

## Performances and Egg Quality of Laying Ducks Fed Diets Containing Cassava (*Manihot esculenta* Crantz) Leaf Meal and Golden Snail (*Pomacea canaliculata*)

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### ABSTRACT

The objective of this study was to evaluate the effect of feeding cassava leaf meal and golden snail on performances, chemical, and physical qualities of local duck egg. The experiment used 180 Pajajaran laying ducks of 20 weeks of age and was offered dietary treatments up to 26 weeks of age. The experiment was conducted in a completely randomized design with a 3 x 2 factorial arrangement. The first factor was the treatment of cassava leaf meal consisted of 3 levels, i.e., 0%, 5%, and 10%. The second factor was the treatment of golden snail consisted of 2 levels, i.e., 0% and 10%. Each experimental unit used three replicates and each replicate consisted of ten ducks. The results showed that there was no interaction effect of cassava leaf meal and golden snail treatments on laying duck performances and egg qualities. There were significant effects of cassava leaf meal and golden snail treatments ( $p < 0.05$ ) on egg production, feed intake, egg mass, egg index, and egg yolk color. However, egg weight, feed conversion ratio, yolk fat, yolk cholesterol, and yolk TBARS values, albumen weight, eggshell weight, shell thickness, and Haugh unit values were not affected ( $p > 0.05$ ) by treatments of cassava leaf meal and golden snail. The utilization of 10% cassava leaf meal in the diet significantly improved egg production, feed intake, egg mass, and yolk color ( $p < 0.05$ ). The lowest egg index was found in the eggs produced by ducks fed diet containing 5% cassava leaf meal, but it is still within the normal range. Ducks fed a diet containing 5% golden snail significantly had higher feed intake, egg mass, percentage of albumen, and yolk color. It was concluded that there was no interaction effect of cassava leaf meal and golden snail treatments on laying duck performances and egg qualities. A diet containing 10% cassava leaf meal or a diet containing 5% golden snail had the greatest effects on the performance and physical quality of egg without affecting the chemical quality of the egg.

**Keywords:** cassava leaf meal; laying ducks; golden snail; performances; egg quality

### INTRODUCTION

Most laying ducks in Indonesia are raised in a traditional system with low productivity because of limited availability and quality of diet (Widiyaningrum *et al.*, 2016). In addition, duck eggs also contain as much as 450 mg of cholesterol per 50 g of duck egg (Chaiyasit *et al.*, 2019). This high cholesterol content causes consumers to avoid duck egg consumption based on the belief that it raises blood cholesterol.

Dietary of cassava leaf meal (*Manihot esculenta* Crantz) and golden snail (*Pomacea canaliculata*) as local ingredients have a great potential to be used to improve diet quality of laying duck, laying duck performances, and egg qualities as well as to decrease egg cholesterol content. The great quality of diet will be achieved through the use of high quality ingredients with high protein and other active compounds contents. According to Oresangun *et al.* (2016), cassava leaf contains 298.00 µg/g to 816.92 µg/g beta carotene. Beta carotene is one of carotenoid with a yellow-orange pigment which is more common in the plant's leaves (Çalışlar,

2019) and it is closely related to the color of egg yolk (Bovšková *et al.*, 2014). Beta carotene has an important role in reducing free radicals (Fiedor & Burda, 2014) and the formation of egg follicles (Palupi *et al.*, 2018). In this study, beta carotene in cassava leaf meal as a natural antioxidant is expected to protect fatty acids from oxidation, which is indicated by the decreased Thiobarbituric Acid Reactive Substances (TBARS) levels (mg MDA/kg). According to Dauqan *et al.* (2013), malondialdehyde (MDA) is one of the markers for final products of polyunsaturated fatty acids peroxidation. Moreover, cassava leaf meal also contains high protein that can increase egg production. Cassava leaf meal contains 86.25% of dry matter, 25.81-39.90% of crude protein, and 16.28% of crude fiber (Nnaji *et al.*, 2010; Ukanwoko & Ukandu, 2011; Zanu & Avukpor, 2013). However, it contains low sulfur amino acids, such as methionine and tryptophan (Adeyemi *et al.*, 2012). Cassava leaf meal can be combined with golden snail to increase the protein quality and fatty acids in the diet. Golden snail is rice pests, which is difficult to eradicate because it can reproduce rapidly and survive in the dry land for the long term.

