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Implementation of Microcapsules of Noni Fruit Extract (*Morinda citrifolia* L) as a Feed Additive on Nutritional Digestibility and Performance of Sentul Chickens

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***Abstract*—The continuous use of growth promoter (AGP) antibiotics in rearing chickens will cause residues in the meat. Finding a natural antibiotic derived from herbal plants that noni fruit is necessary. Microencapsulation of noni fruit extract (MNFE) was reported to positively affect poultry nutrition absorption. The research was conducted to determine the effect of MNFE with maltodextrin and its implementation as a feed additive to nutrient digestibility and the performance of Sentul chicken. The experiment used 100 Sentul chicks with a Completely Randomized Design (CRD), with five treatments and four replications. The treatment consisted of basal ration T0 (control), T1 (basal ration + 50 mg/kg Zinc-Bacitracin), T2 (basal ration + 125 mg/kg MNFE), T3 (basal ration + 125 mg/kg MNFE), and T4 (basal ration + 375 mg/kg MNFE). Variables observed were nutrient digestibility (crude protein digestibility, dry matter digestibility, organic matter digestibility, metabolic energy, nitrogen retention) and performance (feed consumption, body weight gain, feed efficiency). The results showed that Crude Protein Digestibility (CPD), Dry Matter Digestibility (DMD), Organic Matter Digestibility (OMD), metabolic energy, nitrogen retention, and performance of Sentul chicken were significantly ($p<0.05$) different in the group when compared to controls. It was concluded that adding 250 mg/kg MNFE could improve Sentul chicken's best nutrient digestibility and growth performance. It is recommended to be used as a feed additive to replace AGP.**

***Keywords*—Sentul chicken; microencapsulation; noni fruit extract; nutrient digestibility; performance.**

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I. INTRODUCTION

The need for animal protein continues to increase, in line with the population growth rate. Local chickens contribute quite a lot to poultry meat production. The large and continuous demand for local chicken products has not been able to be fulfilled by breeders, so it is necessary to develop local chickens. Sentul chicken is a local chicken, including the dual-purpose type, because it acts as a producer of meat and eggs that have the potential to be developed to fulfill the community's source of animal protein. The advantage of Sentul chickens compared to other domestic chickens is their good productivity (meat, eggs) and relatively faster body weight growth, and they are more resistant to disease. Proper management during rearing must support increasing the productivity of Sentul chickens. Feeding is a significant factor in their growth because it contains several essential nutrients. Growth promoter (AGP) antibiotics should be added to the feed to improve growth performance. The addition of feed additives to ration components has a vital role in optimizing livestock productivity and improving livestock health [1]. AGP has been forbidden from being used as a feed additive in poultry for the past few years because it may cause residues in meat and eggs, which will endanger the health of consumers throughout the food chain and spread widely in the environment through livestock manure [2].

Noni fruit *Morinda citrifolia Linn* is a possible alternative to AGP, which can be used as an additive for feeding stuff. Morinda can increase the digestion of food substances through its photogenic components and ingredients, which serve as antimicrobials, antioxidant agents, and anticancers [3], [4]. These compounds are anthraquinones, scopoletin, *proxeronins*, and *xeronins, iridoids, coumarins, flavonoids, lignans, phytosterols,* and *carotenoids* [3] [5]. Noni fruit is a medicinal plant commonly found in Indonesia and contains bioactive antioxidant and antimicrobial compounds. The

antimicrobial effect of Morinda inhibits the growth-inhibiting effects of *Staphylococcus aureus, Pseudomonas aeruginosa, Proteus mirabilis, Staphylococcus epidermidis, Proteus vulgaris, Streptococcus oralis, Enterococcus faecalis, and Escherichia coli* [6], so they can be used as an alternative to antibiotic use in poultry.

Noni fruit as a feed additive for poultry must be processed first so that the bioactive compounds' components can be attracted, so an extraction process must be performed. Solvent extraction is the process of separating active substances from materials or liquids. The characteristics of the antioxidant compounds present in natural fruit extracts, such as instability, sensitivity to heat, rapid reactions, and easy oxidation, need to be protected. The microencapsulation method is a way of avoiding damage, increasing quality and stability, and being safe during storage by protecting biological products against any potential influence on the environment [7], [8]. This encapsulation method or technique has proven more effective and efficient because when entering the body's tissue, it can optimize the absorption of the active substance so that the active or core substance's function is absorbed optimally. Maltodextrin is a coating that dissolves easily in water, has a low viscosity, and is colorless.

