University of Hohenheim

Faculty of Agricultural Sciences

Department of Farm Animal Ethology and Poultry Science

Prof. Dr. Michael Grashorn

EFFECT OF OMEGA-3 FATTY ACIDS AND PHYSICAL EXERCISE ON EGG QUALITY, BONE CHARACTERISTICS AND PHYSIOLOGICAL PARAMETERS IN LAYING HENS

Doctoral Dissertation

Submitted in fulfilment of the requirements for the degree

“Doctor der Agrarwissenschaften”

(Dr.sc.agr. / Ph.D. in Agricultural Sciences)

to the

Faculty of Agricultural Sciences

presented by

Ardita JAHJA

(born in Prishtina, Kosovo)

Stuttgart-Hohenheim, 2013

This thesis was accepted as a doctoral dissertation in fulfilment of the requirements for the degree "Doktor der Agrarwissenschaft" by the Faculty of Agricultural Sciences at the University of Hohenheim, Stuttgart, Germany on 30 January 2013.

Date of oral examination: 17 July, 2013

Examination committee:

Supervisor and reviewer:	Prof. Dr. Michael Grashorn University of Hohenheim, Faculty of Agricultural Sciences, Department of Farm Animal Ethology and Poultry Science
Co-supervisor and co-reviewer:	Prof. Dr. Ivan ŠTUHEC University of Ljubljana, Biotechnical Faculty, Department of Animal Science
Additional examiner:	Prof. Dr. Ludwig Hölzle University of Hohenheim, Faculty of Agricultural Sciences, Institute for Environment and Animal Hygiene
Vice-Dean and Head of the Committee:	Prof. Dr. Markus Rodehutscord

I hereby declare, that I completed this doctoral thesis independently and only the indicated sources and resources were used and marked.

Ardita JAHJA

TABLE OF CONTENTS

1 GENERAL INTRODUCTION

1.1 BACKGROUND AND MAIN RESEARCH OBJECTIVE

Foods of animal origin such as eggs take an important place in human diets because of their nutritional qualities. Polyunsaturated fatty acids (PUFA) such as 18:3 n-3 and 18:2n-6 are essential and cannot be synthesized in the metabolism of animals and humans; however they can be incorporated into egg or tissue lipids through dietary fat. Incorporation of 18:3n-3 in the laying hens’ diet has been reported to modify the omega-3 (n-3) and omega-6 (n-6) fatty acid composition of egg yolk. The biochemical pathway of fatty acid biosynthesis or tissue deposition may be influenced by the nature of dietary fatty acids. In addition, factors other than diet, such as locomotor activity, may affect lipid metabolism in the laying hens.

Increasing concern on the relationship between animal fats high in saturated fatty acids and coronary heart disease has lead health experts to recommend a reduction in the consumption of animal products in general. However, enrichment of animal product with omega-3-fatty acids may present an opportunity to reduce health risks in humans. The human organism is not able to synthesize the required amounts of polyunsaturated fatty acids (PUFA) by itself (NEWTON, 1996) and, therefore, depends on a sufficient dietary supply for proper functioning of the body (VAN ELSWYK, 1997). Due to the cholesterol lowering (CASTON and LEESON, 1990; JIANG et al., 1991; WATKINS, 1992; FERRIER et al., 1995; SCHEIDELER and FRONING, 1996; SARI et al., 2002) and protective effects of n-3 PUFA against coronary disease (ZEGHICHI-HAMRIS et al., 2010; ADKINS and DARSHAN., 2010), incorporating PUFA and increasing the polyunsaturated to saturated fatty acids ratio of egg yolk or tissue lipids would make poultry products more acceptable to health-conscious consumers. PUFA are mainly needed to synthesize eicosanoids which have an important role to play in controlling cardiovascular, inflammation and immunological processes. Two different types (series) of eicosanoids are synthesized starting either from linoleic (n-6) or linolenic (n-3) fatty acids by using the same enzymes. The optimum ratio between n-6 and n-3 fatty acids in the food is between 5:1 and 10:1 for human nutrition. In Western countries, due to the consumption of food rich in linoleic acid, the dietary content of n-6 fatty acids in relation to n-3 fatty acids is higher than >25:1 (SINGER, 2000). Therefore, any strategies to increase the content of n-3 fatty acids in human food are appreciated. Traditionally, see fish is a suitable source of n-3 fatty acids, but the consumer acceptance of fish varies distinctly between countries (KROMHOUT et al., 1985). An alternative strategy may be to develop food with higher contents of n-3 PUFA, e.g. 'functional eggs' which are enriched with n-3-fatty acids (e.g. FARRELL, 1995; ALBRECHT and KLEIN, 1995; NEWTON, 1996).

Poultry meat and eggs are gaining importance in human nutrition, especially in low income countries of Europe (e.g. Balkan countries), in Africa, Asia and Latin America (FAO, 2010). It has been shown in numerous studies that the level of Omega-3-fatty acids and the ratio of n-6/ n-3 fatty acids poultry products can be improved considerably through special diets (such as poultry meat and eggs enriched with n-3 PUFA). Enriching eggs with ingredients like omega-3- fatty acids has become a broad field of research. Besides sea fish products, several n-3 containing fats, algae products, linseed, rapeseed and herbs have been used as feeding stuffs for enriching eggs with n-3 PUFA (NARAHARI, 2003). Besides nutrition further factors may enhance deposition of n-3 fatty acids in egg yolks. STEINHILBER (2003) found differences in deposition of n-3 fatty acids in egg yolk among different layer breeds and husbandry systems. Eggs from organic and free-range farms contained higher n-3 fatty acids levels than eggs from indoor systems. Yet, it is not clear which factors in free range systems are the main contributors to this enrichment. Since hens in free range show a high level of locomotion, it has been assumed that physical exercise may play a role in this context.

Physical exercise not only influences the physiological mechanisms of bone formation (modelling and remodelling) (WHITHEAD, 2004; RUTTEN et al., 2002) but also the metabolism of fatty acids. This effect has been demonstrated in different animal species: dogs and goats (MCCLELLAND et al., 1995), horses (GOTTLIEB et al., 1989), rabbits (MENG and PEIRCE, 1990) as well as in humans (BROUNS and van der VUSSE, 1998; HELGE et al., 2001).

Bone breakage is a serious welfare problem of laying hens in both intensive and extensive husbandry systems. There are numerous reports on changes in bone criteria and other physiological characteristics of laying hens kept under management systems with varying levels of locomotor activity. Higher bone strength of hens kept in cages with perches vs. cages without perches has been reported by HUGHES and APPLEBY (1989), DUNCAN et al. (1992) and LEYENDECKER et al. (2005). Similar results have been observed when bone strength of layers in non-cage systems and conventional cage systems were compared (ROWLAND and HARMS, 1970; ROWLAND et al., 1968; NORGARD-NIELSEN, 1990; FLEMING et al., 1994; ABRAHAMSSON and TAUSON, 1995; NEWMAN and LEESON, 1998; LEYENDECKER et al., 2005).

Most bone fractures are commonly seen in hens selected for egg production and the fractures are attributed to osteoporosis (THORP and MAXWELL, 1993). The metabolic competition for calcium and phosphorus in eggshell formation and bone formation has been considered as important factor of osteoporosis and weak bones in layers. With sexual maturation, the medullary bone develops on the endosteal surface of long bones. The medullary bone has a capacity of remodeling and provides Ca for eggshell formation (DACKE et al., 1993). This usually leads to bone weakness. In addition, limited opportunity for exercise in conventionally caged laying hens reduces osteoplastic processes and thus, increases the susceptibility to bone fractures. This compromises hen's welfare and has negative consequences for production (JENDRAL et al., 2008). The extent of physical exercise in different husbandry systems affects structural bone loss and bone strength in laying hens (FLEMING et al., 1994). KNOWLES and BROOM (1990) found that in birds kept in housing system with varying degrees of spatial freedom bone strength was related to the amount of movement. MEYER and SUNDE (1974) studied bone breakage and bone strength in hens kept on floor and in cages. Bone breakage was higher and bone breaking strength lower in caged reared hens. Physical exercise on a treadmill of caged hens reduced the number of broken bones and increased the breaking strength of humerus while breaking strength of the tibia remained unchanged.

Broken bones were found in about 30% of hens before slaughter and the proportion reached 90% in carcasses at the end of the processing line (GREGORY and WILKINS, 1989). Layers kept in aviaries usually show higher bone strength, however, the incidence of bone fractures of hens of these systems was on similar level. Bone breakage in hens from conventional cages occurred during catching and transport, whereas in contrast, the bone breakages in hens from aviaries mainly were the result of crash landing during switching between levels of the system (BOSCH and VAN NIEKERK, 1994). So, the higher bone strength of hens in aviaries was accompanied by higher risk in this system. This led to the assumption that low bone breaking strength in caged hens is caused by low level of exercise. Bone development also depends on a wide range of other factors. Prostaglandins, for example, derived from polyunsaturated fatty acids (PUFA) of the n-6 and n-3 series play a role in bone development. Prostaglandins of n-6 fatty acids origin inhibit to some extend bone development, while prostaglandins of the n-3 series stimulate osteoblast function and bone development (CHANG et al., 1998).

Calcium, phosphorus, trace elements and vitamins are important nutrients for bone strength (RÄTH et al., 2008). However, we consider that these nutrients are usually adequate in commercial layer diets.