Golden snails contain high unsaturated fatty acids such as oleic acid (20.37%), linoleic acid (20.26%), linolenic acid (12.83%) (Subhan *et al.*, 2010), and crude protein (48.5%), whereas the proportion of essential amino acids is 39.7% (Ghosh *et al.*, 2017). The combination of cassava leaf meal and the golden snail is expected to provide a good quality protein, beta carotene, and unsaturated fatty acid of diet to increase egg production performances and egg qualities. This study aimed to evaluate the effect of cassava leaf meal combined with the golden snail on performances as well as the chemical and physical qualities of egg.

## MATERIALS AND METHODS

### Animal and Dietary Treatment

The experiment used 180 Pajajaran laying ducks of 20 weeks of age and was offered dietary treatments up to 26 weeks of age. The experiment was conducted in a completely randomized design with a 3 x 2 factorial arrangement. The first factor was cassava leaf meal treatment consisted of 3 levels, i.e., 0%, 5%, and 10%. The second factor was golden snail treatment consisted of 2 levels, i.e., 0% and 5%. Each experimental unit was replicated 3 times and each replicate consisted of ten laying ducks. The ducks were allocated randomly in a floor pen with 1 cm x 2 cm x 1 cm of cages. The diet and drinking water were provided ad libitum.

The diet ingredients used were corn, rice bran, soybean meal, cassava leaf meal, fish meal, golden snail, fish oil, CaCO<sub>3</sub>, NaCl, premix, and DL-Methionine (Table 1). The nutritional requirement of laying duck

was arranged based on isocaloric and isoprotein that contains a minimum of 2,850 kcal/kg of metabolizable energy and 16% of protein (Lesson & Summers, 2005).

### Variables and Sampling

The variables measured were duck performances, physical quality of the egg, and chemical quality of the egg. The performance variables measured included feed intake (g/bird/day), feed conversion ratio, egg mass (g/bird/day), egg weight (g/egg), and egg quality. Egg weight and egg production were recorded daily. The physical quality variables measured included haugh unit, egg index, percentage of eggshell weight, eggshell thickness, percentage of yolk weight, percentage of albumen weight, and yolk color. The variables were taken from three eggs from each replicate at 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup>, and 6<sup>th</sup> of the week. Egg weight, yolk weight, eggshell weight, and albumen weight were measured using an electronic digital balance. The eggshell thickness and albumen thickness was measured by a digital micrometer. The eggshell index was calculated as the ratio of the egg width to the egg length multiplied by 100%. The yolk color was measured using the Roche color fan. The Haugh unit was calculated using the Haugh formula (Haugh, 1937).

$$\text{Haugh Unit} = 100 \log (H - 1.7 W^{0.37} + 7.57)$$

where H was Albumen thickness (mm) and W was weight of the entire egg (g).

The variables of egg chemical quality measured included yolk cholesterol, yolk lipid, and Thiobarbituric

Table 1. Ingredients and nutrient content of the treatment diet (as fed)

Ingredients (%)	Treatments					
	R0	R1	R2	R3	R4	R5
Corn	54.20	52.00	52.30	50.00	50.50	48.00
Rice bran	9.80	13.20	8.70	12.00	7.50	11.00
Soybean	18.60	13.00	16.80	11.40	15.00	10.20
Cassava leaf meal	0.00	0.00	5.00	5.00	10.00	10.00
Golden snail	0.00	5.00	0.00	5.00	0.00	5.00
Fish meal	7.00	7.00	7.00	7.00	7.00	6.50
Fish oil	3.00	3.00	3.00	3.00	3.00	3.00
CaCO <sub>3</sub>	6.60	6.00	6.40	5.80	6.20	5.50
NaCl	0.20	0.20	0.20	0.20	0.20	0.20
Premix	0.50	0.50	0.50	0.50	0.50	0.50
DL-Methionine	0.10	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Nutrient content (%)						
Dry matter	88.08	88.34	86.17	87.25	88.95	89.32
Crude protein	18.01	18.08	18.04	18.17	18.02	18.09
Crude fiber	7.36	5.43	4.05	6.51	7.57	6.25
Crude fat	5.85	4.44	0.78	1.31	3.00	4.71
Calcium	2.10	2.38	2.56	2.94	3.28	3.80
Phosphorus	0.75	0.77	0.80	0.82	0.82	0.89
Metabolizable energy (kcal/kg)	2851.44	2851.78	2851.3	2852.98	2851.45	2851.18

Note: R0= 0% of cassava leaf meal and 0% golden snail; R1= 0% of cassava leaf meal and 5% of golden snail; R2= 5% of cassava leaf meal and 0% of golden snail; R3= 5% of cassava leaf meal and 5% of golden snail; R4= 10% of cassava leaf meal and 0% of golden snail; R5= 10% of cassava leaf meal and 5% of golden snail.

