Macedonian Journal of Animal Science, Vol. **1**, No. 1, pp. 139–145 (2011)
024 ISSN 1857 – 6907
Received: July 31, 2009 UDC: 636.5.034.087.7 : 577.115.3
Accepted: November 10, 2009
Original scientific paper

INFLUENCE OF ω-3 FATTY ACIDS SUPPLEMENTED TO LAYING HENS' DIET ON LAYING PERFORMANCE

Aleksandar Andonov[1], Dragan Šefer[2], Radmila Marković[2], Slađana Šobajić[3], Goce Cilev[4]

[1]Provimi Makedonija, Strašo Pindžur str. 7/35, Skopje, Republic of Macedonia
[2]Faculty of Veterinary Medicine, Bul. Oslobođenja 18, Belgrade, Serbia
[3]Faculty of Pharmacy, Vojvode Stepe str. 450, Belgrade, Serbia
[4]University "SS. Cyril and Methodius", Institute of Animal Science, Bul. Ilinden 92a, MK-1000 Skopje, Republic of Macedonia
alexand@mt.net.mk

A group-control experiment for a period of 45 days was conducted in order to determine the effects of use of ω-3 fatty acids on the production and economic results of laying hens. A total of 1264 Lohmann Brown layers were randomly devided into 4 experimental treatments with 79 replicates (4 per cage, 316 hens per treatment). The first group was fed complete feed mixture for laying hens with standard raw material and chemical composition. The feed mixtures for treatments 2., 3. and 4. were supplemented with ω-3 fatty acids. The source of ω-3 fatty acids was a microalgae *Schizochytrium* spp., commercial product "DHA Gold" (Martek, USA) in quantities of 0.5, 0.7 and 1.0%, respectively. The use of ω-3 PUFA supplement in higher inclusion rates, had a positive influence on the laying intensity, significantly higher ($p < 0.01$) in the experimental groups supplemented in the amount of 0.7 and 1.0%. Layers of all experimental groups fed supplemented feed mixtures had lower average egg weights (68.1, 68.7 and 68.4 g) compared to the control group (68.8 g). However, supplementation with higher inclusion rates of ω-3 product resulted in higher total egg mass during the experiment (743 and 764 kg) in the third and fourth experimental groups, compared to the control group (691.9 kg). Experimental groups with a higher inclusion of ω-3 PUFA (0.7 and 1.0%), achieved higher daily consumption of 0.16% and 0.51% in comparison to the control group, but the best feed conversion (2.38 and 2.32), while supplementation in the amount of 0.5% resulted in the weakest conversion in the experimental group 2 (2.63). The lowest feed cost per produced egg was achieved by the control group fed complete, unsupplemented feed. Using supplemented feed with addition of ω-3 PUFA – DHA above the 0.5%, a significant difference was observed regarding the productivity of laying hens.

Key words: ω-3; layers; laying intensity; egg weight; feed conversion

ВЛИЈАНИЕ НА МАСНИТЕ КИСЕЛИНИ ω-3 ДОДАДЕНИ ВО ХРАНАТА ВРЗ ПРОИЗВОДНИТЕ ПАРАМЕТРИ НА НЕСИЛКИТЕ

Со цел да се утврдат ефектите од употребата на масните киселини ω-3 на производно-економските резултати кај кокошките несилки, спроведен е групно-контролен опит во времетраење од 45 дена. Вкупно 1264 несилки Lohmann Brown беа поделени во 4 групи од по 316 единки, сместени по 4 во кафези. Првата група е хранета со комплетна крмна смеска за несилки со стандарден хемиски и суровински состав. Во крмните смески кај групите 2, 3 и 4 се додавани масни киселини ω-3. Како извор на ω-3 е употребена микроалга *Schizochytrium* spp., комерцијален препарат "DHA Gold" (Martek, САД), во количества од 0,5, 0,7 и 1,0 %, кај групите 2, 3 и 4. Употребата на препаратот со повисоко учество во храната на несилките покажаа позитивно влијание врз несливоста, со значително повисок интензитет ($p < 0,01$) кај опитните групи 3 и 4. Кај несилките од сите групи со додаток на препаратот се утврдени пониски просечни маси на јајцата (68,1, 68,7 и 68,4 g) во споредба со контролната група (68,8 g). Меѓутоа, вклучувањето на препаратот ω-3 во повисоки количества резултираше со поголема вкупна јајцева маса за време на опитот (743 и 764 kg) кај третата и четвртата опитна група, споредено со контролната група (691,9 kg). Кај опитните групи со повисоко вклучување на препаратот ω-3 (0,7 и 1,0%) е утврдена поголема дневна потрошувачка на храна за 0,16% и 0,51% во однос на контролната група, но истовремено е утврдена и најдобра конверзија на храната (2,38 и