Recent studies also highlighted the beneficial effects of n-3 fatty acids. LIU et al. (2003a, b) found an improved strength of tibia in Japanese quail in response to supplementation of PUFA from fish oil. MCCORMACK et al. (2006) found better breaking strength in bones of broilers when the n-3/n-6 ratio was increased by replacing maize oil by fish oil. Similar results have been reported by MANSOUB et al. (2011). The breaking strength of broiler bones was significantly improved when the omega-3 fatty acid level was increased through fish oil. JOHNSTON et al. (2006) could not find significant effects of n-3 rich diet on bone strength in turkey breeders. BAIRD et al. (2008) modified the n-6/n-3 ratio in the diet of layers kept in individual cages from 47.8: 1 to 4.7: 1. Only the cortical thickness responded significantly to the decrease in n-6/n-3 ratio. There was a curvilinear response with the lowest values at the highest and lowest ratio. The contrasting results of n-3 fatty acids on the chicken bones in the above cited experiments may be due to interactions with other factors.

The relationship between dietary fatty acids and the deposition of fatty acids in eggs and poultry meat is well established. It is also acknowledged that physical exercise improves bone strength in chickens. There is, however little and inconsistent information on the effect of n-3 fatty acids on bone strength and on the effect of physical activity on the modification of the fatty acids in egg yolks. Furthermore, information on the combined effects of dietary fat source and exercise on metabolic measures in the blood are rare. Therefore, in the present study laying hens were subjected to a controlled physical exercise on a treadmill and fed diets which differed largely in their n-6/ n-3 ratio. The effects of the treatments on egg quality, bone characteristics and physiological criteria have been studied. The results are presented in three papers (Chapter 2)

2 SCIENTIFIC PAPERS

2.1 JAHJA ET AL.: PHYSICAL ACTIVITY OF LAYING HENS

EFFECT OF PHYSICAL ACTIVITY OF LAYING HENS ON EGG QUALITY

Einfluss der Laufaktivität von Legehennen auf die Eiqualität

ARDITA JAHJA[1], M.A. GRASHORN[2], W. BESSEI[2] and I. STUHEC[3]

[1] Agriculture and Veterinary Faculty, University of Prishtina, Prishtina, Kosovo

[2] Dept. of Poultry Science, University of Hohenheim, Stuttgart, Germany

[3] Dept. of Animal Science, Biotechnical Faculty, University of Ljubljana, Domcale, Slovenia

Arch.Geflkde, 75, 3, pp 279-284, 2011, ISSN 0003-9098. © Verlag Eugen Ulmer, Stuttgart, Germany

Summary

The experiment was performed to study the combination of effects of diets and physical body activity (training) on laying hens' performance, egg weight, yolk proportion and fatty acids profiles. Results of present experiment show that dietary fat source affects egg production rate, egg weight and yolk proportion. In diets palm oil, soybean oil and linseed oil were used as fatty acids sources. Physical activity was provoked on a treadmill.

Exercise on the treadmill reduced feed intake and egg production. No significant effect of dietary fat source and running treatment was observed on laying hens performance. Diets significantly influenced egg weight, yolk proportion and fatty acids profiles either egg weight, yolk proportion or fatty acids profiles indicating a dominating effect of dietary fat source.

Keywords

Laying hens, palm oil, soybean oil, linseed oil, fatty acids, yolk

2.2 JAHJA ET AL.: PHYSICAL ACTIVITY AND BONE CONDITION IN LAYING HENS

EFFECT OF PHYSICAL ACTIVITY OF LAYING HENS ON BONE CONDITION

Einfluss von Bewegungsaktivität auf den Knochenzustand von Legehennen

ARDITA JAHJA[1], W. BESSEI[2], M.A. GRASHORN[2], S. MUJI[1] and I. STUHEC[3]

[1] Agriculture and Veterinary Faculty, University of Prishtina, Prishtina, Kosovo
[2] Dept. of Poultry Science, University of Hohenheim, Stuttgart, Germany
[3] University of Ljubljana, Biotechnical Faculty, Department of Animal Science, Domžale, Slovenia

Arch.Geflkde., 77, 3, pp 171-178, 2013, ISSN 0003-9098.

Summary

The experiment was performed to study the combination of effects of fatty acids profiles of diets and physical activity (training) on bone several characteristics. Three experimental diets with different fat sources were fed to 12 laying hens each: Palm oil (PO), Soybean oil (SO), and Linseed oil (LO). The fat sources corresponded to a low content of poly unsaturated fatty acids (PUFA) – PO, a high content of omega-6 (n-6) fatty acids – SO, and a high content of n-3 fatty acids (LO). Half of the hens of each dietary treatment (6 x 3 = 18 birds) were exposed to exercise by walking on a running treadmill (EG) through the four wks lasting experiment, whereas, the remaining 18 hens served as a control group (CG) and were permanently kept in the individual cages with very limited walking space. At the end of the experiment different bone characteristics were determined at the tibia by computer tomography, shear force tool and chemical analyses.

The application of training for the locomotion activity in laying hens has affected some bone characteristics. The same was true for the dietary fat source. But, the overall effect of diets on bone characteristics was not significant. Nevertheless, there is a trend of higher level of total area and corticalis area in LO group as compared with PO and SO groups.

Physical exercise did not significantly affect bone characteristics. But there was a trend of higher level of total area and corticalis area in the LO group as compared with PO and SO group. Total density and cortical density showed the opposite tendency. Significant diet x exercise interactions were observed for total area (TOT_A), corticalis area (CORT_A) and corticalis density (CORT_DEN). In tendency, diet PO resulted in lower TOT_A, CRT_A and SSI, but in higher TOT_DEN and SSI. Running on the treadmill resulted in lower TOT_A and CORT_A for diets LO and PO, whereas, higher values were observed for birds with exercise fed on diet SO. The relation was opposite for corticalis density. Here, lower values were observed for birds without exercise fed on diets LO and PO. CORT_DEN was lower for birds with exercise fed on diet SO. It is concluded that in hens fed on diets low in n-3 fatty acids physical exercise can improve bones condition.

Keywords

Laying hens, physical activity, bone development, feeding mixture, fat sources

2.3 EFFECT OF DIETARY FATTY ACID PROFILES AND PHYSICAL ACTIVITY ON PHYSIOLOGICAL PARAMETERS IN LAYING HENS

ARDITA JAHJA[1], M.A. GRASHORN[2], W. BESSEI[2] and I. STUHEC[3,]

[1] Agriculture and Veterinary Faculty, University of Prishtina, Prishtina, Kosovo

[2] Dept. of Poultry Science, University of Hohenheim, Stuttgart, Germany

[3] Dept. of Animal Science, Biotechnical Faculty, University of Ljubljana, Domzale, Slovenia

Manuscript submitted 16 January 2013, under revision

Introduction

The effects of dietary fat sources on performance and on fatty acid profiles of egg yolks are well investigated in laying hens (e.g. NEWTON, 1996). STEINHILBER (2003) concluded that physical activity of laying hens in a free range husbandry system resulted in the observed increased incorporation of long-chain poly-unsaturated fatty acids (PUFA), mainly of class omega-3 (n-3), into egg yolks. In an experiment where laying hens were fed with diets differing distinctly in their fatty acids profiles and were subjected to physical exercise on a treadmill no clear effects on performance of hens was observed but fatty acids profiles of egg yolks reflected the used dietary fat sources (JAHJA et al., 2011). In other studies it was reported that dietary fatty acids profiles also affect the metabolism in the hens. High dietary contents of n-3 PUFA reduce the blood cholesterol level of laying hens (GRASHORN, 1994; BASMACIOGLU et al., 2003; SVEDOVA et al., 2008), but do not affect the plasma cholesterol level in humans consuming daily several n-3 PUFA enriched eggs (FERRIER et al., 1995). Changing the n-6/n-3 ratio in the diet directly influences the eicosanoid (e.g. thromboxans, prostaglandins, leucotriens) metabolism shifting it either to the production of series-2 eicosanoids (n-6 pathway) or series 3 eicosanoids (n-3 pathway)(VAN ELSWYK, 1994; HERMIER, 1993; BLANCH and GRASHORN, 1996). F2 prostaglandin e.g. increases the aggregation of blood platelets whereas F3 prostaglandin counteracts. This effect was be proven by YEH et al. (2009) and

PITA et al. (2011) when feeding laying hens with diets containing high contents of n-3 PUFA. Furthermore, JAHJA et al. (2013) observed higher bone total area, corticalis area, and bone strength for higher n-6/n-3 ratios (0.8 vs 8.5 and 10.3) which was in agreement with observations of WHITEHEAD (2007).

In contrast to the lipid metabolism information on the effects of dietary fatty acids profiles on other metabolic processes (e.g. liver functioning, stress compensation) is lacking.

Physical exercise has clear metabolic effects, depending both on intensity and type of exercise. Moderate exercise appears to be of first importance (TURCOTTE, 1999). In contrast, a long term training protocol results in distinct changes in substrate metabolism (GEOR at al., 2002). Several data have been published on training-induced physiological changes in humans (BROUNS and VAN DER VUSSE, 1998; HELGE at al., 2001), horses (GOTTLIEB et al., 1989), dogs, goats (MC CLELLAND et al., 1995) and rabbits (MENG and PIERCE, 1990), but rarely in laying hens. According to VINCENT and BRACKENBURY (1988) and BRACKENBURY et al. (1993) training increases the use of free fatty acids for energy generation and improves the nutrient supply of thigh muscles (BRACKENBURY et al., 1990) as indicated by several blood characteristics.

To better understanding the effects of dietary fat sources and physical exercise on the metabolism in the hen studies on metabolic indicators in the blood seem to be feasible. Especially, metabolic activity of the liver is of interest as this organ is the main site for lipid metabolism. Alanin-Aminotransferase (ALAT) is a measure for hepatocellular injury. Significantly elevated levels of ALAT indicate the existence of heart failure or/and damage or liver functioning problems. Total cholesterol (CHOL) level is measured in order to indicate normal functioning of lipid metabolism and actual stress status. Creatinkinase (CK) is involved in energy metabolism in cells. Increased values are observed under stress and after excessive activity (HALLBACH, 2006).

The objectives of the present study have thus been to investigate the effects of dietary fat sources in combination with physical exercise on heart and liver weight and on some physiological indicators in laying hens.

