Coconut meal as a feed ingredient and source of prebiotic for poultry

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Abstract. The low quality protein of coconut meal, coupled with high fibre content, leads to limited use of this agricultural by-product in the poultry diet. Attempts to maximize the amount of coconut meal included in the broiler feed have been made through amino acids supplementation, enzyme addition and pelleting coconut meal. Among these feed technologies and manipulation, pelleting coconut meal appears to be more powerful in promoting the growth of broiler chickens. The reasons for the improvement of broiler growth due to pelleting coconut meal have not been established yet. The mechanisms of improved growth of birds might be through increased feed intake, less energy spent and increased bulk density. Coconut meal contains a high concentration of mannose – based polysaccharides or mannan. This substance has long been believed to have prebiotic properties due to its capability to bind certain species of pathogenic bacteria in the digestive tract of birds. Voluminous reports of the positive effects of mannose-based polysaccharides from yeast have been published. Mannose –based polysaccharides from legumes, on the other hand, have been reported to have anti-nutrient property. Surprisingly, mannose-based polysaccharides from coconut behave like yeast mannan. A number of current studies indicated that mannose based polysaccharides improved body weight gain and feed digestibility. The growth of birds was negatively impacted when the birds were challenged against pathogenic bacteria of *E. coli*. Wet droppings and diarrhea incidences were not found in *E. coli*-challenged birds when the diets were supplemented with coconut mannan. In conclusions, coconut meal can be used as a feed ingredient for poultry unless the coconut meal was pelleted or enzymatically treated. Mannose-based polysaccharide from coconut was effective to promote growth and acted as prebiotic.

1. Introduction
Global production of coconut in 2017 was 60.8 million tons and 31.2% of the production was contributed by Indonesia [1]. Today, Indonesia has been the largest coconut producer in the world. The valuable product of coconut is coconut oil, derived from the meat of the nut. Two common ways to produce coconut oil in Indonesia are through wet and dry processes, generating coconut dregs and copra cake respectively. Although these two coconut by-products are abundantly produced in the coconut-producing provinces in Indonesia, their utilization in poultry feed is still limited due to the presence of fibrous carbohydrates, particularly mannose-based polysaccharides [2] and thus negatively affected the passage time of the diets in the digestive tract of broilers [3].

Attempts to optimize the use of coconut by-products such as copra cake and coconut dregs have been the main concern in our laboratory over the last two decades. Nutritional manipulation, biological treatment, physical modification and enzymatic application were some of the ways used in our laboratory to improve the feeding value of these agricultural by-products. Research on the improvement of nutritive
value of the coconut by-products reported worldwide come up with inconsistent results. Instead of focusing on improving their feeding value, we are also now looking at another side of the coin by investigating mannose-based polysaccharides present in the coconut [4].

Over the last three decades, studies on the use of prebiotic from mannose-based polysaccharide have been the main focus of animal nutritionists due to the resistance of antibiotic uses in poultry feed. The use of prebiotic has come up as one of the choices to replace antibiotic growth promoter. Mannose based carbohydrate from yeast *Saccharomyces cerevisiae* has been available in the market and its use has been widespread and regarded as a pro-nutrient. However, mannose based carbohydrate from legume was believed to be anti-nutrient and thus its inclusion in the diets downgraded the quality of the diet [5]. It seems that mannose based carbohydrates had different phisyco-chemical properties, depending upon their chemical structureand their origin. Since mannose based carbohydrates in the coconut were presents in large quantity, a question needs to be addressed whether coconut mannose based polysaccharides behave like yeast or legume-based polysaccharides ?. A number of recent findings confirmed that mannose based polysaccharides from coconut could be used as prebiotic to replace antibiotic growth promoter.

2. Physical and nutritional profiles of coconut by-products

2.1. Physical profile

Database on nutrients profile of feedstuffs has well been recorded by NRC [6]. Therefore, formulating a poultry diet was mainly based on NRC recommendation, either in the aspects of nutrient requirements or nutrients contents of feed ingredients. Feed formulation for poultry recommended by NRC [6] produced, in many cases, disappointing results, particularly when non-conventional raw materials were used. This is because each ingredient possesses its own physical and biochemical characteristics Ezieshi and Olomu [7]. Unfortunately, data on physical characteristics of feedstuffs were scarcely reported. Sundu et al. [8] have initiated to list the physical characteristics of nine feedstuffs, but this might be the only report available in the database.

