



INDUSTRIALLY PROCESSED OILSEED RAPE IN THE PRODUCTION OF TABLE EGGS

Mária Angelovičová, Michal Angelovič, Zdenko Tkáč, Juraj Jablonický, Marek Angelovič

ABSTRACT

The purpose of this study was to investigate the effectiveness of feed mixtures with varying proportions of rape cakes to the weight of table eggs, its components, thickness and strength of egg shell. The eggs were from the final laying hybrid ISA Brown reared in the enriched cage system under experimental conditions. An age of laying hens was from 48 to 54 weeks. Egg weight and its components were measured on scales type KERN 440-35N, with an accuracy of 0.01 g and a maximum weight of 400 g. Egg white weight was calculated. The thickness and strength of the egg shell were measured from the dried samples at 55 °C. From each egg shell were cut 3 pcs of samples in the equatorial plane, one sample from the blunt end and one sample from the sharp end. Egg shell thickness was measured by test instrument SOME, type 60/0.01mm with a range of 0 – 10 mm. Egg shell strength was measured according to test instrument Instron with the small body, having a diameter 4.48 mm to exert pressure on the egg shell. The obtained data were assessed in the program system SAS, version 8.2. Based on the results observed in egg weight of our experiment we can conclude that in the group with share 5% of rape cakes was non-statistically significant ($p > 0.05$) decreased egg weight compared to the control group. Egg weight was reduced in the group with share 10% of rape cakes, which confirmed a statistically significant difference compared to egg weight of control group ($p < 0.05$). The differences among experimental groups with share 5% and 10% of rape cakes in feed mixture and as well as to control group were not statistically significant ($p > 0.05$) in weight of egg yolk, egg white, egg shell and egg shell strength. Egg shell thickness was no statistically significant ($p > 0.05$) increased in experimental group with share 5% of rape cakes and decreased in experimental group with share 10% of rape cakes versus control group. Increase of egg shell thickness in experimental group with share 5% of rape cakes versus decrease in experimental group with share 10% of rape cakes was statistically significant ($p < 0.05$).

Keywords: table egg; white; yolk; shell; quality; oilseed rape

INTRODUCTION

Poultry breeding recorded a boom in technology of nutrition but also breeding in the twentieth century. The average body weight and the number of laid the eggs were increased. It changes the methods used in poultry breeding, the programs of hybridization and breeding, as well as the principles of nutrition and feeding. The production of hybrid chickens a laid type of hens is in the developed world by breeding provided through specialized reproductive breeding (Capcarová et al., 2009).

Modern chickens were domesticated from the Red Jungle Fowl (*Gallus gallus*) over the last four or five thousand years for eggs and meat, for game and for exhibition (Klasing, 2005) and they are scientifically classified as the same species (Wong et al., 2004).

Consumers of agricultural commodities are increasingly sensitive to animal welfare, and new systems aiming at improving this have recently been introduced to EU livestock production. For example, the conventional battery cage system used for chicken egg production was banned in the European Union in 2012 (Council Directive 1999/74/EC), and fully housed production was mainly

replaced by new enriched colony cages (or free range production) (Leinonen et al., 2014).

According to a study conducted in the U.S.A., the quality of eggs from different production systems does not substantially differ. United States department of agriculture-agricultural research service developed a study in which examined various quality criteria for eggs. One of the many findings was that the organically produced eggs and eggs of usual production, there is no significant difference in quality (Kvasničková, 2010).

Nutrition of laying hens is an important factor for the quality and safety of the table egg production. A feeding of laying hens with share 20% of secondary industrial products of oilseed rape has no negative effects on egg weight. These results indicate that the utilization of nutrients from the feed mixture containing secondary industrial products were similar as in the control group without secondary rapeseed products. Based on these results it can be assumed that laying hens good use the nutrients from rapeseed meal (Gheisari et al., 2011).

The selection of appropriate feedstuffs for nutrition of the laying hens is limited to concentrated kinds with a high concentration of nutrients and energy. Corn together with

wheat and soybean meal presents the basis of feed mixture. Currently, the corn and wheat constitute a proportion 70% and soybean meal 16 – 20% of feed mixture (Angelovičová, 1999).

The oil crops are considered a strategic material. The seeds contain economically significant quantity of oil. The fat is irreplaceable in human nutrition, in animal feed rations but also for an increasing proportion of oil in biodiesel. Angelovič et al., (2013) state that rapeseed oil constitutes a main raw material in the EU and presents two thirds of total input in biodiesel production.

Rapeseeds are a rich source of oil and their industrial remnants also of proteins. Oilseed rape is one of the most important and most fertile oilseeds in Slovakia (Božík, 2007). Oilseed rape ranks the second among oilseeds (USDA, 2011).