2,32) кај истите групи, додека додавањето на препаратот во количество од 0,5% резултираше со најслаба конверзија кај втората огледна група (2,63). Најниска цена на чинење по произведено јајце е постигната кај контролната група, хранета без додаток на препаратот ω-3. При користењето на храна со додаток на ω-3 PUFA–DHA над 0,5% се забележени значајни разлики во производните параметри кај несилките.

Клучни зборови: ω-3; несилки; интензитет на несливост; јајцева маса; конверзија на храна

1. INTRODUCTION

Food today has one of the leading roles in quality of life. It is not viewed only from the aspect of meeting the needs in basic nutrients, but the raising awareness of people about caring for health, directed the development of food industry towards the production of foods that are proven in more favorable health effects.

As a part of modern livestock production, there is greater production of functional food, which promotes the health benefits for consumers of animal products. The concept of functional foods was introduced in the eighties of the last century and involves a modification of the nutritive values of foods providing a healthier nutrition. This concept is widely accepted, especially after numerous investigations and confirmation by the relevant authorities in the field of nutrition who claim that functional foods have the potential to provide a healthier population.

Nutritional value of products of animal origin depends on multiple factors, but certainly the animal feed has most influence. Recently, increasing attention is focused on the production of so called designed eggs.

By nutritional treatment is almost impossible to affect and change the total content of protein and amino acids in the egg. However, with the use of various ingredients in the laying hens'diet it is quite easy to manipulate the content of lipids, fatty acids (Meluzzi et al., 2000) vitamins soluble in fats (Flachowsky et al., 2000) and minerals (Surai, 2002). Only 3–5% of the total world production of eggs is produced in the form of designed products, where the nutrient content is different from the contents of regular table eggs *(*HE Shalom, Egg Nutrition Center, Washington, DC). These designned eggs are produced using nutritional solutions that lead to the increase of various useful nutrients such as omega fatty acids, folic acid, vitamin E, selenium, iodine, chromium, etc. (Watkins, 1995).

Content and ratio of fatty acids in foods of animal origin is usually observed through the aspect of human nutrition. One of the most important fact is that the relationship omega-6/omega-3 fatty acids should be as close to the relation 1:1 (Okuyama et al., 1997). In contemporary nutrition the ratio of ω-6 : ω-3 PUFA is high (10–15 : 1) so that today there are efforts toward the human diet to enrich foods with ω-3 fatty acids.

In this respect special attention is given to omega 3 PUFA (EPA and DHA) that are considered to have a stronger physiological effect than their precursor α-LNA (Ollis et al., 1999).

Increasing ω-3 PUFA content in eggs conventionally is achieved by adding flax oil or fish meal in hens' diet. However, the use of these two ingredients manifests negative effects on production parameters and sensory properties of eggs (smell, taste), so that these sources of ω-3 PUFA have limited application.

Recent approaches to this problem involve the use of marine microalgae having satisfactory FA composition, and do not affect the sensory characteristics of products.

Table eggs are a good source of PUFA n-6, but on the other hand are poor in PUFA n-3. Therefore, the design of the eggs generally is directed to enrichment of egg with n-3 fatty acids. Change of the relationship of omega n-6: omega n-3 PUFA in the production of eggs is achieved mainly by adding flax oil and rapeseed oil for hens (Jiang et al., 1991; Ceylan et al., 2004; Mirghelenj et al., 2004), and rarely with use of ingredients of animal origin (Simopoulos, 2000; Cherian et al., 2002).

When manipulating the content of fatty acids in feed we should take into account the amount of added oils or fats to feed for laying hens as a higher energy value would not adversely affect the production and quality of eggs (Goencueoglu and Erguen, 2004); (Sari et al. 2001).

