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(RESEARCH ARTICLE)

Tofu waste product processing and utilization in ration affecting reproduction age of Indonesian local ducts

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Abstract

This study aims to determine the effect of tofu waste product (TWP) utilization in feed rations on duck growth, age of sexual maturity, age of initial laying eggs of ducks including weight and size of eggs produced as well as income over feed cost. The experimental animals used were 64 female and 32 male ducks, all at 90 days old. This study used a Completely Randomized Design, with four treatments and eight replications with three ducks (two females and one male) in each pen or cage unit. The treatments were including R0: Feed without TWP (0%), R1: Feed with 5% TWP, R2: Feed with 10% TWP, and R3: Feed with 15% TWP. The results showed that Tofu waste product (TWP) flour in ration did not significantly affect the amount of feed consumption, growth body weight and feed conversion of ducks (g/head/day). The treatments using the levels of TWP flour significantly affected the shortening of the age of sexual maturity and the initial age of laying eggs of local ducks. The treatment of using the level of Tofu waste product (TWP) flour significantly affected the production of egg mass produced by ducks (g/head/day). The TWP use in ration reduced the size of the egg weight from a large size spreading into a medium size (g/egg). The highest income over feed cost (IOFC) was achieved by using the R3 treatment containing the TWP flour level of 15%, reached by an IOFC of 1,721.71 (IDR/head/day) with increasing 14.76 percent compared to ration without TWP flour from the sale of eggs produced.

Keywords: Duck Early Laying Ages; Egg Sizes; Food Industrial By-Product; Income Over Feed Cost.

1. Introduction

Ducks are one of the largest contributors of animal protein from livestock and are a superior commodity. Ducks are known as new poultry rivals of native chickens with their distinctive taste and high meat content [1]. Ducks have made a large contribution to the income of farmers, absorbing labor, increasing community productivity with their main products being duck meat and eggs which can fulfill the community's need for animal protein [1].

Ration is one of the factors that must be considered in duck maintenance. Quality rations will affect the final results of duck maintenance to achieve high meat and egg production [2, 3)] as well as achieving fast reproductive age and high egg weight [4, 5)]. The high price of feed ingredients for rations, such as corn, soybean meal and fish meal, means that farmers must be able to utilize the potential sources of cheap and quality animal feed ingredients, including utilizing industrial waste. The cost of feed that must be spent on duck farming is very large, namely 60-70% of the total production cost [6]. These high production costs need to be overcome by compiling our own rations using ingredients that are easy to obtain, at a relatively cheaper price, but still have good nutritional content for production, reproduction and the health of the livestock itself [7].

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Tofu dregs or tofu waste product (TWP) are a by-product in the process of making tofu in solid form and are obtained from squeezed soybean pulp. The TWP still have a relatively high protein content because in the process of making tofu not all protein content is extracted, especially if using a simple and traditional grinding process [8]. However, TWP have not been optimally utilized, and there are still tofu craftsmen who simply throw away waste, which causes environmental pollution in the surrounding area [9, 10]. The average weight of TWP is 1.12 times the weight of dry soybeans, while the volume is 1.5 to 2 times the volume of dry soybeans. Based on these figures, from 1 kg of soybeans made into tofu, 1.2 kg of wet TWP will be produced [8].

The TWP can still be used as animal feed that contains a lot of protein. Judging from its chemical composition, TWP can be used as a source of protein. The content of TWP is 8.66% protein, 3.79% fat, 51.63% water and 1.21% ash [2, 11]. Fresh TWP have a water content of around 84.5% of its weight [7, 11]. High water content can cause a short shelf life. Dried TWP contain around 10.0 to15.5% water, so their shelf life is longer than fresh TWP [11, 12]. Currently, not many farmers use the TWP as additional feed for livestock other than concentrate. This is because the feed ingredients usually contain quite high crude fiber such as TWP [13]. Apart from its high crude fiber content, its high arabinoxylan content also limits its use in compiling poultry rations [14].

