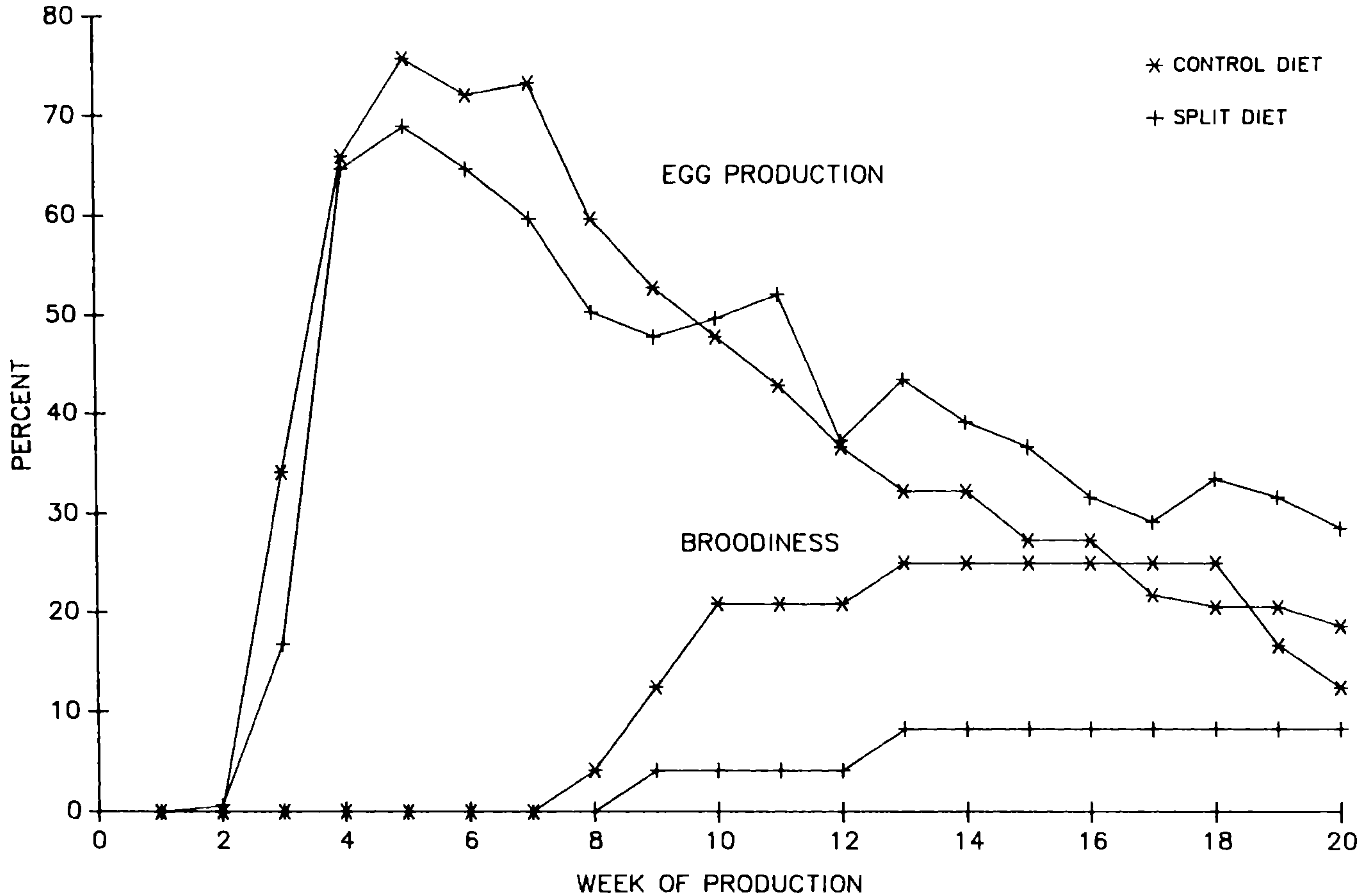

Figure 1. Percent egg production and broodiness of turkey hens fed conventional and split diets over a 20 week production cycle.

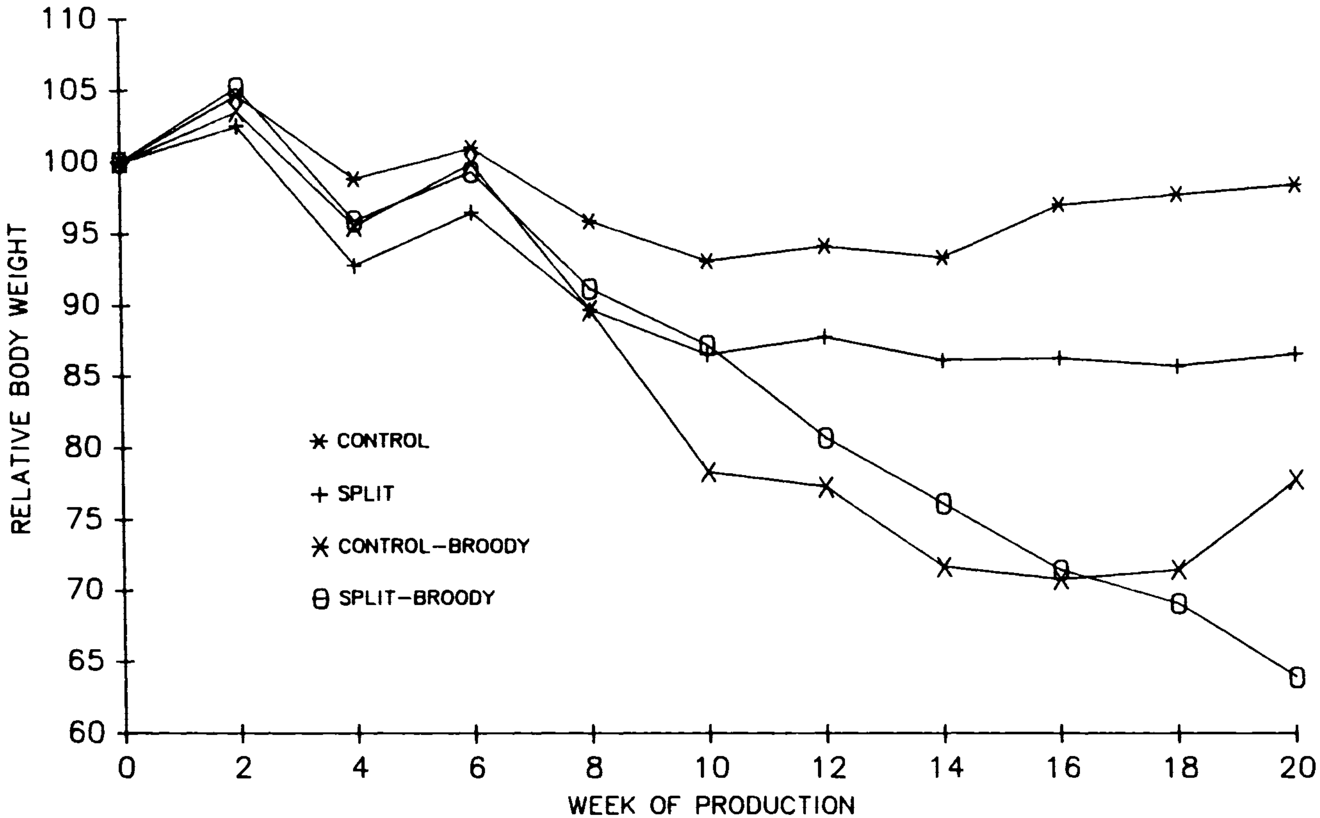

Figure 2. Relative body weight (% of initial weight) of turkey hens fed conventional and split diets over a 20 week production cycle.

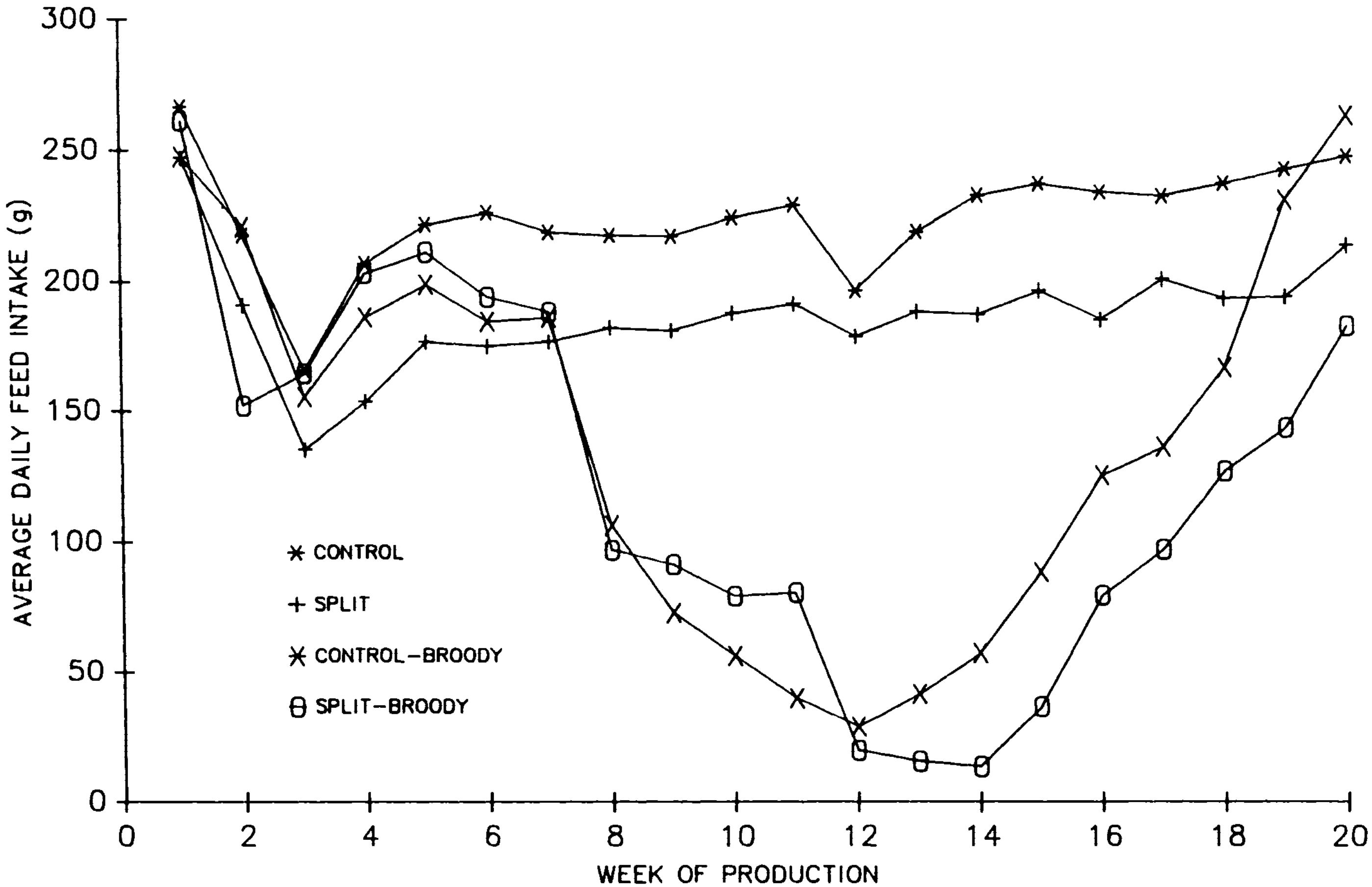

Figure 3. Average daily feed intake (g) of turkey hens fed conventional and split diets over a 20 week production cycle.

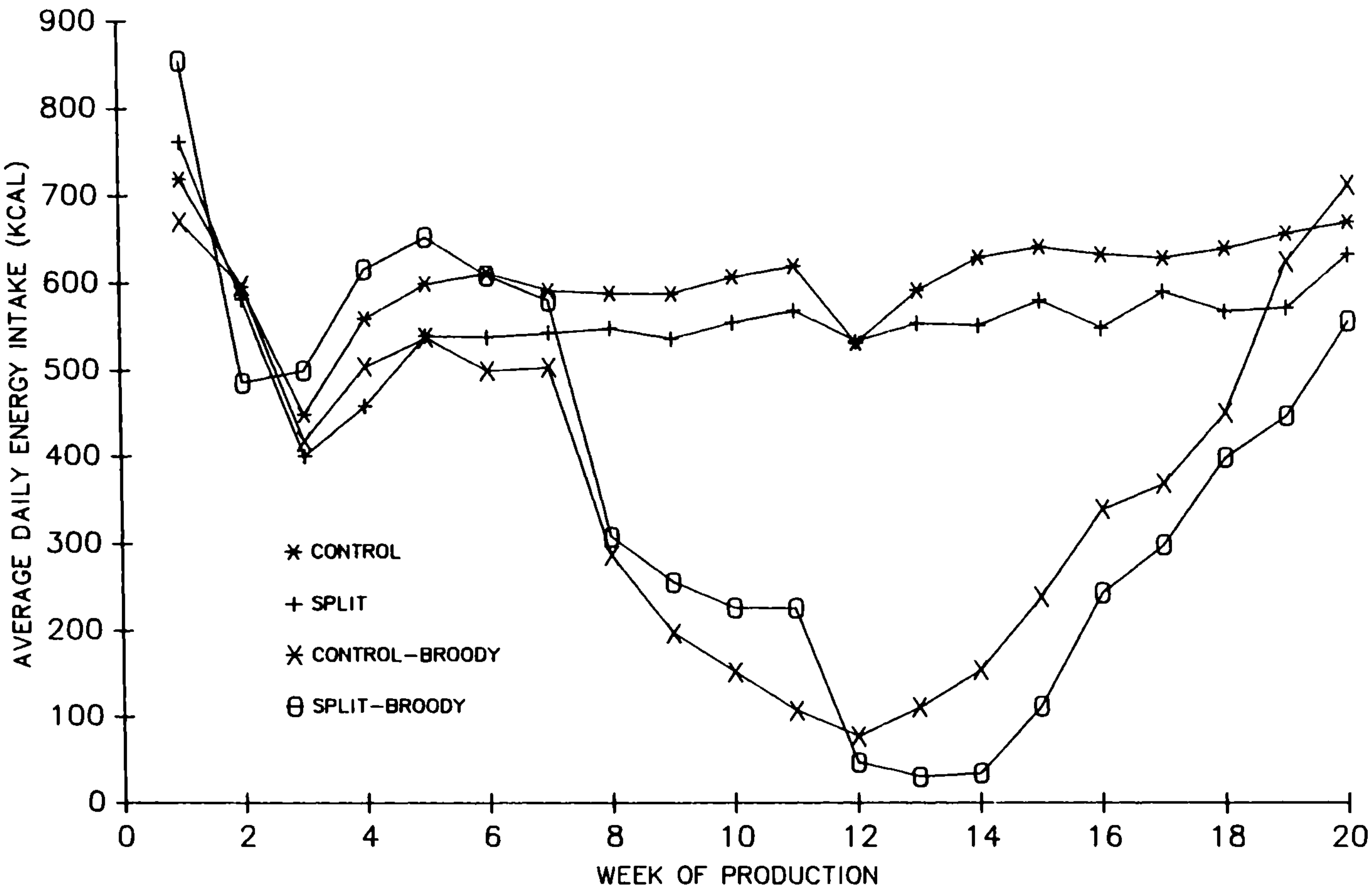

Figure 4. Average daily energy (kcal) intake of turkey hens fed conventional and split diets over a 20 week production cycle.