Materials and methods

Birds and housing

In total, 36 young brown non-beak-trimmed laying hens (Bovans Brown) were used in the experiment. Hens were randomly taken from group pens of 120 birds each. At 22 wks of age the hens were moved to individual cages (area 2,250 cm^2, 38-48 cm in height). Each cage was equipped with a feeder (18.5 cm wide) and two drinking nipples. Complete layer diet and water were available ad libitum (for details see JAHJA et al., 2011).

Treatments

Hens were fed on diets low in PUFA – palm oil (PO), rich in n-6 fatty acids – soybean oil (SO) or rich in n-3 fatty acids – linseed oil (LO). Half of the hens (6 birds) of each dietary treatment were exposed to exercise by walking on a running treadmill (EG) through the four wks lasting experiment. The remaining hens were kept in individual cages with limited walking space (CG). Details of treatments are given by JAHJA et al. (2011).

Data collection

At the end of the experiment laying hens were slaughtered for collecting blood serum, tibia bones (JAHJA at al., 2013) and for determining liver and heart weight. After 12 h starvation hens were stunned by hitting the head and killed by cutting the blood vessels at the neck. Blood was immediately collected in tubes without coagulant for retrieval of blood serum. After clotting of the blood tubes were centrifuged at 2,500 rpm for 15 minutes. The serum was then transferred to serum tubes for further analyses.

After debleeding, carcasses were scalded and mechanically defeathered. During evisceration hearts and livers were withdrawn and weights of carcass, heart and liver were determined with an accuracy of 0.1 g. Relative weights of hearts and livers were calculated by dividing weights through carcass weight.

Laboratory analysis

Contents of main nutrients and fatty acids in diets have been analyzed as described previously (JAHJA et al., 2011).

Blood serum was sent refrigerated to Vet Med Laboratory GmbH, Ludwigsburg, Germany, for analysis of contents of Alanin-Aminotransferase (ALAT), cholesterol (CHOL) and creatinkinase (CK).

Statistical analysis

Prior to statistical analysis data were tested for deviation from normal distribution. As no significant deviation was observed data were subjected to a two-way analysis of variance using the software package SAS (JMP, 2007).

Results and discussion

Diet SO contained the highest level of n-6 fatty acids, while LO contained the highest level of n-3 fatty acids (Table 1). The n6/n3 ratios decreased from PO to SO and LO (10.3, 8.5 and 0.8 %, respectively). Effects on performance, fatty acids profiles of egg yolks and bone condition have been publisher previously (JAHJA et al., 2011; JAHJA et al., 2013).

Diets significantly reduced life body weight (Table 2) and in tendency egg production rate (JAHJA et al., 2011) in laying hens fed on PO diet. This may be caused by the low content of linoleic acid (0.7 %; Table 1) in diet PO. HAERTEL (1972) has shown that linoleic acid has some additional effects beside the fat effect in the intermediary metabolism resulting in improved performance. For an optimal performance level a content of 1.0 % linoleic acid is recommended for laying hens (GFE, 1999). In contrast to the dietary fat source exercise did not affect body weight. As interactions between diet and exercise were not significant for body weight the dietary content of linoleic acid seems to be the reason for observed differences in body weights.

Carcass weights mainly reflect treatment effects on body weight (Table 2). In contrast to body weight effects of diets on carcass weight were not significant. But, relative organ weights have been partly influenced by diet and/or exercise. In tendency, relative heart weights have been higher for diets PO and SO and for exercised hens. The interaction between diets and exercise is significant and indicates that training is improving heart functioning. The biggest difference is visible between treatments LO-CG and SO-EG. The high content of linoleic acid in diet SO results mainly in the formation of series-2 eicosanoids which e.g. increase heart rate and blood pressure (FARRELL, 1995). In combination with the expected increased metabolic activity due to improved performance (HAERTEL, 1972) and with the training effect the high relative heart weight in treatment SO-EG may be explained. Both, metabolic and physical activity require oxygen and energy which has to be transported to the target tissues by blood.

Relative liver weights have mainly been affected by diet (Table 2). Feeding PO diet resulted in a significantly higher relative liver weight. According to HAERTEL (1972) a low content of linoleic acid results in an increased fat catabolism and in an enlargement of the liver due to an accelerated de novo fat synthesis from sugar. Unfortunately, the chemical composition of the liver was not determined in the present experiment. Exercise in general enlarges energy demand resulting in increased metabolic activity and efficacy as already indicated. Therefore, training on the treadmill reduced relative liver weights in tendency. These effects are also reflected by diet x training interactions. Especially, training of hens fed on LO diets resulted in a significantly lower relative liver weight. Probably, the high content of n-3 fatty acids in diet LO improved the metabolic efficacy due to the favorable n-6/n-3 ratio.

No standard serum ALAT levels are known for chicken. Therefore, an assessment whether the observed values indicate pathological changes is not possible. In general, treatments did not significantly affect ALAT levels in blood (Table 2) but distinct differences were observed between dietary treatments. The highest ALAT level has been determined for diet SO which may reflect the high metabolic activity of this group. In general, exercise on the treadmill resulted in lower blood ALAT levels. Probably, high metabolic activity of hens fed with diet SO resulted in a higher stress to the liver, but exercise may relieve the liver. This assumption seems to be confirmed by the diet x exercise interaction. Exercise did not result in distinct differences in ALAT levels for diets LO and PO, but clearly reduced ALAT levels for diet SO. This seems to be in contrast to the assumption of BRACKENBURY et al. (1993) that exercise increases liver activity. This should also be visible by increased ALAT values. In the present experiment feeding diet SO resulted in distinctly higher ALAT levels for hens without exercise. Obviously, exercise improves the metabolic efficiency in the liver and reduces liver load.

Blood cholesterol level was significantly higher for diet PO (Table 2). This is in agreement with the observations of BASMACIOGLU et al. (2003), GRASHORN (1994), SARI et al. (2002) and SVEDOVA et al. (2008) that high contents of n-3 fatty acids and more favorable n-6/n-3 ratios in diets reduce blood cholesterol levels. Exercise resulted in a slight increase in serum cholesterol level. This may be a side-effect of training what is also visible by the interaction. Activity enhances the energy metabolism (BRACKENBURY et al., 1990; BRACKENBURY et al., 1993; VINCENT and BRACKENBURY, 1988) what is paralleled by higher blood cholesterol levels for all dietary fat sources due to the increased insulin secretion (DOENECKE et al., 2005). The distinctly higher cholesterol level of PO-CG and PO-EG is caused by the low content of PUFA, mainly n-3 fatty acids, in the this diet. For diet PO, exercise may partly compensate the unfavorable lipid metabolism. This is in agreement with the observed higher relative liver weight and a confirmation of the proposed higher lipid content due to de novo fatty acids formation.

No significant treatment effects could be observed on blood creatinkinase (CK) levels (Table 2). CK is involved in lipid metabolism and is an indicator of stress (IMAEDA, 1999). Higher CK levels for treatments PO and SO may indicate enhanced lipid metabolism and/or increased formation of series-2 eicosanoids, respectively. Comparable CK levels for exercised and non-exercised hens do not point at a general stress situation due to training. But, based on diet x training interactions exercise seems to have a positive effect for treatments PO and SO. The negative effect for treatment LO is difficult to explain. Maybe, this is a specific effect of the series-3 eicosanoids derived from α-linolenic acid (n-3) which enhance metabolic efficacy and stabilize the cardio-vascular system. In general, interactions for serum CK levels do not follow interactions for serum cholesterol levels. Especially, low serum CK levels for treatment SO-EG indicate that CK is not a primary source for energy supply.

Conclusions

Diet and exercise mainly affected performance characteristics of hens and fatty acids profiles of egg yolks, whereas, effects on blood characteristics have been less clear. In general, blood characteristics are more affected by dietary fat sources than by physical exercise. But, exercise can improve metabolic efficacy if dietary PUFA content is low. Nevertheless, diets with a higher content of poly-unsaturated fatty acids seem to have a more beneficial effect on the metabolism. LO results in the highest metabolic efficacy, whereas, SO results in the highest metabolic turnover. In general, PO has a negative impact on the metabolism of the hen and this may not be fully compensated by exercise.

Summary

Thirty six young Bovans Brown laying hens were used to determine the effect of treadmill exercise and dietary fat source (palm oil - PO, soybean oil - SO, linseed oil - LO) on performance, some relative organ weights and some blood indicators of metabolism. Results show that mainly dietary fat source affects weight of laying hens, relative liver weight and serum cholesterol level. Die PO resulted in lower body weight, increased relative liver weight and increased serum cholesterol level. Hens fed with diet SO (rich in n-6 fatty acids) showed the highest serum ALAT level indicating an accelerated metabolic activity. There were no significant effects of exercise in a treadmill on determined characteristics. But, in tendency exercise increased relative heart weight and decreased relative liver weight. Observed interactions between dietary fat and exercise reveal that exercise can compensate negative side-effects of an increased metabolic activity for diets SO and LO, whereas, the unfavorable effects of a diet with a low content of linoleic acid (PO) cannot be equalized.

