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Fermented Leaves in Broiler Rations: Effects on Growth Performance, Physiological Condition, and Meat Characteristics

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Abstract

In recent years, the increasing price of protein-rich feed ingredients and retraction of antibiotic growth promoters from diets have become serious problems for broiler producers worldwide. Plant leaves are considered as alternative and cheap protein-rich feed ingredient for broilers owing to their high protein content. Studies have also shown that fermented plant leaves could serve as natural growth promoter, which is beneficial for broilers during the post-antibiotic era. Fermented leaves can also be used as natural antimicrobial and antioxidant agents for broilers as they consist of phytochemical compounds. This review presents the effects of dietary incorporation of fermented plant leaves on growth performance, physiological condition, and meat characteristics of broiler chickens based on the most recent literature.

Keywords: Broilers, fermentation, health, meat quality, phytochemicals, plant leaves

Introduction

In recent years, the search for alternative protein-rich feed ingredients for broiler production has accelerated due to the increasing and erratic prices of feedstuffs. Plant leaves have been used in broiler rations as they are among the most potential alternatives to protein-rich feedstuffs (Sugiharto et al., 2019). However, some limitations may be encountered when using plant leaves as feed ingredients. The high fiber content and the presence of antinutritional and toxic compounds may confine the incorporation levels of plant leaves in broiler rations (Sugiharto et al., 2019). Fermentation is a simple process that can be employed to improve the nutritional and functional properties of plant leaves. The latter improvement could thereby increase the proportion of plant leaves in broiler rations.

Several studies have reported the efficacy of fermented leaves in promoting the growth rate as well as the feed efficiency of broiler chickens (Zhang et al., 2012; Zhang et al., 2015). In this respect, fermented plant leaves can be considered as potential alternatives to antibiotic growth promoters, which have recently been banned for broiler production in most countries. Fermented leaves have also been shown to improve the antioxidative status of broilers (Zhang et al., 2020). For this reason, incorporation of fermented leaves in diets may be beneficial in mitigating the negative impacts of oxidative disruption due to stress. Other studies have also revealed that dietary inclusion of fermented leaves could improve the intestinal ecology (Zhang et al., 2015), physiological conditions (Cao et al., 2012; Zhang et al., 2020), and thereby enhance the health status of broiler chickens. Moreover, the positive effects of dietary incorporation of fermented leaves has also been shown in the carcass traits and meat quality of broilers (Santoso et al., 2015a; Santoso et al. 2015b; Zhang et al., 2020). This review aimed to update the knowledge and elucidate the effects of dietary incorporation of fermented plant leaves on growth performance, physiological condition, and meat characteristics of broiler chickens based on the most recent literatures.

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Fermented leaves as dietary ingredients for broilers

Feed has become a major cost in broiler production, and protein-rich feed ingredients are a major part of feed costs. To deal with the increasing price of protein-rich feed ingredients, the incorporation of unconventional protein feedstuffs has been practiced by many broiler producers. Among these unconventional protein feedstuffs, plant leaves or green foliage, such as cassava leaf (Adeyemi et al., 2012), *Moringa oleifera* leaf (Tesfaye et al., 2013), and *Leucaena leucocephala* leaf (Ayssiwede et al., 2010; Hussain et al., 1991), may be used as alternatives for protein-rich feed ingredients for broilers. Although plant leaves are potential alternatives to conventional protein-rich feed ingredients in broiler rations, they contain high amounts of fiber and antinutritional and toxic compounds such as cyanoglucoside and alkaloid mimosine that may confine the incorporation of leaves in poultry diets (Sugiharto et al., 2019). The less soluble protein, which contribute to the low protein digestibility, of plant leaves may also limit the incorporation levels of such green protein source in broiler rations (Teixeira et al., 2014).