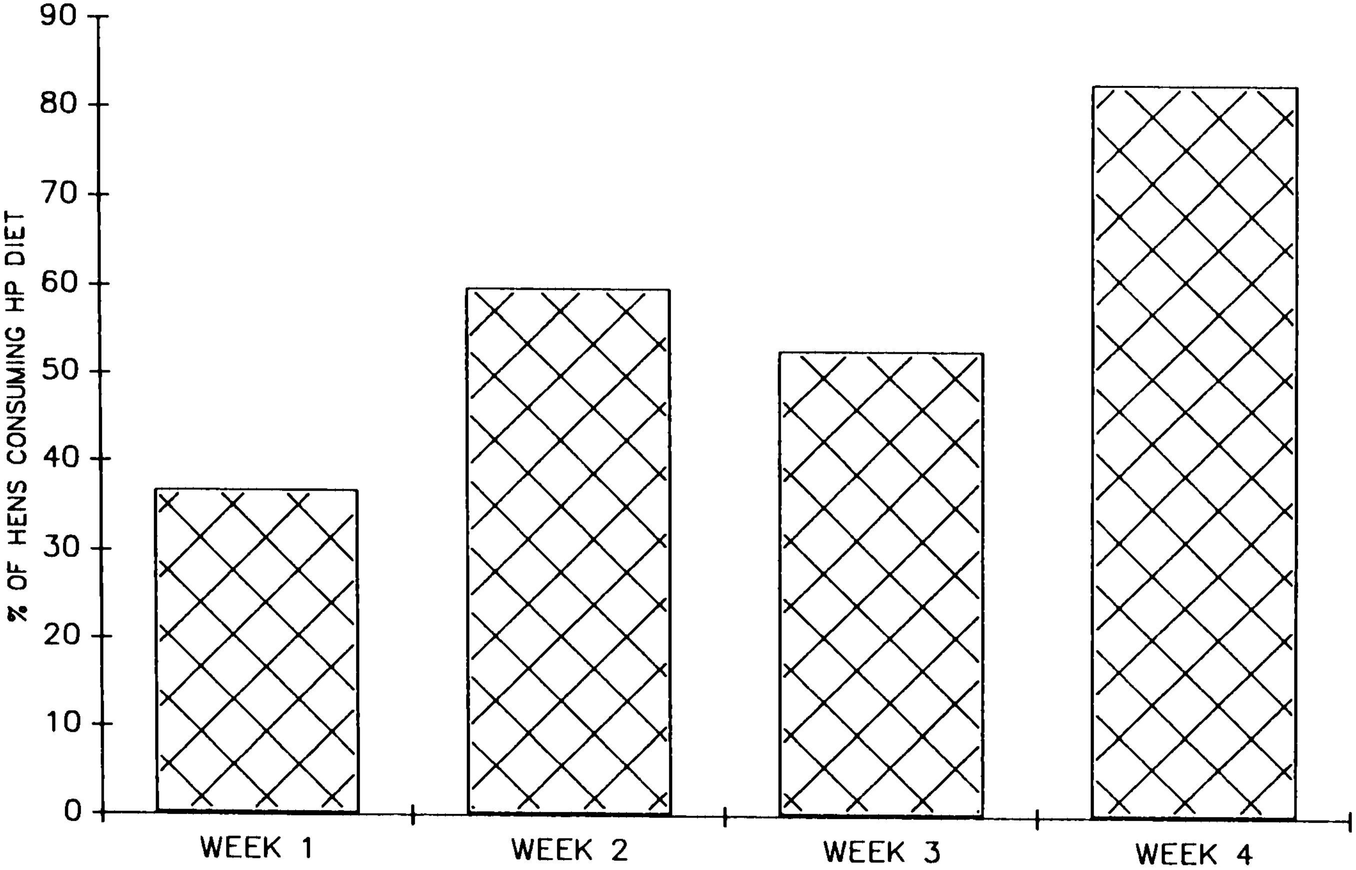

Figure 5. Percentage of choice fed hens consuming the high protein diet during the first four weeks of photostimulation.

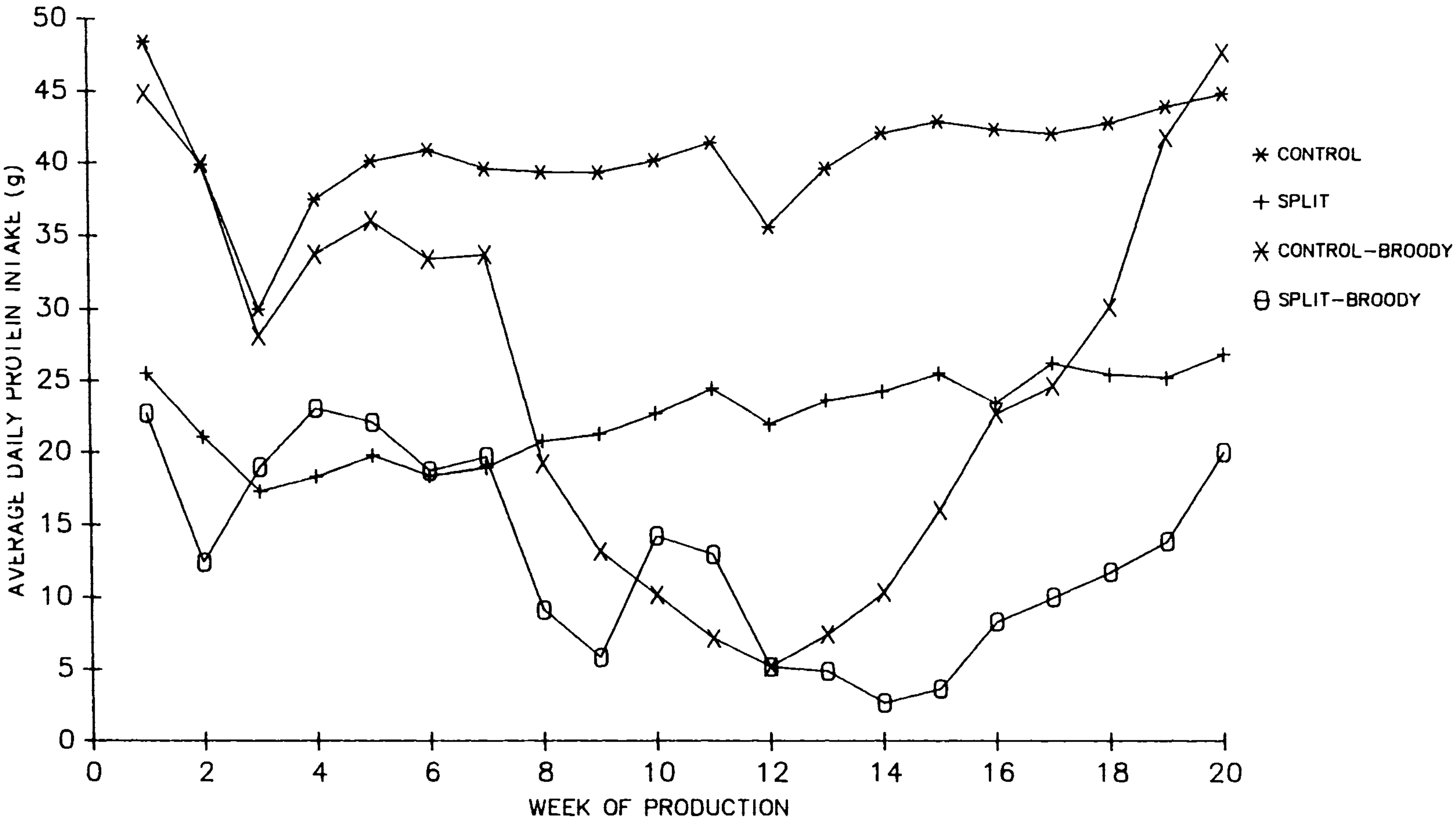

Figure 6. Average daily protein intake of turkey hens fed conventional and split diets over a 20 week production cycle.

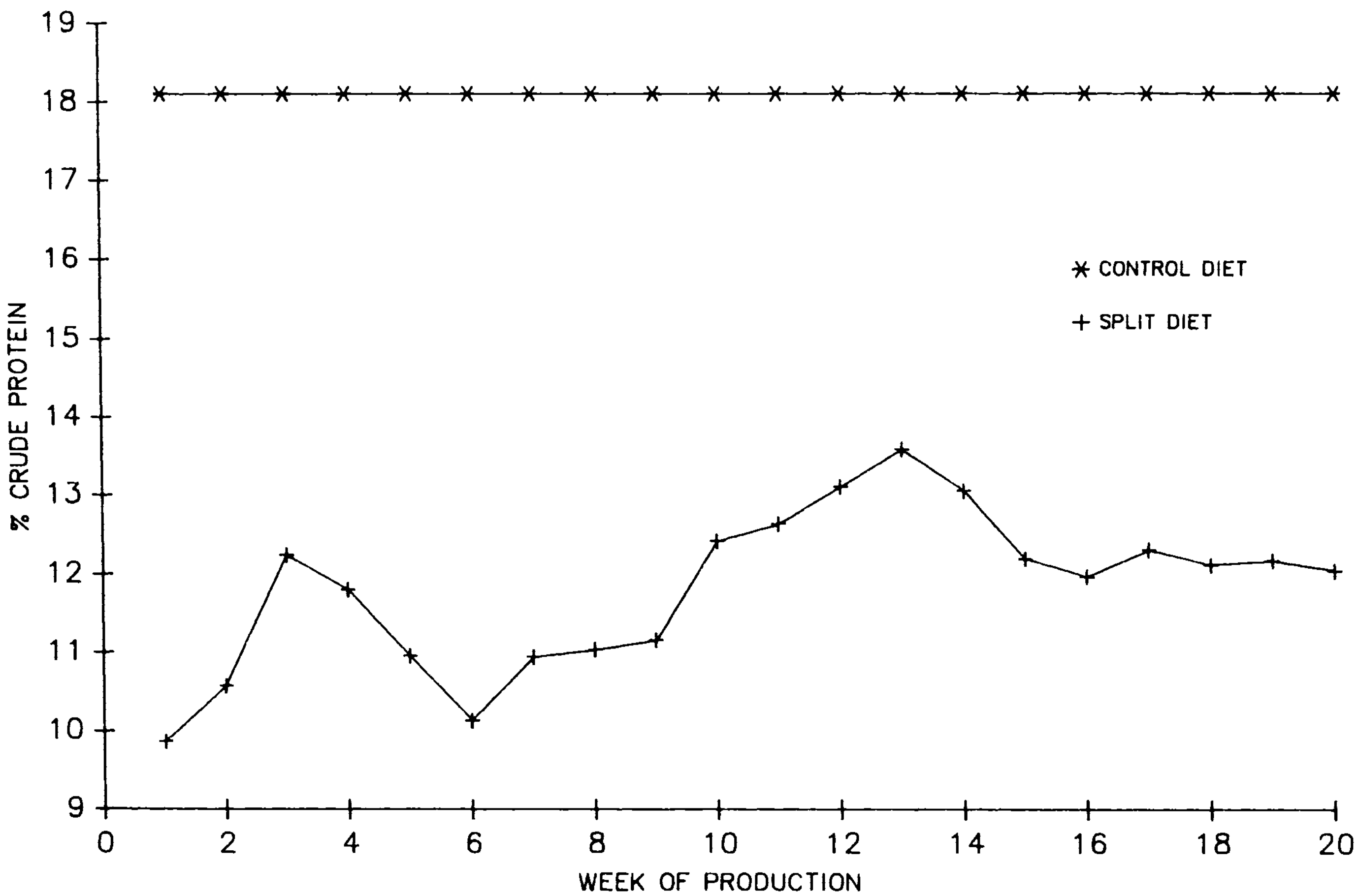

Figure 7. Percent crude protein (g protein/100 g diet) of the diet selected by turkey hens fed conventional and split diets over a 20 week production cycle.