The limited knowledge of farmers regarding information on raw materials, feed formulation and the manufacturing process has caused this potential to not be utilized optimally. Therefore, the objective of this study was that it is necessary to conduct research using tofu waste product (TWP) given at different levels in feed rations to determine the effect of TWP utilization in feed rations on duck age of sexual maturity, age of initial laying eggs of ducks including weight and size of eggs produced.

2. Materials and methods

This research was conducted from May 2025 to July 2025 in East Kotamobagu district, North Sulawesi of Indonesia. A total of 64 female ducks and 32 male ducks were used, all at age of 90 days old. The equipment used was individual cages, scales, feeders, drinkers, and other equipment. The feed ingredients used were tofu waste product (TWP), corn, bran, and broiler concentrate (KLK super). The TWP were taken from a tofu factory in Kotamobagu (Figure 1).

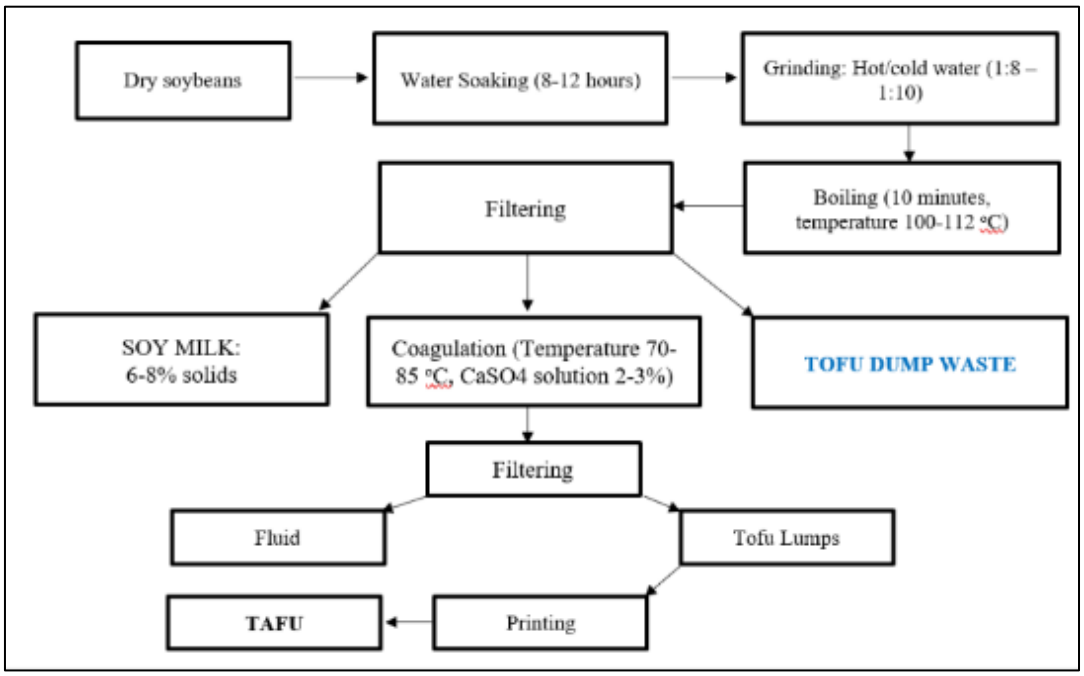

Figure 1 Flowchart of Tofu Waste Production Processing used in the Research

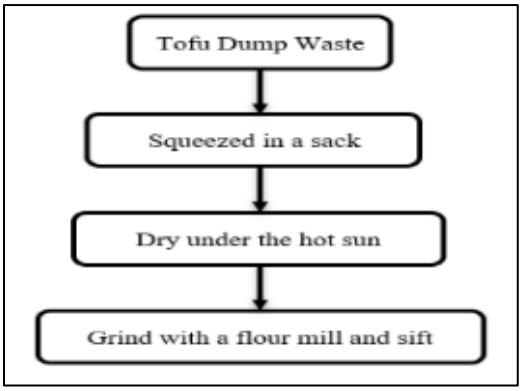

Figure 2 Scheme of processing tofu waste product flour

The TWP were squeezed with a cloth to reduce the water content and then dried under the hot sun for ± 3 days until completely dry (Figure 2). The TWP that have gone through the drying process under the hot sun were ground into TWP flour that was ready to be used in the preparation of duck feed rations (Figure 3). After the TWP were dried, other feed ingredients such as corn, bran and concentrate were prepared. The feed ingredients were formulated according to the nutritional needs of laying duck phase with crude protein of 14% and Metabolic Energy of 2900 kcal / kg [15].