Acid Reactive Substances (TBARS) value. Yolk cholesterol was determined at the end of the study by using three eggs for each replicate. These sample eggs were taken randomly and analyzed using the Liebermann Burchard method. Egg yolk lipid peroxidation value was determined using Thiobarbituric Acid Reactive Substances by the method of Rice-Evans & Anthony (1991). The absorbance was read using a spectrophotometer (Hitachi U-2001, Japan).

### Statistical Analysis

The study used a completely randomized design with a 3 x 2 factorial assignment with three replicates and each replication used 10 laying ducks. The data were subjected to analysis of variance (ANOVA) on main and interaction effects. When a significant effect of treatment was found, Duncan's Multiple Range Test was used to determine the significant difference among mean values. Analysis of variance was performed using SPSS vr.21.0 program.

### RESULTS

No interaction effect of the usages of cassava leaf meal and golden snail was found on laying duck performances and egg qualities (Table 2). There were significant effects ( $p < 0.05$ ) of cassava leaf meal and golden snail treatments on egg production, feed intake, egg mass, egg index, and egg yolk color. The treatments of cassava leaf meal and golden snail did not give a significant effect on egg weight, feed conversion ratio, yolk fat, cholesterol, TBARS values, albumen weight, eggshell weight, shell thickness, and Haugh unit value. The best egg production ( $p < 0.05$ ) was found in the ducks fed a diet containing 10% cassava leaf meal (67.27%) compared to ducks fed a diet containing 5% cassava leaf meal (63.30%) and 0% cassava leaf meal (64.36%). The highest feed intake was found ( $p < 0.05$ ) in ducks fed a diet containing 10% cassava leaf meal

(184.55 g/day/bird) compared to ducks fed a diet without cassava leaf meal (174.46 g/day/bird). In addition, egg mass produced by duck fed diet containing 10% cassava leaf meal (44.22 g/day/bird) was higher than those produced by ducks fed a diet containing 5% cassava leaf meal (41.93 g/day/bird) which was statistically similar to the treatment without cassava leaf meal. Ducks fed a diet containing 5% golden snail had better ( $p < 0.05$ ) feed intake (182.52 g/day/bird) than those fed diets without golden snail (173.54 g/day/bird). The use of 5% golden snail in the diet also increased ( $p < 0.05$ ) egg mass compared to treatment without golden snail (Table 2).

The effects of cassava leaf meal and golden snail dietary on chemical and physical qualities of the egg are shown in Table 3 and Table 4. The lowest egg index ( $p < 0.05$ ) was found in ducks fed a diet containing 5% cassava leaf meal (79.07%) compared to those fed diet containing 10% cassava leaf meal (79.93%) and diet without cassava leaf meal (82.75%), but it is still within the normal range. Yolk color in eggs produced by ducks fed a diet containing 5% or 10% cassava leaf meal was higher ( $p < 0.05$ ) than those produced by ducks fed a diet without cassava leaf meal. A diet containing 5% golden snail significantly ( $p < 0.05$ ) increased the percentage of albumen compared to diet without golden snail. Ducks fed a diet containing 5% golden snail also very significantly ( $p < 0.01$ ) had higher egg yolk color compared to ducks fed a diet without golden snail.

### DISCUSSION

#### Performances of Laying Duck

The previous studies had reported that cassava leaf meal and the golden snail could be fed to laying duck and broiler chicken without negative effects on performances. Inclusion of 10% cassava leaf meal in the diet of laying hens (Zanu & Avukpor, 2013), 20% cassava leaf meal in broiler diets (Abu *et al.*, 2015) did not result in any adverse effects on performances. The golden apple