The successful utilization of noni fruit extract microcapsules as a feed additive in Sentul chickens is by analyzing the value of metabolic energy, nitrogen retention, and digestibility. The metabolic energy value is a component needed for metabolic processes in the livestock body, so it needs to be known. Digestibility is also an important parameter in evaluating the utilization of food substances consumed by livestock. A feed ingredient's digestibility reflects how much of the nutrient in the ingredient the livestock can extract and use. The higher the digestibility, the more benefits the material will provide to the livestock, which will be reflected in the performance of the chickens. Based on this description, the authors were interested in examining the dietary use of noni fruit extract microcapsules for metabolic energy, nitrogen retention, digestibility, and the performance of Sentul chickens.

II. Materials and Methods

A. Noni Fruit Extract Microcapsules (preparation)

Noni fruit powder samples were collected from Surade-Sukabumi, West Java, Indonesia. The noni fruit, with a ratio of 1:3 and 48 hours of macerated time, is extracted from its flour by the maceration method using methanol solvent. At this time, the filtrate was filtered with paper filters, and then it was concentrated using a rotary evaporator at a temperature of 60°C and a speed of 40 rpm. In addition, 5 ppm CuSO4 and 40 ppm ZnO were added as catalysts to the resulting concentrated extract [9]. The microencapsulation process was carried out by mixing noni fruit extract and distilled water, maltodextrin, and distilled water in a ratio of 1: 1, mixed using a homogenizer for 30 minutes at 800 rpm. The viscous extract and maltodextrin, which were utterly homogeneous, were then formulated (70% Extract: 30% Maltodextrin). The final stage of microencapsulation is drying using the dry oven method at 60ºC. Fig.1 shows the flowchart for making noni extract, whereas Fig. 2 shows the Microencapsulation process.