Keywords
Laying hens, palm oil, soybean oil, linseed oil, fatty acids, and heart

References

BASMACIOĞLU, H., M. ÇABUK, K. ÜNAL, K. ÖZKAN, S. AKKAN, H. YALÇIN, 2003: Effects of dietary fish oil and flax seed on cholesterol and fatty acid composition of egg yolk and blood parameters of laying hens. S. African J. Anim. Sci. **33**, 266-273

BLANCH, A., M.A. GRASHORN, 1996: Ernährungsphysiologische Bedeutung der Omega-3-Fettsäuren und Möglichkeiten der Anreicherung in Eiern. Arch. Geflügelkde. **60**, 49-58

BRACKENBURY, J.H., M.S. EL-SAYED, C. DARBY, 1990: Effects of treadmill exercise on the distribution of blood flow between the hindlimb muscles and abdominal viscera of the laying fowl. Br, Poult. Sci. **31**, 207-214

BRACKENBURY, J.H., M.S. EL-SAYED, A.L. JACQUES, 1993: Blood flow distribution during graded treadmill exercise in domestic cockerels. Br. Poult. Sci. **34**, 785-792

BROUNS, F., G.J. VAN DER VUSSE, 1998: Utilization of lipids during exercise in human subjects: metabolic and dietary constraints. Br. J. Nutr. **79,** 117-128

DOENECKE, D., J. KOOLMAN, G. FUCHS, W. GEROK, 2005: Karlsons Biochemie und Pathobiochemie. Thieme Verlag Stuttgart, ISBN 3-13-357815-4

FARRELL, D. J., 1995: The hearty egg is good for you. World Poultry Misset **11**(4), 27-29.

FERRIER, L.K., L.J. CASTON, S. LEESON, J. SQUIRES, B.J. WEAVER, B.J. HOLUB, 1995: Alpha – Linolenic acid- and Docosahexaenoic acid- enreached eggs from hens fed flaxseed: influence on blood lipids and platelet phospholipid fatty acids in humans. Am. J. Clin. **62**, 81-86.

GEOR, R.J., L.J. MCCUTEHCON, K.W. HINCHCLIFF, R.A. SAMS, 2002: Training-induced alterations in glucose metabolism during moderate-intensity exercise. Equine Vet. J. Suppl. **34,** 22-28.

GFE, 1999: Empfehlungen zur Energie- und Nährstoffversorgung der Legehennen und Masthühner (Broiler). DLG Verlag Frankfurt a. M., ISBN 3-7690-0577-5

GOTTLIEB, M., B. ESSEN-GUSTAVOSS, A. LINDHOLM, S.G. PERSSON, 1989: Effects of a draft-loaded interval-training program on skeletal muscle in the horse. J. Appl. Physiol. **67,** 570-577.

GRASHORN, M.A., 1994: Einfluss verschiedener Futterfette auf den Blut- und Dottercholesteringehalt von Legehennen. Arch. Geflügelkde. **58**, 224-231

HAERTEL, H., 1972: Zur Bedeutung der essentiellen Fettsäuren, insbesondere der Linolsäure, für die Ernährung von Hühnern. Kraftfutter **55**(11-12), 1-27

HALLBACH, J., 2006: Klinische Chemie und Hämatologie für den Einstieg. Thieme Verlag Stuttgart, ISBN 978-3-13-106342-7

HELGE, J.W., B.J. WU, M. WILLER, J.R. DAUGAARD, L.H. STOLIEN, B. KIENS, 2001: Training affects muscle phospholipid fatty acid composition in humans. J. Appl. Physiol. **90,** 670-677

HERMIER, D., 1993: Modifying fatty acids in egg: physiological and nutritional basis. 5th European Symposium on the Quality of Eggs and Egg Products, Tours (France), 4-8 October, 384-390

IMAEDA, N., 1999: Characterization of serum enzyme activities and electrolytes levels in broiler chickens after death from sudden death syndrome. Poult. Sci. **78**, 66-69

JAHJA, A., M.A. GRASHORN, W. BESSEI, I. STUHEC, 2011: Effect of physical activity of laying hens on egg quality. Arch. Geflügelk. **75**, 279-284

JAHJA, A., W. BESSEI, M. A. GRASHORN, S. MUJI, I. STUHEC, 2013: Effect of physical activity of laying hens on bone condition. Arch. Geflügelk. accepted August 2012

JMP, 2007: SAS/STAT User’s quide, version 7, SAS Institute Inc.

MCCLELLAND, G., G. ZWINGELSTEIN, C.R. TAYLOR, J.M. WEBER, 1995: Effect of exercise on the plasma nonesterified fatty acid composition of dogs and goats: species with different aerobic capacities and diets. Lipids **30,** 147-153

MENG, H., G.N. PIERCE, 1990: Metabolic and physiological response of the rabbit to continuous and intermittent treadmill exercise. Can. J. Physiol. Pharmacol. **68,** 856-862.

NEWTON, I.S., 1996: Long chain fatty acids in health and nutrition. J. Food Lipids **3**, 233-249.

PITA, M.C.G., de P.R. CARVALHO, E. PIBER NETO, de C.X. MENDONÇA JÚNIOR, 2011: Vegetable and marine sources of supplementary PUFAs in the diet of laying hens: effect on lipid composition of the plasma and of the egg yolk and time of incorporation of omega 6 PUFAs. J. Appl. Sci. Res. **7**(5), 654-671

SARI, M., M. AKSIT, M. OZDOGAN, H. BASMACIOLU, 2002: Effects of addition of flaxseed to diets of laying hens on some production characteristics, levels of yolk and serum cholesterol, and fatty acid composition of yolk. Arch. Geflügelk. **66**, 75-79.

SAS, 2007: JMP start statistics, a guide to statistics and Data Analysis Using JMP® and JMP. IN® Software, Version 7, SAS Inst Inc. USA.

ŠVEDOVÁ, M., L. VAŠKO, A. TREBUNOVÁ, R. KAŠTEL, M. TUČKOVÁ, M. ČERTÍK, 2008: Influence of linseed and fish oil on metabolic and immunological indicators of laying hens. Acta Veterinaria Brno **77**(1), 39-44

STEINHILBER, S., 2003: Einfluss von genetischem Typ, Legeabschnitt und Futterfett auf die Anreicherung von Hühnereiern mit Omega-3-Fettsäuren und die Auswirkungen auf die Produktqualität. Doctoral Thesis University of Hohenheim, Stuttgart, Germany

TURCOTTE, L.P., 1999: Role of fats in exercise. Types and quality. Review. Clin. Sports Med. **18,** 485-498.

VAN ELSWYCK, M., 1994: Looking ahead: will eggs become a dietary alternative to fish? Poult. Int. **33**(14), 82-88

VINCENT, R., J.H. BRACKENBURY, 1988: Utilisation of energy substrates in treadmill-exercised domestic fowl (*Gallus gallus domesticus*): blood plasma free fatty acids. Br. Poult. Sci. **29**, 469-479

WHITEHEAD, C.C, 2007: Causes and prevention of bone fracture. Austr. Poult. Sci. Symp. **19**, 122-129

YEH, E., R.D. WOOD, S. LEESON, E.J. SQUIRES, 2009: Effect of dietary omega-3 and omega-6 fatty acids on clotting activities of Factor V, VII and X in Fatty Liver Haemorrhagic Syndrome-susceptible laying hens. Br. Poult. Sci. **50**, 382-392

Correspondence: Ardita Jahja, Agriculture and Veterinary Faculty, University of Prishtina , Bill Clinton Bld. nn, 10000 Prishtina, Kosovo; e-mail: ardita.jahja@gmail.com

Table 1. Fatty acids profiles of experimental diets

Nutrients		PO	SO	LO
C 16:0	mg/g	19.7	4.7	3.0
C 18:0	mg/g	3.6	1.4	1.4
C 18:1n9c	mg/g	5.6	9.8	8.4
C 18:2n6c	mg/g	7.3	22.4	11.1
C18:3n3	mg/g	0.58	2.5	14.2
SAT	%	64.9	14.1	12.0
MUFA	%	13.8	20.3	20.8
PUFA	%	21.1	55.6	67.1
n6	%	19.3	49.7	29.2
n3	%	1.9	5.8	37.8
n6/n3		10.3	8.5	0.8

Table 2. Effect of diet and exercise on body weight, carcass weight, relative organ weight and blood serum characteristics (ALAT, Cholesterol, CK)

Treatment	Body weight (kg)	Carcass weight (g)	Heart (%)	Liver (%)	ALAT (U/I)	Chol (mg/dcl)	CK (U/I)
Diet							
LO	1.74 a	1093	0.42	1.37b	3.09	67.4ab	3746
PO	1.63 b	1022	0.46	1.60a	3.66	83.8a	4104
SO	1.76 a	1065	0.47	1.43ab	4.70	63.8b	4283
Exercise							
CG	1.71	1067	0.43	1.50	4.12	69.9	4032
EG	1.72	1053	0.47	1.44	3.51	73.4	4056
Diet x Exercise							
LO – CG	1.84	1100	0.41b	1.48ab	3.16	65.2	2994
LO – EG	1.80	1087	0.44ab	1.27b	3.01	69.7	4498
PO – CG	1.72	1021	0.45ab	1.60a	3.41	88.3	4364
PO – EG	1.70	1024	0.47ab	1.61a	3.91	79.2	3843
SO – CG	1.83	1082	0.44ab	1.44ab	5.78	56.2	4739
SO – EG	1.83	1049	0.51a	1.43ab	3.61	71.5	3828
Error terms							
Diet	0.022	0.107	0.184	0.048	0.099	0.042	0.586
Exercise	0.795	0.589	0.069	0.364	0.318	0.591	0.955
Diet*Exercise	0.923	0.855	0.6944	0.421	0.180	0.323	0.062

3 GENERAL DISCUSSION AND CONCLUSIONS

3.1 GENERAL DISCUSSION

Foods of animal origin and mainly poultry products, especially eggs due to their high nutritive value, take a very important place in human diets. Enrichment of eggs with omega-3 fatty acids is gaining importance due to increasing demand for healthy food. At the same time animal welfare and health condition of poultry is in focus in intensive production systems. One critical point is insufficient available space for locomotion. As indicated by STEINHILBER (2003) enhanced activity of hens may improve the deposition of n-3 fatty acids into egg yolks. Therefore, the question arises whether induced exercise may improve deposition of n-3 fatty acids to egg yolks, performance and bone health in laying hens. It may be expected, that both the nutritive value of the egg may be enhanced for human consumption and at the same time welfare and health of the laying hen may be improved. On the basis of this hypothesis the present project was conducted.