The chemical composition of oilseed rape was significantly changed by breeding. The term "rape" is currently used in Canada. It is incorporated in Great Britain, Australia and the United States to the characteristics of the species *Brassica napus* L. Oilseed rape provides edible oil with an erucic acid content of less than 2% and less than 30 mmol per gram of aliphatic glucosinolates. The use of rapeseed meal or cakes is restricted to full replacement of soybean meal due to the low level of available energy and the occurrence of anti-nutritional factors (Khajali and Slominski, 2012).

Anti-nutrients of secondary rapeseed products include glucosinolates, sinapines, tannins and phytates, indigestible oligosaccharides and non-starchpolysaccharides (Kocher et al., 2000).

So far it has been identified more than 120 different species of glucosinolates (Chen and Andreasson, 2001).

It is generally assumed that the glucosinolates by themselves are non-toxic. However, they are always accompanied by the enzyme myrosinase (thioglucoside glucohydrolase) in seed. Glucosinolates are subject to hydrolysis in moist and cracked seed. The results of glucosinolate hydrolysis are degradation products, such as isothiocyanates, goitrin, nitriles and isothiocyanates, which interfere with the function of the thyroid gland (Tripathi and Mishra, 2007).

As a result of these effects on thyroid function, it is affected the metabolism of almost all tissues, including the reproductive system. In addition, various hydrolysis products of glucosinolates are irritating to the mucous membranes of the gastrointestinal tract and consequently are result local necrosis and hepatotoxicity (Mawson et al., 1994b; Mithen et al., 2000; Burel et al., 2001; Conaway et al., 2002).

The negative consequences are described in farm animals as growth retardation, decreased production, impaired reproductive activity, and hepatic and renal function (Mawson et al., 1994a).

The earlier published work indicating that the effect of glucosinolates is associated with reduced production of eggs, and the mortality syndrome related to bleeding of the liver (Ibrahim and Hill, 1980).

In another study warn Smith and Campbell (1976) on the harmful effects of high levels of glucosinolates in rapeseed meal and rapeseed cake for laying hens. According to them, these adverse effects may be caused by the degradation products of glucosinolates, such as nitrile.

They found that these decomposition products of glucosinolates are in the digestive tract of laying hens.

In the conclusions of the published work by Mawson et al., (1994a) is indicated the recommended share of low glucosinolate oilseed rape in feed mixture for laying hens.

The recommended proportion of low glucosinolate oilseed rape ranges up to 10%, in which there were no adverse effects on egg production Khajali and Slominski (2012). They recommend share 20% of low oilseed rapes. Over the past few years, glucosinolate content of was decreased by breeding, particularly as regards double zero oilseed rapes compared to indigenous species.

According to the current annual report of the Canadian International Grains Institute, current oilseed rapes contain 10 µmol per gram of seed (in non-fat dry matter) (Newkirk, 2009). Earlier report indicates reduced glucosinolate content, an average 11 µmol per gram of rapeseed meal (Mailer and Cornish, 1987) or 18 µmol per gram (in non-fat dry matter) (Brand et al., 2007).

Oilseed rape cultivated in conditions of Europe, concretely in France, reached glucosinolate content 10 µmol per gram (Labalette et al., 2011).

The level of glucosinolates 4.3 µmol per gram of grown oilseed rapes was also achieved in conditions of Poland (Mikulski et al., 2012).

Glucosinolate content 1.5 µmol per gram could correspond to a share of rape cakes or rapeseed meal from 15 to 20% of current types '00' oilseed rape (Khajali and Slominski, 2012).

The genetic potential of laying hens can be fully utilized. The condition is that laying hens must efficiently convert feed nutrients to eggs as food for human consumption. Laying hens must be healthy and their breeding must be well managed. Laying hens must consume highly digestible, concentrated and well balanced a feed mixture (Jeroch et al., 2013b).

Industrial secondary products of oilseed rape can constitute a substantial proportion of laying hens feed mixture. The valuable components of feed mixture are modern genotypes (F1, F2 and F3 generation, i.e. 0-, 00- and 000-oilseed rape) (Jahreis, 2003; Jahreisa Schöne, 2006; Jeroch et al., 2013a).

Rapeseed secondary products can replace 35 – 40% of soybean meal from the aspect of physiologically acceptable combination of amino acids (Roth-Maier et al., 2004).

A representation of different share of soybean meal by rapeseed industrial secondary products were recommended based on the results of experiments (Janjecic et al., 2002; Mushtaq et al., 2007; Tripathi a Mishra, 2007).

The purpose of this study was to investigate the effectiveness of feed mixtures with varying proportions of rape cakes to the weight of table eggs, its components, thickness and strength of egg shell.

MATERIAL AND METHODOLOGY

Characteristics of the object for research

The objects of the research were the table eggs and quality their components. The eggs were from the final laying hybrid ISA Brown reared in the enriched cage system under experimental conditions. An age of laying hens was from 48 to 54 weeks.