Table 2. Performance of laying ducks at 26 weeks of age

Variables	Golden snail (%)	Cassava leaf meal (%)			Average
		0	5	10	
Egg production (%)	0	62.16±1.38	63.77± 3.08	66.28± 0.85	64.07± 2.51
	5	66.56±2.26	62.84± 3.25	68.26± 1.83	65.88± 3.24
	Average	64.36±2.93 <sup>a</sup>	63.30± 2.88 <sup>a</sup>	67.27± 1.68 <sup>b</sup>	64.97± 2.96
Egg weight (g/egg)	0	64.66±1.67	66.11± 1.95	65.93± 2.50	65.57± 1.92
	5	66.53±2.31	66.45± 0.85	65.50± 2.35	66.20± 1.78
	Average	65.60±2.07	66.28± 1.36	65.71± 2.18	65.86± 1.82
Feed intake (g/day/bird)	0	170.18±8.38	164.63± 6.01	185.81±11.45	173.54±12.24 <sup>a</sup>
	5	178.73±9.23	185.52± 2.99	183.30± 3.05	182.52± 5.90 <sup>b</sup>
	Average	174.46±9.17 <sup>a</sup>	175.07±12.20 <sup>ab</sup>	184.55± 7.62 <sup>b</sup>	178.03±10.41
Egg mass (g/day/bird)	0	40.18±0.24	42.12± 0.97	43.70± 1.86	41.99± 1.86 <sup>a</sup>
	5	44.25±0.46	41.75± 1.90	44.74± 2.82	43.57± 2.21 <sup>b</sup>
	Average	42.21±2.25 <sup>ab</sup>	41.93± 1.36 <sup>a</sup>	44.22± 2.21 <sup>b</sup>	42.27± 2.13
Feed conversion ratio	0	4.24±0.23	3.91± 0.09	4.25± 0.27	4.13± 0.25
	5	4.04±0.17	4.45± 0.26	4.11± 0.30	4.20± 0.29
	Average	4.14±0.21	4.18± 0.34	4.18± 0.27	4.17± 0.26

Note: Means in the same row or column on each variable with different superscripts differ significantly ( $p < 0.05$ ).

Table 3. Fat, cholesterol, and thiobarbituric acid reactive substances (TBARS) value of egg yolk

Variables	Golden snail (%)	Cassava leaf meal (%)			Average
		0	5	10	
Fat (%)	0	31.88±0.44	30.86±1.11	29.61±2.71	30.78±1.77
	5	30.54±1.92	30.67±3.17	31.12±0.63	30.78±1.89
	Average	31.21±1.44	30.76±2.13	30.36±1.94	30.78±1.78
Cholesterol (mg/g)	0	2.04±0.56	1.47±0.48	1.13±0.01	1.55±0.54
	5	1.56±0.55	1.62±0.39	1.43±0.29	1.54±0.37
	Average	1.80±0.56	1.55±0.40	1.28±0.24	1.54±0.45
TBARS (µgMDA/g)	0	10.36±2.23	8.97±5.35	6.26±2.45	8.53±3.62
	5	8.23±2.22	9.90±3.50	9.07±2.29	9.07±2.48
	Average	9.30±2.31	9.44±4.08	7.67±2.62	8.80±3.03

Table 4. Physical egg quality of laying duck

Variables	Cassava leaf meal (%)	Golden snail (%)		Average
		0	5	
Egg index (%)	0	82.61±3.12	82.89±1.51	82.75±2.20 <sup>a</sup>
	5	80.17±1.94	77.98±1.25	79.07±1.89 <sup>b</sup>
	10	80.14±1.30	79.72±1.90	79.93±1.47 <sup>ab</sup>
	Average	80.97±2.30	80.20±2.55	80.58±2.39
Albumen weight (%)	0	50.91±2.85	54.40±2.09	52.46±2.89
	5	53.40±4.69	48.05±2.95	50.73±2.99
	10	48.93±5.47	53.71±3.76	52.24±3.56
	Average	51.08±2.38 <sup>a</sup>	52.06±4.14 <sup>b</sup>	51.37±3.25
Eggshell weight (%)	0	12.33±0.39	12.14±0.82	12.27±0.56
	5	11.99±0.16	12.12±0.30	12.08±0.22
	10	12.28±0.73	12.92±1.54	12.83±1.04
	Average	12.20±0.43	12.39±0.95	12.39±0.73
Shell thickness (mm)	0	0.39±0.03	0.39±0.02	0.39±0.02
	5	0.37±0.02	0.38±0.04	0.38±0.03
	10	0.42±0.01	0.44±0.02	0.44±0.02
	Average	0.39±0.03	0.40±0.04	0.40±0.03
Haugh unit	0	91.99±2.74	91.38±7.23	90.73±4.18
	5	91.38±7.23	91.70±2.89	90.11±3.74
	10	90.00±1.25	93.53±4.26	92.81±2.76
	Average	91.12±3.31	92.21±3.97	91.22±3.59
Yolk color score	0	5.56±1.07	7.44±0.51	6:50±1.34 <sup>a</sup>
	5	6.78±0.38	8.89±0.19	7.89±1.06 <sup>b</sup>
	10	7.78±0.51	7.89±0.19	7.89±0.33 <sup>b</sup>
	Average	6.70±1.20 <sup>A</sup>	8.07±0.66 <sup>B</sup>	7.41±1.18