The cages used in this study were grouped cages with 64 cages, size of 80x80x60 cm per cage. Each cage was filled with 2 female ducks and 1 male duck with a total of 96 ducks used. All cage blocks were observed for the early initial age of natural mating (sexual maturity) and the early initial age of laying eggs (reproductive maturity). The duck cages and their equipment were cleaned daily. The cages were sprayed with disinfectant to kill bacteria in the cages.

The wet tofu waste product in sacks at the tofu manufacturing factory

White wet tofu waste product dried on the first day under the sun slight

Grey humid tofu waste product dried on the second day under sun slight

Brownish tofu waste product dried on the third day under sun slight

Dark brownish grinded tofu waste product ready to be used as animal feed ingredients

Tofu waste granules become duck feed material for research

Figure 3 Stages of processing tofu waste granules as the alternative feedstuff for ducks.

The feed used in this study was a mixed concentrate feed (KLK Super) with corn, rice bran and tofu waste product (TWP) flour with the composition as shown in Table 1. The feed used in this study was feed for 15-week-old ducks using the feed ingredients presented in Table 1, with the formulation of treatment rations and the nutritional content of each treatment feed as presented in Table 2.This study used a Completely Randomized Design (CRD), with 4 treatments and

8 replications with 3 ducks (2 females and 1 male) in each pen or cage unit. The treatments were including R0: Feed without TWP (0%), R1: Feed with 5% TWP, R2: Feed with 10% TWP, and R3: Feed with 15% TWP. The formulation of the treatment ration and the nutritional content of each treatment feed are presented in Table 2. The observed variables included the sexual maturity by age (day) at the first natural mating, reproductive maturity by age (days) at the first laying egg, long period between the sexual maturity and the reproductive maturity (days), and the frequency distribution of the number of egg weights in the small egg size category (≤ 60 g), medium egg size category (≥61–≤70 g), and large egg size category (≥ 71 g) in each treatment (R0, R1, R2, R3), Figure 5.

Table 1 The composition of nutritional substances in feed rations of ducks in the starter phase

Nutrients	**Protein (%)**	**Crude Fiber (%)**	**Fat (%)**	**Ca (%)**	**P (%)**	**Gross Energy (kcal/kg)**
Corn *	10,19	1,86	1,52	1,55	1,48	3301
Rice bran *	8,20	21,51	6,96	0,27	0,23	3185
Tofu Waste	24,50	19,94	9,96	0,14	1,13	2830
Concentrate #	35,00	5,00	12,00	1,10	0,50	2800
*) Analysis results [16].; #) Nutritional content of KLK Super concentrate feed ingredients of PT. Charoen Pohphand Indonesia.						

Table 2 Feed formulation and nutritional content of duck feed in the grower phase

Feed Ingredients	**Treatments**			
	R0	**R1**	**R2**	**R3**
Yellow corn (%)	42	42	42	42
Concentrate (%)	25	20	15	10
Tahu waste product, TWP (%)	0	5	10	15
Rica bran (%)	33	33	33	33
Total (%)	100	100	100	100
Nutrient substances *				
Protein (%)	15.74	15.21	14,71	14,17
Crude Fiber (%)	9.13	9.87	10,59	11,16
Fat (%)	5.93	5.83	5.73	5.63
Ca (%)	1.06	1.09	1.12	1.19
P (%)	0.85	0.89	0.97	1.05
Gross Energy (kcal/kg)	3137.47	3138.72	3139.97	3141.22
Energy Metabolism (kcal/kg) #	2862,25	2893,60	2924,95	2956,36
*) Calculated based on the composition of nutrients Table 4. #) Calculated based on reference instructions [17].				