REFERENCES

Atkinson, R.L., J.W. Bradley, J.R. Couch, and J.H. Quisenberry, 1960. Effect of protein level and electric shock on reproductive performance and incidence of broodiness. Poultry Sci. 39:1231.

Atkinson, R.L., J.W. Bradley, T.M. Ferguson, J.R. Couch, and J.H. Quisenberry, 1970. Protein level and reproductive performance of turkey hens. Nutr. Rep. Int. 1:353-366.

Atkinson, R.L., K.K. Krueger, J.W. Bradley, J.R. Couch, and W.F. Krueger, 1974. Relation of protein level and grain source to turkey reproduction. Nutr. Rep. Int. 4:259-266.

Blake, A.G., F.B. Mather and E.W. Gleaves, 1984. Dietary self-selection of laying hens inadequate to overcome the effects of high environmental temperature. Poultry Sci. 63:1346-1349.

Booth, D.A., 1979. Feeding control systems within animals. Pages 13-62 *in*: Food Intake Regulation in Poultry. K.N. Boorman and B.M. Freeman, ed. Br. Poultry Sci. Ltd., Edinburgh.

Bradley, J.W., R.L. Atkinson, J.R. Couch, and J.H. Quisenberry, 1969. Protein requirement of breeder turkeys. Poultry Sci. 48:1788.

Bradley, J.W., R.L. Atkinson, J.R. Couch, and J.H. Quisenberry, 1971. Relation of protein level and grain type to egg production of turkeys. Poultry Sci. 50:1555.

Brody, T.B., J.A. Cherry, and P.B. Siegel, 1984. Responses to dietary self selection and calories in liquid form by weight selected lines of chickens. Poultry Sci. 63:1626-1633.

Cherms, F.L., M.G. Stoller, and J.J. MacIlraith, 1978. A comparison of 22 and 35 grams of daily protein intake and the effects on reproduction of turkey hens. Poultry Sci. 57:1126.

Cherry, J.A., 1979. Adaptation in food intake after changes in dietary energy. Pages 77-86 *in*: Food Intake Regulation in Poultry. K.N. Boorman and B.M. Freeman, ed. Br. Poultry Sci. Ltd., Edinburgh.

Cherry, J.A., K.S. Young, and D.E. Jones, 1984. Feed intake response to the dilution of high-protein and high-energy diets under self-selection feeding. Poultry Sci. 63:744-749.

Cohen-Parsons, M., A.T. Leighton, and G.B. Meyer, 1982. Reproductive performance of female breeder turkeys fed on maize-soyabean diets supplemented with methionine. Br. Poultry Sci. 23:135-143.

Cowan, P.J., and W. Michie, 1978. The use of barley in choice feeding of the turkey. Br. Poultry Sci. 19:1-6.

Creger, C.R., R.L. Atkinson, and J.R. Couch, 1970. Fat levels in the diet of turkey breeders. Nutr. Rep. Int. 2:1-8.

Emmans, G.C., 1977. The nutrient intake of laying hens given a choice of diets, in relation to their production requirements. Br. Poultry Sci. 18:227-236.

Funk, E.M., 1932. Can the chick balance its ration? Poultry Sci. 11:94-97.

Harms, R.H. and H.R. Wilson, 1983. Improved performance of turkey hens from the addition of dietary fat. Poultry Sci. 62:2283-2284.

Harms, R.H., R.E. Buresh, and H.R. Wilson, 1984. The influence of the grower diet and fat in the layer diet on performance of turkey hens. Poultry Sci. 63:1634-1637.

Hill, F.W. and L.M. Dansky, 1954. Studies of the energy requirements of chickens 1. the effect of dietary energy level on growth and feed consumption. Poultry Sci. 33:112-119.

Hughes, B.O. and D.G.M. Wood-Gush, 1972. Hypothetical mechanisms underlying calcium appetite in fowls. Rev. Comp. Anim., 6:95-106.

Hughes, B.O., 1979. Appetites for specific nutrients. Pages 141-169 *in*: Food Intake Regulation in Poultry. K.N. Boorman and B.M. Freeman, ed. Br. Poultry Sci. Ltd., Edinburgh.

Hughes, B.O., 1984. The principles underlying choice feeding behavior in fowls-with special reference to production experiments. World's Poultry Sci. 40:141-150.

Jensen, L.S. and J. McGinnis, 1961. Nutritional investigation with turkey hens 1. quantitative requirement for protein. Poultry Sci. 40:288-290.

Kaufman, L.W., G. Collier, and R.L. Squibb, 1978. Selection of an adequate protein-carbohydrate ratio by the domestic chick. Physiol. Behav. 20:339-344.

Leeson, S., and J.D. Summers, 1981. Dietary self-selection and use of reverse-protein diets for developing broiler breeder pullets. Poultry Sci. 60:168-171.

Massey, J.H., and H.L. Fuller, 1962. Methods of feeding turkeys. Poultry Sci. 41:145-150.

Minear, L.R., D.L. Miller and S.L. Balloun, 1970. Protein requirement of turkey breeder hens. Poultry Sci. 49:1415-1416.

Minear, L.R., D.L. Miller and S.L. Balloun, 1972. Protein requirements of turkey breeder hens. Poultry Sci. 60:2709-2712.

Morris, T.R., 1968. The effect of dietary energy level on the voluntary calorie intake of laying birds. Br. Poultry Sci. 9:285-295.

National Research Council, 1984. Nutrient requirements of poultry. 8th ed. Nat. Acad. Sci., Washington, DC.

Potter, L.M., J.R. Shelton, and G.B. Meyer, 1978. Added fat, ipropan, and rofenaid in diets of breeder turkeys. Poultry Sci. 57:485-488.

Powell, T.S., C.R. Douglas, R.H. Stonerock, 1972. Feed intake of hens fed various levels of energy from feed and/or sucrose-water. Poultry Sci. 51:1851.

Robel, E.J., 1981. Relationships of age and body weight to reproductive traits in turkey hens. Poultry Sci. 60:2709-2712.

Robel, E.J., 1984. Weight loss as related to body composition in aging white turkey hens. Poultry Sci. 63:1281-1283.

Rose, S.P., and W. Michie, 1982. The food intakes and growth of choice-fed turkeys offered balancer mixtures of different compositions. Br. Poultry Sci. 23:547-554.

Reid, B.L. and P.M. Mairino, 1980. Interaction of dietary metabolizable energy and protein in laying hens diets. Poultry Sci. 59:1451-1454.

Summers, J.D., and S. Leeson, 1981. Diet selection of protein and energy by pullets and broilers. Br. Poultry Sci. 19:425-430.

Touchburn, S.P. and E.C. Naber, 1962. Effect of nutrient density and protein-energy interrelationships on reproductive performance of the hen. Poultry Sci. 41:1481-1488.

Wharton, F.D. Jr., J.C. Fritz and L.J. Classen, 1960. Chick diet studies 1. discrimination between diets of differing nutritional value. Poultry Sci. 39:1018-1023.

Wolford, J.H., R.K. Ringer, T.H. Coleman and H.C. Zindel, 1963. Individual feed consumption of turkey breeder hens and the correlation of feed intake, body weight and egg production. Poultry Sci. 42:599-604.

CHAPTER 2

SEASONAL EFFECTS ON THE PROTEIN AND ENERGY SELECTION OF TURKEY BREEDER HENS

INTRODUCTION

A recent study investigating the self-selection of protein and energy by turkey hens has demonstrated some beneficial effects on reproductive performance (Chapter 1). Hens fed a split-diet consumed approximately 10% less feed than controls but were able to maintain an equal level of egg production. Hens fed a split-diet also consumed approximately 35% less protein than control birds. In addition, there was a three-fold reduction in the incidence of broodiness among birds fed the split-diet.

Seasonal effects on the reproductive performance of turkey hens are well documented. Mitchell and Kosin (1954) found that persistent warm temperatures reduced the egg production and increased the incidence of broodiness of turkey hens. Although hens maintained in this environment commenced egg laying and reached peak production sooner than hens housed under cooler temperatures, a high rate of egg production could not be maintained at warmer temperatures. Poor late season egg production was presumably the result of a greater incidence of broodiness and greater length of broody periods when hens were maintained at higher ambient temperatures. In addition, egg weights were significantly reduced in this environment. Marsden *et al.* (1966) found similar effects on broodiness during warm periods. Thomason *et al.* (1972) observed reduced egg production and increased broodiness among hens housed at 29.4 C compared to hens housed at 12.8 and 21 C. Therefore, changes in production that occur with different seasons of the year can influence the metabolic needs and, consequently, the nutrient requirements of turkey hens.

In addition to its effect on reproduction, high environmental temperature has been reported to reduce energy requirements (Peterson *et al.*, 1960; Thornton and Whittet, 1960; Kurnick *et al.*, 1961; Daghir, 1973) and feed intake (Peterson *et al.*, 1960; Thornton and Whittet, 1960; Bray and Gesell, 1961; Kurnick *et al.*, 1961; Daghir, 1973; Leeson *et al.*, 1973). High ambient temperatures have been reported to reduce food intake between 10 and 25% in laying hens (Kurnick *et al.*,1961) and turkey breeder hens (Thomason *et al.*, 1972). Although energy requirements are still being met in this situation, deficiencies of other nutrients may occur if their supply in the diet is marginal (Thornton and Whittet, 1960; Bray and Gesell, 1961). Therefore, seasonal effects on food intake can influence the results of many investigations into nutrient requirements.

The ability of domestic fowl to regulate protein intake when presented with a choice between high and low protein diets is well established (Boorman, 1979; Hughes, 1979, 1984). Broiler chicks

(Funk, 1932; Kaufman *et al.*, 1972), growing chickens (Summers and Leeson,1978; Leeson and Summers, 1981; Huey *et al.*, 1982; Brody *et al.*, 1984), growing turkeys (Massey and Fuller, 1962; Cowan and Michie, 1978; Rose and Michie, 1982), laying hens (Holcombe *et al.*, 1976; Cowan *et al.*, 1978) and turkey breeder hens (McDonald and Emmans, 1980) have been shown to possess this ability. Self-selection regimes allow birds to adjust nutrient intake based on metabolic requirements independent of energy and food intake. Although palatability and learning place constraints on the interpretation of such studies (Booth, 1979; Hughes, 1979, 1984), self-selection experiments can provide useful information concerning changes in nutrient requirements over the course of production without the confounding effects of seasonal changes in food intake.

The objective of the present experiment was to obtain additional information concerning the self-selection of protein and energy by turkey hens and to determine if patterns of selection are influenced by seasonal effects. In addition, the effect of diet selection on the incidence of broodiness was investigated.

MATERIALS AND METHODS

Birds.- Three weeks prior to the initiation of stimulatory lighting, ninety-six Large White turkey hens were placed in individual cages in four adjacent rooms. Forty-eight of the females were 64 weeks of age and had previously been through one production cycle and force molted. The other half of the females were 30 weeks of age and in their first season of production.

Diets and Treatment Groups.- The composition of the experimental diets is presented in Table 1. Hens were randomly assigned to one of two treatment groups. Control birds were fed a complete diet while birds in the split-diet treatment were allowed to simultaneously select from two dietary sources; one relatively high in protein and one relatively high in energy. The control diet was a standard breeder diet containing an adequate supply of all nutrients. The split-diets were formulated by separating the ingredients in the control diet. All ingredients relatively high in energy were were placed in the high energy diet (HE) diet. Conversely, components relatively high in protein were included in the high protein diet (HP). The vitamin and mineral supplements were then distributed between the HE and HP diets proportional to the major feed ingredients present in these diets. Limestone and dicalcium phosphate were added to the HE and HP diets so that the calcium contents and the calcium:phosphorus ratios of the two diets were equivalent.

At the time of feed mixing, a basal mix containing all feed ingredients common to the HE and HP diets was mixed. The HE and HP diets were then prepared by mixing the major feed ingredients with the appropriate amount of the basal mix. The control diet was prepared by blending the HE and HP diets in the correct proportions. The hens were allowed to adapt to the experimental diets for a period of three weeks before the photoperiod was increased to 14 hours of light per day.

Experiment.- Hens were individually weighed at the initiation of stimulatory lighting and at four week intervals thereafter. The production period for this experiment began in March and ended in July of 1987. Egg production and feed intake were recorded daily and individual energy and protein consumptions were calculated on a daily basis throughout a 20-week production cycle.

Birds were examined daily for evidence of molting and broodiness. Broody birds were detected based on three criteria: reduced feed intake, nesting behavior and lack of egg production. Only birds that met all three criteria were considered broody. Since the effect of the dietary treatments on the incidence of broodiness was of interest, no attempt was made to prevent birds from going broody or to break up broodiness when it occurred.

Semen from Large White toms was collected and mixed to form a pooled sample. The pooled sample was then diluted with an equal volume of Beltsville Poultry Semen Extender. Hens were inseminated twice in the first week of lighting and on a bi-weekly basis thereafter with 0.05 cc of diluted semen.

Eggs were collected twice daily and stored at 12.8 C and 75% relative humidity. Eggs were allowed to accumulate for a period of one week and then set in a forced air incubator. After 24 days of incubation, the eggs were transferred to a forced draft hatcher. At 28 days of incubation, all eggs were removed from the incubator and those which had not hatched were broken out and visually examined to determine fertility.

Statistical Analysis- Egg production, feed intake, energy intake, protein intake and feed, energy and protein efficiencies were analyzed by analysis of variance in a 2 by 2 factorial design with hen age (first season or second season hen) and dietary treatment (control or split-diet) as main factors. Means were separated using Duncan's New Multiple Range Test (Duncan, 1955). When significant interactions were encountered, the analysis was broken down by individual factors to determine the cause of the interaction. Percentage data were transformed to arcsine square roots prior to analysis. Chi-square analysis was used to determine if there was a difference in the incidence of broodiness of the two dietary treatment groups. Significance implies $p \leq .05$ unless otherwise stated.