Physical, chemical, and microbiological processes may be conducted to improve the nutritional characteristics of plant leaves prior to feeding to broilers. With regard particularly to microbiological means, solid-state fermentation is a simple and cheap approach to improve the nutritional traits and reducing the toxic and antinutritional compounds of plant leaves (Sugiharto and Ranjitkar, 2019). Zhang et al. (2017) recently reported that solid-state fermentation using *Bacillus pumilus* CICC 10440 increased the soluble protein content of *M. oleifera* leaf powder. Fermentation using lactic acid bacteria (*B. coagulans*, *L. plantarum* and *P. pentosaceus*) has also been reported to improve the physico-chemical properties of *Cinnamomum osmophloeum* Kaneh leaves (Kurniawati et al., 2017). Further, Wang et al. (2018) reported elevated crude protein, total and essential amino acids, reduced sugar and flavonoids in *Ginkgo*-leaves following solid-state fermentation with the fungus *Aspergillus niger*. Moreover, fermentation using *Trichoderma viride* resulted in increased crude protein and reduced crude fiber in banana leaf meal (Mandey et al., 2015). In the *in vivo* trial, Syahruddin et al. (2011) included the fermented *Morinda citrifolia* L. leaf meal in broiler rations up to 21% without detrimental effect on growth performance of broiler. The fermented *Sauropus androgynus* L. Merr leaf using the fungus *Trichoderma harzianum* was also supplied up to 10% in diets by Syahruddin et al. (2013) with no adverse effects on the feed intake, weight gain, and feed conversion of broilers. Further, Santoso et al. (2015a) incorporated fermented *Sauropus androgynus* leaf meal using either *Neurospora* crassa, *Lactobacillus* sp. or *Saccharomymes cereviceae* at 5% in broiler rations to reduce the proportion of protein feed ingredients in the rations. It was apparent in the study of Has et al. (2013) that fermentation using rumen liquor increased the proportion of mulberry leaves in broiler diets. At the level of 10% in diets, feeding unfermented mulberry leaves reduced final body weight, dry matter, and fiber digestibility and metabolic energy in broilers. At the same level, feeding fermented mulberry leaves had no negative impact on the above-mentioned parameters in broilers. In agreement with this, Mandey et al. (2015) documented that fermentation with the fungus *Trichoderma viride* increased the proportion of banana leaf meal in the diets of broilers. However, the dietary inclusion of fermented leaves should be conducted with care as high levels of incorporation may result in compromised growth performance of broilers (Mandey et al., 2015). In agreement, Syahruddin et al. (2013) reported that dietary inclusion of *Trichoderma harzianum*-fermented *Sauropus androgynus* L. Merr leaf was safe until 10%, but higher inclusion levels (12 and 14%) resulted in reduced feed consumption, weight gain, and feed efficiency of broilers as compared to control. Overall, it should be noted that the safe levels of inclusion of fermented plant leaves in broiler rations may vary depending on the nature of plant leaves, duration and starter of fermentation, other dietary ingredients, and broiler conditions during the studies (Mandey et al., 2015).

Effect of fermented leaves on growth performance of broilers

Maximizing the growth potential of modern broilers has been attributed to maximal economic performance of broiler enterprise. Following the ban of antibiotic growth promoters, the broiler producers are now searching for antibiotic alternatives to maximize the genetic growth potential of modern broiler strains. Owing to the potential of fermented feed in improving the growth rate of broilers (Sugiharto and Ranjitkar, 2019), Mandey et al. (2015) included the *T. viride*-fermented banana leaf in broiler rations. They found that inclusion of 10% of fermented banana leaf improved the weight gain and feed efficiency of broilers more significantly as compared to those of fed control diet. In agreement, Kim et al. (2017) showed that dietary administration of 5 and 10% fermented *Ginkgo biloba* leaves increased daily gain of broilers during starter and finisher phases. In addition, Niu et al. (2019) reported that inclusion of 3.5-4.5 g/kg of fermented *Ginkgo biloba* leaves improved the growth performance of broilers. Likewise, Siaboc (2018) reported that supplementation of fermented jute leaves (*Corchorus olitorius*) resulted in the similar effect as antibiotic growth promoters in term of growth performance of broilers. Other example was reported by Xie et al. (2016) at which administration of 10% of *A. niger* and *C. utilis*-fermented olive leaf residue boosted the growth of broiler chickens. Moreover, dietary inclusion of 0.35% *Bacillus licheniformis*-fermented *Ginkgo biloba* leaves improved growth performance and feed efficiency of broilers (Yu et al., 2015). Incorporation of 0.5% fermented *Ginkgo*-leaves (using *A. niger* or combined *A. niger* and *Candida utilis*) has also been reported to improve the feed efficiency of broiler chickens (Zhang et al., 2015). In line with this, study by Cao et al. (2012) documented that *A. niger*-fermented *Ginkgo biloba* leaves improved the growth performance of broilers. Zhang et al. (2012) reported that feeding *A. niger*-fermented *Ginkgo biloba* leaves at the level of 0.35% from rations improve the growth performance and feed efficiency of broiler.