Gonzalez-Esquerra and Leeson (2000) investigated the influence of different quantity of fish oil (0%, 2%, 4% and 6%) in production results and the composition of fatty acids in eggs. Egg weight linearly decreased, and the content PUFA n-3 increased linearly with increasing content of fish oil in feed.

Whitehead et al., (1993) and Marshall and Van Elswyk (1994) highlighted the negative impact of fish oil on production results, especially in the reduced weight of eggs.

Abril et al. (2000) used marine microalgae (up to 4.3% included in hens' diet), where they didn't determine negative impact on health and production parameters of laying hens. Gonzalez-Esquerra and Leeson (2000) also confirmed the above data in their works.

2. MATERIAL AND METHODS

The experiment was conducted in field conditions. For the experiment layers Lohmann Brown Classic, a total of 1264 laying hens divided into four equal groups of 316 individuals were used. Hens were kept in cages (4 groups of 79 cages) of 4 layers. The first group (control) was fed a complete feed mixture for laying hens with standard raw material and chemical composition. The feed mixtures for treatments 2., 3. and 4. were supplemented with ω-3 fatty acids (Tabs. 1, 2). The source of ω-3 fatty acids was a microalgae *Schizochytrium* spp., commercial product "DHA Gold" (Martek, USA) in quantities of 0.5; 0.7 and 1.0%, respectively. During the experiment clinical examinations were performed, all individuals were healthy, vital and in good condition. All groups were of equal weight.

The treatment during the experiment regarding the applying of preventive measures, housing, and feeding was adapted to the cage system. Feeders and drinkers were filled automatically, with feed and fresh water ad lib. Daily light duration was 16 h.

The experiment lasted 45 days. Control measurements of body weight were performed at the beginning and the end of the experiment, and the quantity of feed consumed was determined. The rate of lay (%) and egg weight (g) were followed daily. The value of feed consumed per produced egg was calculated for each group separately. Obtained from data on consumption and egg mass, the conversion of feed was calculated, separately for each group. On the basis of price of used raw materials differences in the cost of eggs with and witut addition of algae supplement were determined.

Table 1

Ingredient composition of the diets, %

Ingredient	Groups in the experiment			
	Control	2	3	4
DHA Gold	–	0.5	0.7	1
Corn	57.72	57.22	57.02	56.72
Wheat bran	5.5	5.5	5.5	5.5
Soybean meal	23.34	23.34	23.34	23.34
DL methionine	0.09	0.09	0.09	0.09
Choline chloride	0.05	0.05	0.05	0.05
Limestone	9.70	9.70	9.70	9.70
Monocalcium phosphate	0.77	0.77	0.77	0.77
Salt	0.33	0.33	0.33	0.33
Sunflower oil	2	2	2	2
Vitamin/mineral premix for layers	0.5	0.5	0.5	0.5
Tot\al:	100.0	100.0	100.0	100.0

3. RESULTS

During the experiment there were no health disorders, and mortality ranged in the technological norms, while differences between groups were not significant.

Table 2

Chemical composition of the diets, (%)

Chemical analysis	Groups			
	1 (control)	2	3	4
Moisture	11.4	11.42	11.3	11.4
Ash	13	13	13	13
C. protein	15.5	15.44	15.42	15.4
C. fat	4.94	4.92	5	5
C. fibre	3.5	3.47	3.47	3.47
Nitrogen-free extracts	51.66	51.75	51.81	51.73
Ca	3.8	3.8	3.8	3.8
P	0.54	0.54	0.54	0.54
ME, MJ/kg	10.5	10.5	10.5	10.5
Methionine + cystine	0.61	0.6	0.6	0.6
ω-3 PUFA C22:6n3 (DHA)		0.09	0.126	0.18

The hens at the beginning and the end of the experiment had adequate body mass for the hybrid, and differences in body weight between groups at the beginning and the end of the experiment were not statistically significant ($p > 0.05$). An impact of addition of microalgae to body mass during the investigated period is also not determined.

Consumption of feed is shown in Table 3, from which it can be seen that it was similar for all experimental groups. Hens from the group with the highest level of added supplement of algae in diets had the highest daily consumption (122.16 g).