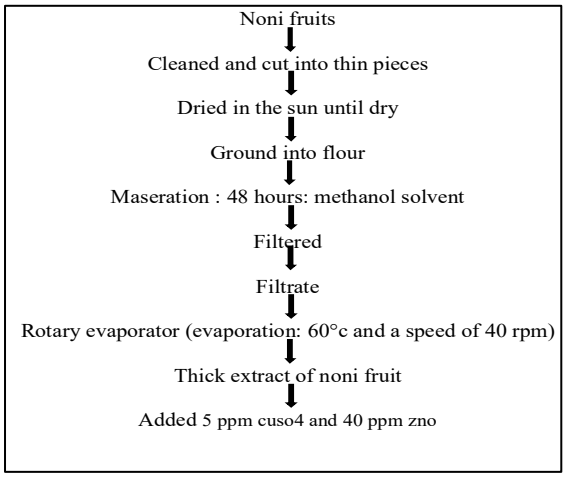

Fig. 1 Making Noni Extract

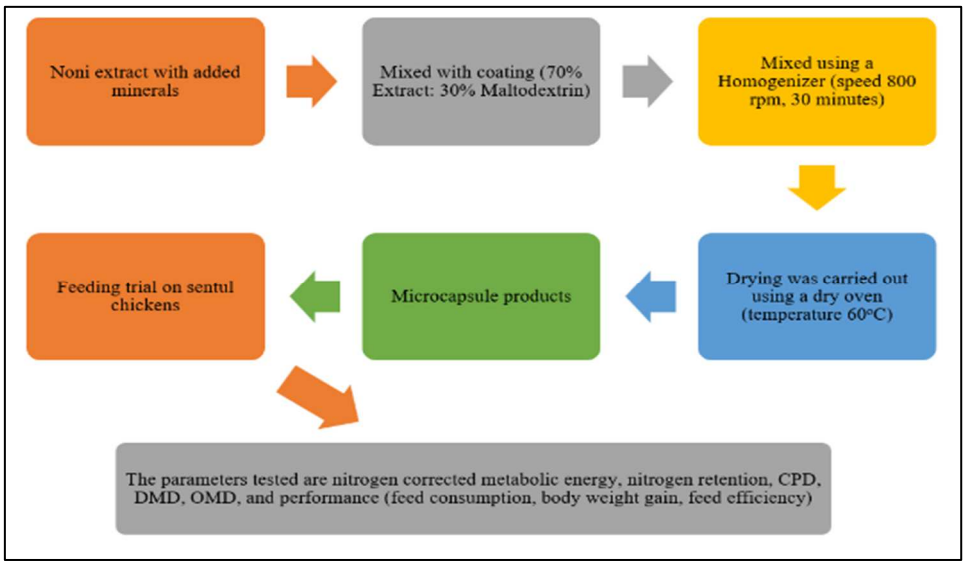

Fig. 2 Microencapsulation process

B. Animal and Experimental Feed

The Sentul chickens used in this study were 12 weeks old. Chickens were obtained from BPTTU Jatiwangi-West Java, Indonesia, and randomly placed in 20 experimental plots. Each treatment consisted of four replicates. Chickens in individual cages were given treated feed and drinking water ad libitum. The composition of the feed ingredients used are fine bran (15%), yellow corn (59%), fish meal (9.5%), soybean meal (15%), bone meal, CaCo3, and top mix (0.5%). The nutrient content of the basal ration includes crude protein (16.57%), crude fat (9.59%), crude fiber (8.65%), and metabolic energy 2,952 (kcal/kg). Levels of treatment in research include:

T0 = Basal ration
T1 = Basal ration + 50 mg/kg Zinc-Bacitracin.
T2 = Basal ration + 125 mg/kg MNFE
T3 = Basal ration + 250 mg/kg MNFE
T4 = Basal ration + 375 mg/kg MNFE

C. Parameter measurement

Variables measured in this experiment included nitrogen-corrected metabolic energy, nitrogen retention, CPD, DMD, OMD, and performance (feed consumption, body weight gain, feed efficiency). Fig. 3 shows the flowchart nutrient digestibility and performance measurement.

D. Nutrient Digestibility Sampling

- Sampling was carried out in the 12th week
- Chickens are given feed treatment, and drinking water is given ad libitum.
- Chicken is slaughtered and cut open on the chest
- The intestine is removed, and the large intestine is cut to take a stool sample.
- The fecal samples are dried and analyzed for lignin content, crude protein, and dry and organic matter.

E. Metabolic Energy sampling

- Sentul chicken is prepared with as many as 20 tails. Sampling was carried out in the 12th week
- Chickens are placed into individual cages, then fasted for 24 hours to eliminate the remaining previous ration from the digestive tract
- The amount of ration given is 80 grams per head. Drinking water is provided ad libitum.
- Perform sample collection. Excreta was collected after the ration was given, and the excreta released from it was sprayed with 5% boric acid every three hours to overcome the volatilization of nitrogen. Stool storage time is 24 hours.
- The excreta from the shelter is cleaned of hair and other impurities, then weighed and dried in an oven at 45-50°C for three days.
- Excreta that has been dried is analyzed for its nitrogen content and gross energy

F. Statistical Analysis

Statistical analysis was performed using SPSS software (IBM SPSS version 21). The mean difference for all parameters was determined using a one-way analysis of variance (ANOVA). The difference is considered significant at the 0.05 level. In addition, Duncan's test compares different treatments in different ways.