Diets significantly influenced egg weight, yolk proportion and fatty acids profiles. The highest egg weight was observed for diet SO and the highest yolk proportion for diet LO. The distinct effect of SO on egg production and egg weight is probably caused by the high content of linoleic acid which is assumed to exhibit extra-caloric effects (HAERTEL, 1972). The lowest egg production rate in group PO may be the result of the low content of linoleic and linolenic acid in the diet.

Contents of SAT and MUFA were significantly higher in eggs of group PO, whereas, eggs of treatments LO and SO showed a comparable content of PUFA which was significantly higher than for PO. The changes in fatty acids profile of yolks are in accordance with expectations. Palm fat is rich in saturated fatty acids and thus SAT and MUFA are the dominant fatty acids classes in yolks. The n-6 and n-3 contents were significantly highest in SO eggs and in LO eggs, respectively. SO is rich in linoleic acid and contains as well distinct amounts of linolenic acid thus resulting in higher contents of n-6 and n-3 fatty acids in yolks than for PO. The total PUFA content did not differ between SO and LO. In the same way diet SO resulted in a double as high n-6 content in yolks than for PO and LO, whereas, the content of n-3 was about four times higher in yolks of LO than in SO and 10 times higher than in PO. Despite the clear differences in n-6 and n-3 contents in yolks between groups PO and SO the n-6 to n-3 ratio was. In contrast, the n-6 to n-3 ratio was significantly improved for treatment LO and was eight times lower than for PO and SO. In general, the result was quite interesting that n-6 to n-3 ratios of all egg yolks were within the recommended range for human consumption and were distinctly better than the values given for today's situation in human nutrition (e.g. SINGER, 2000). Thus, it may be concluded that chicken eggs are a suitable source of fatty acids in human food.

Dietary fat source affected laying hens weight and cholesterol level in serum. It was also shown in previous studies that diets rich in omega 3 PUFA reduced cholesterol levels (CASTON and LESSON, 1990; JIANG et al., 1991; WATKINS, 1992; FERRIER et al., 1995; SCHEIDELER and FRONING, 1996; BASMACIOGLU et al., 2003; SVEDOVA et al., 2008). Dietary fat source with higher content of linoleic acid exhibits extra-caloric effects (HAERTEL, 1972) resulting in higher body weight of laying hens. The enhanced metabolism of hens fed with SO diet is reflected by higher ALAT and CK values in the blood, standing for a higher liver activity. In contrast, fat source with lower content of linoleic and linolenic acid in the diet (PO) causes a decrease of laying hens' body weight and an increase of cholesterol level in blood. At the same time relative liver weight was also significantly increased for diet PO due to the increased lipid catabolism and do novo fatty acid synthesis from sugar (HAERTEL, 1972). This was paralleled by high serum CK levels and increased ALAT levels. As expected, dietary fat sources did not affect relative heart weight.

GREGORY and WILKINS (1989) stated that the high incidence of bone breakage in laying hens under commercial conditions in cage systems indicates that bone strength is generally not satisfactory. The present study revealed that although the overall effect of the diets on bone characteristics was not significant, there was a consistent trend showing a greater Total Area, Corticalis Area and higher SSI with decreasing dietary ratio of n-6/n-3 fatty acids in the control birds. The negative effect of the high n-6/n-3 fatty acid ratio on the bone formation was paralleled by increased bone breaking strength. The cortical density area, however, showed the opposite tendency. The positive effect of n-3 fatty acids on Corticalis Area, breaking strength, bone ash and bone mass which has been reported in growing broilers (MCCORMACK et al., 2006; MANZOUB et al., 2011) and by LIU et al. (2004) in Japanese Quail may not be expressed in laying hens birds. BAIRD et al. (2008) did not find significant effects of dietary changes in the n-6/n-3 ratio from 48/1 to 5/1 on the breaking strength in the tibia bones of laying hens kept in individual cages. The cortical thickness responded significantly to the n-6/n-3 ratio with a inverse U-shape pattern. The highest and lowest level of n-6/n-3 ratio showed the lowest value. The moment of inertia, which corresponds with the SSI, showed the same tendency as the cortical thickness. Considering that the management conditions of this experiment (individual cages) were similar to the conditions of the control birds in our experiment there was a similarity of the response with regard to the cortical density in our results and the cortical thickness reported by BAIRD et al. (2008), but the Corticalis Area and total bone area showed an opposite trend. The opposite direction of the response of Corticalis Area and cortical density in our result may be explained by a compensatory effect. The reduced bone mass as expressed in the Corticalis Area and the total bone area which may lead to a reduced bone strength was obviously compensated by a higher density. This effect also explains the missing response of the breaking strength to the dietary treatments in our own results as well as in the results of BAIRD et al. (2008).

Exercise of laying hens does not result in differences for egg weight, yolk proportion or fatty acids profiles indicating a dominating effect of dietary fat source (JAHJA et al., 2011). But, exercise of laying hens in treadmill caused a reduction of feed intake and egg production. Obviously, activity of hens increases production costs without additional benefits for product quality. A small effect of exercise on yolk proportion was visible by the interaction diet x exercise. Exercise significantly improved yolk proportion for diet LO but decreased it for diet SO. This can be explained by the observed differences in egg production, which has been lower for treatment LO-EG and higher for treatment SO-EG. The negative correlation between egg production rate and yolk proportion is well documented (e.g. GRASHORN, 2012).

Exercise contributed in tendency to animal welfare as there was a significant diet x exercise interaction for corticalis area and cortical density. The means between exercised and non-exercised hens were not significantly different in the LO and PO diets. In hens fed the SO diet, physical exercise significantly increased the Corticalis Aerea and decreased the cortical density. This particular effect of SO cannot be explained by the differences in the n-6/n-3 ratio, since it was similar in the SO and PO diet. The high level of linoleic acid in the SO diet may be the cause for this particular effect.

Surprisingly, exercise did not affect physiological parameters in blood. But, it was observed that exercise may compensate negative side-effects of an accelerated metabolism when feeding diets rich in linoleic acids (SO) and/or of an increased lipid catabolism when feeding diets poor in linoleic acids (PO). In general, high contents of PUFA in diets (SO, LO) have a more beneficial effect on the metabolism of the hen than diets low in PUFA (PO).

3.2 CONCLUSIONS

In the frame of the thesis, the combined effects of diets with different contents of omega-3 fatty acids and of exercise on performance, yolk fatty acids profiles, bone characteristics and indicators of metabolism have been investigated. Based on the obtained results, it can be concluded that

1. The dietary fat source affected clearly egg weight, yolk proportion and yolk fatty acids profile. A minor effect on egg production was observed. In contrast to diets exercise on the treadmill caused a reduced feed intake and egg production, but did not affect either egg weight, yolk or yolk fatty acids profiles. Therefore, dietary fat source has a main effect on performance and product quality, whereas, exercise in tendency increases production costs.

2. There was a consistent trend showing a greater Total Area, Corticalis Area and higher SSI with increasing dietary ratio of n-3: n-6 fatty acids, although the overall effect of the diets on bone characteristics was not significant. The positive effect of the high n-6: n-3 fatty acid ratio on bone formation was paralleled by increased bone breaking strength. The observed negative effect of high n-6/n-3 ratio of diet SO on Total area and Corticalis Area was alleviated by exercise. Hence physical exercise seems to compensate for low levels of n-3 fatty acids. Physical exercise improved cortical density in combination with the diet with a higher n-6/n-3 ratio (PO) and decreased it

in combination with the diet with a low n-6/n-3 ratio (LO). But, there was an increase of bone area for the LO diet (lower n-6/n-3 ratio) and a decrease of bone area for diets SO and PO (higher n-3/n-6 ratio). While the production of bone mass was stimulated by a high n-6/n-3 fatty acid ratio, physical exercise can ensure the bones resistance to injuries under n-3 deficient situations. The generally low response of adult hens to dietary fatty acids and to exercise in the present study may also be caused by the short experimental period and the advancing age of the experimental birds.

3. The dietary fat source affected laying hens' weight and some blood values. In general, blood characteristics are more affected by dietary fat than by exercise. Exercise may improve metabolic efficiency if the dietary PUFA content is low, but cannot compensate it. In contrast, diets rich in PUFA result in the highest metabolic turnover and efficiency.

4 SUMMARY (ZUSAMMENFASSUNG)

4.1. Summary

Foods of animal origin such as eggs take an important place in human diets. Polyunsaturated fatty acids (PUFA) such as 18:3n-3 and 18:2n-6 cannot be synthesized in the metabolism of animals and humans; however they can be incorporated into eggs or meat through dietary fat. Enriching eggs with ingredients like omega-3 fatty acids has become a broad field of research. Besides sea fish products, several n-3 fats, algae products, linseed, rapeseed and herbs have been used as feeding stuffs for enriching eggs with n-3 PUFA. Besides nutrition other factors may enhance deposition of n-3 fatty acids in egg yolks. Differences in deposition of n-3 fatty acids in egg yolks between eggs from organic/free-range and indoor production have been reported. Egg yolks from hens kept in free range contained higher n-3 fatty acids levels. It has been assumed that physical exercise may play a role in this context.

Physical exercise not only influences the metabolism of fatty acids but also the mechanisms of bone formation. This effect has been demonstrated in different animal species: dogs and goats, horses, rabbits as well as in humans. Bone breakage is a serious welfare problem of laying hens in both intensive and extensive husbandry systems. Most bone fractures commonly occur in hens selected for egg production and the fractures are attributed to osteoporosis. Broken bones were found in about 30% of hens before slaughter and the proportion reached 90% in carcasses at the end of the processing line. Recent studies also highlighted the beneficial effects of n-3 fatty acids on bone strength of Japanese Quail and growing chickens. Therefore, the present study has been undertaken to elucidate the relationships between different sources of dietary fatty acids and physical exercise in laying hens on performance, egg quality, bone characteristics and some other physiological criteria of the fatty acid metabolism.