Note: Means in the same row or column on each variable with different lowercase superscripts differ significantly ( $p < 0.05$ ). Means in the same row with different uppercase superscripts differ significantly ( $p < 0.01$ ).

snail was reported to be able to improve egg yolk color (Syaharuddin *et al.*, 2019). Galon *et al.* (2017) reported that a diet containing cassava leaf meal improved the egg production.

In the present study, the use of 10% cassava leaf meal improved egg production and feed intake. Diet supplemented with 5% golden snail also increased feed intake and egg mass. This study resulted in a better egg weight (65.86 g/egg) than reported by Darmawan *et al.* (2013). This effect was due to the highest feed intake in diet supplemented with cassava leaf meal (184.6 g/bird) so that it led to an adequate nutritional intake for egg formation. According to Olarotimi & Adu (2017), inad-

equacies in nutrients supply will lead to a decrease in egg production as well as a decline in the growth performance of broiler. Cassava leaves contained high crude protein, minerals (zinc, iron, magnesium, and calcium), vitamins such as riboflavin, niacin, thiamin, vitamin A (Ukanwoko & Ukandu, 2011; Zanu & Avukpor, 2013), and 298.00 µg/g to 816.92 µg/g beta carotene (Oresegun *et al.*, 2016) that were needed for improving the egg production. According to Viana *et al.* (2017), the protein in the diet is important for the yolk and albumen synthesis and formation. Nassiri *et al.* (2012) also state that methionine is the first limiting amino acid for egg weight. Also, beta carotene also increased vitamin A formation.

Palupi *et al.* (2015) state that beta carotene in the rations will be converted into vitamin A that is needed in the synthesis of steroid hormones and the development of egg yolks.

### Chemical and Physical Quality of Egg

Fat content, egg cholesterol, and TBARS values were not influenced by dietary of cassava leaf meal and golden snail. Egg cholesterol content was lower than that reported by Sumiati *et al.* (2016), who used fish oil and vitamin E and Zinc mineral as an antioxidant. Low cholesterol (1.28 mg/g) and TBARS value (7.67 µgMDA/g) in eggs produced by ducks fed a diet containing 10% cassava leaf meal indicates that beta carotene in cassava leaf meal can act as an antioxidant. In the present study, beta carotene might be effectively protected unsaturated fatty acids (omega-3 and omega-6) from the oxidation. Omega-3 fatty acids can reduce the concentration of triglyceride by inhibiting the secretion of low-density lipoprotein (LDL) cholesterol in the liver (Innes & Calder, 2018). Carotenoids can decrease cholesterol synthesis through inhibition of the enzyme 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) activity (Palozza *et al.*, 2012; Salem, 2015).

The treatment using 5% cassava leaf meal reduced the egg index (79.07%), but it was still within the normal range. This decreased in the egg index may be due to the increase in egg weight of eggs produced by ducks fed diet containing 5% cassava leaf meal. According to Begli *et al.* (2010) and Yilmaz *et al.* (2011), there is a negative correlation between egg weight and shape index. According to Srigandono (1991), a normal duck egg index ranged between 63.30% to 81.70%. The egg will be more round and vice versa, with the greater the index number of the egg shape (Shoimah *et al.*, 2019). The egg shape in the oviduct is under genetic and hormonal control (Sah & Mishra, 2018) during the formation of eggs. The treatment of 5% golden snail increased the percentage of albumen. This increased percentage of albumen was probably caused by high protein and essential amino acids content in golden snail (Subhan *et al.*, 2010; Ghosh *et al.*, 2017) as a protein constituent in albumen with an average amount of 8.8% to 12.15% (Quan & Benjakul, 2018; Chaiyasit *et al.*, 2019). According to Huang & Lin (2011), the main proteins in duck albumen are ovalbumin (40%), ovotransferrin (2%), ovomucoid (10%), lysozyme (1.2%), and ovomucin(3%). The average of eggshell weight ranged from 11.99% to 12.92% and eggshell thickness ranged from 0.37 mm to 0.44 mm. The standard of eggshell weight was 11% to 13% (Huang & Lin, 2011). According to Śiątkiewicz *et al.* (2015), Ca is the most important nutritional factor to determine the eggshell quality, and 95% of the shell is made up of calcium carbonate. The Haugh unit score in the present study was higher than those reported by Fouad *et al.* (2016) and Chaiyasit *et al.* (2019), which were 72.20 and 66.28, respectively. USDA categorizes for haugh unit of 72 or higher is AA quality grade for a chicken egg, and there is no standard for a duck egg (Chaiyasit *et al.*, 2019) and a high score of the haugh unit