Table 3

Feed consumption, hen per day (g)

	Group 1	Group 2	Group 3	Group 4
	121.54	120.77	121.74	122.16
Index	100	99.37	120.16	100.51
Difference, %		**–0.63**	**0.16**	**0.51**

The laying rate is shown in Table 4, from which a positive impact of use of the supplement, which was most pronounced in the experimental group 4 is observed.

Table 4

Rate of lay (%)

	Group 1	Group 2	Group 3	Group 4
	69.44±6.33 abAB	67.41±5.34 cdCD	74.55±6.88 acAC	76.88±6.32 bdBD
Index	100	97.08	107.36	110.71
Difference		–2.92	7.36	10.71

$\bar{X}$ ± Sd; a,b,c,d $p < 0.05$ A,B,C,D $p < 0.01$
Mean values having the same superscripts are significantly different (Tukey's HSD, $P < 0.05$ and $P < 0.01$)

Hens fed the diet where was algae supplement included achieved somewhat lower average weight of eggs in relation to the control group (Table 5), but taking into account the overall Egg mass throughout the experiment (Table 6), adding higher quantities of algae resulted in greater Egg mass of 7.21%, and 10.14% in the third and fourth experimental groups, compared to the control group.

Table 5

Egg weight (g)

	Group 1	Group 2	Group 3	Group 4
	68.77±0.54^{aAB}	68.06±0.57^{abAC}	68.66±0.36^{bC}	68.38±0.60^{aB}
Index	100	98.97	99.84	99.43
Difference, %		–1.03	–0.16	–0.57

$\bar{X}$ ± Sd; a, b, c, d $p < 0.05$; A, B, C, D $p < 0.01$
Mean values having the same superscripts are significantly different (Tukey's HSD, $P < 0.05$ and $P < 0.01$)

Table 6

Total egg mass, kg

	Group 1	Group 2	Group 3	Group 4
	691,9	664.8	743.0	764.0
Index	100	96.08	107.38	110.42
Difference, %		**–3.92**	**7.38**	**10.42**

Despite the slightly higher average daily consumption, the best feed conversion was achieved in hen groups whose diet was supplemented to a larger amount of algae (3. and 4. experimental groups) for 6.3 and 8.66% compared to the control group (Table 7).

Table 7

Feed conversion

	Group 1	Group 2	Group 3	Group 4
	2.54	2.63	2.38	2.32
Index	100	103.54	93.70	91.34
Difference, %		**3.54**	**–6.30**	**–8.66**

It can be seen Tables 8 and 9that there are significant differences in the cost of feed production and the price of eggs with the use of feed with the addition of algae.

Table 8

Feed per egg (g). Raw material feed cost (Mkd den.)

	Group 1	Group 2	Group 3	Group 4
Feed per egg	175.03	179.16	163.30	158.90
Feed cost	10.71	15.67	17.66	20.63
Index	100.00	146.31	164.89	192.62
Difference, %		**46.31**	**64.89**	**92.62**

Table 9

The share of feed cost in the egg cost , (Mkd den.)

	Group 1	Group 2	Group 3	Group 4
Share of feed in egg cost	1.87	2.81	2.88	3.28
Index	100.00	150.27	154.01	175.40
Difference, %		**50.27**	**54.01**	**75.40**

4. DISCUSSION

The task of this study was to examine the impact of using ω-3 fatty acids on production and economic results. Oils derived from algae, rich in omega-3 PUFA are approved for use in food intended for human nutrition in the United States and Canada.

The purpose of adding DHA Gold is a modification of fat (FA profile) of eggs, with no negative impact on production parameters of laying hens and sensory properties of the obtained products – eggs. Unlike previous research (Herber and Van Elswyk, 1996.) where they established the negative effect of adding marine algae on the weight of yolk, the results obtained in this experiment indicate a positive impact of added ω-3 fatty acids (DHA Gold) to the production results and quality of eggs, which agrees with the findings of Abril et al. (2000). Using ω-3 PUFA in the larger inclusion rate had a positive effect on the percentage of lay, so that the experimental groups with algae ω-3 PUFA added to the amount of 0.7 and 1.0% achieved significantly higher ($p < 0,01$) percentage of lay (Fig. 1)