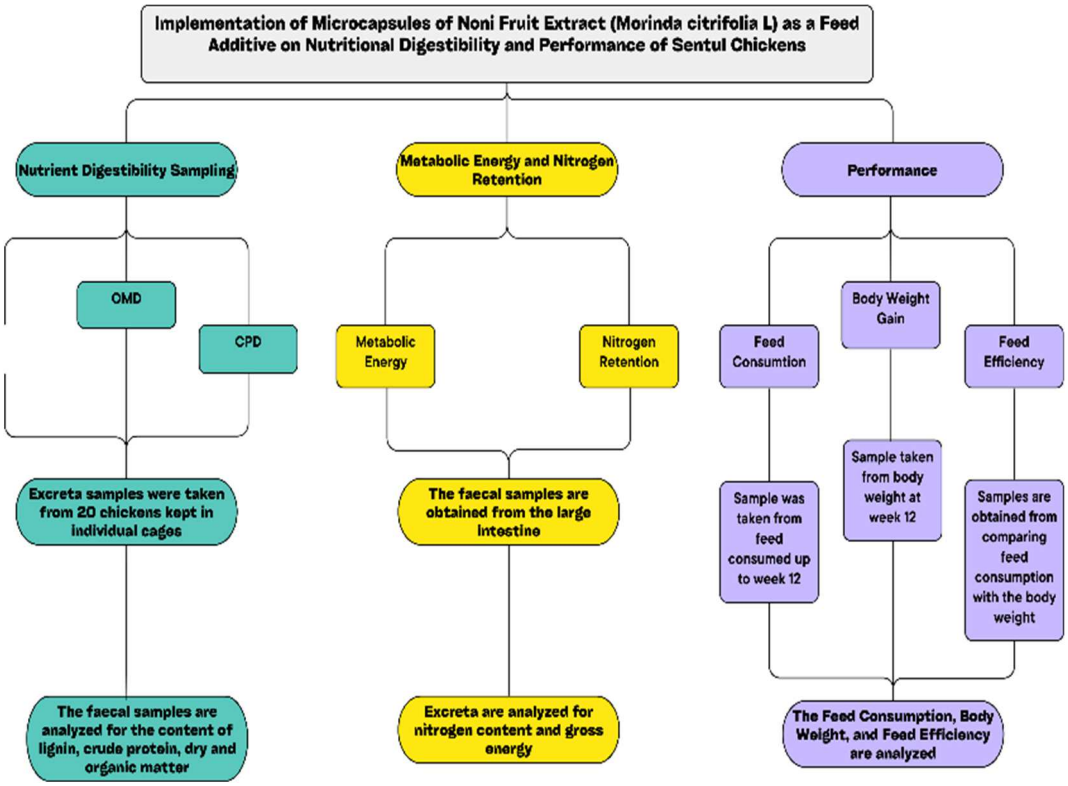

Fig. 3 Nutrient Digestibility and Performance Measurement Flowchart

III. Results and Discussion

A. Effect of Microcapsule Extract of Noni Fruit on The Nutrient Digestibility of Sentul Chicken

1) Organic Matter Digestibility

The results showed that the administration of noni fruit extract encapsulates had a significant effect ($p < 0.05$) on DMD. T4 has an average organic matter digestibility of 77.46%, followed by T3 = 77.11%, T1 = 72.46%, T2 = 72.31% and T0 = 69.28%. The addition of noni fruit extract encapsulated in the Sentul chicken ration was able to increase OMD at a level of 250-375 mg/kg better than positive and negative controls. T4 is significantly higher than T0, T1, and T2, but not significantly different from T3. Sentul chickens that were not given AGP in the ration had lower OMD compared to the administration of bacitracin antibiotics and the addition of encapsulated noni fruit extract with various levels. The average OMD of Sentul chicken diets for each treatment is shown in Table 1.

TABLE I
AVERAGE OF NUTRIENT DIGESTIBILITY IN SENTUL CHICKEN

Parameter	T0	T1	T2	T3	T4
DMD (%)	69.41 ± 1,98 a	73.86 ± 1.11 b	72.94 ± 1.03 b	78.09 ± 0.88 c	77.02 ± 1.24 c
OMD (%)	69.28 ± 1.57 a	72.46 ± 1.20 b	72.31 ± 1.01 b	77.11 ± 0.92 c	77.46 ± 1.25 c
CPD (%)	61.57 ± 2.71 a	69.23 ± 1.43 b	64.13 ± 1.48 a	73.74 ± 1.05 c	79.63 ± 1.46 d

Different superscript letters on the same line show significantly different effects ($P<0.05$).

The noni fruit was found to contain phytochemical compounds including *alkaloids, terpenoids, saponins, carbohydrates, proteins, flavonoids, tannins, steroids, scopoletin, anthraquinone and ascorbic acid* [3], [5],[10], [11]. Using encapsulated noni fruit extract is the best treatment to increase OMD in the ration. The ability of the anthraquinones, which are contained in noni fruit extract capsules that could influence the acidity of the intestinal pH to become more acidic and thereby inhibit pathogenic bacteria from establishing themselves in the digestive tract has been shown to increase growth and stability of lactic acid bacteria in producing organic acids so that the digestibility of organic matter will increase. [12] stated that anthraquinone compounds (acidic materials) can affect the pH of the intestinal to make it more acidic. Where, when in an acidic environment, the protein-breaking enzyme in the proventriculus (pepsin) can work optimally, so that more ration protein is absorbed by the body which supports optimal growth.

The increased digestibility of organic matter appears to be in line with a higher digestibility of dried matter, given that the majority of its components are organic. Therefore, factors that affect high or low DMD also affect low or high organic matter. A high digestibility indicates a high rate of absorption of food substances by the body. Rations with a good balance of amino acids show optimal growth performance [13].