Experimental conditions of laying hens ISA Brown

Hens of laying type ISA Brown were included in the experiment. They lay eggs with brown shell. ISA Brown hens are a hybrid combination of color sexing type of lower body weight. Body weight to end of young hen rearing is 1450 g and to end of egg laying 2100 g. They reach sexual maturity at 145 days of age, when they begin laying. They reached high laying eggs 295 pcs to 500 days of age. Average egg weight is 63.3 grams. It is currently one of the most common hen hybrid combinations in the European Union, about 60% of large-scale breeding. Feed consumption, is around 115.0 g to 118.0 g per day, and 2.2 kg of feed per one kg of egg mass.

The experiment was conducted at the experimental facilities of Slovak University of Agriculture, Faculty of Biotechnology and Food, Department of Food Hygiene and Safety no. SK P 10011. Hens were housed individually in two-storey enriched cages. The cage space is in accordance with the recommendation for the implementation of the natural activity of laying hens, i.e. 750 cm². Laying hens had unrestricted access to feed in the feeder and water in the watering place. Feeder and watering place were completed daily. Laying hens was fed by feed mixture of soybean-cereal type, which is usually used in practical conditions. A share of corn and wheat constitute about 66% (33% corn and 33% wheat) and soybean meal 20% of feed mixture.

This feed mixture was used in control group. In the first experimental group was fed a feed mixture with a 5% rape cakes at the expense of soybean meal and other experimental group with share 10% of rape cakes at the expense of soybean meal. Rape cakes were obtained as remnant after pressing of seeds of oilseed rape. Double-zero rape seeds generally contain less than 30 µmol of glucosinolates per gram (Widharna, 2012).

Replenishment of feed and water, as well as egg collection was carried out by hand, and each day at 9:00 am.

Sampling and investigated indicators

Sampling of eggs was carried out three times for 10 eggs in each group of laying hens. An age of laying hens was 50, 52 and 54 weeks when sampling.

Investigated indicators were: egg weight, yolk weight, white weight, shell weight, shell thickness and shell strength.

The methods of investigation of indicators

An egg weight was measured on scales type KERN 440-35N, with an accuracy of 0.01 g and a maximum weight of 400 g.

Sample preparation: The egg was broken, separated the yolk and the white. The yolk placed in pre-weighed watch glass and the egg shell with membranes were washed with tap water and dried in a drying cabinet preheated to 55 °C. Yolk and shell were weighed on scales of type KERN 440-35N, with an accuracy of 0.01 g and a maximum weight of 400 g.

White weight was calculated using the formula:

$$x = \text{egg weight, g} - (\text{weight of egg yolk, g} + \text{weight of egg shell, g})$$

The thickness and strength of the egg shell were measured from the dried samples at 55 °C. From each egg shell were cut 3 pcs of samples in the equatorial plane, one sample from the blunt end and one sample from the sharp end.

Egg shell thickness was measured in the laboratory of the Department of Machines and Production Systems, Slovak University of Agriculture in Nitra; by test instrument SOME, type 60/0.01mm with a range of 0 – 10 mm.

Egg shell strength was measured in the laboratory of the Department of Machines and Production Systems, Slovak University of Agriculture in Nitra; according to test instrument Instron with the small body, having a diameter 4.48 mm to exert pressure on the egg shell by the method of Angelovičová et al. (1994) and Rataj (1994).

Statistical methods

The obtained data were assessed according to basic statistical characteristics (\bar{x} = mean, SD = standard deviation and c_v = coefficient of variation). Scheffe's test at the significance level of $\alpha = 0.05$ was used to compare a difference between indicator values in the program system SAS, version 8.2.

RESULTS AND DISCUSSION

Table eggs are among the valuable foodstuffs (Sparks, 2006). Type of laying hens is used to produce table eggs. In our experiment, it was used type of ISA Brown hens. Composition of eggs is influenced by genetic factors, age and diet. Nutrition is a very important factor for the production of quality and safe table eggs. The feed mixture of soybean-type cereal was used in our experiment.

According to Angelovičová (1999), excluding maize and wheat is the basis of feed mixture the soybean meal too. We do not know soybeans to grow in our country, so we are forced to import it. We are focused on solving partial substitution of soybean meal with our domestic feed-rape cake in our experiment. It is a product that has a relatively high nutritional value and can be a useful component in feed mixture for laying hens in the production of the table eggs.

Mawson et al., (1994a) recommend incorporating into the feed mixture for laying hens with share of low glucosinolated oilseed rape. This amount is up to 10%. These authors conclude that in such proportion were no adverse effects on the production of table eggs. Some authors state that the appropriate proportion may be up to 20% (Khajali and Slomiński, 2012).

The study by Ibrahim and Hill (1980) stated that the feed mixture of 20% rapeseed high in glucosinolates suppressed egg production in laying hens. However, the feed mixture with 20% of rapeseed meal produced from low glucosinolated rape did not cause a reduction in egg production.

Weight of eggs, yolk and white

Egg weight

Najib and Al-Kateeb (2004) noted that the results of their experiment confirmed that 10% of rapeseed in the feed mixture of laying hens not adversely affects the egg mass and egg weight. These authors further stated that the

daily egg production, egg mass and egg weight was lower if the in the feed mixture of laying hens was an addition of 30% rapeseed. They also stressed that the highest egg production was found if the laying hens fed feed mixture with a share of 5% and 10% of rape seed.