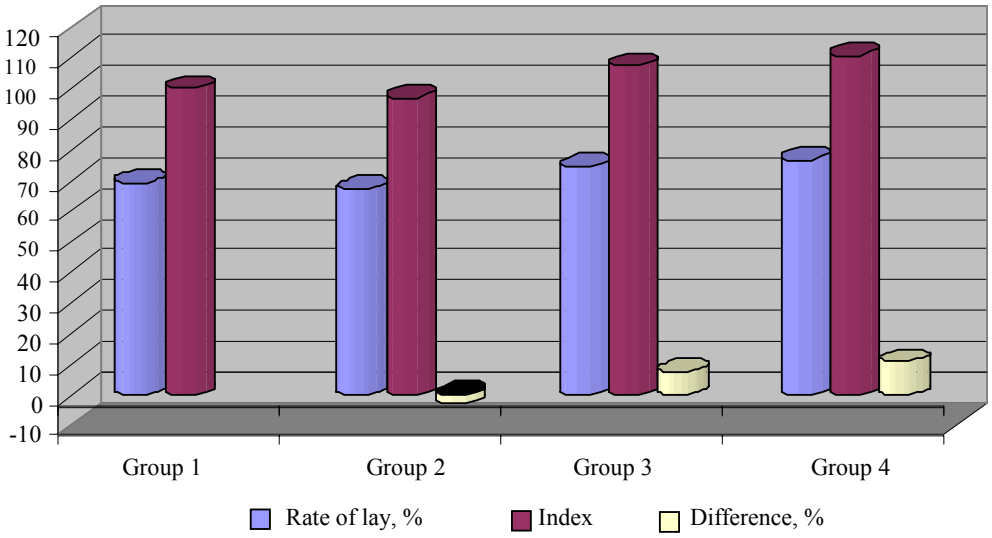

Fig. 1. Rate of lay

Experimental groups fed ω-3 PUFA supplement diets achieved less average weight of eggs (68.1, 68.7 and 68.4 g) compared to the control group (68.8 g), but taken into account the total mass produced during the experiment, adding higher quantities of the supplement ω-3 PUFA resulted in a greater Egg mass (743.0 and 764.0 kg), which was 7.38% and 10.42% higher compared to the control group (691.9 kg) (Fig. 2). When using microalgae in high concentrations (2.57 and 4.29%) in hens' feed, Abril, Barclay 2000 observed a further reduction of weight of eggs, up to 1 g average differences compared to the control group, which is explained by the decline of ω-6 PUFA (at higher concentrations of ω-3 PUFA), which positively affects the eggs weight.

Experimental groups of hens that were fed the supplemented diets, but in larger quantities (0.7 and 1.0%), achieved higher daily consumption (121.8 and 122.2 g) of 0.16 and 0,51% compared to the control group.

It has been shown that the addition ω-3 PUFA showed a positive effect on feed conversion (Fig. 3), at hen groups fed diets in which ω-3 PUFA was added in the highest quantity. They achieved the best conversion (2.320 g), which is in accordance with the results obtained by Abril et al. (2000).