indicates fresh egg with a thick albumen (Lee *et al.*, 2016; Chaiyasit *et al.*, 2019).

Dietary containing 5% cassava leaf meal significantly increased the egg yolk color score from 6.50 to 7.83. The use of 5% golden snail also increased the egg yolk color score from 6.70 to 8.07. The increasing yolk color score was caused by carotenoids in cassava leaf meal and golden snail. Beta carotene is a yellow-orange pigment, which is closely related to egg yolk color (Hien *et al.*, 2016). This result was in line with the result reported by Syaharuddin *et al.* (2019) that the golden apple snail was able to improve the egg yolk color. Galon *et al.* (2017) also reported that cassava leaf meal significantly increased the yolk color.

### CONCLUSION

It is concluded that there was no interaction effect of cassava leaf meal and golden snail treatments on laying duck performance and egg qualities. Dietary containing 10% cassava leaf meal or 5% golden snail had the greatest effect on the performance and physical quality of egg without affecting the chemical quality of the egg.

### CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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### REFERENCES

- Abu, A. O., I. F. Olaleru, & A. B. Omojola. 2015. Carcass characteristics and meat quality of broilers fed cassava peel and leaf meals as replacements for maize and soya-bean meal. *J. Agric.Vet. Sci. Ver.* 8: 2319-2372. <https://doi.org/10.9790/2380-08324146>
- Adeyemi, O. A., J. A. Adekoya, & R. Abayomi. 2012. Performance of broiler chickens fed diets containing cassava leaf : blood meal mix as replacement for soybean meal. *Rev. Cient. Agríc.* 12: 212-219.
- Begli, H. E., S. Zerehdaran, S. Hassani, M. A. Abbasi, & A. R. K. Ahmadi. 2010. Heritability, genetic and phenotypic correlations of egg quality traits in Iranian Native Fowl. *British. Poult. Sci.* 51: 740-744. <https://doi.org/10.1080/00071668.2010.528750>
- Bovšková, H., K. Míková, & Z. Panovská. 2014. Evaluation of egg yolk colour. *Czech. J. Food Sci.* 32: 213-217. <https://doi.org/10.17221/47/2013-CJFS>
- Çalışlar, S. 2019. The Important of beta carotene on poultry nutrition. *Selcuk. J .Agric. Food. Sci.* 33: 252-259. <https://doi.org/10.15316/SJA.FS.2019.185>
- Chaiyasit, W., R. G. Brannan, D. Chareonsuk, & W. Chanasattru. 2019. Comparison of physicochemical and functional