RESULTS AND DISCUSSION

Although there was no significant difference in egg production of the two treatment groups (Table 2), there was a difference in the pattern of egg production (Figure 1). Hens in the control group had significantly greater egg production than split-fed birds through the first ten weeks of the production cycle but were not able to maintain this advantage in the later stages of production. The egg production of control birds dropped more precipitously; largely due to the greater incidence of broodiness in birds of this group. The incidence of broodiness was four times as high among control birds as for split-fed birds throughout much of the production period. These findings are consistent with the previous experiment with split-diets (Chapter 1).

Fertility and hatchability of eggs laid by hens fed the split-diet were significantly reduced as compared to eggs laid by control hens (Table 3). In addition, there were significant age by treatment interactions for these traits due to reduced fertility and hatchability of eggs laid by first season hens fed the split-diet as compared to hen in the other treatment groups. Fertility and hatchability may have been reduced due to a protein deficiency. However, a relationship between dietary protein and these traits has not been established. Most researchers have not found fertility and hatchability to be reduced due to the feeding of low protein diets to turkey hens (Cohen-Parsons *et al*, 1982).

These finding are in conflict with the previous self-selection study (Chapter 1).

Although there was a decrease in body weight during the course of production, there was no significant difference in the amount of loss between groups (Figure 2). This is in contrast to our previous study in which hens fed a split-diet lost more weight than did hens fed a control diet (Chapter 1).

Feed intake was not significantly affected by the dietary treatments (Table 2). This is in sharp contrast to the previous experiment where hens fed a split-diet consumed approximately 10% less feed than control birds. This difference is probably responsible for the better maintenance of body weight by split-fed hens in the present experiment as compared to the former one. Hens were better able to maintain body weight because they maintained a higher level of feed intake. There was also a gradual decrease in feed intake over the course of the production cycle (Figure 3). In the previous experiment feed intake increased over the course of production. These trends seem to be related to changes in the ambient temperature. The previous experiment was conducted between July and December when temperatures were decreasing and, therefore, feed intake was increasing (Chapter 1). In the present experiment, feed intake decreased with the as temperatures increased late in the production cycle.

Cumulative energy intake was significantly greater among hens fed the split-diet than among control birds (Table 2). Energy intake was increased through selection of a diet with an energy content (kcal/kg diet) which was greater than that of the control diet rather than through an increase in cumulative food intake. Trends in energy intake followed the same pattern as food intake (Figure 4), however, the energy content of the diet that was selected by split-fed birds did change dramatically over the course of production (Figure 5). Initially the energy content of the diet selected was extremely high. This value then decreased over the production period. As in the case of feed intake, this decrease is attributable to an increase in the ambient temperature during the later periods of the experiment. Birds selected a diet with a lower energy content during the period of higher ambient temperatures.

Unlike food and energy intake, protein intake was significantly reduced among birds fed the split-diet (Table 2). This finding is consistent with the previous experiment (Chapter 1). The reduction in protein intake that was noted in the present experiment represents approximately 35% of the total protein intake of control birds. When protein intake is expressed on a percent basis (grams protein/100 grams feed), hens fed the split-diet selected a diet containing approximately 11% crude protein. This value is considerably below NRC (1984) and industry standards and may indicate that turkey hens are routinely fed a diet containing excess protein.

Figure 6 displays trends in protein intake over the production cycle. As in the previous experiment, there was a trend toward increasing protein intake over the course of production. This occurred despite a decrease in total food intake over the same period (Figure 2). Therefore, hens that were allowed to self-select protein selected a diet with a progressively increasing protein content (Figure 7). This pattern of protein selection may be partially due to the fact that the later portion of the experiment took place during the summer. Dietary protein content is generally increased during warmer periods in order to offset the effect of reduced feed intake that results from reduced energy needs (Thornton and Whittet, 1960; Bray and Gessell, 1961). However, birds fed a split-diet are able to decrease energy intake independent of protein intake. A trend towards the selection of a diet with a higher protein content was also noted in the previous self-selection experiment (Chapter 1). It appears, therefore, that the increase in protein intake is independent of seasonal effects and is probably attributable to an increased metabolic need for protein. In addition, approximately ten weeks into the production cycle there was a relatively sharp increase in the protein content of the diet which was selected. If regression lines are fitted through the protein content of the diet selected during the first 11 weeks of production and the last 9 weeks of production, these lines have equal slopes but significantly different intercepts. This indicates that the protein level of the diet selected during these two periods was significantly different. This finding is an close agreement with the previous experiment (Chapter 1). For this reason, it may be advantageous to feed turkey hens a series of diets containing increasing levels of protein over time rather than feeding a single diet throughout the production period.

The net result of birds selecting less protein and an equal energy level as controls is an altered dietary energy:protein ratio. Indeed, the average energy:protein ratio of the diet selected was 26.5 (megcal/kg protein) which compares with an E:P ratio of 14.8 in the control diet. The E:P ratio of the diet that was selected in this experiment corresponds very closely with the energy:protein ratio of the diet selected in the previous experiment (Chapter 1).

Four consistent results were noted in the two self-selection experiments. First, the incidence of broodiness was greatly reduced among hens that were allowed to self-select. Second, the diet that was selected had a protein content that was much lower than NRC standards. Third, birds selected a diet with progressively more protein over the course of production. Fourth, the diet that was selected had a higher E:P ratio than the control diet. Further research is needed to determine if the reduction in the incidence of broodiness that was observed in these experiments is attributable to the self-selection regime itself or to the difference in the diet that was selected and consumed.

SUMMARY

An experiment was conducted to determine the effect of protein and energy self-selection on the reproductive performance of Large White turkey hens. Ninety-six turkey hens were equally divided into two treatment groups. One-half the birds were allowed to select their diet from two feed sources: a high protein-low energy feed (18.1% crude protein, 2685 kcal ME/kg) and a high energy-low protein feed (7.9% crude protein, 3130 kcal ME/kg). The control group was fed a complete diet prepared by blending the high protein and high energy diets to produce a diet intermediate in protein and energy (35.1% crude protein, 1940 kcal ME/kg).

There was no significant difference in the total egg production of control and split-fed birds. Feed and energy intakes were not significantly effected by the dietary treatments. However, total protein consumption (kg) for the production period was significantly reduced among birds that were allowed to self-select ($p \leq .001$). The protein content of the diet selected increased over the course of production with a sharp increase occurring approximately 10 weeks after the initiation of stimulatory lighting. This change in diet selection suggests a need for different diet formulations during different stages of the production cycle. Also in agreement with previous work, the self-selection of protein and energy resulted in a significant reduction in the incidence of broodiness ($p \leq .10$). Fertility and

hatchability were significantly reduced among first season hens fed the split-diet as compared to the other treatment groups. There were no significant treatment effects on average egg or body weights.

Table 1. Composition of Experimental Diets

Ingredients	Control (%)	High Energy[1]	High Protein[2]
Ground yellow corn	57.11	55.98	1.13
Stabilized fat	1.0	1.0	-
Dehulled soybean meal	12.00	-	12.00
Menhaden fish meal	5.00	-	5.00
Meat and bone meal	5.00	-	5.00
Dehydrated alfalfa meal	12.00	-	12.0
Dried whey	1.00	-	1.00
Deflourinated phosphate	0.80	0.50	0.30
Ground limestone	5.45	4.62	0.83
Iodized salt	0.32	0.20	0.12
Trace mineral mix[3]	0.08	0.05	0.03
Vitamin and additive premix[4]	0.24	0.15	0.09
Total	100.0	62.5	37.5
% Crude protein[5]	18.1	7.9	35.1
Metabolizable energy (Kcal)[5]	2685	3132	1941

[1]Expressed as parts per 62.5 parts

[2]Expressed as parts per 37.5 parts

[3]A trace mineral mix guaranteed to contain: 15% manganese, 10% zinc, 7% iron, 1.0% copper, and 0.22% iodine from manganese oxide, zinc oxide, ferrous sulfate, copper oxide and calcium carbonate as a diluent.

[4]The vitamin and feed additive premix supplied in milligrams per kilogram diet unless otherwise stated: 16,500 IU vitamin A, 5,500 ICU vitamin D_3, 40 IU vitamin, 6.6 menadione dimethyl-pryimidinol bisulfite, 2.2 thiamine HCl, 18 riboflavin, 25 calcium pantothenate (D), 66 niacin, 600 choline chloride, 0.013 vitamin B_{12}, 2.2 folic acid, 0.11 biotin, 2.2 pyridoxine HCl, 62 ethoxyquin, 0.2 selenium from sodium selenite, 55 bacitracin from zinc bacitracin.

[5]Calculated based on book values

Table 2. Consumption and production measures of turkey hens fed complete and split diets over a 20-week production cycle[1]

Period	Control Diet	Split Diet
Feed consumption (kg)	27.67 ± 1.32	28.72 ± 1.18
Protein consumption (kg)	5.01 ± 0.24 a	3.25 ± 0.17 b
Energy consumption (megcal)	74.36 ± 3.51 a	86.02 ± 3.43 b
Feed efficiency (eggs/kg)	1.73 ± 0.09	1.67 ± 0.09
Protein efficiency (eggs/kg)	12.85 ± 0.76	11.78 ± 0.71
Energy efficiency (eggs/kg)	0.61 ± 1.01	0.59 ± 0.03
Egg production	51.74 ± 3.55	48.77 ± 3.27
Days to first egg	21.50 ± 0.65	21.88 ± 0.54
Egg weight (g)	101.03 ± 1.02	98.31 ± 1.60
Body weight (kg)	9.07 ± 0.26	9.04 ± 0.24
Weight change (kg)	-1.88 ± 0.18	-2.01 ± 0.21

1 Values represent mean ± standard error.

a, b Means within same row with different superscripts are significantly different ($P \leq .05$).

Table 3. Percent fertility, hatchability, and hatch of fertile eggs laid by turkey hens fed complete and split diets over a 20-week production period[1]

Group	% Fertility	% Hatchability	% Hatch of Fertile
Control Diet			
First Season	91.21 ± 1.82 a	72.98 ± 3.00 a	79.57 ± 2.24 a
Second Season	91.29 ± 2.08 a	72.39 ± 3.31 a	79.57 ± 2.55 a
Split Diet			
First Season	83.99 ± 1.67 b	54.07 ± 4.23 b	64.06 ± 4.69 b
Second Season	89.09 ± 2.25 a	70.64 ± 3.32 a	78.77 ± 2.87 a

1 Values represent mean ± standard error.

a, b Means within same column with different superscripts are significantly different ($P \leq .05$).

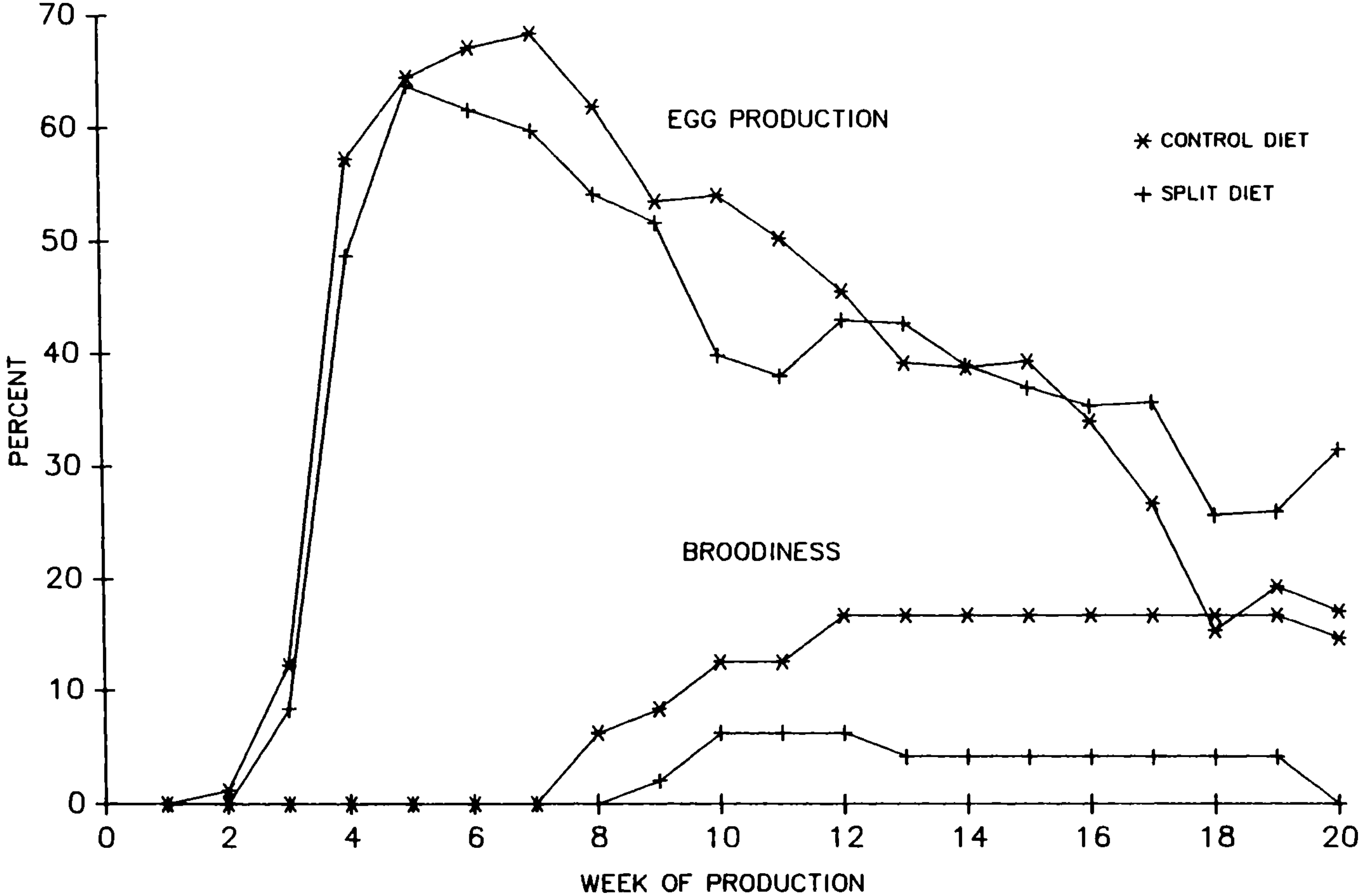

Figure 1. Percent egg production and broodiness of turkey hens fed conventional and split diets over a 20 week production cycle.