2) Crude Protein Digestibility

Based on statistical analysis, the feeding treatment had a significant effect ($p<0.05$) on CPD. T4 had the highest crude protein digestibility with a percentage of 79.63%, followed by T3 = 73.74%, T1 = 69.23%, T2 = 64.13%, and T0 = 61.57%. The results of the Duncan test show that T0 and T2 are significantly different from T1, T3, and T4. The addition of the encapsulated level of noni fruit extract tends to increase the digestibility of crude protein rations; this is presumably because the active substance serotonin accumulates more and more as more noni fruit extract is added. [14] stated that the identified alkaloid was *proxeronine*, a precursor of *xeronine.* Alkaloids are the most active biological compounds found in herbal plants [15]. One of them is found in noni fruit. In the intestinal organs, *proxeronine* is converted into *xeronine* by the enzyme *proxeroninase* [16]. Thus, the role of *xeronine* in the body is vital. Supported by [17] xeronine regulates the structure and function of proteins to regenerate damaged cells, activates all body functions, and plays a vital role in nutrient absorption.

The high digestibility of crude protein at P3 was also due to a positive correlation attributed to the DMD in the diet, which also tended to be superior to other treatments. The digestibility of dietary protein is proportional to the DMD and OMD in the diet. This is because the CPD is directly related to the digestibility coefficient of OMD in the feed. Therefore, addition of 375 mg/kg of encapsulated noni fruit extract was the best treatment to improve crude protein digestibility in Sentul chicken feed. [18] suggested that improving feed ingredients' nutritional value and digestibility is essential to improve broiler performance. Low *faecal* protein content also affects digestibility values. A number of studies show that the use of *phytogenic* feed additives can increase the digestibility of feed nutrients, especially protein digestion, namely by stimulating appetite, saliva secretion, intestinal mucus production, bile acid secretion, and the activity of digestive enzymes such as trypsin and amylase as well as having an effect on positive for intestinal morphology [19].

3) Dry matter digestibility

Dry matter digestibility percentage sequentially from the largest, namely T3 (78.09%), T4 (77.02%), T1 (73.86%), T2 (72.94%), and P0 (69.41%). Based on statistical analysis, it was shown to have a significant effect on dry matter digestibility (DMD) ($P<0.05$). This is because the administration of microcapsule noni fruit extract gave a positive response to the digestibility of dry matter. Treatment T1-T4 is significantly higher than P0. Administration of bacitracin (P1) antibiotics was significantly higher than T0 and T2. The administration of encapsulated noni fruit extract (P3) and (P4) was significantly higher than all treatments.

It is because noni fruits are phytogenic plants that can be used as feed additives. It's got a lot of important substances. Phytogenic feed additives have been reported to increase nutrient digestibility (less excretion of undigested nutrients) in the gastrointestinal tract and increase carcass weight in chicken [20], [21]. Thus, the addition of noni fruit extract encapsulates causes better absorption of nutrients in the digestive tract and results in a high digestibility value.

According to [22] most of the absorption of nutrients occurs in the small intestine, and their absorption is affected

by the intestinal mucosa. This is supported by the statement [23] that high digestibility values are caused by a wider surface area of intestinal villi and increased secretion of digestive enzymes. One of the things that affect livestock's ability to digest feed properly is a healthy digestive tract. With healthy livestock, the digestive tract of livestock will get better.

B. Effect of Microcapsule Extract of Noni Fruit on Metabolic Energy and Nitrogen Retention in Sentul Chicken

1) Metabolic Energy

Table 2 shows the metabolic energy values from the administration of noni fruit extract microcapsules. The average metabolizable energy values of Sentul chickens range from 3005.14 kcal/kg to 3019.28 kcal/kg. The highest metabolic energy value was obtained from chickens that received T4 treatment (3019.28 kcal/kg), followed by chickens that received T3 treatment (3016.05 kcal/kg), T1 (3012.48 kcal/kg), T2 (3005.60 kcal/kg) and T0 (3005.14 kcal/kg). The effect of each treatment can be known by analysis of variance. The results showed that the treatment significantly differed ($p< 0.05$) on metabolic energy.