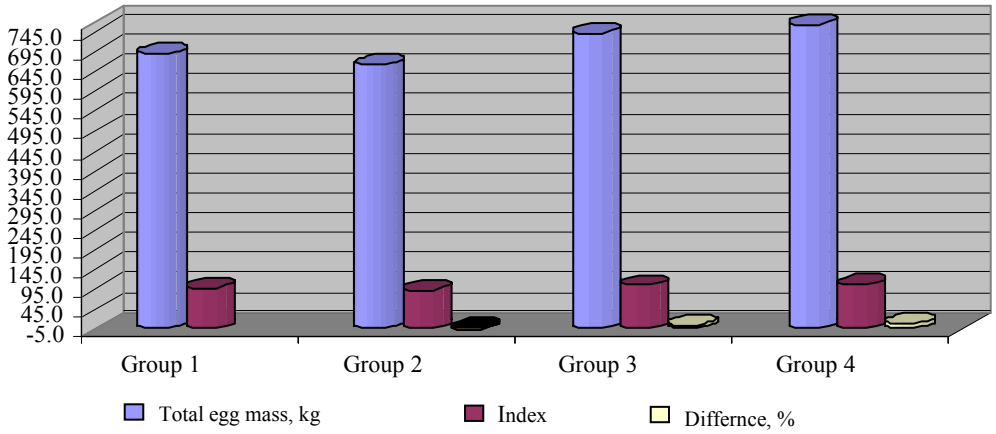

Fig. 2. Total egg mass

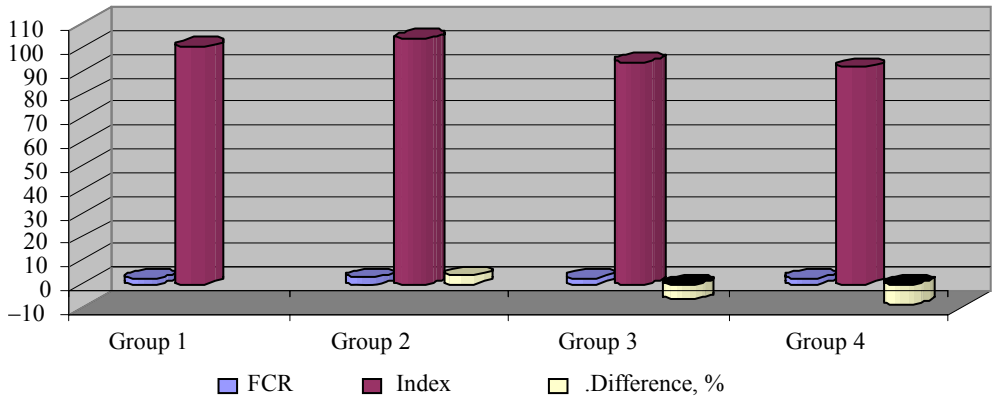

Fig. 3. Feed conversion

The lowest feed consumption per egg (158.9 g) was accomplished by the group of laying hens fed the feed mixture with the addition of 1% DHA gold (group 4), but that experimental group also had the highest share of feed price in the price of the product.

Although the less consumption of feed (g) per egg was at the experimental groups with the highest inclusion of microalgae DHA Gold, the share of feed price is much higher in the production cost of eggs, as a result of high raw material prices of produced feed with a higher portion of algae DHA Gold, because of the relatively high price of the supplement.

Nevertheless, this production price could be worthwhile, taking in consideration that the higher selling price could be achieved for such a designed product – omega-3 egg.

5. CONCLUSIONS

Based on the results obtained in the experiment, the following conclusions can be drawn:

1. During the experiment there was not observed occurrence of any clinical symptoms of health disorders of laying hens fed diets with the addition of ω-3 PUFA.

2. Using supplemented feed with addition of ω-3 PUFA – DHA above the 0.5%, a significant positive effect was observed regarding the production parameters of laying hens.

3. Using ω-3 PUFA as feed supplement for laying hens has its nutritive and economic justification.

REFERENCES

Adams C. A., Nutricines in poultry production: focus on bioactive feed ingredients. *Nutrition abstracts and reviews*, Series B 74, 1–12, Nutritional Services Department, Kemin Europa, Belgium (2004).

Bean L. D. and S. Leeson, Long-term effects of feeding flaxseed on performance and egg fatty acid composition of brown and white hens. *Poult. Sci*., 82, 388–394 (2003).

Bosstraeten Van Filiep, *Egg Product Developments in the EU*, part 1, Poultry international, November, 16–21 (2001):.

Cachaldora P., J. C. De Blas, P. García-Rebollar, C. Álvarez, J. Méndez, Effects of type and level of supplementation with dietary n-3 fatty acids on yolk fat composition and n-3 fatty acid retention in hen eggs, *Spanish Journal of Agricultural Research*, **3** (2), 209–212 (2005).

Calvani M., P. Benatti, Polyunsaturated fatty acids. Sigma-tau S.p.A – Scientific Department (2003).

Ching Kuang Chow, *Fatty Acids in Foods and their Health Implications*. Third edition, CRC Press (2007).

Etherton P. K., D. S. Taylor S. Yu-Poth, Polyunsaturated fatty acids in the food chain in the United States. *Am. J. Clin. Nutr*. **71** (1), 179–188 (2000).