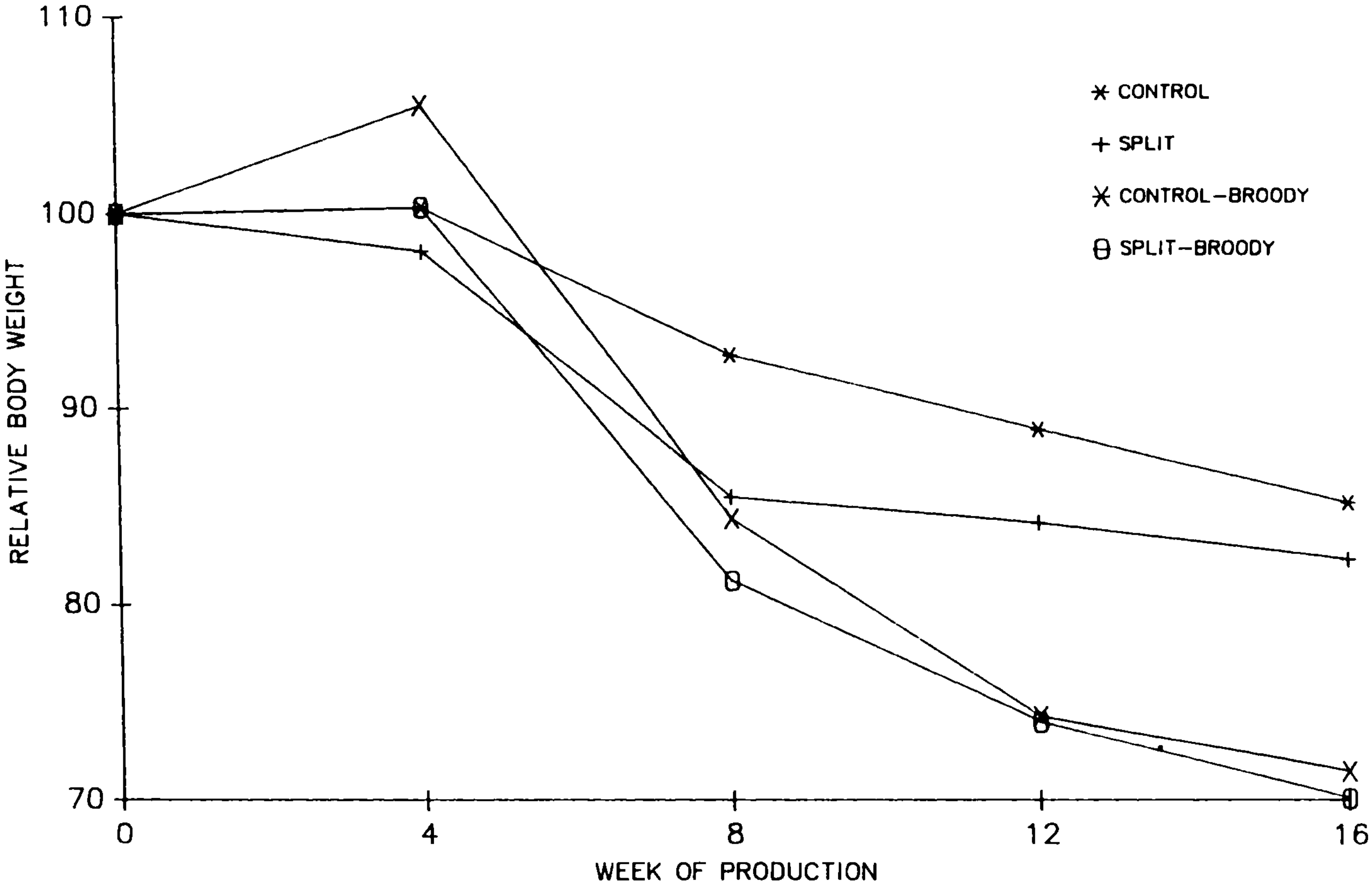

Figure 2. Relative body weight (% of initial weight) of turkey hens fed conventional and split diets over a 20 week production cycle.

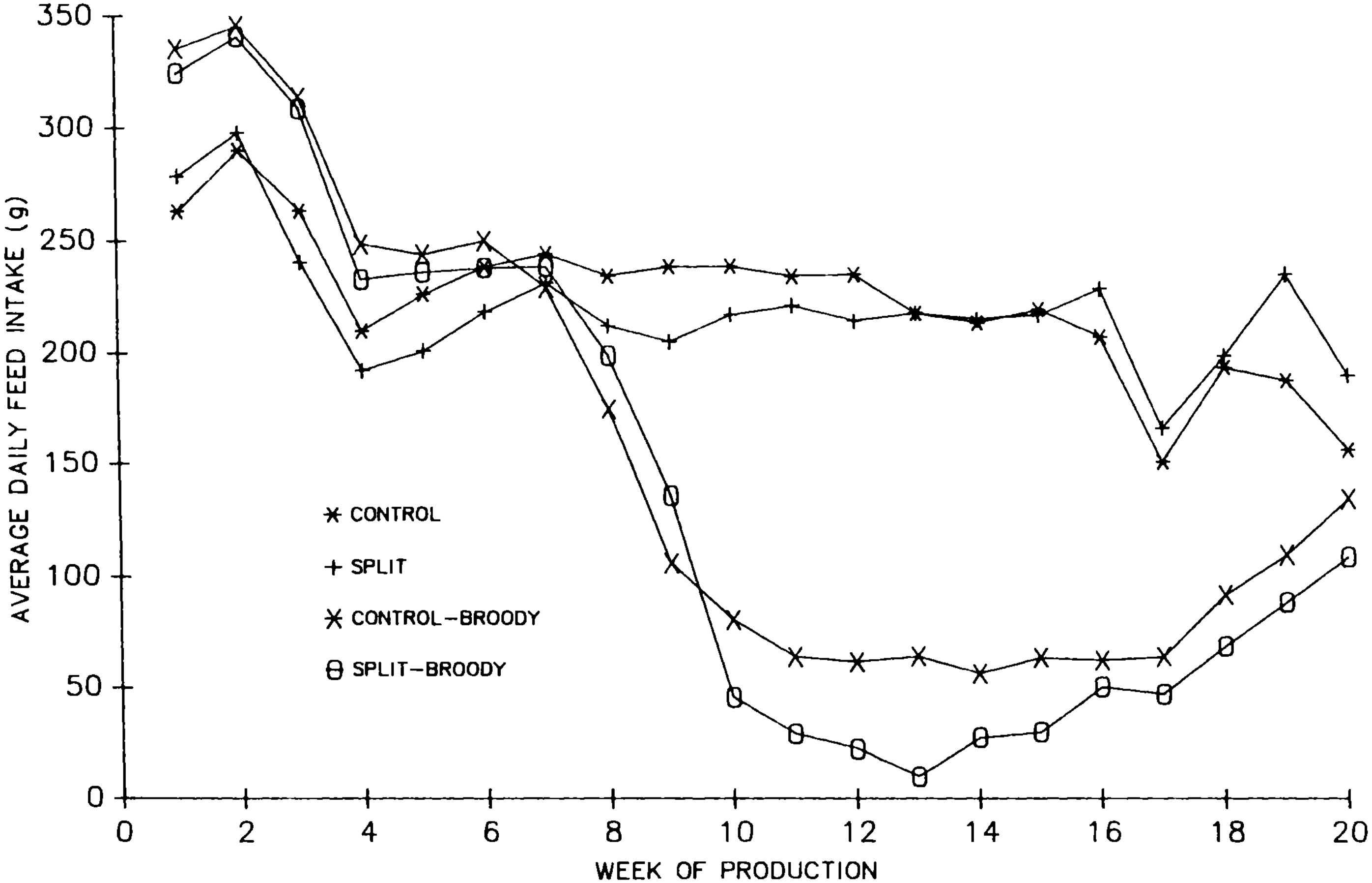

Figure 3. Average daily feed intake (g) of turkey hens fed conventional and split diets over a 20 week production cycle.

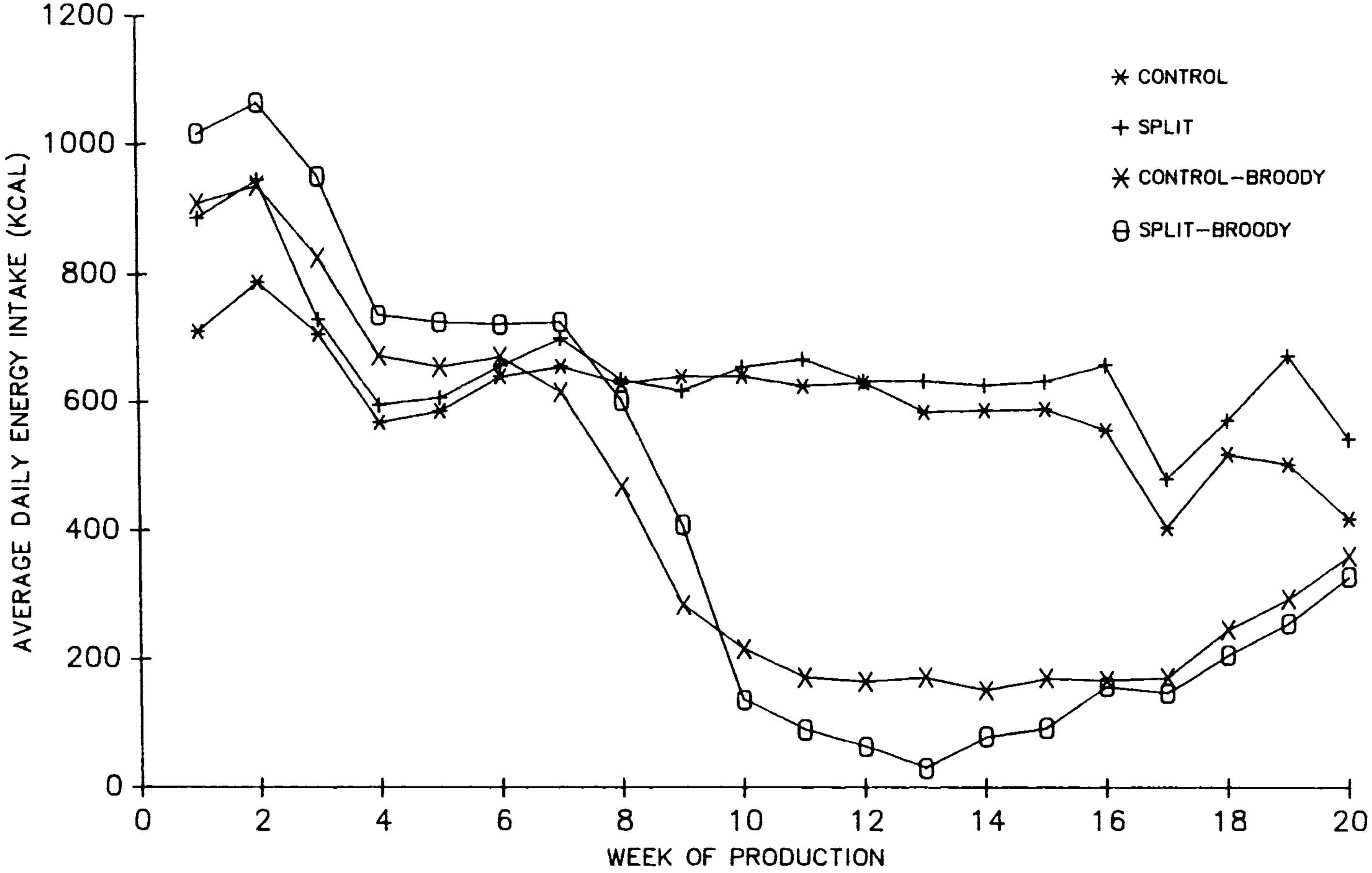

Figure 4. Average daily energy (kcal) intake of turkey hens fed conventional and split diets over a 20 week production cycle.