Two females with a male ducks fed ration treatments in a pen cage

Observation of the age of first natural mating in 118-day old ducks fed ration treatments

Observation of the first age of laying eggs at 141-day old ducks fed ration treatments

Collection of egg production of ducks fed with ration treatments

Figure 4 Ratio of female and male duck in a pen cage and observation of the first age of natural mating and laying eggs fed by ration containing levels of Tahu waste product

The sexual maturity and reproductive maturity were observed in all pens containing 2 female ducks and 1 male duck every day, starting from observations on 100-day-old ducks until the first natural mating occurred (determining the age of sexual maturity) until the first initial egg-laying process occurred (determining the age of duck maturity after the initial reproductive function of laying eggs) (Figure 4).

Production of eggs were collected and weighed daily using digital scale at the first age of laying eggs by female ducks fed four different treatments of rations (R0, R1, R2, R3) finding data accumulation of 1400 eggs in each treatment. The egg weight was weighed in the early period of duck laying eggs at 20-weeks old ducks using a digital scale (Figure 5) during the period of one hundred and twenty days (four months) at 36-weeks old of adult ducks. The weight of duck eggs in each treatment was classified into 3 (three) egg weight categories with the low egg weight category (small egg size ≤ 60 g), medium egg weight (≥61 medium egg size ≤70 g) and high egg weight (large egg size ≥ 71 g) as shown in Figure 5.

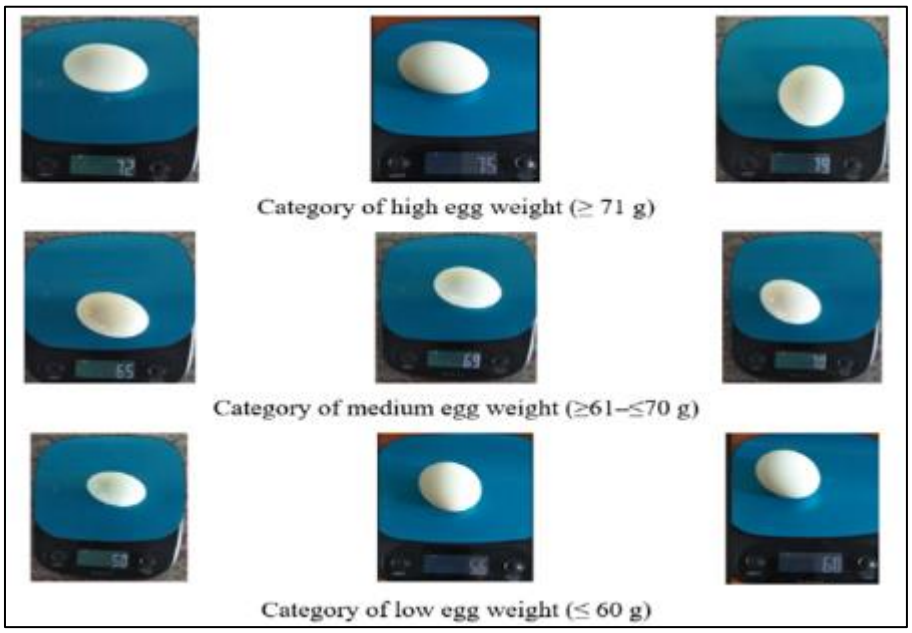

Figure 5 Duck egg size categories (large, medium and small sizes) based on egg weight range (grams/egg) with digital scales

The data obtained were analyzed using analysis of variance (ANOVA). The significant different variables ($p<0.05$) were continued to be statistically tested with the BNT test to define the differences between levels of tofu waste product treatments in ration [18, 19, 20)].

3. Result and discussion

3.1. Duck age of sexual maturity and first laying egg

The first reproduction of duck bird animal was observed in this study (Figure 4) with the results as presented in Table 3. Duck ages of the first natural mating were significant different among treatments of R0, R1, R2 and R3. Duck ages of the first natural mating fed ration of R2 and R3 started mating earlier compared with those fed ration of R0 (control ration). However, duck age of the first natural mating fed ration of R1 (containing 5% tofu waste product) was not significantly different with those fed ration of R2 (containing 10% tofu waste product). These conditions might be due to ration of R3 and R2 containing slightly high crude fiber in these rations. Slightly high crude fiber in ration do not accumulate fat in the body which may cause low weight and late sexual maturity [21, 22, 23].

