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Production Performance of Eri Silkworm (*Samia cynthia ricini*) with Cassava Leaves Feed (*Manihot utilissima*) on Different Mountages Media

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ABSTRACT

Eri silkworm (*Samia cynthia ricini*) is a potential silk producing insect in Indonesia. This study aimed to analyze the production performance of the *S. c. ricini* silkworm with cassava leaves feed (*Manihot utilissima*) and their cocoon productivity that mounting on different mountages (wood and carton), and also calculate the financial analysis. The silkworm was reared in altitude 176 m asl. Production performance observed were feed consumption (ingesta and digesta), larval productivity (length, breadth, and weight), and cocoon productivity (the effective rate of rearing and cocoon quality). Feed consumption and larval production were analyzed descriptively, the effective rate of rearing was compared using a t-test, cocoon quality was analyzed using a completely randomized design factorial 2 × 2 pattern. The first factor was sex and the second factor was mountages media that were used with three replications. Financial analysis was calculated using profit, R/C ratio, and BEP. The results showed the optimum consumption of cassava leaves during the study was 27.17 ± 2.39 g of feed ingestion and 19.15 ± 2.30 g of feed digestion. Mountages media did not significantly (P>0.05) influence the effective rate of rearing and cocoon quality. Cocoon weight, pupal weight, and shell ratio was affected by cocoon sex. Financial analysis calculation result showed that wood mountages gives the best value, with the profit value was Rp 21.877.819/year, R/C ratio was 1.61, BEP of yarn was 5.67 kg, BEP of eggs was 110.10 box.

Keywords: cassava leaves, cocoon quality, financial analysis, mountages media, *Samia cynthia ricini*

ABSTRAK

Ulat sutra Eri (*Samia cynthia ricini*) merupakan serangga penghasil serat sutra yang berpotensi untuk dikembangkan di Indonesia. Penelitian ini bertujuan untuk menganalisis performa produksi dari ulat sutra *S. c. ricini* yang diberi pakan daun singkong (*Manihot utilissima*) dan dikokonkan menggunakan media pengokonan berbeda (kayu dan sobekan karton), serta melakukan perhitungan analisis usaha budidayanya. Pemeliharaan ulat dilakukan pada ketinggian 176 m dpl. Performa produksi yang diamati adalah konsumsi pakan (konsumsi ingesta dan konsumsi digesta), produktivitas ulat (panjang, lebar, dan berat), dan produktivitas kokon (persentase pemeliharaan efektif dan kualitas kokon). Konsumsi pakan dan produktivitas ulat dianalisis secara deskriptif, persentase pemeliharaan efektif dianalisis menggunakan uji-t, dan kualitas kokon dianalisis menggunakan Rancangan Acak Lengkap Pola Faktorial 2 × 2. Faktor pertama adalah jenis kelamin dan faktor kedua adalah media pengokonan dengan tiga kali ulangan. Analisis usaha dihitung menggunakan keuntungan, rasio R/C, dan BEP. Hasil menunjukkan konsumsi optimum daun singkong selama penelitian adalah 27.17 ± 2.39 g untuk konsumsi ingesta dan 19.51 ± 2.30 g untuk konsumsi digesta. Penggunaan media pengokonan kayu dan sobekan karton tidak signifikan (P>0.05) terhadap persentase pemeliharaan efektif dan kualitas kokon. Jenis kelamin kokon berpengaruh terhadap bobot kokon, bobot pupa, dan persentase kulit kokon. Hasil perhitungan analisis usaha menunjukkan media pengokonan kayu memberi nilai terbaik dengan keuntungan Rp 21.877.819/tahun, nilai R/C rasio 1.61, nilai BEP benang 5.67 kg, dan nilai BEP telur 110.10 kotak.