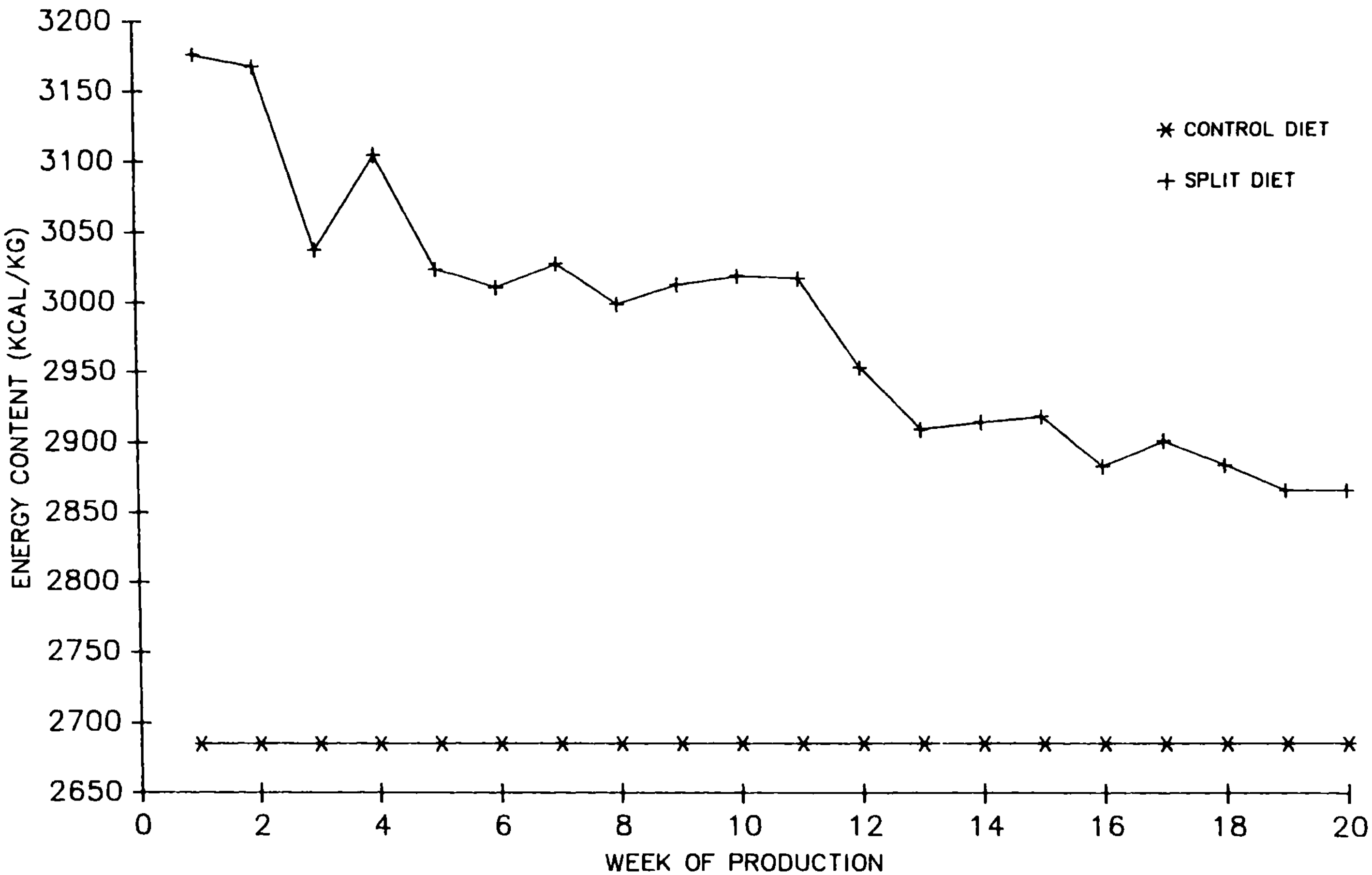

Figure 5. Energy content (kcal/kg diet) of the complete diet and the diet selected by split fed hens during a 20 week production cycle.

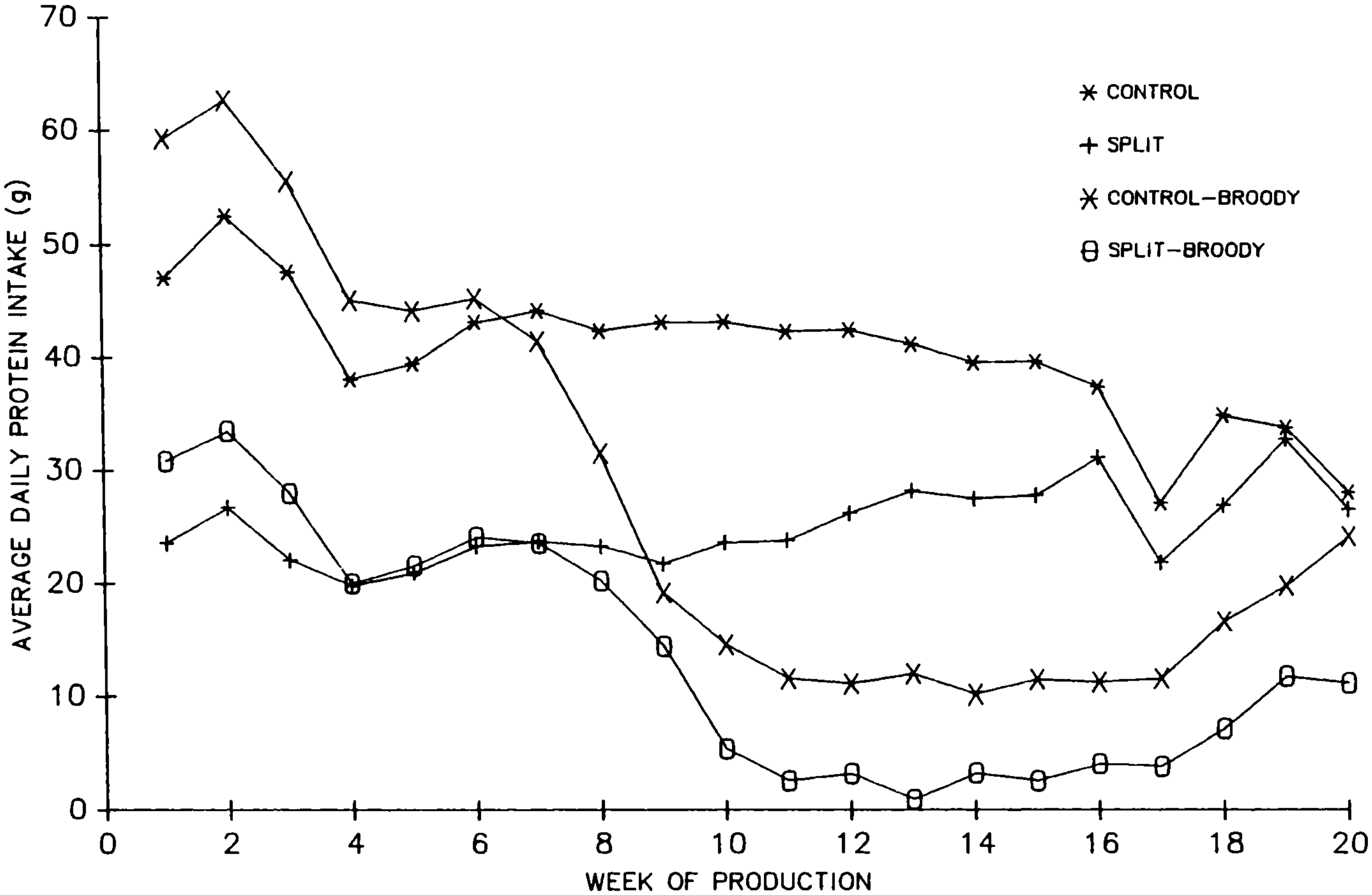

Figure 5. Average daily protein intake (g) of turkey hens fed conventional and split diets over a 20 week production cycle.

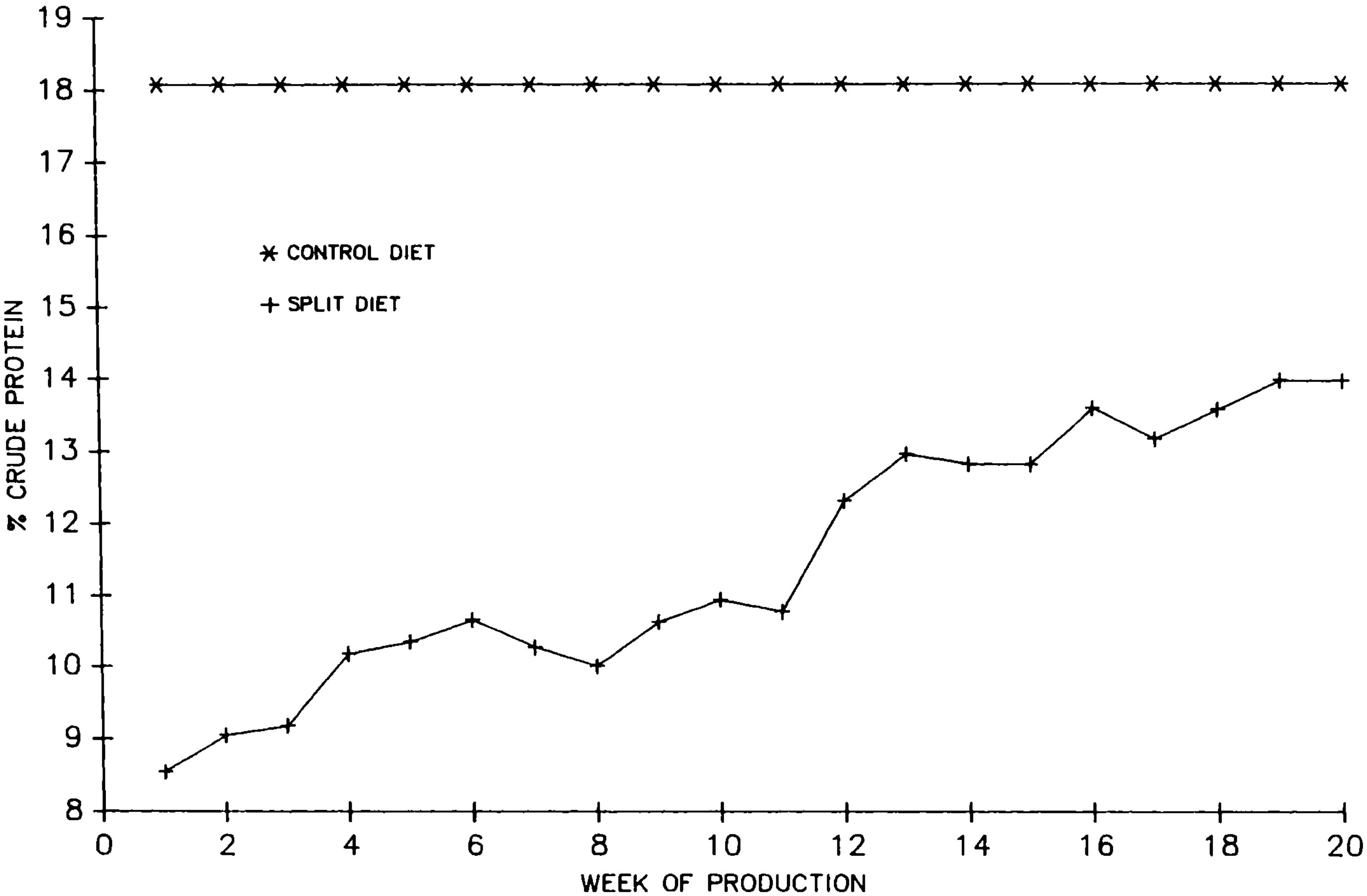

Figure 6. Percent crude protein (g protein/100 g diet) of control diet and the diet selected by split fed turkey hens over a 20 week production cycle.

REFERENCES

Bray, D.J., and J.A. Gesell, 1961. Studies with corn-soya laying diets 4. environmental temperature-a factor affecting performance of pullets fed diets suboptimal in protein. Poultry Sci. 40:1328-1335.

Boorman, K.N., 1979. Regulation of protein and amino acid intake. pages 87-126 *in*: Food Intake Regulation in Poultry. K.N. Boorman and B.M. Freeman ed. Br. Poultry Sci. Ltd, Edinburgh.

Booth, D.A., 1979. Feeding control systems within animals. pages 13-62 *in*: Food Intake Regulation in Poultry. K.N. Boorman and B.M. Freeman ed. Br. Poultry Sci. Ltd, Edinburgh.

Brody, T.B., J.A. Cherry, and P.B. Siegel, 1984. Responses to dietary self selection and calories in liquid form by weight selected lines of chickens. Poultry Sci. 63:1626-1633.

Cohen-Parsons, M., A.T. Leighton, and G.B. Meyer, 1982. Reproductive performance of female breeder turkeys fed on maize-soyabean diets supplemented with methionine. Br. Poultry Sci. 23:135-143.

Cowan, P.J., and W. Michie, 1978. The use of barley in choice feeding of the turkey. Br. Poult Sci. 19:1-6.

Cowan, P.J., W. Michie, and D.J. Roele, 1978. Choice feeding of the egg-type pullet. Br. Poultry Sci. 19:153-157.

Daghir, N.J., 1973. Energy requirements of laying hens in a semi-arid continental climate. Br. Poultry Sci. 14:451-461.

Duncan, D.B., 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Funk, E.M., 1932. Can the chick balance its ration? Poultry Sci. 11:94-97.

Holcombe, D.J., D.A. Roland Sr., and R.H. Harms, 1976. The ability of hens to regulate protein intake when offered a choice of diets containing different levels of protein. Poultry Sci. 55:1731-1737.

Huey, D.F., J.A. Cherry, D.M. Denbow, and H.P. Van Krey, 1982. Self-selection of dietary protein and energy by diverse populations of chickens. Nutr. Behav. 1:55-64.

Hughes, B. O., 1979. Appetites for specific nutrients. Pages 141-169 *in*: Food Intake Regulation in Poultry. K.N. Boorman and B.M. Freeman, ed. Br. Poultry Sci. Ltd., Edinburgh.

Hughes, B.O., 1984. The principles underlying choice feeding behavior in fowls-with special reference to production experiments. World Poultry Sci. 40:144-150.

Kaufman, L.W., G. Collier, and R.L. Squibb, 1978. Selection of an adequate protein-carbohydrate ratio by the domestic chick. Physiol. Behav. 20:339-344.