TABLE II
AVERAGE OF METABOLIC ENERGY AND NITROGEN RETENTION IN SENTUL CHICKEN

Parameter	T0	T1	T2	T3	T4
ME (kkal/kg)	3005.14 ± 4.28 a	3012.48 ± 6.54 ab	3005.60 ± 4.96 a	3016.05 ± 7.27 b	3019.28 ± 5.35 b
NR (%)	72.98 ± 0.52 a	75.05 ± 0.45 b	74.94 ± 0.41 b	77.01 ± 0.19 c	77.43 ± 0.75 c

ME = Metabolic Energy
NR = Nitrogen Retention
Different superscript letters on the same line show significantly different effects (P<0.05).

This proves that the ration containing encapsulated noni fruit extract causes a positive response in Sentul chickens to the value of metabolic energy. This means that the nutrient content of processed feed can increase metabolizable energy values because the treated ration can increase digestibility so that many components are easily digested due to the addition of encapsulated feed additives so that the ration quality increases proportionally. The opinion of [24] is that a high metabolic energy value means that the energy contained in the feed is utilized well by the chicken. Encapsulated amounts of noni fruit extract up to 375 mg/kg were shown to have a more positive impact on metabolizable energy values than the control diet (TO). Metabolizable energy values are directly proportional to digestibility. Therefore, by increasing digestibility, the metabolic energy value will increase. The *proxeronine* bioactive compound in noni fruit extract works in the digestive tract. [25] states that *xeronine* can increase the activation of enzymes, which can help absorb nutrients and increase digestibility. Metabolic energy will increase if digestibility increases, following the opinion of [26] that feed additives can increase energy availability due to their effect on the digestive process.

2) Nitrogen Retention

The average retention value by administering encapsulated noni fruit extract is listed in Table 2. The average nitrogen retention value of rations containing noni extract encapsulated with maltodextrin ranged from 72.98% to 77.43%. The highest nitrogen retention values were obtained from the treatment ration T4 (77.43%), followed by the treatment ration, T3 (77.01%), T1 (75.05%), T2 (74.94%), and T0 (72.98%). Based on the analysis of variance results, using different amounts of encapsulated noni fruit extract had a significant effect on nitrogen retention ($p<0.05$), meaning that all levels of adding feed additives positively responded to nitrogen retention values. This shows the efficient use of digested protein from various levels of encapsulated noni fruit extract in the ration, so much protein is digested.

The average value of nitrogen retention for all treatments was higher than 67%, namely 72.98% to 77.43%. Thus, there is an efficient use of protein so that more protein is digested. Rations containing antibiotic treatment (T1) and encapsulated noni fruit extract (T2, T3, T4) had better nitrogen retention values than the control treatment. Even those who were given noni fruit extract with levels of 250 mg/kg and 375 mg/kg were better than those who were given bacitracin antibiotics. Many factors can affect the nitrogen retention value. Research results [27] prove that not only food factors influence the composition of broiler chicken feces but also the age of the bird. The excreta urine N ratio can reflect differences in broiler N utilization between different age categories, the higher the urine N content in the finisher phase, the higher the urine N content, and the lower the N retention in that phase. Nitrogen retention is dependent on metabolic energy and nitrogen consumption values. Increased nitrogen retention may occur due to the role of *proxeronine* as a bioactive compound. It supports the process of nutrient absorption in the digestive tract and is aided by acting as an antibacterial agent, thereby increasing nitrogen retention. The higher the nitrogen retained in the poultry body, the lower the nitrogen in the feces and urine.

C. Effect of Microcapsule Extract of Noni Fruit on Performance of Sentul Chicken

1) Feed Consumption

Feed consumption is determined by calculating the difference between the number of feeds given and the remaining feed. Optimal ration consumption has an impact on optimal productivity as well. Table 3 shows the average feed consumption of the Sentul chickens during the study, which ranges from 239.71 ± 0.84 to 242.77 ± 0.53 gram/head. The highest feed consumption was obtained in the T0 treatment, 242.77 ± 0.53 gram/head, while the lowest was at T3 of 239.71 ± 0.84 gram/head. Highest to lowest average sequentially, T0, T4, T2, T1, and T3.

Based on the results of the Duncan test, microcapsule administration significantly decreased food consumption ($P<0.05$). This reduction was due to the presence of bioactive compounds in each treatment that may improve food digestion; therefore, feed consumption was relatively low. The treatment feed consumption value (T2 – T4) was relatively lower than the control. This condition is believed to be caused by various microencapsulation processes in noni fruit, such as drying and soaking in a solvent, thereby reducing unwanted secondary compounds. [3] that noni fruit contains components of phenolic compounds, especially

coumarin, flavonoid, and iridoid compounds which are useful as antioxidants, and antibacterial.