Kata kunci: analisis usaha, daun singkong, kualitas kokon, media pengokonan, *Samia cynthia ricini*

INTRODUCTION

The raw materials of the eri silk industry were obtained entirely from *Samia cynthia ricini* cultivation which the majority is produced in India. Renuka and Shamita (2014) state that *S. c. ricini* is a type of polyvoltine silkworm that is capable of raising five to six crops in a year. Eri silkworm is also a polyphagous insect with the main host plants castor (*Ricinus communis* L.) and kesseru (*Heteropanax fragans* Seem.) and other important host plants such as payam (*Evodia fraxinifolia* Hook.), cassava (*Monihot utilissima* Phol.) and barpat (*Ailanthus grandis* Roxb.).

Feed is one of the factors that affect the productivity of *S. c. ricini*. Cassava (*M. utilissima*) is one of the potential host plants for *S. c. ricini* which is widely cultivated in Indonesia. The effective rate of rearing *S. c. ricini* with cassava leaves feed (87.85%) was below the primary hosts of castor (89.40%), and above the other host plants leaves: arduso (85.93%), indian almond (75.04%), and banyan (65.48%) (Birari *et al*. 2019). Larval productivity is also influenced by environmental conditions, low environmental temperatures will extend the larval cycle which causes the duration of feeding to be longer. This will affect in increase larval and cocoon productivity (Subramanian *et al*. 2013). Indonesia has a diverse topography that will affect environmental conditions. The study was conducted in a lowland area (176 m asl) which is prone to high temperatures and low humidity. A study of the productivity of eri silkworms with cassava leaves in the lowlands is needed to add the data collection regarding the potential for *S. c. ricini* development in Indonesia. This is because generally silkworms are kept in the highlands with cool air.

The economic value of silkworm rearing can be known from cocoon productivity. Atmosoedarjo *et al.* (2000) stated that cocoon productivity was influenced by mature larval handling, cocoon handling when harvested, and the mountages media that were used. Various mountages were used by *S. c. ricini* cultivators. The most mountages commonly used in Indonesia were dried banana leaves, cartons, and woods. This may influence the cocoon productivity and economic traits. Wood and carton mountages were used in this study to determine the efficient mountages for *S. c. ricini* based on productivity and economic. This study aimed to analyze the production performance of the *S. c. ricini* silkworm that reared with cassava leaves fed (*M. utilissima*) and their cocoon productivity that mounting on different mountages (wood and carton) and calculate the financial analysis.

MATERIAL DAN METHODS

Material

This research was conducted at The Silk Laboratory, Departement of Animal Production and Technology, Faculty of Animal Science, IPB University for 5 months. The altitude of the research location is 176 m asl. The materials used were 360 *S. c. ricini* larval. *S. c. ricini* seed were derivatives from Jantra Mas Sejahtera Farm, Yogyakarta which had been maintained for a generation at the Silk Laboratory. Other materials used were cassava (*M. utilissima*) leaves and 2% formalin solution to disinfect the eggs.

Methods

Eggs collection and incubation

Cocoon seeds were cleaned from floss fibers and placed in the mating place. The moth that had to emerge and copulate was transferred to a new mating place at 08.00 am. After copulating for four hours, female and male moths were separated and female moths were oviposited for 20 hours. Eggs were collected and disinfected using a 2% formalin solution for five minutes then the eggs were washed under cleaning water until clean. Eggs were divided into trays and incubated until hatching.

Larval rearing

The eri silkworm larvae were fed three times during the young ages (1^{st}-3^{rd} instar) and four times during the late ages (4^{th}-5^{th} instar). Young ages larva was given sliced cassava leaves while late ages larva was fed with cassava leaves without being sliced. The content of cassava leaves given as feed is presented in Table 1. The second and third instar were reared with a density of 0.10 larva cm^{-2} and expanded to 0.05 larva cm^{-2} when entering late ages larval. Data collection began on the second instar to avoid high mortality because the first instar was very susceptible to touch and pressure. Data collected were temperature, humidity, feed consumption (ingesta and digesta), feed consumption efficiency, and larval productivity (length, breadth, and weight of larvae). The consumption of ingesta is the weight of the leaves consumed by the larvae, while the consumption of digesta is the weight of the leaves consumed by the larvae minus the weight of the faeces. Feed consumption efficiency is the percentage increase in larval weight divided by the amount of feed consumed by the larvae.