Based on the results observed in egg weight of our experiment we can conclude that in the group with share 5% of rape cakes was non-statistically significant ($p > 0.05$) decreased egg weight compared to the control group. Egg weight was reduced in the group with share 10% of rape cakes, which confirmed a statistically significant difference compared to egg weight of control group ($p < 0.05$). In the group with share 10% of rape cakes were observed the greatest variation in egg weight values expressed by standard deviation and coefficient of variation.

Table 1 Average egg weight.

Group	n	\bar{x} , g	SD	c_v , %
Control	30	61.8 ^a	1.72	2.78
Experimental 5	30	60.3 ^{ab}	2.10	3.48
Experimental 10	30	59.7 ^b	2.36	3.95

n – number of samples, \bar{x} – mean, SD – standard deviation, c_v – coefficient of variation, a, b – value within a column compared between groups with different superscript letter is significantly different ($p < 0.05$).

In contrast to our results, **Gheisar et al., (2011)** reported that feeding of the laying hens with share 20% of rapeseed products in feed mixture did not cause a reduction in egg weight. However **Ciurescu (2009)** takes the opposite view. The author notes based on the results his experiments, if the proportion of the rapeseed meal is greater than 15%, egg weight decreases.

Egg yolk weight

With this statement we can agree with the difference that in our experiment, there was a decrease in egg weight at share 10% of rape cakes. Average egg weight was in our experiment, by the proportion of rape cakes in the feed mixture, from 59.70 g in experimental group 10 and 60.30 g in experimental group 5. Higher egg weight (65.00, 71.25 g, respectively) in laying hens of the same age reported **Angelovičová and Polačková (2015)**. The laying hens were different type, Moravia SSL.

Based on our results of yolk weight we can conclude that differences among experimental groups with share 5% and 10% of rape cakes in feed mixture and as well as to control group were not statistically significant ($p > 0.05$). Our results are in agreement with the results of yolk weight recorded by **Ciurescu (2009)**. However, our results

Table 2 Average yolk weight.

Group	n	\bar{x} , g	SD	c_v , %
Control	30	15.7	0.83	5.29
Experimental 5	30	15.9	1.14	7.17
Experimental 10	30	15.2	1.19	7.83

n – number of samples, \bar{x} – mean, SD – standard deviation, c_v – coefficient of variation, No significant differences between groups in yolk weight between groups ($p > 0.05$).

indicate that the greatest variation of yolk weight values were in the group with share 10% of rape cakes.

Egg white weight

Table 3 Average white weight.

Group	n	\bar{x} , g	SD	c_v , %
Control	30	40.2	2.17	5.4
Experimental 5	30	38.5	2.09	5.43
Experimental 10	30	38.8	3.14	8.09

n – number of samples, \bar{x} – mean, SD – standard deviation, c_v – coefficient of variation, No significant differences between groups in white weight between groups ($p > 0.05$).

We did not met s literary knowledge about the impact of rape products on an egg white quality. The results of our experiment showed that between groups (control, with share 5% of rape cakes and 10% of rape cakes) no statistically significant difference ($p > 0.05$). Even at egg white weight was observed the biggest variation of values in the experimental group with share 10% of rape cakes.

Egg shell quality

Egg shell weight

The egg shell constitutes the skeletal or external support of the egg (**Ar et al., 1979**) and, as such, egg shell quality is very important to the poultry industry (**Takahashi et al., 2009**).

Table 4 Average egg shell weight.

Group	n	\bar{x} , g	SD	c_v , %
Control	30	5.9	0.12	2.03
Experimental 5	30	5.9	0.16	2.71
Experimental 10	30	5.7	0.19	3.33

n – number of samples, \bar{x} – mean, SD – standard deviation, c_v – coefficient of variation, No significant differences between groups in shell weight between groups ($p > 0.05$).

We did not met s literary knowledge about the impact of rape cakes on an egg white quality. Literary knowledge is known about the impact of rapeseed meal on this indicator. **Riyazi et al., (2009)** indicate that the proportion 10% of rapeseed meal in feed mixture caused an increase of the egg shell weight. Our results disagree with this conclusion. We have found that, among the groups no statistically significant difference ($p < 0.05$) in weight of the egg shell being compared according to the share 5 and 10% of rape cakes in feed mixture or compared to control group.

Egg shell thickness

Likewise at a thickness of the egg shell **Riyaz et al. (2009)** state that was observed no significant difference in the thickness, as well as in strength of egg shells, if laying hens fed rapeseed meal. Authors further state that the values of these indicators were higher in group of laying hens that were fed share 10% of rapeseed meal in feed mixture compared with the control group. Our results are consistent with ones of these authors.

Table 5 Average egg shell thickness.