In total of 36 brown laying hens (Bovans Brown) were used in the experiment. Three experimental diets which differed only in the fat source, namely Palm oil (PO), Soybean oil (SO), and Linseed oil (LO) were used. The fat sources corresponded to a low content of poly unsaturated fatty acids (PUFA) – PO, a high content of omega-6 (n-6) fatty acids –

SO, and a high content of n-3 fatty acids – LO. Experimental diets were fed to 12 hens each. Half of the hens of each dietary group (6 birds) were exposed to exercise by walking on a treadmill (EG), whereas, the remaining 6 hens in the control group (CG) were kept in individual cages. EG birds were exposed to a running treadmill every d for the whole experimental period (4 wk). The speed of the treadmill belt was adjusted from 0.5 to 0.7 miles/h. On the first day of the experiment the birds walked 5 min with the speed of 0.5 miles/h. Then duration of walking was prolonged for 2 min/day until day eleven and the speed was increased progressively. After eleven days until the end of experiment the hens walked 25 min/day. On the first day the distance walked was 67 m and increased up to 469 m/day on eleventh day. So the experimental design was 3 diets x 2 activities x 6 birds = 36 hens. At the end of the experiment eggs were collected to determine yolk fatty acids profiles and hens were slaughtered to collect blood indicators for lipid metabolism, tibia bones were removed to determine bone characteristics and relative weights of hearts and livers were calculated.

Diets significantly influenced egg weight, yolk proportion and fatty acids profiles. The highest egg weight was observed for SO and the highest yolk proportion for LO. Contents of SAT and MUFA were significantly higher in eggs of group PO, whereas, LO and SO showed a higher content of PUFA. Eggs of treatment PO showed the highest proportion of palmitic acid and oleic acid, whereas, eggs of treatments SO and LO showed the highest proportions of linoleic acid and linolenic acid, respectively. The n-6 and n-3 contents were significantly highest in PO eggs and in SO eggs, respectively. The n-6 to n-3 ratio did not differ between PO and SO, but was eight times higher than for LO. Exercise of the birds did not result in differences in egg weight, yolk proportion or fatty acids profiles indicating a dominating effect of dietary fat source. The interaction of exercise x diet was significant for the yolk proportion only.

Neither diet nor physical exercise did significantly affect bone characteristics determined by computer tomography, but, there was a consistent trend of higher level of total area and corticalis area in the LO group as compared with PO and SO group. Total density and cortical density showed the opposite tendency. Significant diet x exercise interactions were observed for total area, corticalis area and corticalis density. Running on the treadmill resulted in lower total area and corticalis area for diets LO and PO, whereas, higher values were observed for birds with exercise fed on diet SO. The relation was opposite for corticalis density. Here, lower values were observed for birds without exercise fed on diets LO and PO. Bone breaking strength, dimensions and composition of tibia were not significantly influenced by the main factors or their interaction. In general, differences between diets and exercise treatments have been relatively small. But, tibia of birds fed on diet PO showed the highest ash, Ca and P contents on a dry matter basis.

Diet PO resulted in lower body weight, increased relative liver weight and increased serum cholesterol level. Hens fed with diet SO showed the highest serum ALAT level indicating an accelerated metabolic activity. There were no significant effects of exercise on other characteristics. But, in tendency exercise increased relative heart weight and decreased relative liver weight. Interactions between dietary fat and exercise revealed that exercise can compensate negative side-effects of an increased metabolic activity for diets SO and LO, whereas, the unfavorable effects of a diet with a low content of linoleic acid (PO) cannot be removed.

In summary, the pattern of fatty acid in the egg yolk has been modified by the different diets as expected. Physical exercise, in contrast did not show any influence on the fatty acid contents of the egg yolk. The higher levels of omega-3 fatty acids in eggs from free range, which have been found in earlier studies, are obviously not caused by the higher physical exercise under these conditions. The effect of physical exercise and diet on bone stability is not caused by the individual factors but by their interactions. While physical exercise in the LO and PO diet reduced the bone area and increased the bone density, the opposite effect was observed in the SO diet. Since lower bone density was compensated by the larger bone area the treatments did not affect bone breaking strength.

4.2. Zusammenfassung

Nahrungsmittel tierischen Ursprungs wie zum Beispiel Eier nehmen einen wichtigen Platz in der menschlichen Ernährung ein. Mehrfach ungesättigte Fettsäuren (PUFA) wie zum Beispiel die Linolensäure (18:3-3n-3) und die Linolsäure (18:2n-6) können von Mensch und Tier nicht selbst synthetisiert werden. Sie müssen mit der Nahrung aufgenommen werden. Die Anreicherung von Eiern mit Omega-3 Fettsäuren ist in den letzten Jahren zu einem wichtigen Forschungsbereich ausgebaut worden. Zur Anreicherung von Eiern mit Omega-3 Fettsäuren werden neben Fischprodukten verschiedene Pflanzenöle, Produkte aus Algen, Leinsamen, Raps Samen und Kräuter als Futterkomponenten genutzt. Außer durch Futterkomponenten kann die Einlagerung von Omega-3 Fettsäuren im Eidotter durch eine Reihe anderer Faktoren beeinflusst werden. So wurden zum Beispiel höhere Gehalte an n-3 Fettsäuren in Eiern aus ökologischer und aus extensiver Erzeugung gefunden. Es wurde vermutet, dass hierbei die größere Bewegungsaktivität der im Auslauf gehaltenen Hennen eine Rolle spielt. Der Einfluss von Bewegungsaktivität auf den Fettstoffwechsel wurde bei verschiedenen Tierarten, wie z.B. Hunden, Ziegen, Pferden, Kaninchen und auch bei Menschen festgestellt.

Die Bewegungsaktivität spielt auch für den Aufbau und die Stabilität des Knochengerüsts eine zentrale Rolle. Knochenbrüche stellen ein ernsthaftes Problem bei Legehennen in intensiver und extensiver Haltung dar. Die meisten Knochenbrüche treten während der Produktionsperiode auf und sind auf Osteoporose zurückzuführen. Bei etwa 30 % der Legehennen wurden vor dem Schlachten Knochenbrüche gefunden. Am Ende des Schlachtprozesses wiesen 90 % der Hennen Knochenbrüche auf. Neuere Studien zeigten, dass n-3 Fettsäuren einen positiven Effekt auf die Knochenstärke bei der Japanischen Wachtel und bei wachsenden Hühnern ausübten. Es kann deshalb angenommen werden, dass nicht nur die Bewegungsaktivität über die direkte Belastung auf die Knochen einwirkt, sondern dass auch n-3 Fettsäuren indirekt die Knochenbildung positiv beeinflussen können.

Das Ziel der vorliegenden Studie war deshalb, die Auswirkungen der Laufaktivität und der Fettsäurequelle im Futter auf die Leistung, die Eiqualität, die Knochenmerkmale sowie eine Reihe Indikatoren für den Leberstoffwechsel bei den Legehennen zu untersuchen.

Für die Untersuchung standen 36 Legehennen (Bovans Brown) zur Verfügung. Drei Versuchsfutterrationen mit unterschiedlichen Fettquellen wurden eingesetzt: Palmöl (PO), Sojaöl (SO) und Leinöl (LO). Die Fettquellen waren entweder arm an mehrfach ungesättigten Fettsäuren (PUFA) - PO, oder reich an Omega-6 Fettsäuren - SO bzw. an Omega-3 Fettsäuren - LO. Die Versuchsrationen wurden jeweils an 12 Hennen verfüttert. Die Hälfte der Hennen einer Futtergruppe (6) wurden einem gezielten Training auf einem Laufband (EG) unterzogen, während die andere Hälfte (6) als Kontrolle in Einzelkäfigen gehalten wurde. Die Tiere der Behandlung EG wurden täglich über eine Periode von vier Wochen trainiert. Die Geschwindigkeiten des Laufbandes wurden von 0,5 auf 0,7 Meilen/h erhöht. Zu Beginn des Experiments liefen die Tiere täglich 5 min mit einer Geschwindigkeit von 0,5 Meilen/h. Die Dauer wurde täglich um 2 min verlängert und die Geschwindigkeit kontinuierlich erhöht. Nach elf Tagen wurde eine Laufdauer von 25 min und eine Geschwindigkeit von 0,7 Meilen/h erreicht. Daraus resultierte eine täglichen Laufleistung von 67 m zu Beginn des Experiments und 469 m am 11. Tag bis zum Ende des Experiments. Das Versuchsdesign war somit: drei Fütterungsgruppen x zwei Trainingsgruppen x 6 Tiere = 36 Tiere. Am Ende des Versuchs wurden Eier zur Bestimmung der Dotterfettsäuremuster gesammelt. Danach wurden die Hennen geschlachtet, um Blutproben zur Bestimmung von Indikatoren des Lipidstoffwechsels und Tibien zur Ermittlung von Knochencharakteristika zu gewinnen sowie um die relativen Gewichte der Herzen und der Lebern zu kalkulieren.

Die Rationen beeinflussten signifikant das Eigewicht, den Dotteranteil und die Fettsäureprofile. Das höchste Eigewicht wurde bei den Sojaöl-Gruppen und der höchste Dotteranteil bei den Leinöl-Gruppen festgestellt. Der Anteil an SAT und MUFA war signifikant höher in den Eiern der Palmölgruppe, während Lein- und Sojaöl zu einem höheren Gehalt an PUFA führten. Die mit Palmöl gefütterten Tiere wiesen den höchsten Anteil an Palmitin- und Ölsäure auf, während die Eier der mit Soja- und Leinöl gefütterten Tiere die höchsten Anteile an Linol- und Linolensäure hatten. Das Verhältnis von n-6 zu n-3 Fettsäuren war bei den Palm- und Sojaölrationen am höchsten. Der Unterschied war zwar nicht signifikant, die Werte waren jedoch gegenüber der Leinölgruppe um das 8-fache höher. Das Lauftraining hatte keinen signifikanten Effekt auf Eigewicht, Dotteranteil und die Fettsäureprofile. Dies unterstreicht den dominanten Effekt der Fettsäuren in den

Rationen auf die Ergebnisse. Die Interaktion von Lauftraining und Ration war nur für den Dotteranteil signifikant.