Physical characteristics of feedstuffs (table 1) such as bulk density and water holding capacity can be used as the quick predictors to determine the quality of the ingredients [9]. The association of these physical characteristics with feed intake has long been believed [9,10] since the low bulk density and high water holding capacity could deteriorate the nutritive value of the diets. These two physical characteristics are possibly related to fibrous components. Bulky feed might occupy bigger space in the digestive tract of chickens and high WHC diet might bind more water leading to the chickens having higher water intake. Relationship between bulk density and feed intake was linearly correlated with the equation of $Y = 985.44 X + 121.15$ and $R^2 = 0.9577$ while the relationship between water holding capacity and feed intake was $Y = -62.57 X + 489.56$ and $R^2 = 0.7951$ [11]. A possible reason to elaborate on the decreased intake due to these physical characteristics is that the ability of feedstuffs to bind water trigger the birds to consume more water than the feed. Sundu et al. [11] fed birds with the diets with different water holding capacity. The authors found that the birds fed with high water holding capacity consumed less feed.

Studies on the area of the effect of water holding capacity on growth performance of broilers were limited. Robertson *et al.* [12] reported that a 20% lower body weight gain of broilers was found when the chickens were offered a lower bulk density diet. Dansky [13] reported that fibrous diet did not negatively affect the growth performance of birds provided that the bulk density was over 0.44 g/cm$^3$. However, this value of bulk density might not work in the modern strain of broilers with a higher growth rate. Sundu *et al.* [11] offered diets with a bulk density of 0.53 g/cm$^3$, but optimal growth could not be reached. The authors recommended a diet with the bulk density of over 0.69 g/cm$^3$.

2.2. Nutritional value of coconut meal

Coconut meal is the residue of the extraction of coconut oil. This by-product has long been used in poultry diet. Results of the coconut meal use in the poultry diet come up with limited success due to the fact that coconut meal quality varies widely according to its intrinsic nutrients, extraction process, and storage conditions. Nutrients profiles of coconut meal are shown in tables 2 and 3.
Table 1. Physical characteristics of some feedstuffs

| Feedstuffs       | Bulk density | Water Holding Capacity | Relative volume |
|------------------|--------------|------------------------|-----------------|
|                  | Unmodified   | 0.5 mm 0.5 mm          | 1 mm            |
| Copra meal       | 0.56         | 0.49                   | 4.14 4.69       | 10.6            |
| Titricale        | 0.69         | 0.65                   | 3.08 3.47       | 6.3             |
| Rye              | 0.73         | 0.57                   | 2.32 3.36       | 5.8             |
| Millrun          | 0.36         | 0.44                   | 4.16 6.64       | 11.7            |
| Palm kernel cake | 0.67         | 0.57                   | 2.93 3.52       | 6.9             |
| Wheat            | 0.72         | 0.66                   | 2.49 3.29       | 5.3             |
| Fishmeal         | 0.55         | 0.53                   | 1.64 1.51       | 5.0             |
| Soybean meal     | 0.73         | 0.58                   | 2.77 3.30       | 6.5             |
| Corn             | 0.69         | 0.56                   | 1.71 1.94       | 4.8             |

Source: Sundu et al. [11]

Table 2. Nutrient content of coconut meal

| Fractions       | Percentage | References       |
|-----------------|------------|------------------|
| Dry matter      | 91-96      | [6,14]           |
| Crude protein   | 15-25      | [6,14,15]        |
| Gross energy    | 4,375 – 5,872 | [6,14]     |
| Metabolizable energy | 1525 - 2179. | [6,8]       |
| Crude fibre     | 7-15       | [6,14,16]        |
| Lipid           | 4.77 - .6.9 | [8,14]          |
| Ash             | 6.7 – 8.0  | [14,16]          |