Group	n	\bar{x} , mm	SD	c_v , %
Control	30	0.38	0.012	3.16
Experimental 5	30	0.4 ^a	0.021	5.25
Experimental 10	30	0.361 ^b	0.019	5.26

n – number of samples, \bar{x} – mean, SD – standard deviation, c_v – coefficient of variation,

a, b – value within a column compared between groups with different superscript letter is significantly different ($p < 0.05$).

Egg shell strength

Our results on the strength of egg shell are different compared to ones by **Khajali and Slomiński (2012)**. They argue that the quality of the egg shell was statistically significant in the control group compared with groups of laying hens, which fed feed with a share of industrial rapeseed products.

Table 6 Average egg shell strength.

Group	n	\bar{x} , N	SD	c_v , %
Control	30	33.1	1.36	4.11
Experimental 5	30	33.5	1.59	4.75
Experimental 10	30	33.8	1.72	5.09

n – number of samples, \bar{x} – mean, SD – standard deviation, c_v – coefficient of variation,

No significant differences between groups in shell strength between groups ($p > 0.05$).

Khajali and Slomiński (2012) reported on the base of experimental results that the values of quality indicators of egg shell were significantly higher ($p < 0.05$) in the control group compared with the indicators of quality of the egg shell hens that fed feed mixture with a share of industrial by-products of oilseed rape. It is believed that the presence of phytic acid in the by industrial oilseed rape forms an insoluble complex with the protein and some minerals, such as e.g. calcium, iron, zinc, manganese and magnesium in a biologically unavailable for laying hens. This complex in turn leads to difficulties in the use of these minerals, protein and other nutrients for the organism of laying hens (**Šašytė et al., 2006**). In addition, a high level of sulfur in rapeseed meal causes indigestion and absorption of calcium (**Summers et al., 1992**). Increasing the pH of the small intestine chyme is another reason that might have impact on the quality characteristics the egg shell, if rapeseed meal is fed, in comparison with the pH of the small intestine chime, if soybean meal is fed (**Zdunczyk et al., 2013**).

Oilseed rape is a farm significant crop suitable for cultivation in our country. Its products after industrial processing of seeds for oil are an important feed material for animals intended for food production. However, definite conclusions about their use as feed material require further investigation. Conclusions of existing experiments are not unanimous as to the extent of their inclusion in feed mixture in relation to the quality production of table eggs, or their safety.

CONCLUSION

Seeds of oilseed rape are an important raw material for obtaining oil. By-product after industrial processing has a

relatively high nutritional value. By-product may be classified as feed material for laying hens. More research is needed for single-valued recommendation of by-product share of oilseed rape in the feed mixture for laying hens. Oilseed rape and industrial by-products contain anti-nutrients according to literary knowledge.

In our work we focus on the verification of rape cake, for their use as feed for laying hens. Rape cakes were obtained as a by-product after pressing of seeds. By pressing of seeds was obtained oil to produce of biodiesel.

On the basis of evaluated results, we can state the following:

- share 5% of rapeseed cakes in the feed mixture had no statistically significant effect on egg weight, its component parts, egg shell thickness and strength,
- share 10% of rapeseed cakes in feed mixture statistically significant negative influenced on egg weight and measured values showed the greatest fluctuations in investigated indicators expressed as the standard deviation and coefficient of variation,
- the issue of the use of rapeseed cakes as feed is highly topical in terms of their production in obtaining of oil for human consumption and biodiesel,
- the conditions for inclusion of rapeseed cakes in the feed mixture for laying hens remain open for further research.

REFERENCES

- Angelovič, M., Tkáč, Z., Angelovič, M. 2013. Oilseed rape as feedstock for biodiesel production in relation to the environment and human health. *Potravinarstvo*, vol. 7, no. 1, p. 101-106. <http://dx.doi.org/10.5219/278>
- Angelovičová, M., Mihálik, V., Rataj, V. 1994. Stability of egg shell depends on nutrition of laying type of hens. *International Agrophysics*, vol. 8, no. 4, p. 607-610.
- Angelovičová, M. 1999. *Nutrition and feeding of high-productive poultry*. Nitra: SPU, 1999. 85 p. ISBN 80-7137-608-6.
- Angelovičová, M., Polačková, D. 2015. Assessment of welfare and egg production of laying hens Moravia SSL in small-scale breeding. *Potravinarstvo*, vol. 9, no. 1, p. 365-374. <http://dx.doi.org/10.5219/514>
- Ar, A., Rahn, H., Paganelli, C. V. 1979. The avian egg: mass and strength. *The Condor*, vol. 81, p. 331-337. <http://dx.doi.org/10.2307/1366955>
- Božík, M. 2007. Economy and prospects of growing oilseed rape in Slovakia and the EU. *Intensive cultivation of oilseed rape during periods of high demand*, no. 12, p. 2.
- Brand, T. S., Smith, N., Hoffman, L. C. 2007. Anti-nutritional factors in canola produced in the Western and Southern Cape areas of South Africa. *South African Journal of Animal Science*, vol. 37, no. 1, p. 45-50.
- Burel, C., Boujard, T., Kaushik, S. J., Boeuf, G., Mol, K. A., Van Der, G. S., Darras, V. M., Kuhn, E. R., Pradet-Balade, B., Quérat, B., Quinsac, A., Krouti, M., Ribaillier, D. 2001. Effects of rapeseed meal-glucosinolates on thyroid metabolism and feed utilization in rainbow trout. *General and Comparative Endocrinology*, vol. 124, no. 3, p. 343-358. <http://dx.doi.org/10.1006/gcen.2001.7723> PMID:11742518
- Capcarová, M., Kováčik, J., Mellen, M. 2009. *Changes of biochemical indicators in poultry blood after application of probiotics*. 1st ed. Nitra: SUA, 61 p. ISBN: 978-80-552-0206-8.
- Chen, S., Andreasson, E. 2001. Update of glucosinolate metabolism and transport. *Plant Physiology and*