Weder die Rationen noch das Training übten einen signifikanten Effekt auf die mittels Computer-Tomographie bestimmten Knochenmerkmale aus. Es war aber ein klarer Trend zu einer höheren Gesamtknochenfläche und Corticalisfläche bei der Leinöl-Gruppe im Vergleich zu den Palmöl- und Sojaöl-Gruppen zu verzeichnen. Die Dichte des Gesamtknochens und der Corticalis zeigten eine entgegen gerichtete Tendenz. Für die Gesamtknochenfläche, die Corticalisfläche und die Corticalisdichte wurde eine signifikante Futterration x Training Interaktion festgestellt. Das Training auf dem Laufband führte bei den Lein- und Palmölgruppen zu einer geringeren Gesamtknochenfläche und Corticalisfläche, während bei den Sojaöl-Gruppen beim Training höhere Werte gefunden wurden. Auch hier zeigte sich die entgegengerichtete Tendenz der Knochenflächen gegenüber den Werten der Knochendichte. Die Bruchfestigkeit, die Dimensionen sowie die chemische Zusammensetzung der Tibia wurden weder durch die Hauptfaktoren noch durch deren Interaktionen signifikant beeinflusst. Insgesamt waren für diese Merkmale die Unterschiede der Einflussfaktoren sehr gering. Lediglich für die Palmöl-Gruppe wurden im Vergleich zu den Soja- und Leinölgruppen höhere Asche-, Ca-und P-Gehalte bezogen auf Trockensubstanz festgestellt.

Die Hennen der Palmöl-Gruppe wiesen ein geringeres Körpergewicht, ein erhöhtes relatives Lebergewicht und einen erhöhter Serumcholesterinspiegel auf. Die Hennen der Soja Öl-Gruppe hatten den höchsten ALAT-Gehalt im Serum, der auf einen intensiveren Stoffwechsel hinweist. Das Training hatte keinen signifikanten Effekt auf die untersuchten Merkmale. Es gab jedoch eine Tendenz zu einem höheren relativen Herzgewicht und einem verminderten relativen Lebergewicht nach dem Training. Die Interaktion zwischen der Futterration und dem Lauftraining deutet darauf hin, dass ein Training negative Nebeneffekte einer erhöhten metabolischen Aktivität bei den Rationen mit Sojaöl und Leinöl kompensieren kann. Im Gegensatz hierzu können die ungünstigen Effekte einer Futterration mit einem geringen Linolsäuregehalt (PO) nicht ausgeglichen werden.

Zusammenfassend kann gesagt werden, dass das Fettsäuremuster im Eidotter wie erwartet durch die Rationen verändert wurde. Die Bewegungsaktivität hatte dagegen keinen Effekt auf das Fettsäuremuster im Dotter. Die in früheren Untersuchungen gefundenen erhöhten Anteile an Omega-3 Fettsäuren in Eiern, die von Hennen in Auslaufhaltung produziert wurden, sind somit nicht auf die erhöhte Bewegungsaktivität zurückzuführen. Der Einfluss der Bewegungsaktivität und der Fettsäuremuster im Futter auf die Knochenstabilität ist nicht durch die Wirkung der einzelnen Faktoren, sondern durch deren Wechselwirkung bestimmt. Während in der Lein- und Palmöl-Gruppe die Knochenfläche durch Lauftraining verringert und die Knochendichte vergrößert wurden, war dies bei der Sojaöl-Gruppe umgekehrt. Die Verringerung der Knochenfläche wurde jeweils durch eine erhöhte Knochendichte kompensiert, weswegen die Knochenbruchfestigkeit nicht beeinflusst war.

5 REFERENCES

ABRAHAMSSON, P., R. TAUSON, 1995: Aviary systems and conventional cages for laying hens. Effects on production, egg quality, health and bird location in three hybrids. Acta Agric. Scand., Sect. A, Anim. Sci. **45**, 191–203.

ADKINS, Y., K. DARSHAN, 2010: Mechanisms underlying the carioprotective effects of omega – 3 polyunsaturated fatty acids. Journal of Nutritional Biochemistry **21**, 781 – 792.

ALBRECHT, M., M. KLEIN, 1995: Oleum lini: Portrait eines pflanzlichen Öls. Pharmazie **7**, 36-40.

BAIRD, H.T., D.L. EGGET, S. FULLMER, 2008: Varying ratios of omega – 6: omega – 3 fatty acids on the pre and post-mortem bone mineral density, bone ash, and bone breaking strength of laying chickens. Poult. Sci. **87** (2), 232-8.

BASMACIOĞLU, H., M. ÇABUK, K. ÜNAL, K. ÖZKAN, S. AKKAN, H. YALÇIN, 2003: Effects of dietary fish oil and flax seed on cholesterol and fatty acid composition of egg yolk and blood parameters of laying hens. S. African J. Anim. Sci. **33**, 266-273

BOSCH, J. G. M. J., T. G. C. M. VAN NIEKERK, 1994. Health. Pages 75–106 *in:* The aviary system for laying hens. H. J.Blokhuis and J. H. M. Metz, ed. Report IMAG- DLO 95-5. IMAG-DLO, Wageningen, the Netherlands. (in Dutch)

BROUNS, F., G. J. VAN DER VUSSE, 1998: Utilization of lipids during exercise in human subjects: metabolic and dietary constraints. Br. J. Nutr. **79,** 117.128. Review.

CASTON, L., AND S. LEESON, 1990: Research note: dietary flexseed and egg composition. Poultry Sci. **69**, 1617 – 160.

CHANG, D.J., C. JI, K.K. KIM, S. CASINGHIO, T.L. MACCARTHY, M. CENTRELLA, 1998: Reduction in transforming growth factor β receptor I expression and transcription factor CBF a 1 on bone cells by glucocorticoid. Journal of Biological Chemistry **273**, 4892-4896.

DACKE, C.G., S. ARKLE, D.J. COOK, I.M. WORMSTONE, S. JONES, M. ZAIDI, Z.A. BASCAL, 1993: Meduallary bone and avian calcium regulation. J. Exp. Biol. **184**, 63-68.

DUNCAN, E. T., M. C. APPLEBY, B. O. HUGHES, 1992: Effect of perches in laying cages on welfare and production of hens. Br. Poult. Sci. **33**, 25–35.

FAO, 2010: Poultry Meat and Eggs. Agribusiness handbook.

FARELL, D.J., 1995: The problems and practicabilities of producing omega–(n)-3 fortified egg. 6 th Europian Symposium on the Quality of Eggs and Egg Products, Zaragoza (Spain), Sept. 25th-29th, 351-360.

FERRIER, L.K., L.J. CASTON, S. LEESON, J. SQUIRES, B.J. WEAVER , B.I.J. HOLUB, 1995: Alpha – Linolenic acid- and Docosahexaenoic acid- enreached eggs from hens fed flaxseed: influence on blood lipids and platelet phospholipid fatty acids in humans. Am. J. Clin. **62**, 81-86.

FLEMING, R.H., C.C. WHITEHEAD, D. ALVEY, N.G. GREGORY L.J. WILKINS, 1994: Bone structure and breaking strength in laying hens house din different husbandary systems. Brit. Poult. Sci. **35**, 651-662.

GOTTLIEB, M., B. ESSEN-GUSTAVOSS, A. LINDHOLM, S.G. PERSSON, 1989: Effects of a draft-loaded interval-training program on skeletal muscle in the horse. J. Appl. Physiol. **67,** 570.577.

GRASHORN, M.A., 2012: Faustzahlen zur Eiqualität. in K. DAMME and C. MÖBIUS 'Geflügeljahrbuch 2013', Eugen Ulmer Publisher, ISBN 978-3-8001-7785-1

GREGORY, N.G., L.J., WILKINS, 1989: Broken bones in domestic fowl: handling and processing damage in end-of-lay battery hens. Brit. Poult. Sci. **30**, 555-562.

HAERTEL, H., 1972: Zur Bedeutung der essentiellen Fettsäuren, insbesondere der Linolsäure, für die Ernährung von Hühnern. Kraftfutter **55** (11/12), 1-27

HELGE, J. W., B. J. WU, M. WILLER, J. R. DAUGAARD, L. H. STOLIEN, B. KIENS, 2001: Training affects muscle phospholipid fatty acid composition in humans. J. Appl. Physiol. **90,** 670-677.

HUGHES, B. O., M. C. APPLEBY, 1989. Increase in bone strength of spent laying hens housed in modified cages with perches. Vet. Rec. **124**, 483–484.

JAHJA, A., M.A. GRASHORN, W. BESSEI, I. STUHEC, 2011: Effect of physical activity of laying hens on egg quality. Arch. Geflügelk. **75**, 279-284

JENDRAL, M.J., D.R. KORVER, J. S. CHURCH, J. J. R. FEDDES, 2008: Bone mineral density and breaking strength of white leghorns housed in conventional, modified, and commercially available colony battery cages. Poultry Science Association Inc. 2008**,** 828-837.

JIANG, Z., D.U. AHN J.S. SIM, 1991: Effect of feeding flaxseed and sunflower seed on fatty acid composition of yolk lipid classes. Poultry Sci. **70**, 2467-2475.