Table 3. Amino acids profiles of coconut meal

| Protein        | NRC [6] | Lachanche and Molina [17] | Sundu [18] |
|----------------|---------|----------------------------|------------|
| Crude protein  | 19.2    | 21.9                       | 21.7       |
| Arginine       | 1.97    | 2.32                       | 0.31       |
| Cysteine       | 0.28    | NC                         | NC         |
| Glycine        | 0.82    | 0.60                       | 0.93       |
| Histidine      | 0.36    | 0.24                       | 0.57       |
| Isoleucine     | 0.63    | 0.50                       | 0.81       |
| Leucine        | 1.18    | 0.99                       | 1.59       |
| Lysine         | 0.50    | 0.55                       | 0.55       |
| Methionine     | 0.28    | 0.31                       | 0.33       |
| Phenylalanine  | 0.88    | 0.60                       | 1.03       |
| Threonine      | 0.58    | 0.48                       | 0.84       |
| Tyrosine       | 0.44    | 0.35                       | 0.45       |
| Serine         | 0.79    | 0.68                       | 1.20       |
| Valine         | 0.91    | 0.78                       | 1.02       |
| Tryptophane    | 0.12    | 0.14                       | NC         |

NC: not calculated

Protein contents of coconut meal were between 15 and 25%. This relatively high protein of coconut meal might be beneficial if the protein is available for the chickens. However, data on the solubility of
coconut meal indicate that the protein quality of coconut meal was low. Lachance and Molina [17] reported a 35% solubility of coconut meal when it was extracted by using bromelain. Using Protease enzyme could increase protein solubility of coconut meal to 45%. Our in-vivo study indicated the protein digestibility of coconut meal was 55% when it was fed to broiler chickens. The low in essential amino acids content only meets 45 – 50% and 34-62% of the methionine and lysine requirements [1]. The low amino acids digestibility (table 2) and availability might be due to the fact that the amino acids undergo heat damage due to drying and oil extraction processes.

| Nutrients                        | Digestibility |
|---------------------------------|---------------|
| Dry matter                      | 44.7          |
| Neutral Detergent Fibre         | 39.8          |
| Jejunal viscosity (cP)          | 1.41          |
| Apparent Metabolizable energy (Mj/kg) | 9.12    |
| Crude protein (%)               | 63.1          |
| Arginine                        | 85.6          |
| Glycine                         | 69.7          |
| Histidine                       | 61.4          |
| Isoleucine                      | 73.6          |
| Leucine                         | 76.1          |
| Lysine                          | 51.3          |
| Methionine                      | 71.1          |
| Phenyalanine                    | 79.3          |
| Threonine                       | 63.0          |
| Tyrosine                        | 65.2          |
| Serine                          | 71.4          |
| Valine                          | 75.6          |

Source: Sundu [18]

Saittagaroon et al [19] identified the mono-saccharides profiles of coconut polysaccharides. The authors reported that of the total carbohydrates present in coconut meal, 61% was polysaccharides, containing 42% mannose and 58% glucose. Balasubramaniam [20] found that the majority of coconut polysaccharides were mannann and galactomannan, being 26 and 61% respectively. Studies on the extraction of coconut meal by using 24% NaOH [21] and 18% NaOH [22] generated residue as mannose-based polysaccharides or mannan. We duplicated the procedure of Kusakabe and Takashi [21] in our laboratory and found 29 to 34% residue as mannan [2]. These values were comparatively higher than legume mannan (1.49 and 2.12% in soybean meal) and 31% yeast mannan [23, 24].

3. Growth performance of broilers fed the coconut-supplemented diets
Although coconut meal contains up to 25% protein, its quality was low due to the presences of Maillard product and fibrous fraction such as mannan. These two components impaired the digestibility of the nutrients. Since the coconut protein is partly located inside the cell wall and the protein might be damaged due to heat treatments during oil extraction, the amino acids were not fully available for poultry. Accordingly, the use of coconut meal in poultry diet could deteriorate the growth of 3-weeks old broiler chicks [25]. Attempts to improve the quality of the coconut meal-containing diets have been done by amino acids supplementation. Thomas and Scott [26] formulated a coconut diet with the addition of lysine. The authors found an increased body weight gain of birds fed lysine-supplemented coconut diet. However, the growth of birds was still far below the growth of birds fed the corn-soy diet. Sundu et al. [11] even added the coconut diet with lysine and methionine, but the results were disappointing when it was compared to the growth of birds fed the corn-based diet.
The failure to improve the quality of coconut meal diet by supplementation of amino acid in young chicks is partly due to the smaller gut capacity of chicks and poor capability of young chicks to digest nutrients entrapped inside the cell wall. It is not difficult to explain that when the gut is small and the capability to digest fibrous components is low, the birds consume less feed and thus growth is impaired. Addition of exogenous enzyme into the diet to break down the cell wall could logically beneficial to improve the feeding value of the diet. Since β-mannan is present in coconut meal with relatively high concentration, supplementation of the diet with mannan degrading enzymes could generate more available carbohydrate for the broiler. An early study of Pluske et al. [27] on the use of mannan degrading enzyme in coconut containing diets indicated that the use of mannan-degrading enzyme increased body weight of birds and decreased mortality. A more current study conducted by Sundu et al [25] indicated that dry matter digestibility and AME of the diet was also increased.