Table 1. Cassava leaves (*Manihot utilissima*) content

Content	Composition (%)
Ash[1)]	7.98
Lipid[1)]	2.38
Protein[1)]	22.23
Crude fiber[1)]	13.77
Tannin[2)]	0.07

[1)]The results of the proximate analysis of the Laboratory of the Center for Research on Biological Resource and Biotechnology of IPB. [2)]Tannin test results of the Laboratory of the Center for Biopharmaceutical Studies LPPM IPB.

Mounting

At the late stage fifth instar, larval that release wet fecal matter, the body became shorter and translucent, and crawl on the rearing area seeking a place to spin cocoons was transferred into mountages media. Larval was divided into two different mountages media (wood and carton). Cocoon harvested on the sixth day after being transferred into mountages for data collection. The data observed were the effective rate of rearing and cocoon quality. The effective rate of rearing was the percentage of cocoons produced divided by the initial number of larvae kept, while observations of cocoon quality consisted of cocoon weight, pupa weight, floss weight, single shell weight, and shell ratio.

Financial Analysis

Financial analysis was calculated based on profit, revenue cost ratio (R/C ratio), and break-event point (BEP). The feed consumption, cocoon production, and egg production from both mountages was calculated based on the result of the study. Investment costs consist of rearing racks, trays, mountages, and rearing equipment, while the total cost consist of employee payment, building fees, and depreciation expenses.

Data Analysis

The effective rate of rearing between wood and carton mountages was analyzed by t-test. The confidence interval used was 95%. The mathematical model used was as follows (Montgomery 2013):

$$t_0 = \frac{\bar{y_1} - \bar{y_2}}{S_p \cdot \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

t0 = T value;
y1 = the average of wood mountages treatment;
y2 = the average of carton mountages treatment;
Sp = pooled standard deviation;
n1 = the number of wood mountages sample;
n2 = the number of carton mountafes sample.

Cocoon quality was analyzed using a completely randomized design factorial 2×2. The first factor was cocoon sex and the second factor was different mountages (wood and carton). Each treatment was repeated three times with the following mathematical model (Walpole *et al*. 2012):

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

Yijk = observed value of i mountages media and j cocoon sex in k replication;
μ = general mean;
αi = the effect of i mountages media;
βj = the effect of j cocoon sex;
(αβ) ij = the effect of interaction i mountages media with j cocoon sex;
εijk = treatment error of i mountages media and j cocoon sex in k replicate.

The data were analyzed with analysis of variance (ANOVA) and if there were differences between treatments, it was continued with the Tuckey test.

RESULT AND DISCUSSION

Temperature and Humidity

Rearing room temperature and humidity results are presented in Table 2. Temperature and humidity had a significant affect on animal behavior, productive and reproductive performance, and distribution of insects. According to Hailu *et al.* (2018) the optimum rearing temperature for young ages larval (1^{st}-3^{rd} instar) is in the range of 26-28 °C, while late ages larval (4th-5th instar) is in the range of 24-26 °C. The results showed that the rearing temperature of young ages larval was in the range of optimum range temperature, but the rearing temperature of late ages larval was in the range of optimum rearing temperature range. Teronpi *et al.* (2020) stated that rearing temperature will affect the physiological condition of silkworms in nutrient absorption, digestion, transportation, and circulation systems. It affected larval duration and survivability.