Biochemistry, vol. 39, no. 9, p. 743-758.

[http://dx.doi.org/10.1016/S0981-9428\(01\)01301-8](http://dx.doi.org/10.1016/S0981-9428(01)01301-8)

Ciurescu, G. 2009. Efficiency of soybean meal replacement by rapeseed meal and/or canola seeds in commercial layer diets. *Archiva Zootechnica*, vol. 12, no. 1, p. 27-33.

Conaway, C. C., Yang, Y. M., Chung, F. L. 2002. Isothiocyanates as cancer chemopreventive agents: their biological activities and metabolism in rodents and humans. *Current Drug Metabolism*, vol. 3, no. 3, p. 233-255.

<http://dx.doi.org/10.2174/1389200023337496>

PMid:12083319

Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens. OJ L 203, 3.8.1999, p. 53-57.

Gheisari, A. A., Ghayor, P., Egbal-Saeid, S., Toghyani, M., Najafi, A. A. 2011. Effect of different dietary levels of rapeseed meal on reproductive performance of iranian indigenous breeder hens. *Asian Journal of Animal and Veterinary Advance*, vol. 6, no. 1, p. 62-70.

Ibrahim, I. K., Hill, R. 1980. The effects of rapeseed meals from brassica napus varieties and the variety tower on the production and health of laying fowl. *British Poultry Science*, vol. 21, no. 6, p. 423-430.

Jahreis, G. 2003. Physiological effects of plant oils in human nutrition (in German). *UFOP-Schriften, Öl-und Faserpflanzen*, vol. 20, p. 91-99.

Jahreis, G., Schöne, F. 2006. Rapeseed oil – physiologically particularly valuable chosen from oils (in German). In *Oil and proteinplants - The conference proceedings Oil 2005*, UFOP-Schriften, vol. 29, p. 7-17.

Janjecic, Z., Grbeša, D., Muzic, S., Curic, S., Rupic, V., Liker, B., Dikic, M., Antunovic, B., Zupanic, D. 2002. Influence of rapeseed meal on productivity and health of broiler chicks. *Acta Veterinaria Hungarica*, vol. 50, no. 1, p. 37-50.

<http://dx.doi.org/10.1556/AVet.50.2002.1.6>

PMid:12061234

Jeroch, H., Jankowski, J., Lipiec, A., Kozłowski, K., Matusevičius, P., Mikołajczak, J., Schöne, F. 2013a. *Rapeseed feedstuffs in animal nutrition* (in Polish). Olsztyn : UWM.

Jeroch, H., Simon, A., Zentek, J. 2013b. *Poultry nutrition* (in German). Stuttgart : Eugen Ulmer Verlag.

Khajali, F., Slominski, B. A. 2012. Factors that affect the nutritive value of canola meal for poultry. *Poultry Science*, vol. 91, no. 10, p. 2564-2575.

<http://dx.doi.org/10.3382/ps.2012-02332>

PMid:22991543

Klasing, K. C. 2005. Poultry nutrition: a comparative approach. *The Journal of Applied Poultry Research*, vol. 14, no. 2, p. 426-436.

Kocher, A., Choct, M., Porter, M. D., Broz, J. 2000. The effects of enzyme addition to broiler diets containing high concentration of canola or sunflower meal. *Poultry Science*, vol. 79, no. 12, p. 1767-1774.

<http://dx.doi.org/10.1093/ps/79.12.1767>

PMid:11194039

Kvasničková, A. 2010. The quality of eggs from conventional and organic production [online] Praha : Informative Centre of the Ministry of Agriculture [cit. 2015-09-08]. Available at: <http://www.bezpecnostpotravin.cz/kvalita-vajec-z-konvencni-a-bio-produkce.aspx>.

Labalette, F. R., Dauguet, S., Merrien, A., Peyronnet, C., Quinsac, A. 2011. Glucosinolate content, an important quality parameter monitored at each stage of the French rapeseed production chain. In *Proceeding 16th Rapeseed Congress*. Prague, Czech Republic, p. 438-442.