Ganong W. F., *Review of Medical Physiology*, Xth Ed., Lange Medical Publication, Los Altos, California (1989).

Haasman M., Mellentin J., *The Functionl Food Revolution*, Earthscan Publ. London (2001).

Halle I., Effects of dietary fat on egg components, fatty acids composition of egg yolk, hatchability and growth of progeny by breeding hens. *11th European Symposium on Poultry Nutrition*. August, 24–28, 1997, Faaborg, Denmark, 46–56 (1997).

Halloran H. R., I. R. Sibbald, Metabolizable energy values of fats measured by several procedures. *Poultry Sci*. 58, 1299–1307 (1979).

Jacqueline P. Jacob and Richard D. Miles, Designer and Specialty Eggs, document PS51, Animal Science Department, (2000), http://edis.ifas.ufl.edu

Krogdahl Digestion and absorption of lipids in poultry. *J. Nutr*. 115, 675–685(1985).

Leaf A., P. C. Waber, A new era for science nutrition. *Am. J. Clin. Nutr.*, 45, 1048–1053 (1987).

Leskanich Co and Noble R. C., Manipulation of the n-3 polyunsaturated fatty acid composition of avian eggs and meat. *World's Poult. Sci. J.*, 53, 155–183 (1997).

Meluzzi A., Sirri F., Tallarico N. and Franchini A., Effect of different vegetable lipid sources on the fatty acid composition of egg yolk and on hen performance. *Archiv für Geflugelkunde*, 65, 207–213. (Poult. Abstr., 28, 786) (2001).

Miletić I., S. Šobajić, B. Đorđević, Funkcionalna hrana – Uloga u unapređenju zdravlja, *JMB*, 27, 367–370 (2008).

National Research Council, *Nutrient Requirements of Poultry*. Ninth Revised Edition, National Academy Press, Washington, D.C. (1994):

Okuyama H., T. Kobayashi, S. Watanabe, Dietary fatty acids – the n-6/n-3 balance and chronic elderly diseases. Excess linoleic acid and relative n-3 deficiency syndrome seen in Japan. *Prog. Lipid Res*., 35, 409–457 (1997).

Raper N. R., F. J. Cronin, J. Exler, Omega-3 fatty acid content of the US food supply. *Am. J. Coll. Nutr*., 11, 304–308 (1992).

Schmidt R. H., Turner R. E., Functional food and nutraceuticals. *Food Safety Handbook*, J. Rose (ed.), Wiley interscience, New Jersey (2003).

Sim J. S., Designer Egg Concept: Perfecting Egg Through Diet Enrichment with Omega-3 PUFA and Cholesterol Stability. In: *Egg Nutrition and Biotechnology*, eds J. S. Sim, S. Nakai, W. Guenter. CAB International, pp. 135–150 (2002).

Simopoulos A. P., Omega-6/omega-3 Essential Fatty Acid Ratio: The Scientific Evidence – Preface. *World's Review of Nutrition and Dietetics*. Ed. A. P. Simopoulos, Cleland LG Vol **92** (2003).

Simopoulos A. P., N. Salem jr., n-3 fatty acids in eggs from range-fed Greek chickens. *N. Engl. J. Med.,* 321, 1412 (1989).

Šefer D., Sinovec Z., *Opšta ishrana*, Fakultet veterinarske medicine, Beograd (2008).

Škrtić Z., Kralik G., Bogut I., Gajčević Z., Influence of hens' diet on the EPA and DHA yolk content. Page 153 in *Proc. 12nd Eur. Poultry Conf. WPSA*, Verona, Italy (2006).

Wiley Encyclopedia of Food Science and Technology (2nd Edition), Vol. 1–4. Ed. Francis Frederick J., John Wiley & Sons (1999).

Wiseman J., The influence of dietary factors on fat and fatty acid digestibility and utilisation. *11th European Symposium on Poultry Nutrition*. August, 24–28, 1997, Faaborg, Denmark, 34–45 (1997).

Y. C. Gao and E. A. Charter, Nutritionally Important Fatty Acids in Hen Egg Yolks from Different Sources, Canadian Inovatech Inc., 31212 Peardonville Road, Abbotsford, British Columbia, V2T 6K8, Canada, *Poultry Science*, 79, 921–924 (2000).