Table 2. Temperature and humidity of rearing room

Variable	Time	Young ages (1^{st}-3^{rd})	Late ages (4^{th}-5^{th})
		Average ± SD	
Temperature (°C)	8	25.75 ± 0.40	26.12 ± 0.48
	12	27.40 ± 0.45	27.40 ± 0.59
	16	27.45 ± 0.55	27.88 ± 0.58
Kelembapan (%)	8	81.73 ± 3.36	83.31 ± 3.02
	12	72.45 ± 5.77	76.62 ± 4.63
	16	73.00 ± 5.61	74.85 ± 5.05

Hailu *et al.* (2018) stated that the optimum humidity for young ages larvae is in the range of 85-90%, while the optimum humidity for late ages larvae is 70-80%. The humidity of the young ages larval during the observation was below the optimum humidity, while the humidity of the late ages larval exceeded the maximum optimum humidity limit. The humidity conditions of the rearing room fluctuated because of frequent rain during the observation. The humidity of the rearing room will play a role in the regulation of the body temperature which indirectly affects the growth and physiological condition of larval (Teronpi *et al.* 2020). The rearing site was in the lowlands (below 250 m asl), so it was sensitive to high temperatures and low humidity. Ventilation of the rearing room was opened when the room humidity was high and ventilation was reduced and placing trays of water when the room humidity was low.

Feed Consumption and Feed Consumption Efficiency

The quality and quantity of leaves given to silkworms affected the animal productivity. The results of feed consumption are presented in Table 3. Feed consumption results were higher than the observations of Gururaj *et al.* (2017) using Bangalore local variety castor leaves with total feed ingestion of 26.25 g and total feed digestion of 17.11 g. Nursita (2008) stated that the consumption of silkworms is

Table 3. Feed consumption of 2nd-5th instar

Instar	Feed ingestion	Feed digestion
	Average ± SD (g larval^{-1} day^{-1})	
II	0.16 ± 0.11	0.15 ± 0.11
III	0.29 ± 0.08	0.25 ± 0.10
IV	1.69 ± 0.65	1.41 ± 0.51
V	2.14 ± 1.98	1.38 ± 1.53
Total (g larval^{-1})	27.17 ± 2.39	19.51 ± 2.30

increasing as the moisture content of leaves. Cassava leaves moisture content (84.59%) was higher than castor leaves (80.49%) (Deuri *et al*. 2017).

Feed conversion efficiency resulted in this study (Table 4) were lower than Gururaj *et al.* (2017) on instar III, IV, and V respectively were 18.02, 28.78, and 19.25 for efficiency of conversion of ingested feed, also 33.83, 68.45, and 33.98 for efficiency of conversion of digested feed. The presence of antinutrient components such as tannin and crude fiber can reduce feed digestibility (Shifa *et al.* 2014). Deuri *et al.* (2017) reported that tannins and crude fibers content in castor leaves was 1.46% and 5.53%, very different from the feed content given during the research. Lower feed conversion efficiency in this study was a result of the presence of high crude fiber content of cassava leaves. In addition, the temperature and humidity of the rearing room were not at optimum conditions, which also affects the feed conversion efficiency. The feed consumed was not only used for larval growth but also used for adjusting body conditions to the environment. This leads to the low feed conversion efficiency.

Table 4. Feed conversion efficiency of 3rd-5th instar

Instar	Efficiency conversion of ingested feed	Efficiency conversion of digested feed
	Average ± SD (g larval^{-1} day^{-1})	
III	9.98 ± 1.67	11.42 ± 1.95
IV	8.62 ± 0.63	10.34 ± 0.65
V	19.73 ± 2.59	31.41 ± 6.45

Larval Productivity

Larval productivity was observed including the larval length, breadth, and weight. The length, breadth, and weight of the larval were measured at the end of the instar before larval molting. Larval productivity results (Table 5) were still lower than larvae with castor leaves feed that reaches maximum larval length (58.45±1.19 mm), larval breadth (11.93±0.36 mm) (Birari *et al.* 2019), and larval weight (7.65 g) (Birari *et al.* 2019). This may be due feed conversion efficiency rate of cassava leaves being lower than castor leaves. In addition, rapid changes in environmental conditions due to frequent rain events during the study might had an effect on the decrease in larval productivity.