The use of pelleting technology has been reported for more than 6 decades since Patten et al. [28] published a report on the use of pelleted diets. The efficacy of this technology to improve the feeding value of the diets has been well documented [29,30]. This improvement becomes evident when the poultry was feed by a low bulk density diet. The improved broiler performance due to pelleting the diets might be through a number of mechanisms, namely: increased feed intake, increased feed digestibility and less energy spent. Pelleting coconut meal can be a way to improve its quality as this agricultural by-product is bulky. Sundu et al. [11] pioneered a study of inclusion pelleted coconut meal in broiler diet. They found that the growth performance of broiler chickens increased to the same level of the growth of broiler chickens fed the corn-soy diet. These findings could be an indication that the main problem of using coconut meal in poultry diet might be related to its physical properties rather than chemical contents. Interestingly, when the pelleted coconut meal was reground and offered to broiler chickens, the growth performance of birds was poor [11].

4. Coconut mannan as a pro-nutrient

The issue on the antibiotic resistance has triggered the animal nutritionists to replace the use of antibiotic growth promoter in poultry diets. Several products such as prebiotic, probiotic and phytobiotic have appeared in the market to tackle the problem of antibiotic resistance. Mannose based carbohydrates come up as a replacer for antibiotic growth promoter. Studies on these products have been intensively reported and the results of using mannose based carbohydrates as a growth promoter to replace antibiotic were promising.

Mannose based polysaccharides or mannan in nature were mainly derived from three different sources, namely legume mannan, yeast mannan and palm mannan. Mannans in legumes are usually present in the form of galactomannan, having a beta linkage. The linkages were made up of a β (1-4) D-mannopyranose units as a backbone and D-galactopyranose units attaching as a side chain [31]. Majority of mannan in legumes has a large quantity of galactose unit with the mannose to galactose ratio of 1.63 in guar gum and 3.12 in soybean meal. The galactose units present in legume have the capability to strongly bind water and thus make the solutions more viscous. It is well accepted that viscous substrate could block the beneficial nutrients from intestinal enzymatic hydrolysis in the digestive tract of poultry. This condition can downgrade the quality of the diet due to impaired digestibility. From this perspective, it could be said that legume mannans are anti-nutrients and thus its inclusion in the diet deteriorated feed quality.

Mannan in yeast, on the other hand, is an alpha mannan, possessing a backbone of α (1-6) mannose units and being substituted by α (1-2) and α (1-3) mannose units as side chains. This yeast mannan is generally found in Saccharomyces cerevisiae [32]. Mannan from yeast has been believed to be a pro-nutrient as this mannans have prebiotic properties [33]. Mannan in coconut is composed of β (1-4) mannose units with a very small quantity of galactose unit in a side chain [34]. Since mannan from palm nut has not been widely studied, its property might behave like one of the two mannans. The question needs to be addressed here is what does exactly the palm mannan behave, like a legume mannan as anti-nutrient or a yeast mannan as a pro-nutrient?

To answer this challenging question, Sundu et al. [35] extracted mannose based polysaccharides from coconut and used it in broiler diets. The authors found that coconut mannan could effectively improve the
growth performance of broiler chickens. A study of Yamin [36] indicated that inclusion of 0.05% coconut mannan in broiler diet improved body weight gain and feed conversion ratio by about 7 and 12% respectively. More interestingly, supplementation of the diets with coconut mannan increased feed digestibility by 2.5% and decreased fecal moisture by 5.5% (see table 4). Since wet droppings have been the main concern in the poultry industry due to the fact that watery feces are the ideal habitat for bacterial growth and thus increase the ammonia production [37].