- properties of chicken and duck egg albumens. *Braz. J. Poult. Sci.* 21: 1-10. <https://doi.org/10.1590/1806-9061-2017-0705>
- Darmawan, A., K. G. Wiryawan, & Sumiati.** 2013. Egg production and quality of magelang duck fed diets containing different ratio of omega 3 : omega 6 and organic Zn. *Med. Pet.* 36: 197-202. <https://doi.org/10.5398/medpet.2013.36.3.197>
- Dauqan, E., A. Abdullah, & H. A. Sani.** 2013. Lipid peroxidation in rat liver using different vegetable oils. *The Malay. J. Analytical. Sci.* 17: 300-309.
- Fiedor, J. & K. Burda.** 2014. Potential role of carotenoids as antioxidants in human health and disease. *Nutr.* 6: 466-488. <https://doi.org/10.3390/nu6020466>
- Fouad, A. M., D. Ruan, Y. C. Lin, C. T. Zheng, H. X. Zhang, W. Chen, S. Wang, W. G. Xia, W, & Y. Li.** 2016. Effects of dietary methionine on performance, egg quality and glutathione redox system in egg-laying ducks. *Brit. Poult. Sci.* 57: 818-823. <https://doi.org/10.1080/00071668.2016.1222603>
- Galon, E. M., D. Lorenzo, & F. Claveria.** 2017. Growth and egg production performance of Dekalb layers (*Gallus gallus domesticus*) supplemented with cassava leaf meal (*Manihot esculenta Crantz*). *Asian J. Agric. Biol.* 5: 83-87.
- Ghosh, S., C. Jung, & V. B. Meyer-Rochow.** 2017. Snail as mini-livestock: nutritional potential of farmed *Pomacea canaliculata* (*Ampullariidae*). *Agric. Natur. Res.* 51: 504-511. <https://doi.org/10.1016/j.anres.2017.12.007>
- Haugh, R. R.** 1937. A new method for determining the quality of an egg. *US Poultry Magazine.* 39: 27-49.
- Hien, T. Q., N. D. Hoan, T.T. Hoan, & T. Q. Trung.** 2016. Relation between carotenoids content in egg yolk and hatching egg quality according to the time laying hens are fed diet containing leaf meal. *Bulgarian. J. Agric. Sci.* 22 (Supple. 1): 92-98.
- Huang, J. F. & C. C. Lin.** 2011. Production, Composition, and Quality of Duck Eggs. Woodhead Publishing Limited. <https://doi.org/10.1533/9780857093912.4.487>
- Innes, J. K, & P. C. Calder.** 2018. The differential effects of eicosapentaenoic acid and docosahexaenoic acid on cardiometabolic risk factors: A systematic review. *Int. J. Mol. Sci.* 19: 532. <https://doi.org/10.3390/ijms19020532>
- Lee, M. H., E. J. Cho, E. S. Choi, & S. H. Sohn.** 2016. The effect of storage period and temperature on egg quality in commercial eggs. *Korean. J. Poult. Sci.* 43: 31-38. <https://doi.org/10.5536/kjps.2016.43.1.31>
- Lesson, S. & J. D. Summers.** 2005. Commercial Poultry Nutrition. 3<sup>rd</sup> Ed. Department of Animal and Poultry Science, University of Guelph. University Books, Guleph.
- Nassiri, M. H., M. K. Fard, M. J. Agah, S. J. Hosseini, & M. T. Mirakzehi.** 2012. Effect of different levels of methionine, protein and tallow on the productive performance and egg quality of laying hens in the late-phase production. *Rev. Bras. de Ciencia Avic.* 14: 149-158. <https://doi.org/10.1590/S1516-635X2012000200010>
- Nnaji, J.C., F. C. Okoye, & V. O. Omeje.** 2010. Screening of leaf meals as feed supplements in the culture of *Oreochromis niloticus*. *Afric. J. Food. Agric. Nutr. Develop.* 10: 2112-2123. <https://doi.org/10.4314/ajfand.v10i2.53354>
- Olarotimi, O. J. & O. A. Adu.** 2017. Potentials of non-conventional protein sources in poultry nutrition. *Arch. de Zoot.* 66: 287-299. <https://doi.org/10.21071/az.v66i255.2524>
- Oresegun, A., O. A. Fagbenro, P. Ilona, & E. Bernard.** 2016. Nutritional and anti-nutritional composition of cassava leaf protein concentrate from six cassava varieties for use in aquafeed. *Cogent Food. Agric.* 2: 1-6. <https://doi.org/10.1080/23311932.2016.1147323>
- Palozza, P., A. Catalano, R. E. Simone, M. C. Mele, & A. Cittadini.** 2012. Effect of lycopene and tomato products on cholesterol metabolism. *Ann. Nutr. Met.* 61: 126-134. <https://doi.org/10.1159/000342077>