TABLE III
AVERAGE OF NUTRIENT DIGESTIBILITY IN SENTUL CHICKEN

Parameter	T0	T1	T2	T3	T4
Feed Consumption (gr/head/week)	242.77 ± 0.53 b	240.65 ± 0.92 a	240.78 ± 1.76 a	239.71 ± 0.84 a	241.18 ± 0.49 a
body weight gain (gr/head/week)	52.86 ± 2.40 a	57.42 ± 4.08 b	58.52 ± 3.09 b	62.00 ± 2.83 b	58.84 ± 1.93 b
Feed Efficiency (%)	21.78 ± 0.95 a	23.86 ± 1.66 b	24.30 ±1.17 b	25.87 ± 1.15 b	24.40 ± 0.76 b

Different superscript letters on the same line show significantly different effects (P<0.05).

The potential of *M. citrifolia* fruit extract microcapsules can ensure healthy growth of chickens, especially due to the presence of potential bioactive compounds. Bioactive analysis reported from research results [6] shows that M. *citrifolia* fruit contains an excellent source of antioxidants and polyphenols including alkaloids, flavonoids, tannins and anthocyanins. This potential can suppress anti-radical activity against stress factors such as pathogens which affect the growth rate of chickens.

2) Body Weight Gain

Weight gain is a sign of cell changes, meaning that Sentul chickens experience an increase in the number of cells and an increase in cell size over a certain period. Thus, the productivity of Sentul chickens can be increased with quality feed [28]. The average body weight gain for Sentul chickens ranged from 52.86 ± 2.40 to 62.00 ± 2.83 g/head/week (Table 3). The highest body weight gain was in the T3 treatment of 62.00 ± 2.83 gram/head/week, and the lowest was in T0, 52.86 ± 2.40 gram/head/week. Analysis of variance showed that administration of noni fruit microcapsules was significantly different from body weight gain (P<0.05). The increase in body weight gain was seen in the treatment given by microcapsules.

Based on the results of the Duncan test, the T2-T4 microcapsule treatment gave significantly higher body weight gain (P<0.05) than the control treatment. High weight gain is influenced by the effect of diet on carcasses. From Table 3, it can be seen that food consumption was relatively lower at T2-T4 than in the control treatment. Increased feed efficiency and absorption of nutrients in this treatment due to bioactive compounds, namely anthraquinones, are believed to be used more effectively and efficiently in the gastrointestinal tract of Sentul chickens. Noni extract, which contains anthraquinone substances (acidic material), can affect the pH of the proventriculus to be more acidic because, in an acidic environment, the protein-breaking enzymes in the proventriculus (pepsin) can work optimally, so that more ratio protein is absorbed by the body which supports the occurrence of optimal growth [9]. The better the digestion and absorption of nutrients, the better the body weight gain and indirectly the higher the final body weight. The utilization of artificial antibiotics can be substituted with organic components that have been verified to enhance performance [29].

3) Feed Efficiency

Feed efficiency is a measure used to assess the efficiency of feed use in livestock. Efficiency is the ability of the ration consumed in a certain time unit to produce the body weight of an animal at the same time. The average feed efficiency for Sentul chickens ranged from 21.78 to 25.87% (Table 3). The highest feed efficiency was in the T3 treatment, which was 25.87 ± 1.15 and the lowest was in T0, which was 21.78 ± 0.95%. Analysis of variance showed that treatment had a significant effect on feed efficiency (P<0.5). It can be seen in Table 1 that the feeding efficiency was higher for the T1, T2 and T3 treatments than for the T0 and T1 treatments. Adding noni fruit extract microcapsules to the feed also improves feed efficiency, because the bioactive compounds contained in noni fruit can work in the intestine by providing conditions that will increase nutrient absorption. The anthraquinone compounds in noni fruit extract microcapsules can help digestion by improving the structure of the small intestinal villi during the absorption of nutrients from food and have the potential to inhibit the growth of pathogenic bacteria in the small intestine. Anthraquinone compounds will be absorbed in the intestines, distributed in other tissues and organs, and reabsorbed into the blood [12]. This condition causes the surface of the small intestine's villi to expand for better absorption of nutrients. Increasing nutrient absorption by the intestinal villi can support the productivity of Sentul chicken. Gut health determines overall animal health and can increase productivity [30]. The mechanism of action of noni fruit extract on poultry nutrition can be seen in Fig. 4.