Duck ages of the first laying day were also significant different among treatments of R0, R1, R2 and R3. It showed that utilization of tofu waste product in ration of 5, 10, and 10 percents in ration may reduce duck ages of the first laying day of almost regularly two days of initial laying day. These conditions were proved by the variable of time duration between age at the first sexual maturity and age at the first laying day indicating shorter time duration (20.63%) from 27.875 ± 0.885 days to 22.125 ± 0.501 days of ducks fed R0 ration and fed R3 ration (Table 3).

Table 3 Duck ages at the initial reproduction phases at the period of 98-day observation among treatments using tofu waste product in ration

Variables observed	**Treatment**			
	R0	R1	R2	R4
Duck age at the first natural mating (day)	125.812 ± 2.257 [a] (n = 24)	124.562 ± 2.988 [ab] (n = 24)	124.251 ± 2.817 [bc] (n = 24)	124.062 ± 3.043 [c] (n = 24)
Duck age at the first laying day (day)	153.687 ± 2.414 [a] (n = 16)	150.625 ± 2.872 [b] (n = 16)	148.312 ± 2.701 [c] (n = 16)	146.187 ± 2.811 [d] (n = 16)
Time duration between age at the first sexual maturity and age at the first laying day (day)	27.875 ± 0.885 [a] (n = 16)	26.062 ± 0.250 [b] (n = 16)	24.062 ± 0.250 [c] (n = 16)	22.125 ± 0.501 [d] (n = 16)
[abcd] Means in the same row without common letter are different at $p<0.05$				

The utilization of tofu waste product (TWP) in ration affected significantly the reduction of duck reproduction phases in term of age at the first natural mating, duck age at the first laying day and time duration of age at the first sexual maturity and age at the first laying day as seen on Figure 6. These cases might be due to the effect of useful high protein content in tofu waste product, although its higher content of crude fiber, as reported by several researchers. Tofu waste product contains high level of crude fiber, but it also still has high content of protein [1, 22, 23] that might be useful as the ration ingredient, mainly for birds on the initial reproduction phase due to low fat content [14].