JOHNSTON, N. P., L. L., NASH, E. MACEDA, R.T. DAVIDSON, A. ARMSTRONG, 2006: Effect of feeding diets enriched with either omega-3 or omega-6 polyunsaturated fatty acids on bone characteristics of turkey breeder hens. World's Poult. Sci. J. Suppl. 1, **62**, 342.

KNOWLES, T.G., D.M. BROOM, 1990: Limb bone strength and movement in laying hens from different housing systems. Vet. Rec. **126**, 354-356.

KROMHOUT, D., E. B. BOSSCHIERTER, C.D. COULNADER, 1985: The inverse relation between fish consumption and 20-year mortality from coronary heart disease. N. Eng. J. Med. **312**, 1205-1209.

LEYENDECKER, M., H. HAMMANN, J.HARTUNG, J. KAMPHUES, U. NEUMANN, C. SURIE, O. DISTI, 2005: Keeping laying hens in furnished cages and an aviary housing system enhances their bone stability Br. Poult. Sci. **46**, 536-44.

LIU, D., H.P. VEIT., J.H. WILSON, and D.M. DENBOW, 2003a: Long term supplementation of various dietary lipids alters bone mineral content, mechanical properties and histological characteristics of Japanese quail. Poult. Sci. **82**, 831 – 839.

LIU, D., H.P. VEIT., J.H. WILSON., D.M. DENBOW, 2003b: |Maternal dietary lipids after bone chemical composition, mechanical properties, and histological characteristics of Japanese quail. Poult. Sci. **82**, 463 – 473.

LIU, D., H. P. VEIT, D. M. DENBOW. 2004. Effects of long-term dietary lipids on mature bone mineral content, collagen, crosslinks, and prostaglandin e_2 production in Japanese Quail. Poult. Sci. **83**:1876–1883

MANSOUB, F. H., N.H. MANSOUB, L. MAJEDI, 2011: Investigating the effect of different fats and antioxidants on the performance and resistance of bone in broiler chickens. Adv. Environm. Biol. **5**, 1184-1187.

MCCLELLAND, G., G. ZWINGELSTEIN, C.R. TAYLOR, J. M. WEBER, 1995: Effect of exercise on the plasma nonesterified fatty acid composition of dogs and goats: species with different aerobic capacities and diets. Lipids **30,** 147.153.

MCCORMACK, H., R. FLEMING, L. MCTIER, L., C. C. WHITEHEAD, 2006: Influence of dietary fatty acid n-3/n-6 balance on bone characteristics in young broilers. Br. Poult. :Abstr., **3**, 25-26.

MEYER, W. A. M. L. SUNDE, 1974: Bone breakage as affected by type housing or an exercise machine for layers. Poult. Sci. **3**, 878-885

MENG, H., G. N. PIERCE, 1990: Metabolic and physiological response of the rabbit to continuous and intermittent treadmill exercise. Can. J. Physiol. Pharmacol. **68,** 856.862.

NARAHARI, D., 2003: Health-promoting and therapeutic uses of egg. Poult. Int. **42** (10), 45-47.

NEWMAN, S., LEESON, S., 1998: Effect of housing birds in cages or an aviary system on bone characteristics. Poult. Sci. **77**, 1492–1496.

NEWTON, I.S., 1996: Long chain fatty acids in health and nutrition. J. Food Lipids, **3**, 233-249.

NORGAARD-NIELSEN, G., 1990: Bone strength of laying hens kept in an alternative system, compared with hens in cages and on deep-litter. Br. Poult. Sci. **31**, 81-89.

RÄTH, C., R. MONETTI, J. BAUER, I. SIDORENKO, D. MULLER, M. MATSUURA, E-M. LOCHMULLER, P. ZYSSET and F. ECKSTEIN, 2008: Strength through structure: visualization and local assessment of trabecular bone structure. New Journal of Physics **10**: 125010 (18 pp).

ROWLAND, L. O. J., HARMS, R. H., 1970: The effect of wire pens and cages on bone characteristics of laying hens. Poult. Sci. **49**, 1223-1225.

ROWLAND, L. O., JR., R. H. HARMS, H. R. WILSON, E. M. AHMED, P. W. WALDROUP, J. L. FRY, 1968; Influence of various dietary factors on bone fragility of caged layers. Poult. Sci. **47**, 507–511.

RUTTEN, M., CH. LETTERRIER, P. CONSTANTIN, K. REITER, W. BESSEI. 2002: Bone development and activity in chickens in response to reduced weight – load on legs. Anim. Res. **51**, 327-336

SARI, M., M. AKSIT, M. OZDOGAN, H. BASMACIOLU, 2002: Effects of addition of flaxseed to diets of laying hens on some production characteristics, levels of yolk and serum cholesterol, and fatty acid composition of yolk. Arch. Geflügelk. **66**, 75-79.

SCHEIDELER, S.E., G. W. FRONING, 1996: The combined influence of dietary flaxseed variety, level, form and storage conditions on egg production and composition among vitamin E – supplemented hens. Poultry Sci. **75**, 1221-1226.

SINGER, P., 2000: Was sind, wie wirken Omega-3-Fettsäuren? Uni Umschau Zeitschriftenverlag, Bredenstein GmbH, Germany.

STEINHILBER, S., 2003: Einfluss von genetischem Typ, Legeabschnitt und Futterfett auf die Anreicherung von Hühnereiern mit Omega-3-Fettsäuren und die Auswirkungen auf die Produktqualität. Dr.sc.agr. Uni Hohenheim.

ŠVEDOVÁ, M., L. VAŠKO, A. TREBUNOVÁ, R. KAŠTEL, M. TUČKOVÁ, M. ČERTÍK, 2008: Influence of linseed and fish oil on metabolic and immunological indicators of laying hens. Acta Veterinaria Brno **77**(1), 39-44

THORP, B.H, M. H. MAXWELL, 1993: Health problems in Broiler Production. 4-th European Symposium on Animal Welfare p. 208-218.Milinsk M.C, Murakami A.E, Gomes S.T.M, Matsushita M. De Souza N.E. 2003. Fatty acids profile of egg yolk lipids from hens fed diets rich in n-3 fatty acids. Food Chem. **83**, 287-292.

VAN ELSWYCK, M.E., 1997: Nutritional and physiological effects of flax seed in diets for laying fowl. WPSJ **53**, 253-264.

WATKINS, H. W., 1992: Influence of dietary n-6 and n-3 polyunsaturates on lipids in chickens divergently selected for body weight. Poultry Sci. **77**, 1513 – 1519.

WHITEHEAD, C.C., 2004: Overview of Bone Biology in the Egg – Laying Hen. Poult. Sci. **83**, 193 -199.

ZEGHICHI – HAMRIS, S., M. LORGERIL, P. SALEN, M.CHIBANE, J. LEIRIS, F. BOUCHER, F. LAPORTE, 2010: Protective effect of dietary n-3 polyunsaturated fatty acids to ischemia – reperfusion injury in rats. Nutr. Res. **12**, 849-57

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Prof. Dr. Michael Grashorn and Prof. Dr. Werner Bessei who accepted the role of my supervisor and made my Ph.D. at the University of Hohenheim possible. I appreciate your help, kindness, readiness for discussion, suggestions in preparing and conducting the research, publications and thesis.

I would also like to thank Prof. Dr. Ivan Štuhec, Prof. Dr. Skender Muji who helped me and supported all the time.

Further on, I would like to express my gratitude to the staff at the Experimental station for animal husbandry, animal breeding and small animal breeding of Hohenheim University, Unterer Lindenhof, Eningen u.A., Germany for their acceptance and kindness. I would like to express my sincere gratitude to the workers responsible for the poultry, especially Jan Abegg, who always helped me whenever I asked for help.

With gratitude and deep sense of devotion, I wish to thank Mrs. Karin Heisler for her support at all times.

I will always be proud of meeting with all colleagues and friends in the Institute- they were there always when it needed help and support.

I own deep thanks Dusanka for the encouragement that she gave me all the time.

Where I would be without you my mother? – THANK YOU

I am privileged to mention the feelings to my dearest father that was always my moral support.

A special thanks goes to my husband, Arben for his continues encouragement, help, patience and support. My dearest Jorik, Ar and Teo, I was not there when you most needed me. Thank you for your understanding.

CURRICULUM VITAE

Personal data

Family name:	Hoxha – Jahja
First name:	Ardita
Date of birth:	18 November 1978
Place of birth:	Prishtina, Kosovo
Sex:	Female
Nationality:	Kosovo
Permanent address:	Veternik, n. Nr. 10000 Prishtina, Kosova
Contact:	ardita.jahja@gmail.com; ardita.hoxha@uni-pr.edu

Education

1997 - 2004 Doctor of Veterinary Medicine

University of Prishtina, Agriculture and Veterinary Faculty, Kosovo

2004 - 2006 Master degree in Food Science

University of Perugia, Veterinary Faculty, Italy

Thesis: "Hygiene and Quality of animal products and its finalization for human consumption"

2008 - 2012 Ph.D. in Agricultural Sciences

University oh Hohenheim, Germany

Thesis: "The effect of omega 3 and physical exercise on egg quality, bone and physiological parameters at laying hens"

Employment:

2007 – to date Assistant for animal anatomy, animal hygiene and animal ethology

	at the Department of Biotechnology and at the Department of Veterinary, Agriculture and Veterinary Faculty, University of Prishtina, Kosovo

Additional education:

2004 - 2005	Training course “Veterinary Border Control”, Sofje, Bulgaria
2007	International HACCP Alliance accredited training course covering the theoretical and practical aspects of HACCP plan development and implementation, Kansas State University, USA.
2007	Research fellowship training program on Food Technology, Safety and Quality Standards on Farm Milk Quality Practices, University of Missouri, USA.
2009-2010	Train – a – Trainer Animal Welfare Program
2010	Training course: Agriculture Rural Development Policies, Washington, USA.

Date: 21 September 2012 Signature: Ardita Jahja