IV. CONCLUSION

The addition of noni fruit extract microencapsulates 250 mg/kg to feed increases metabolic energy, nitrogen retention, digestibility, and performance in Sentul chickens. Because they have a positive effect on the digestive tract, they can be used as good feed additives to replace AGP.

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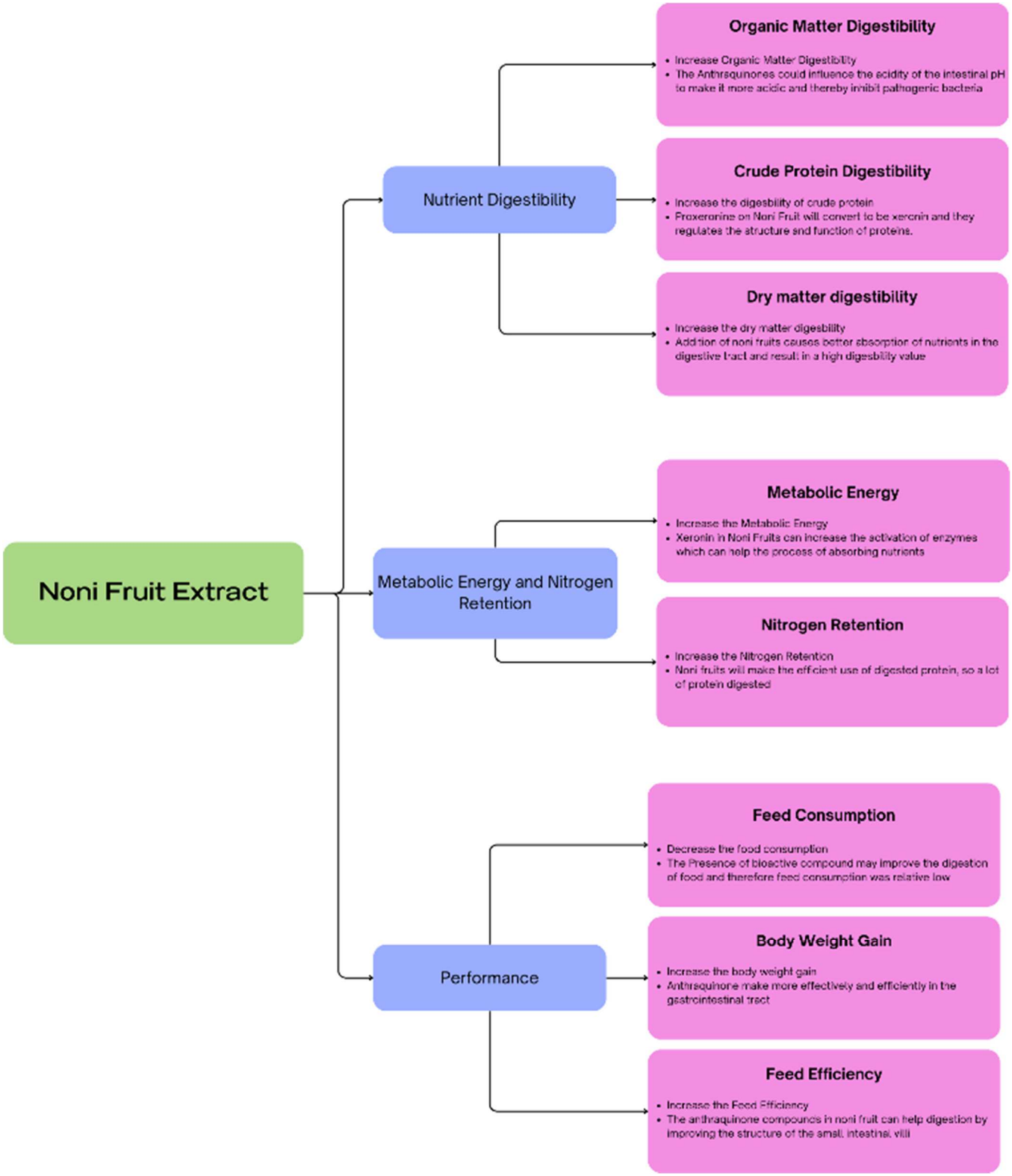

Fig. 4 Mechanism of Action of Noni Fruit Extract in Poultry Nutrition

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