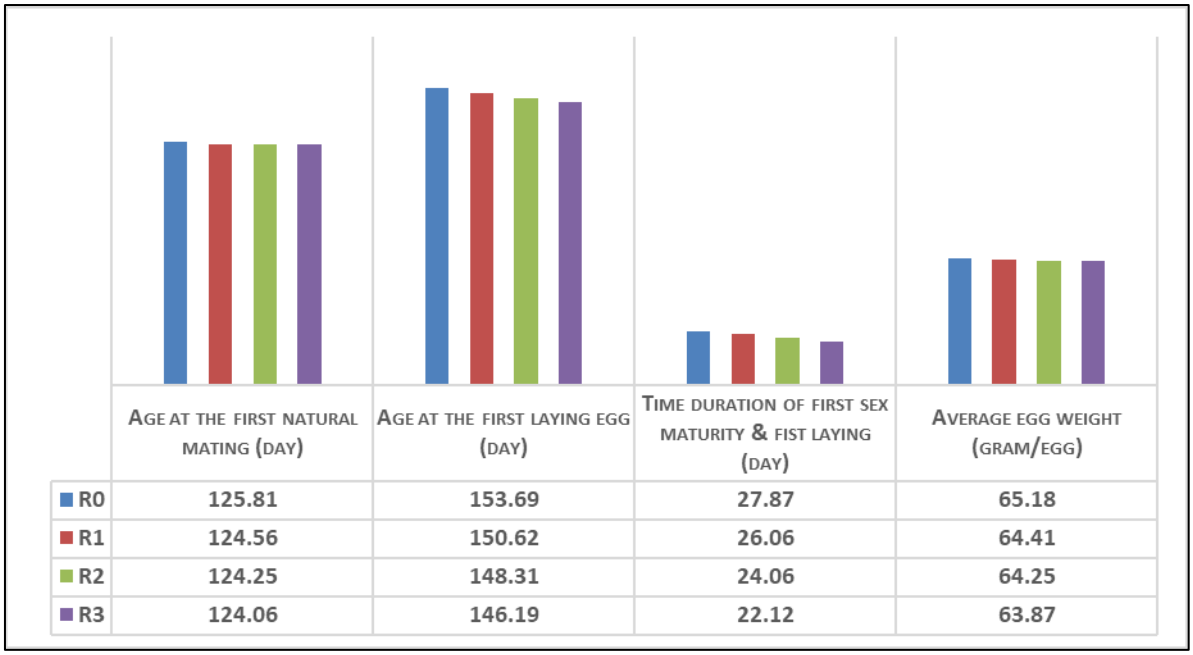

Figure 6 Treatment effects of using tofu waste product in ration on the initial reproduction phases and egg weights of ducks

3.2. Egg sizes in the early reproductive phase

The egg weights of ducks of 1400 eggs in each treatment of R0, R1, R2 and R3 were categorized into three classes of small egg sizes with low weight (small egg size ≤ 60 g), medium egg sizes with Medium Weight ((≥ 61 medium egg size ≤70 g), and large egg sizes with High Weight (large egg size ≥ 71 g) (Figure 5). The distributions of large, medium and small egg sizes based on egg weight (g/egg, Figure 5) of ducks given ration treatments of R0, R1, R2 and R3 were presented in Table 4.

Table 4 The amount of large, medium and small egg sizes of ducks given ration treatments containing Tofu Waste Product (TWP)

Egg Sizes	Laying period	Treatments			
		R0 (n = 16)	R1 (n = 16)	R2 (n = 16)	R3 (n = 16)
Small	100 days	322 $^{a\,x}$	259 $^{b\,x}$	462 $^{c\,x}$	490 $^{d\,x}$
Medium	100 days	595 $^{a\,y}$	686 $^{b\,y}$	483 $^{c\,y}$	469 $^{c\,y}$
Large	100 days	483 $^{a\,z}$	455 $^{b\,z}$	455 $^{b\,x}$	441 $^{c\,z}$
	Total	1,400	1,400	1,400	1,400
^{abcd} Means in the same row without common letter are different at p<0.01					
^{xyx} Means in the same column without common letter are different at p<0.01					

Using the least significantly different test, distribution for the treatment of R0 showed that the total of medium egg size production was dominating significantly (p = 0.0000024) the total of 595 egg sizes compared to the total of 483 large egg sizes and 322 small egg sizes. Real production, the total of large egg sizes was dominating significantly (p = 0.0000037) the total of small egg sizes. Similarly, the distribution for the treatment of R1 showed that the highest amount of 686 medium egg sizes was dominating significantly (p = 0.000012) egg production of large and small egg sizes with the amount of 455 and 259 eggs, respectively. Real production, the large egg sizes were also dominating significantly (p = 0.000037) the small egg sizes. Finally, the distribution for the treatment of R2 showed that the highest amount of 483 medium egg sizes was dominating also egg production of the small and large egg sizes with the amount of 462 and 455 eggs, respectively. Real production, the medium egg size was dominating the small and large egg sizes, while these amount between small egg sizes and large egg sizes were not significantly different (p = 0.131243). In contrast, the distribution for the treatment of R3 showed that the highest amount of 490 small egg sizes was dominating

significantly (p = 0.002529) egg production of medium and large egg sizes with the amount of 469 and 441 eggs, respectively. Real production, the medium egg sizes were dominating significantly (p = 0.000415) egg production of the large egg sizes.