Kurnick, A.A., H.B. Hinds, M.W. Pasvogel and B.L. Reid, 1961. Dietary energy levels for laying hens as related to age and environmental temperatures. 1. effect on egg production, body weight and feed conversion. Poultry Sci. 40:1483-1491.

Leeson, S., D. Lewis, and D.H. Shrimpton, 1973. Multiple linear regression equations for the prediction of food intake in the laying fowl. Br. Poultry Sci. 14:595-608.

Leeson, S., and J.D. Summers, 1981. Dietary self-selection and use of reverse-protein diets for developing broiler breeder pullets. Poultry Sci. 60:168-171.

Marsden, S.J., L.M. Lucas, and S.P. Wilson, 1966. The influence of daylength and environment on reproduction, broodiness, and mortality of turkeys. Poultry Sci. 45:668-675.

Massey, J.H., and H.L. Fuller, 1962. Methods of feeding turkeys. Poultry Sci. 41:145-150.

McDonald, R., and G.C. Emmans, 1980. Choice feeding of turkey breeder hens in single cages. World Poultry Sci. 36:68-73.

Mitchell, M.S., and I.L. Kosin, 1954. The effect of controlled ambient temperature on some factors associated with egg laying in turkeys. Poultry Sci. 33:186-191.

National Research Council, 1984. Nutrient requirements of poultry. 8th ed. Nat. Acad. Sci., Washington, DC.

Peterson, C.F., E.A. Sauter, D.H. Conrad and C.E. Lampman, 1960. Effect of energy level and laying house temperature on the performance of white leghorn pullets. Poultry Sci. 39:1010-1018.

Rose, S.P., and W. Michie, 1982. The food intakes and growth of choice-fed turkeys offered balancer mixtures of different compositions. Br. Poultry Sci. 23:547-554.

Summers, J.D., and S. Leeson, 1978. Dietary selection of protein and energy by pullets and broilers. Br. Poultry Sci. 19:425-430.

Thomason, D.M., A.T. Leighton, and J.P. Mason Jr., 1972. A study of certain environmental factors on the reproductive performance of Large White turkeys. Poultry Sci. 51:1438-1449.

Thornton, P.A., and W.A. Whittet, 1960. Protein requirement for egg production as influenced by management, genetic background and dietary energy level. Poultry Sci. 39:916-921.

CHAPTER 3

THE EFFECT OF DIET SELF-SELECTION ON SERUM LUTEINIZING HORMONE AND PROLACTIN CONCENTRATIONS

INTRODUCTION

Broodiness remains a major problem which limits the production of turkey hatching eggs (Etches and Cheng, 1982). Although its specific role in broodiness is not yet fully known, prolactin (PRL) has long been associated with the development of behavioral broodiness in chickens (Riddle *et al.*, 1935; Saeki and Tanabe, 1955; Lea *et al.*, 1981), turkey hens (Burke and Dennison, 1980; Proudman and Opel, 1981; Etches and Cheng, 1982; Lea and Sharp, 1982; Wentworth *et al.*, 1983), geese (Akesson and Raveling, 1981) and ruffed grouse (Etches *et al.*, 1979).

In two previous experiments (Chapter 1, Chapter 2), the incidence of broodiness was significantly reduced among turkey hens that were allowed to self-select their diet from a relatively high protein feed source and a relatively high energy feed source as compared to hens fed a complete diet. Therefore, the objective of the present study was to determine if serum LH and PRL concentrations were affected by the self-selection regime.

MATERIALS AND METHODS

Animals and Husbandry - Two experiments (Chapter 1, Chapter 2) were conducted with a total of 144 Large White turkey hens to determine the effect of diet self-selection on reproductive performance. Hens were housed in individual cages in a light controlled environment. Hens were placed in the cages approximately one week prior to photostimulation. At this time they were placed on one of two dietary treatments. Half of the hens were fed a complete diet (18% CP, 2700 kcal/kg) with a composition similar to diets fed in the poultry industry. The remaining hens were allowed to select their diet from two feed sources:a diet relatively high in protein (35% CP, 1850 kcal/kg) and a diet relatively high in energy (8% CP, 3220 kcal/kg).

Sample Collection - Blood samples were obtained via the brachial vein on a monthly basis from Large White turkey hens fed either a split or conventional diet. Diets and management procedures were as outlined in Chapters 1 and 2. Samples were then centrifuged and serum was harvested and frozen at -70 C for later analysis. Samples were analyzed for blood LH and PRL concentrations by radioimmunoassay using the techniques described by Burke and Papkoff (1980) and Burke *et al*. (1979) for LH and PRL, respectively.

Statistical Analysis - Blood samples from the two breeder experiments (Chapters 1 and 2) were combined and means and variances were computed for serum PRL and LH levels within each treatment at each time period. Because the variances of the treatment groups were not homogeneous, differences between PRL and LH concentrations in the two treatment groups were analyzed non-parametrically using Wilcoxon's paired sample test. Differences between the incidence of broodiness in the two treatment groups were determined by Chi-square analysis.

RESULTS AND DISCUSSION

As displayed in Figure 1, the incidence of broodiness was markedly different in the two treatment groups. The incidence of broodiness was approximately four times as high among hens fed a conventional diet as among those fed a split-diet. This represents a significant reduction in the incidence of broodiness ($p \leq .05$).

Mean LH and PRL levels for the two treatment groups at the five time periods are presented in Table 1. Although there was a consistent trend toward higher serum PRL among hens fed the split-diet, there were no significant differences in the serum LH or PRL levels of the two treatment groups. Therefore, it appears that the split-diet regime altered the incidence of broodiness in these experiments without significantly altering serum LH or PRL. Therefore, it appears that dietary self-selection attenuates broodiness without altering serum LH or PRL concentrations.

SUMMARY

An experiment was conducted to determine if a dietary treatment which influenced the incidence of broodiness in previous experiments also altered serum luteinizing hormone (LH) and prolactin (PRL) concentrations. In these experiments, the incidence of broodiness was four times as high among turkey hens fed a conventional diet as among hens that were allowed to self-select the protein and energy level of their diet. Therefore, blood sera from these hens was analyzed for LH and PRL concentrations to determine if these hormones were also affected by the dietary treatments. Serum LH and PRL were not significantly affected by the dietary treatments. Therefore, it appears that the self-selection regime that was used in these studies altered broodiness without affecting serum LH or PRL.

Table 1. Prolactin and luteinizing hormone concentrations of serum from turkey breeder hens fed conventional and split diets.[1] [2]

Week of production	Luteinizing hormone (ng/ml)		Prolactin (ng/ml)	
	Control diet	Split-diet	Control diet	Split-diet
0	3.61 ± 0.20	3.12 ± 0.12	33.79 ± 3.24	44.99 ± 6.94
4	2.76 ± 0.10	2.82 ± 0.08	19.24 ± 1.43	17.59 ± 1.26
8	2.99 ± 0.13	2.96 ± 0.13	135.38 ± 21.81	57.53 ± 15.55
12	2.70 ± 0.17	2.21 ± 0.07	36.61 ± 5.96	30.91 ± 3.86
16	2.56 ± 0.11	2.83 ± 0.10	28.70 ± 5.19	22.28 ± 2.53

[1] Values represent means ± standard error

[2] There were on significant differences.

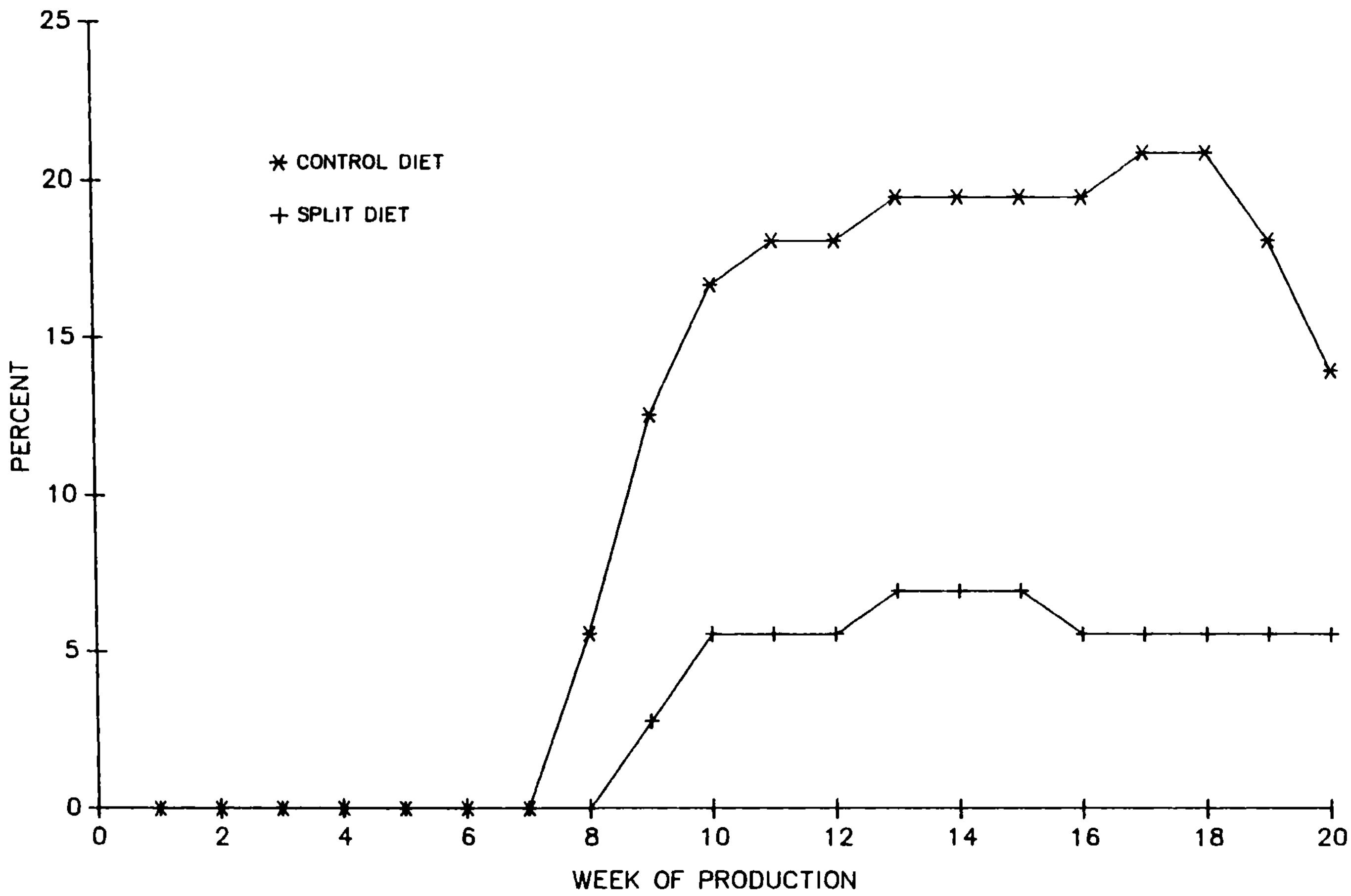

Figure 1. Incidence of broodiness (%) of turkey hens fed conventional and split diets over a 20 week production cycle.

REFERENCES

Akesson, T.R., and D.G. Raveling, 1981. Endocrine and body weight changes of nesting and non-nesting Canada geese. Biol. Repro. 25:792-804.

Burke, W.H., P. Light, H. Papkloff, and A. Bona Gallo, 1979. Isolation and characterization of luteinizing hormone and follicle-stimulating hormone from pituitary glands of the turkey (*Meleagris gallopavo*). Gen. Comp. Endocrinol. 37:508-520.

Burke, W.H. and P.T. Dennison, 1980. Prolactin and Luteinizing hormone levels in female turkeys (*Meleagris gallopavo*) during a photoinduced reproductive cycle and broodiness. Gen. Comp. Endocrin. 41:92-100.

Burke, W.H., and H. Papkoff, 1980. Purification of turkey prolactin and the development of a homologous radioimmunoassay for its measurement. Gen. Comp. Endocrinol. 40:297-307.

Etches, R.J., 1977. A homologous radioimmunoassay for turkey prolactin: changes during the reproductive and ovulatory cycle. Poultry Sci. 61:1354-1362.

Etches, R.J., A. Garbutt, and A.L. Middleton, 1979. Plasma concentrations of prolactin during egg laying and incubation in the ruffed grouse (*Bonasa umbellus*). Can. J. Zool. 57:1624-1627.

Etches, R.J., and K.W. Cheng, 1982. A homologous radioimmunoassay for turkey prolactin: changes during the reproductive and ovulatory cycle. Poultry Sci. 61:1354-1362.

Lea, R.W. A.S. Dods, P.J. Sharp, and A. Chadwick, 1981. The possible role of prolactin in the regulation on nesting behavior and the secretion of luteinizing hormone in broody bantams. J. Endocrinol. 91:88-97.

Lea, R.W., and P.J. Sharp, 1982. Plasma prolactin concentrations in broody turkeys: lack of agreement between homologous chicken and turkey prolactin radioimmunoassays. Br. Poultry Sci. 23:451-459.

Proudman, J.A., and Opel, 1981. Turkey prolactin: validation of radioimmunoassay and measurement of changes associated with broodiness. Biol. Reprod. 25:573-580.

Riddle, O., R.W. Bates, and E.L. Lahr, 1935. Prolactin induced broodiness in fowl. Am. J. Physiol. 111:352-360.

Saeki, Y., and Y. Tanabe, 1955. Changes in prolactin content of fowl pituitary during broody periods and some experiments in the induction of broodiness. Poultry Sci. 34:909-919.