- Palupi, R., L. Abdullah, D. A. Astuti, & Sumiati.** 2015. Potential and utilization of *Indigofera* sp shoot leaf meal as soybean meal substitution in laying hen diets. *J. Ilmu Ter. Vet.* 19: 210-219. <https://doi.org/10.14334/jitv.v19i3.1084>
- Palupi, R., F. N. Lubis, R. Rismawati, I. Sudiby, & R. A. R. Siddiq.** 2018. Effect of *Indigofera zollingeriana* top leaf meal supplementation as natural antioxidant source on production and quality of pegagan duck eggs. *Bul. Pet.* 42: 301-307. <https://doi.org/10.21059/buletinpeternak.v42i4.22881>
- Quan, T. H. & S. Benjakul.** 2018. Quality, protease inhibitor and gelling property of duck egg albumen as affected by storage conditions. *J. Food Sci. Tech.* 55: 513-522. <https://doi.org/10.1007/s13197-017-2960-6>
- Rice-Evans, C. & T. D. Anthony.** 1991. Techniques in Free Radical Research. Elsevier. pp. 146-202.
- Sah, N. & B. Mishra.** 2018. Regulation of egg formation in the oviduct of laying hen. *World's Poult. Sci. J.* 74: 509-522. <https://doi.org/10.1017/S0043933918000442>
- Salem, S.** 2015. Effect of two carotenoids (Lycopene and  $\beta$ -Carotene) supplementation on hyperlipidemia and lipid peroxidation in experimental albino rats. *J. High. Inst. Pub. Health* 45: 1-7. <https://doi.org/10.21608/jhiph.2015.20262>
- Shoimah, D., I. H. Djunaidi, & O. Sjoefjan.** 2019. Quality of duck eggs maintained using a different maintenance system in the Malang Raya area. *Int. Res. J. Adv. Eng. Sci.* 4: 273-277.
- Śiątkiewicz, S., A. Arczewska-Włosek, J. Krawczyk, M. Puchała, & D. Józefiak.** 2015. Effects on performance and eggshell quality of particle size of calcium sources in laying hens' diets with different Ca concentrations. *Archiv. Tierzucht.* 58: 301-307. <https://doi.org/10.5194/aab-58-301-2015>
- Srigandono, B.** 1991. The Science of Waterfowl. Gadjah Mada University Press, Indonesia.
- Subhan, A., T. Yuwanta, H. P. S. Jafendi, & E. S. Rohaeni.** 2010. Pengaruh pemberian kombinasi sagu kukus (*Metroxylon* Spp) dan tepung keong mas (*Pomacea* Spp) sebagai pengganti jagung kuning terhadap penampilan itik jantan Alabio, Mojosari dan MA. *J. Ilmu Ter. Vet.* 15: 165-173.
- Sumiati, A. Darmawan, & K. G. Wiryawan.** 2016. Egg quality and blood hematology of magelang laying duck fed with diets containing different ratios of omega 3 and omega 6 fatty acids and organic Zn. *Int. J. Poult. Sci.* 15: 448-453. <https://doi.org/10.3923/ijps.2016.448.453>
- Syahrudin, N., R. Rasdyanah, D. K. Sari, W. S. Monica, & A. W. Jamaluddin.** 2019. Combination effect of golden snail powder and fermented coconut cake on quality of duck eggs. *J. Ind. Vet. Res.* 3: 47-56. <https://doi.org/10.20956/jrv.v3i2.6627>
- Ukanwoko, A. I. & C. Ukandu.** 2011. Proximate composition of cassava peels ensiled with cassava, gliricidia and Leucaena leaf meals prepared under a humid environment. *Continental J. Animal and Veterinary Research.* 3: 36-40.
- Viana, E. de F., J. H. Stringhini, F. B. de Carvalho, D. M. P. Viana, & M. A. da Costa.** 2017. Effects of crude protein levels on egg quality traits of brown layers raised in two production systems. *Rev. Bras. de Zoo.* 46: 847-855. <https://doi.org/10.1590/S1806-92902017001100003>
- Widiyaningrum, P., Lisdiana, & N. R. Utami.** 2016. Egg production and hatchability of local ducks under semi intensive vs extensive managements. *J. Ind. Trop. Anim. Agric.* 41: 77-82. <https://doi.org/10.14710/jitaa.41.2.77-82>
- Yilmaz, A., C. Tepeli, & T. Çağlayan.** 2011. External and internal egg quality characteristics in Japanese quails of different plumage color lines. *J. Food. Agric. Env.* 9: 375-379.
- Zanu, H. K. & C. M. Avukpor.** 2013. Effects of enzyme (xzyme) supplementation on the performance of laying hens fed diets containing different levels of cassava (*Manihot esculenta, Crantz*) leaf meal. *Online J. Anim. Feed Res.* 3: 9-14.