Table 5. Broiler performance improvements due to coconut mannan supplementation

| Variables                        | Increase (%) | Authors      |
|----------------------------------|--------------|--------------|
| Body weight gain                 | +7.4         | Yamin [36]   |
| FCR                              | -12          | Yamin [36]   |
| Feed intake                      | +6.0         | Yamin [36]   |
| Dry matter digestibility         | +2.5         | Sundu et al. [38] |
| Faecal moisture                  | -5.5         | Sundu et al. [38] |
| Caecal pH                        | -6.8         | Sundu et al. [38] |
| Abdominal fat                    | -6.1         | Kannan et al. [39] |

The modus operandi of the increased growth of birds fed the coconut mannan – supplemented diets might be through the increase in the health status of birds. The increased population of beneficial bacteria and the reduction in the population of pathogenic bacteria were possibly the reasons for improved health status. To maintain the minimal population of pathogenic bacteria in the gut, beneficial microbes modified the microhabitat of the gut through the reduction in caecal pH. Once the pH of the gut dropped, this environment favors the beneficial microbes to grow [40]. Addition of the diets with coconut mannan was able to reduce caecal pH by 6.8% (table 4). The efficacy of coconut mannan to overcome the pathogenic bacteria intervention become evident when the coconut mannan was offered to *E.coli*-challenged broilers, their growth was not negatively affected, being the same growth as broilers fed the commercial manno-oligosaccharides or antibiotic avilamycin [41].

Table 6. Effect of interaction between diet and *E.coli* challenge on body weight gain, feed intake, FCR and excreta dry matter

| Type of additive | *E. coli* | Body weight gain (g) | Feed intake (g) | FCR | Excreta dry matter (%) |
|------------------|-----------|----------------------|-----------------|-----|------------------------|
| Control          | -         | 479a                 | 866a            | 1.82b | 22.9a                 |
|                  | +         | 334b                 | 679b            | 2.03a | 14.9b                 |
| Control + PKP    | -         | 474a                 | 812a            | 1.71b | 23.8a                 |
|                  | +         | 469a                 | 807a            | 1.72b | 23.7a                 |
| Control + CP     | -         | 474a                 | 813a            | 1.71b | 24.9a                 |
|                  | +         | 471a                 | 815a            | 1.73b | 24.0a                 |
| Control + Avilamycin | -   | 477a                 | 804a            | 1.69b | 25.0a                 |
|                  | +         | 470a                 | 797a            | 1.70b | 24.5a                 |

Source: Sundu et al. [34]

Fitriyani [41] reported that the incidence of wet droppings, diarrhea and decreased weight were not found in the E.Coli-challenged birds when coconut mannan was added into the diets [41]. Sundu et al. [35] found that when control birds were offered E.coli in the drinking water for a week, their body weight gain dropped. However, coconut mannan could maintain the growth of *E.coli*-challenged birds (See table 5). It seems that coconut mannan might improve the immune status of birds as this was found in the *E.coli* – challenged birds fed the yeast manno-oligosaccharides diet [42]. Reasons for the improvement in growth performance of mannoooligosaccharides-supplemented birds were due to the capability of these
carbohydrates to bind pathogenic bacteria in the digestive tract of broilers and flush them out of the cloaca. This can lead to an increased population of beneficial microbes in the gut. The increased immune status was also found in the birds fed the yeast manno-oligosaccharides diet. The mechanism of improved bird performance because of the supplementation of diets with coconut mannan is not yet understood whether the improvement is due to the role of coconut mannan per se or coconut mannan undergoes physical and chemical hydrolysis in the digestive tract of broilers to produce mannooligosaccharide. However, the production of mannooligosaccharides due to physical grinding in the gizzard and acid hydrolysis in the proventriculus might be low. Accordingly, improved body weight gain of broiler chickens was only statistically detected when the birds fed the 0.05% coconut mannan, below 0.05%, the improvement of body weight was insignificant [43].

5. Conclusions
The use of coconut meal in broiler diet could positively affect the growth performance of broilers provided that coconut meal was physically and enzymatically treated. Coconut mannan behaves like yeast mannan as these two mannans could promote the growth of broilers, even when the birds were challenged against *E. coli* contamination.

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