Cocoon Productivity

Cocoon is a silkworm product that has economic value due it is the raw material for silk fibers and biomaterials. Wood and carton mountages did not affect

Table 5. Larval length, breadth, weight

Instar	Length (mm)	Breadth (mm)	Weight (g)
		Average ± SD	
II	11.18 ± 1.48	2.47 ± 0.29	0.01 ± 0.01
III	18.73 ± 1.78	4.03 ± 0.40	0.12 ± 0.04
IV	33.18 ± 1.87	7.11 ± 0.60	0.85 ± 0.12
V	59.65 ± 4.36	9.80 ± 0.77	4.18 ± 0.60

the effective rate of rearing (Table 6). Ibrahim *et al.* (2015) stated that mountages could affect the cocoon productivity. Based on the results, wood and carton mountages were good as alternative mountages for *S. c. ricini*. Birari *et al.* (2019) reported that the effective rate of rearing using castor leaves and cassava leaves was 89.40% and 87.85% respectively, Kumar and Elangovan (2010) reported that the effective rate of rearing using castor leaves and cassava leaves was 91.05% and 88.00% respectively. The average yield of cocoon production during the study was still lower than the two studies, this is possible due to the influence of environmental conditions and feed conversion effectivity that affects larval survivability.

The mountages used had no significant difference in affected single cocoon weight and pupal weight (Table 6). Single cocoon weight and pupal weight in this study were still lower than Shifa *et al.* (2014) study by using local variety castor leaves with an average single cocoon weights and pupal weights of 3.14 g and 2.70 g respectively. This reflects that feed consumption efficiency plays important role in single cocoon weight and pupal weight. The high feed consumption efficiency of castor leaves will increase the weight of the final instar larval which affects the increase of single cocoon weight and pupal weight. The single cocoon weight and the pupal weight showed significantly different results ($P<0.05$) in different sex (Table 6). Female cocoons were heavier than male cocoons, these results are similar to Endrawati and Fuah (2012) results on the *Attacus atlas* cocoons. Bu *et al.* (2022) stated that female cocoons stored of biomass material to lay eggs so that female cocoons were heavier than male cocoons.

The floss weight and single shell weight during the study were not influenced by the mountages or by sex (Table 6). Estetika and Endrawati (2018) reported floss weight was affected by the mountages. The results showed that the wood and carton mountages had the same good quality based on floss production. The smaller amount of floss was better because the part that was wasted for floss is used to form the cocoon shell (Baskoro *et al.* 2011). Normally, multivoltine races have a greater number of floss than bivoltine and univoltine races (Sahana *et al.* 2019). The average floss weight during the observation was much greater (0.09 g) than the floss weight from *Bombyx mori* in observations by Estetika and Endrawati (2018) which was at an average of 0.015 g. Rajkhowa *et al.* (2015) revealed that characteristics of the *S. c. ricini* cocoon contain more floss than other types of silkworm cocoons. The single shell weight of the cocoon from the study was (0.14 g) still lower than Shifa *et al.* (2014) which was at an average of 0.44 g.