Wentworth, B.C., J.A. Proudman, H. Opel, M.J. Wineland, N.G. Zimmermann, and A. Lapp, 1983. Endocrine changes in the incubating and brooding turkey hen. Biol. Repro. 29:87-92.

GENERAL SYNTHESIS

The two major studies which comprise the greater portion of this thesis investigated the effect of dietary self-selection on the reproductive performance of turkey breeder hens. The results of these experiments indicate that turkey hens can, in some situations, reproduce satisfactorily under a self-selection regime. In addition, such a regime can lead to significantly improved efficiency of protein utilization due to decreased protein consumption. Considering the fact that the cost of high protein feed ingredients comprises a large portion of total feed cost, reductions in protein intake can lead to significant reductions in total feed cost if reproductive performance is maintained. However, this research leaves many questions unanswered and, therefore, provides a foundation for further inquiry.

A significant finding in these studies was the reduced incidence of broodiness among hens that were allowed to self-select. However, the specific cause of this phenomenon must be determined. Is this a result of the dietary regime itself or due to some difference in the diet that was selected and consumed? If the diet consumed is responsible for this difference in broodiness, then conventional diets could be formulated to produce the same effect. This would certainly be more readily accepted by the turkey industry. If the self-selection regime is responsible for reduced broodiness, further research is needed to develop proper diet formulations and management systems for its use.

Seasonal affects on diet self-selection appear to be based largely on maintaining a proper balance between protein and energy intake. This relationship is particularly important when conventional diets are being fed. Seasonal affects on reproduction are also an important consideration. A self-selection regime would seem to be of greater benefit during summer months than during cooler months of the year since both feed intake and reproductive performance are reduced during the summer. This should be an important consideration in any future research of this kind.

A consistent finding in these experiments is an increasing pattern in the protein content of the diets that were selected by choice-fed hens. This might simply be the result of a greater degree of adaptation to the dietary regime over time. However, this increase in protein selection might also be related to increasing protein requirements in the later phases of production. Further research is needed to determine if there is some benefit to feeding turkey hens higher dietary protein levels late in the reproductive cycle.

Considering the relative inefficiency of reproduction of turkey hens as compared to broiler breeder and laying hens, any improvement in reproduction, whether through genetics, management or nutrition, could be of considerable benefit to the turkey industry. Experiments investigating proper energy:protein relationships, changes in protein requirements over the reproductive cycle, and nutritional factors affecting the incidence of broodiness could provide information important to improving reproductive performance. These studies could provide a starting point for such research.

Appendix A Table 1. Analysis of variance of the effect of protein and energy self-selection on egg production of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-Broody				
Diet	1	226.01	0.39	0.5300
Error	36	20703.81		
Total	37	20999.82		
Broody				
Diet	1	45.38	0.74	0.4225
Error	6	367.50		
Total	7	412.88		

Appendix A Table 2. Analysis of variance of the effect of protein and energy self-selection on days to first egg for turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-Broody				
Diet	1	0.14	0.31	0.5841
Error	36	1594		
Total	37	16.08		
Broody				
Diet	1	8.17	2.53	0.1625
Error	6	19.33		
Total	7	27.50		

Appendix A Table 3. Analysis of variance of the effect of protein and energy self-selection on egg weight of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-Broody				
Diet	1	224.44	6.89	0.0090
Month	3	9472.10	96.98	0.0001
Diet x Month	3	118.14	1.21	0.3058
Error	443	14423.30		
Total	450	24311.61		
Broody				
Diet	1	24.92	0.75	0.3912
Month	2	132.09	1.99	0.1492
Diet x Month	1	5.16	0.16	0.6953
Error	43	1427.95		
Total	47	1591.68		

Appendix A Table 4. Analysis of variance of the effect of protein and energy self-selection on feed intake of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-Broody				
Diet	1	293.21	14.17	0.0006
Error	36	745.15		
Total	37	1038.37		
Broody				
Diet	1	11.41	0.87	0.3861
Error	6	78.44		
Total	7	89.86		

Appendix A Table 5. Analysis of variance of the effect of protein and energy self-selection on protein intake of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-broody				
Diet	1	74.49	97.34	0.0001
Error	36	27.55		
Total	37	102.04		
Broody				
Diet	1	6.18	11.77	0.0139
Error	6	3.15		
Total	7	9.33		

Appendix A Table 6. Analysis of variance of the effect of protein and energy self-selection on energy intake of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-Broody				
Diet	1	427.33	2.61	0.1150
Error	36	5896.62		
Total	37	6323.85		
Broody				
Diet	1	1.42	0.01	0.9135
Error	6	664.75		
Total	7	666.17		

Appendix A Table 7. Analysis of variance of the effect of protein and energy self-selection on feed efficiency of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-broody				
Diet	1	0.14	0.31	0.5841
Error	36	15.94		
Total	37	16.08		
Broody				
Diet	1	0.30	2.30	0.1802
Error	6	0.78		
Total	7	1.08		

Appendix A Table 8. Analysis of variance of the effect of protein and energy self-selection on protein efficiency of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-broody				
Diet	1	420.18	19.11	0.0001
Error	36	791.70		
Total	37	1211.89		
Broody				
Diet	1	156.47	12.77	0.0117
Error	6	73.51		
Total	7	229.98		

Appendix A Table 9. Analysis of variance of the effect of protein and energy self-selection on energy efficiency of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-broody				
Diet	1	0.01	0.10	0.7539
Error	36	2.02		
Total	37	2.03		
Broody				
Diet	1	0.01	0.67	0.4431
Error	6	0.09		
Total	7	0.10		

Appendix A Table 10. Analysis of variance of the effect of protein and energy self-selection on body weight of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-Broody				
Diet	1	0.70	1.55	0.2210
Error	36	16.17		
Total	37	16.87		
Broody				
Diet	1	0.20	0.34	0.5789
Error	6	3.51		
Total	7	3.71		

Appendix A Table 11. Analysis of variance of the effect of protein and energy self-selection on body weight loss of turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Non-Broody				
Diet	1	12.35	16.27	0.0003
Error	35	26.68		
Total	36	39.03		
Broody				
Diet	1	3.08	16.39	0.0067
Error	6	1.13		
Total	7	4.21		

Appendix A Table 12. Analysis of variance of the effect of protein and energy self-selection on fertility of eggs laid by turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	94.01	1.84	0.1811
Error	46	2345.27		
Total	47	2439.28		

Appendix A Table 13. Analysis of variance of the effect of protein and energy self-selection on hatchability of eggs laid by turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	281.96	1.58	0.2151
Error	46	8207.87		
Total	47	8489.83		

Appendix A Table 14. Analysis of variance of the effect of protein and energy self-selection on hatchability of fertile eggs laid by turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	134.14	0.96	0.3322
Error	46	6423.16		
Total	47	6557.30		

Appendix A Table 15. Dummy variable analysis on the effect of protein and energy self-selection on the protein content of the diet consumed by turkey breeder hens (Chapter 1).

Source of Variation	df	Sum of Squares	F Value	P
Test for Equal Slopes				
Week	1	0.0001	0.03	0.8595
Group (Dummy Variable)	1	0.0095	5.29	0.0219
Week x Group	1	0.0024	1.32	0.2503
Error	455	.8160		
Total	458	.8496		
Test for Equal Intercepts				
Week	1	0.0005	0.28	0.5942
Group	1	0.0105	5.83	0.0162
Error	456	0.8184		
Total	458	0.8496		

Appendix B Table 1. Analysis of variance of the effect of protein and energy self-selection on feed consumption of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	26.20	0.35	0.5566
Hen Age	1	95.45	1.27	0.2630
Diet*Age	1	14.23	0.19	0.6647
Error	92	6924.06		
Total	95	7059.94		

Appendix B Table 2. Analysis of variance of the effect of protein and energy self-selection on protein intake of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	73.71	35.71	0.0001
Hen Age	1	2.14	1.04	0.3110
Diet*Age	1	1.01	0.49	0.4862
Error	92	189.88		
Total	95	266.75		

Appendix B Table 3. Analysis of variance of the effect of protein and energy self-selection on the energy intake of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	3264.79	5.61	0.0200
Hen Age	3	705.87	1.21	0.2738
Diet x Age	1	68.24	0.12	0.7329
Error	92	53587.47		
Total	95	57626.37		

Appendix B Table 4. Analysis of variance of the effect of protein and energy self-selection on feed efficiency of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	0.09	0.25	0.6186
Hen Age	1	1.60	4.28	0.0415
Diet x Age	1	0.01	0.02	0.8811
Error	90	33.69		
Total	93	35.40		

Appendix B Table 5. Analysis of variance of the effect of protein and energy self-selection on protein efficiency of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	0.09	0.25	0.6186
Hen Age	1	1.60	4.28	0.0415
Diet x Age	1	0.01	0.02	0.8811
Error	90	33.69		
Total	93	35.40		

Appendix B Table 6. Analysis of variance of the effect of protein and energy self-selection on energy efficiency of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	0.0066	0.13	0.7213
Hen Age	1	0.2101	4.09	0.0461
Diet x Age	1	0.0007	0.01	0.9099
Error	90	4.6227		
Total	96	4.8401		

Appendix B Table 7. Analysis of variance of the effect of protein and energy self-selection on egg production of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	189.26	0.36	0.5520
Hen Age	1	2770.10	5.22	0.0247
Diet x Age	1	265.38	0.50	0.4814
Error	91	48330.03		
Total	94	51557.43		

Appendix B Table 8. Analysis of variance of the effect of protein and energy self-selection on days to first egg of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	1.84	0.13	0.7155
Hen Age	1	269.10	19.52	0.0001
Diet x Age	1	22.07	1.60	0.2091
Error	90	1240.86		
Total	93	1532.05		

Appendix B Table 9. Analysis of variance of the effect of protein and energy self-selection on egg weight of eggs laid by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	152.17	1.93	0.1686
Hen Age	1	361.54	4.58	0.0352
Month	2	220.08	1.39	0.2536
Diet x Age	1	54.79	0.69	0.4071
Diet x Month	2	169.13	1.07	0.3471
Age x Month	2	10.00	0.06	0.9386
Diet x Age x Month	2	14.39	0.09	0.9130
Error	84	6628.72		
Total	95	8282.28		

Appendix B Table 10. Analysis of variance of the effect of protein and energy self-selection on body weight of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	0.02	0.01	0.9339
Hen Age	1	0.48	0.16	0.6862
Diet x Age	1	5.26	1.80	0.1832
Error	92	268.95		
Total	47	274.71		

Appendix B Table 11. Analysis of variance of the effect of protein and energy self-selection on body weight loss of turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	0.48	0.31	0.5767
Hen Age	1	3.36	2.22	0.1397
Diet x Age	1	12.18	8.05	0.0057
Error	82	124.02		
Total	85	139.93		

Appendix B Table 12. Analysis of variance of the effect of protein and energy self-selection on fertility of eggs laid by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	0.16	5.62	0.0199
Hen Age	1	0.08	3.05	0.0841
Diet x Age	1	0.07	2.62	0.1088
Error	88	2.44		
Total	91	2.75		

Appendix B Table 12. Analysis of variance of the effect of protein and energy self-selection on hatchability of eggs laid by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	0.39	9.50	0.0027
Hen Age	1	0.16	4.03	0.0479
Diet x Age	1	0.23	5.78	0.0183
Error	88	3.57		
Total	91	4.34		

Appendix B Table 16. Analysis of variance of the effect hen age on hatchability of eggs laid by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
First Season Hens				
Diet	1	0.61	13.25	0.0007
Error	44	2.03		
Total	45	2.64		
Second Season Hens				
Diet	1	0.01	0.27	0.6082
Error	44	1.54		
Total	45	1.55		

Appendix B Table 17. Analysis of variance of the effect of hen age on hatchability of eggs laid by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Control Diet				
Hen Age	1	0.0003	0.08	0.7832
Error	44	1.8430		
Total	45	1.8462		
Split Diet				
Hen Age	1	0.3952	10.04	0.0028
Error	44	1.7327		
Total	45	2.1279		

Appendix B Table 18. Analysis of variance of the effect of protein and energy self-selection on hatchability of fertile eggs laid by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Diet	1	0.22	6.20	0.0146
Hen Age	1	0.14	3.95	0.0499
Diet x Age	1	0.22	6.00	0.0163
Error	88	3.19		
Total	91	3.76		

Appendix B Table 19. Analysis of variance of the effect protein and energy self-selection on hatchability of fertile eggs laid by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
First Season Hens				
Diet	1	0.44167	9.97	0.0029
Error	44	1.94917		
Total	45	2.39085		
Second Season Hens				
Diet	1	0.00003	0.00	0.9743
Error	44	1.23624		
Total	45	1.2363		

Appendix B Table 20. Analysis of variance of the effect hen age on hatchability of fertile eggs laid by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Control Diet				
Hen Age	1	0.00	0.13	0.7196
Error	44	1.30		
Total	45	1.31		
Split Diet				
Hen Age	1	0.37	8.33	0.0060
Error	44	1.88		
Total	45	2.24		

Appendix B Table 21. Dummy variable analysis on the effect of protein and energy self-selection on the protein content of the diet consumed by turkey breeder hens (Chapter 2).

Source of Variation	df	Sum of Squares	F Value	P
Test for Equal Slopes				
Week	1	0.0134	9.59	0.0020
Group (Dummy Variable)	1	0.0060	4.34	0.0376
Week x Group	1	0.0011	0.79	0.3744
Error	910	1.2691		
Total	913	1.4967		
Test for Equal Intercepts				
Week	1	0.0177	12.72	0.0004
Group	1	0.0139	9.98	0.0016
Error	911	1.2702		
Total	913	1.4967		

The vita has been removed from
the scanned document