Leinonen, I., Williams, A. G., Kyriazakis, I. 2013. The effects of welfare-enhancing system changes on the environmental impacts of broiler and egg production. *Poultry Science*, vol. 93, no. 2, p. 256-266.

<http://dx.doi.org/10.3382/ps.2013-03252>

PMid:24570446

Mailer, R. J., Cornish, P. S. 1987. Effects of water stress on glucosinolates and oil concentrations in the seeds of rape (*Brassica napus* L.). *Australian Journal of Experimental Agriculture*, vol. 27, no. 5, p. 707-711.

<http://dx.doi.org/10.1071/EA9870707>

Mawson, R., Heaney, R. K., Zdunczyk, Z., Kozłowska, H. 1994a. Rapeseed mealglucosinolates and their antinutritional effects. Part 3. Animal growth and performance. *Nahrung*, vol. 38, no. 2, p. 167-177.

<http://dx.doi.org/10.1002/food.19940380209>

PMid:8196745

Mawson, R., Heaney, R. K., Zdunczyk, Z., Kozłowska, H. 1994b. Rapeseed meal-glucosinolates and their antinutritional effects. Part 4. Goitrogenicity and internal organs abnormalities in animals. *Nahrung*, vol. 38, no. 2, p. 178-191.

<http://dx.doi.org/10.1002/food.19940380210>

PMid:8196746

Mikulski, D., Jankowski, J., Zdunczyk, Z., Juskiewicz, J., Slominski, B. A. 2012. The effect of different dietary levels of rapeseed meal on growth performance, carcass traits and meat quality in turkeys. *Poultry Science*, vol. 91, no. 1, p. 215-223.

<http://dx.doi.org/10.3382/ps.2011-01587>

PMid:22184447

Mithen, R. F., Dekker, M., Verkerk, R., Rabot, S., Johnson, I. T. 2000. The nutritional significance, biosynthesis and bioavailability of glucosinolates in human food. *Journal of the Science of Food and Agriculture*, vol. 80, no. 7, p. 967-984.

[http://dx.doi.org/10.1002/\(SICI\)1097-0010\(20000515\)80:7<967::AID-JSFA597>3.0.CO;2-V](http://dx.doi.org/10.1002/(SICI)1097-0010(20000515)80:7<967::AID-JSFA597>3.0.CO;2-V)

PMid:11000000

Mushtaq, T., Sarwar, M., Ahmad, G., Mirza, M. A., Nawaz, H., Haroonmushtaq, M. M., Noreen, U. 2007. Influence of canola meal-based diets supplemented with exogenous enzyme and digestible lysine on performance, digestibility, carcass, and immunity responses of broiler chickens. *Poultry Science*, vol. 86, no. 10, p. 2144-2151.

<http://dx.doi.org/10.1093/ps/86.10.2144>

PMid:17878444

Najib, H., Al-Kateeb, S. A. 2004. The effect of incorporating different levels of locally produced canola seeds (*Brassica napus*, L.) in the diet of laying hen. *International Journal of Poultry Science*, vol. 3, no. 7, p. 490-496.

<http://dx.doi.org/10.3923/ijps.2004.490.496>

Newkirk, R. W. 2009. *Canola Meal Feed Industry Guide*. 4th ed. Canadian International. Grains Institute, Winnipeg, Manitoba.

Rataj, V. 1994. Determination of strength of agricultural materials by loading. *Zemědělská technika*, vol. 40, no. 2, p. 87-93.

Roth-Maier, D. A., Böhmer, B. M., Roth, F. X. 2004. Effects of feeding canola meal and sweet lupin (*L. luteus*, *L. angustifolius*) in aminoacid balance diets on growth performance and carcass characteristics of growing-finishing pigs. *Animal Research*, vol. 53, p. 21-34.

<http://dx.doi.org/10.1051/animres:2003048>

Riyazi, S. R., Ebrahimnezhad, Y., Nazeradl, K. Maheri-Sis, N., Salamatus, R., Vahdatpour, T. 2009. The effects of replacing soybean meal with different levels of rapeseed meal on egg quality characteristics of commercial laying hens. *Asian Journal of Animal and Veterinary Advance*, vol. 4, no. 6, p. 337-341.