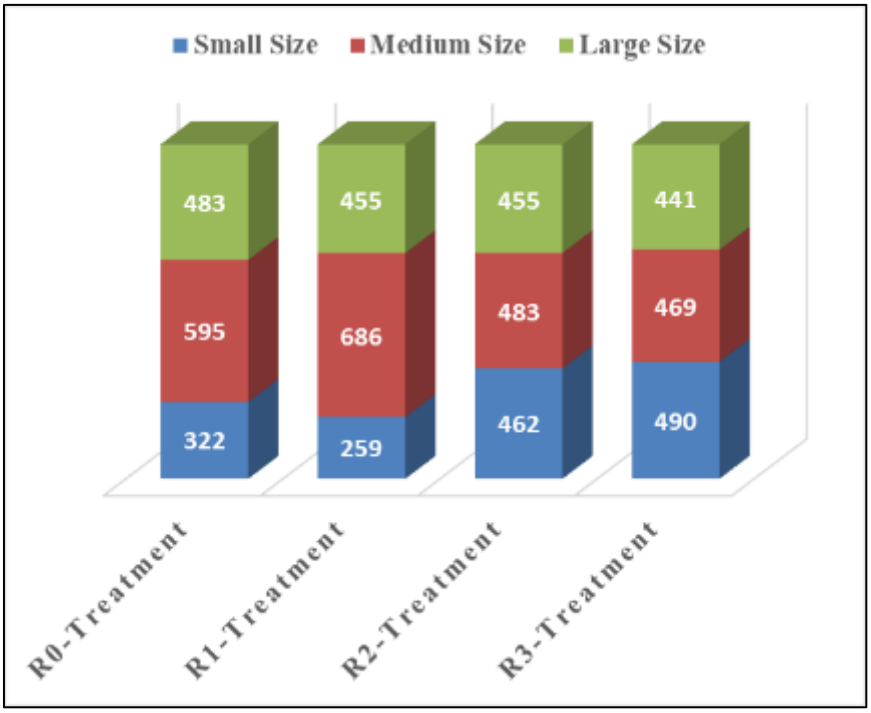

Figure 7 Distribution chart of large, medium and small egg sizes based on egg weight (g/egg, Figure 5) of ducks given ration treatments of R0, R1, R2 and R3

The utilization of tofu waste product contents from 10 to 15 percents in ration could affect distribution of egg sizes (Figure 7). The large egg size of high egg weights of ration R0 (control) and ration R1 (5 percents of tofu waste product) content changed into medium egg sizes of ducks fed rations R2 (10 percents of tofu waste product content) and ration R3 (15 percents of tofu waste product content) as depicted in Figure 7. The decreases of egg sizes from large size into medium sizes of ducks were caused by increasing level of tofu waste product up to 15% in ration.

Ducks fed ration containing high level of tofu waste product could be due to the fact that tofu waste product still contains high level of crude fiber that might reduce the sizes of egg mass from large egg sizes of high weight into medium sizes of egg weights. These results were in agreement with others research [25]. The treatments of R2 (10% TWP) and R3 (15% TWP) contained higher crude fibre (10.59 - 11.16%) compared to those crude fiber (9.87 – 10.59%) of R0 (control) and R1 (5% TWP). These lower crude fibers were increasing the protein contents ranging from 15.21 – 15.74%) in the treatments of R0 and R1 (Figure 6). Therefore, the fulfilment of high protein needs will have an impact on the size of mature ovum ovulated as egg yolk. The size of the egg yolk will then have an impact on the size and weight of eggs produced by ducks [6] as shown in higher Poisson Distribution Probability Value of 78.55 percents in R0 and 81.28 percents in R1.

4. Conclusion

The ration treatment levels using the TWP flour levels of 5 percents (R1), 10 percents (R2) and 15 percents (R3) affected significantly the shortening age of sexual maturity and the initial age of laying eggs of local ducks. Similarly, these treatment levels of Tofu waste product (TWP) flour affected significantly the production of egg mass produced by ducks (g/head/day), reducing the sizes of egg weight from the large egg sizes spreading into the medium and small egg sizes. The use of 10 percents TWP in ration produced significantly the dominating sizes of medium eggs compared with those small and large egg sizes. In addition, the use of 15 percents TWP in ration produced significantly the dominating sizes of small eggs compared with those medium and large egg sizes.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

No conflict of interest to be disclosed.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

All authors declare and confirm that the version of the submitted manuscript have been read and approved.

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