Table 6. Cocoon productivity of *Samia cynthia ricini*

Variable	Sex	Mountages		Average
		Wood	Carton	
Effective rate of rearing (%)		82.78 ± 6.73	77.22 ± 3.85	80.00 ± 5.27
Single cocoon weight (g)	Male	1.34 ± 0.16	1.35 ± 0.19	1.34 ± 0.17b
	Female	1.51 ± 0.22	1.56 ± 0.22	1.53 ± 0.22a
	Average	1.44 ± 0.21	1.47 ± 0.23	
Pupal weight (g)	Male	1.12 ± 0.13	1.13 ± 0.16	1.12 ± 0.14b
	Female	1.28 ± 0.19	1.33 ± 0.19	1.30 ± 0.19a
	Average	1.21 ± 0.19	1.24 ± 0.20	
Floss weight (g)	Male	0.08 ± 0.02	0.08 ± 0.03	0.08 ± 0.02
	Female	0.09 ± 0.02	0.09 ± 0.02	0.09 ± 0.02
	Average	0.09 ± 0.02	0.08 ± 0.02	0,09
Single shell weight (g)	Male	0.14 ± 0.03	0.14 ± 0.03	0.14 ± 0.03
	Female	0.14 ± 0.04	0.15 ± 0.03	0.14 ± 0.04
	Average	0.14 ± 0.04	0.14 ± 0.03	0,14
Shell ratio (%)	Male	10.34 ± 2.30	10.52 ± 1.60	10.43 ± 1.95a
	Female	9.16 ± 1.91	9.29 ± 1.49	9.22 ± 1.71b
	Average	9.66 ± 2.14	9.83 ± 1.65	

Different superscripts in the same column/row show a significant (P<0.05) difference

This is because the single cocoon weight used on this study was relatively low which was supported by Subramanian *et al.* (2013) that there was a positive correlation between single cocoon weight and single shell weight of the cocoon.

Shell ratio showed significantly different results (P<0.05) in different sex (Table 6). This may due to the feed consumed by females is not only used for cocoon formation but also for egg formation which makes female cocoon shells ratio smaller than males. Shell ratio produced was smaller than Shifa *et al.* (2014) which was around 14.07%. This is due to the single cocoon weight produced during the study being lower. Subramanian *et al.* (2013) stated that there is a positive correlation between single shell weight and shell ratio.

Financial Analysis

Based on the calculation results, the lowest investment costs were obtained from carton mountages this is due to the price of the raw material for making carton mountages being cheaper than wood mountages. Although the price was cheap, the carton mountages had lower durability than wood, so it needs to be replaced once a year. This makes total cost of carton mountages become high. Financial analysis based on its components is presented in Table 7.

The highest revenue and profits were obtained from wood mountages, this result as same as Mutiara and NH (2017) with a profit of Rp 1.812.750/month (Rp 21.753.000/year). Highest result of wood mountages due more controlled mounting process, where one larval was mounted at one mounting place. Carton mountages were very susceptible to inaccurate mounting time. The larval moved too early causing the mountages easily damaged due to the last wet fecal matter of excreta. Larval that have not entered mounting time also tend to die due to lack of feed and energy. Dead larvae will make the cocoons that have been formed dirty. The production of yarn and eggs is still above the BEP value and the R/C ratio is above 1, so *S. c. ricini* rearing is still in profitable position.

Table 7. Financial analysis of Samia cynthia ricini rearing

Variable	Mountages	
	Wood	Carton
Investment cost (Rp)	32 715 000	6 615 000
Fix cost (Rp)	7 046 333	8 013 000
Variable cost (Rp)	28 916 631	28 916 631
Total cost (Rp)	35 962 964	36 929 631
Production		
Yarn (Rp)	23.27	22.49
Eggs (box)	452.09	421.74
Revenue (Rp)	57 850 783	55 529 280
Provit (Rp)	21 887 819	18 599 650
BEP		
Yarn (Rp)	5.67	6.77
Eggs (box)	110.1	126.99
R/C ratio	1.61	1.5

CONCLUSION

Maximum larval performance of *S. c. ricini* that reared using cassava feed (*M. utilissima*) under temperature range 26-28 °C and humidity 72-83% were larval length (59.65 ± 4.36 mm), larval breadth (9.80 ± 0.77 mm), and larval weight (4.18 ± 0.60 g). The wood and carton mountages did not affect the cocoon productivity. Female cocoon weight and pupal weight were heavier than males cocoon weight and pupal weight, while females shell ratio was lower than males. Wood mountages give the best value of financial analysis with profit value was Rp 21.887.819/ year, R/C ratio was 1.61, BEP of yarn was 5.67 kg, BEP of eggs was 110.10 box.

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