<http://dx.doi.org/10.3923/ajava.2009.337.341>

- Šašytė, V. A., Gruzauskas, R., Mosenthin, R. 2006. Effect of phytase on P and Ca utilization at different age periods of laying hens fed higher amount of rapeseed meal. *Biologia*, vol. 1, p. 69-72.
- Smith, T. K., Campbell, L. D. 1976. Rapeseed meal glucosinolates: Metabolism and effect on performance in laying hens. *Poultry Science*, vol. 55, no. 3, p. 861-867. <http://dx.doi.org/10.3382/ps.0550861> [PMid:935053](https://pubmed.ncbi.nlm.nih.gov/935053/)
- Sparks, H. C. N. 2006. The hens egg – its role in human nutrition changing. *World's Poultry Science Journal* [online], vol. 62, no. 2, p. 308-315 [cit. 2015-09-12]. Available at: <http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=624024&fileId=S0043933906000201>.
- Summers, J. D., Sprat, D., Bedford, M. 1992. Sulfur and calcium supplementation of soybean and canola meal diets. *Canadian Journal of Animal Science*, vol. 72, no. 1, p. 127-133. <http://dx.doi.org/10.4141/cjas92-014>
- Takahashi, H., Yang, D., Sasaki, O., Furukawa, T., Nirasawa, K. 2009. Mapping of quantitative trait loci affecting eggshell quality on chromosome 9 in an F2 intercross between two chicken lines divergently selected for eggshell strength. *Animal Genetics*, vol. 40, no. 5, p. 779-782. <http://dx.doi.org/10.1111/j.1365-2052.2009.01914.x> [PMid:19780721](https://pubmed.ncbi.nlm.nih.gov/19780721/)
- Tripathi, M. K., Mishra, A. S. 2007. Glucosinolates in animal nutrition: A review. *Animal Feed Science and Technology*, vol. 132, no. 1-2, p. 1-27. <http://dx.doi.org/10.1016/j.anifeedsci.2006.03.003>
- USDA (United States Department of Agriculture), 2011. Oilseeds: World market and trade. *Circular Series*, FOP 11-12. 12. 2011.
- Widharna, R. M. 2012. Evaluation of means of reducing glucosinolate in canola meal. *Jurnal Medika Planta*, vol. 1, no. 5, p. 24-35.
- Wong, G. K., Liu, B., Wang, J., Zhang, Y., Yang, X., Zhang, Z., Meng, Q., Zhou, J., Li, D., Zhang, J., Ni, P., Li, S., Ran, L., Li, H., Zhang, J., Li, R., Li, S., Zheng, H., Lin, W., Li, G., Wang, X., Zhao, W., Li, J., Ye, C., Dai, M., Ruan, J., Zhou, Y., Li, Y., He, X., Zhang, Y., Wang, J., Huang, X., Tong, W., Chen, J., Ye, J., Chen, C., Wei, N., Li, G., Dong, L., Lan, F., Sun, Y., Zhang, Z., Yang, Z., Yu, Y., Huang, Y., He, D., Xi, Y., Wei, D., Qi, Q., Li, W., Shi, J., Wang, M., Xie, F., Wang, J., Zhang, X., Wang, P., Zhao, Y., Li, N., Yang, N., Dong, W., Hu, S., Zeng, C., Zheng, W., Hao, B., Hillier, L.W., Yang, S.P., Warren, W. C., Wilson, R. K., Brandström, M., Ellegren, H., Crooijmans, R. P., van der Poel, J. J., Bovenhuis, H., Groenen, M. A., Ovcharenko, I., Gordon, L., Stubbs, L., Lucas, S., Glavina, T., Aerts, A., Kaiser, P., Rothwell, L., Young, J. R., Rogers, S., Walker, B. A., van Hateren, A., Kaufman, J., Bumstead, N., Lamont, S. J., Zhou, H., Hocking, P. M., Morrice, D., de Koning, D. J., Law, A., Bartley, N., Burt, D. W., Hunt, H., Cheng, H. H., Gunnarsson, U., Wahlberg, P., Andersson, L., Kindlund, E., Tammi, M. T., Andersson, B., Webber, C., Ponting, C. P., Overton, I. M., Boardman, P. E., Tang, H., Hubbard, S. J., Wilson, S. A., Yu, J., Wang, J., Yang, H. 2004. A genetic variation map for chicken with 2.8 million single – nucleotide polymorphisms. International Chicken Polymorphism Map Consortium. *Nature*, vol. 432, no. 7018, p. 717-722. <http://dx.doi.org/10.1038/nature03156> [PMid:15592405](https://pubmed.ncbi.nlm.nih.gov/15592405/)
- Zduńczyk, Z., Jankowski, J., Juśkiewicz, J., Mikulski, D., Slominski, B. A. 2013. Effect of different dietary levels of low-glucosinolate rapeseed (canola) meal and non-starch polysaccharide-degrading enzymes on growth performance and gut physiology of growing turkeys. *Canadian Journal of Animal Science*, vol. 93, p. 353-362.

Acknowledgments:

The research leading to these results has received funding from the European Community under project no 26220220180: Building Research Centre „Agrobiotech“.

Contact address:

Mária Angelovičová, Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Department of Hygiene and Food Safety, Tr. A. Hlinku 2, 949 76 Nitra Slovakia, E-mail: maria.angelovicova@gmail.com.

Michal Angelovič, Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Transport and Handling, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: michal.angelovic@gmail.com.

Juraj Jablonický, Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Transport and Handling, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: juraj.jablonicky@uniag.sk.

Zdenko Tkáč, Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Transport and Handling, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: zdenko.tkac@uniag.sk.

Marek Angelovič, Slovak University of Agriculture in Nitra, Faculty of Engineering, Department of Machines and Production Systems, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, E-mail: marek.angelovic@uniag.sk.