There are a several studies reporting the possibility of use of fermented leaves to improve the growth potential of broilers. Niu et al. (2019) showed that supplementation of fermented *Ginkgo biloba* leaves was associated with improved gut functions; consequently improved nutrient digestion and utilization by broilers. The latter investigators noticed that feeding fermented *Ginkgo biloba* leaves increased the relative weight of duodenum and digestive enzyme activities resulting in enhanced apparent total tract retention. In general, the increased relative weight of small intestine is attributed to the improved intestinal mucosa and elevated intestinal villi height, and therefore, improved nutrient digestibility and absorption are observed. The latter improvement was therefore associated with the increased nutrient availability for broiler growth. Moreover, feeding fermented *Ginkgo biloba* leaves increased feed intake of broilers; thus, the nutrient availability for chicken growth was improved (Niu et al. 2019). In accordance with the findings of the latter authors, Mirnawati et al. (2013) showed that feeding 10% fermented mulberry leaves increased protein digestibility and nitrogen retention resulting in increased protein deposition and growth of broilers. The improved pancreatic enzyme activities as well as intestinal morphometric (increased villi height and villi height to crypt depth ratio) have also been associated with positive effects on feed efficiency and absorption functions of broiler (Yu et al., 2015; Zhang et al., 2015). In their study, Yu et al. (2015) also revealed that feeding *Bacillus*-fermented *Ginkgo biloba* leaves reduced mucosal apoptosis and muscle tissue degradation of the intestine as indicated by the reduced serum urea nitrogen. Reduced intestinal apoptotic cells may be associated with improved intestinal integrity and functions, whereas the reduced muscle tissue degradation implies enhanced muscle tissue deposition; thus, improving the growth rate in broilers. Besides improving the intestinal morphology and structure, dietary incorporation of fermented leaves has been shown to improve the intestinal ecology of broilers. Zhang et al. (2015) previously reported that dietary supplementation of 0.5% of fermented *Ginkgo biloba* leaves increased the populations of lactobacilli in ileum and decreased *Escherichia coli* and *Salmonella* in ileum and caecum of broilers. Such improvement in gut ecology may be attributed to the improved intestinal development and functions of broilers (Sugiharto and Ranjitkar, 2019). The improved gut microbial ecology may also be attributed to the improved intestinal and systemic immune system and health of broilers (Sugiharto, 2016; Sugiharto and Ranjitkar, 2019). In addition, the improvement in physiological conditions and antioxidant system seemed to be associated with improved broiler health and energy allocations, which eventually promote the growth rate of broilers (Santoso et al., 2015a; Zhang et al., 2015).

Despite the numerous growth-promoting effects of the fermented plant leaves, several studies have reported the detrimental or no positive effects of fermented leaves on growth performance of broilers. Zhang et al. (2012) noticed the deleterious effect of *A. niger*-fermented *Ginkgo biloba* leaves on growth performance of broilers when more than 1% was incorporated in diets. In addition, feeding *Trichoderma harzianum*-fermented *Sauropus androgynus* L. Merr leaves at the levels of 12 and 14% of diets reduced feed intake and compromised weight gain and feed conversion of broilers (Syahruddin et al., 2013). Moreover, Zhang et al. (2020) noticed that dietary inclusion of fermented *Radix astragalus-ginkgo* leaves up to 6 g/kg did not affect the growth rate of broilers. Furthermore, Santoso et al. (2015a) did not observe any significant impact of feeding *Sauropus androgynus* leaves fermented with either *Neurospora crassa*, *Lactobacillus* sp. or *Saccharomymes cereviceae* on the growth performance of broiler chickens. In summary, it seems that the effects of feeding fermented leaves may vary in term of growth performance of broilers depending on the natures and proportions of fermented plant leaves used in broiler rations. Xie et al. (2016) suggested that the increased fiber content in diets with high proportions of fermented leaves may be responsible for the reduced feed intake, nutrient digestibility, and utilization in broilers. The latter condition may consequently compromise the growth performance of broilers. Moreover, the presence of toxic compounds in the fermented plant leaves (fermentation may not totally eliminate the toxic compounds) may also negatively impact the growth performance of broilers (Santoso et al., 2015a; Santoso et al. 2015b).

Effects of fermented leaves on physiological condition and health of broilers

Maintaining the normal physiological conditions is crucial for the optimal health and growth performance of broilers. Following the prohibition of use of antibiotic growth promoters and synthetic antioxidants, respectively, the search for natural antibiotic and antioxidant alternatives has accelerated. Fermented plant leaves are one of the natural alternatives that have been exploited to improve the physiological and health status of broilers. Santoso et al. (2015b) formerly reported that dietary inclusion of 50 g/kg fermented *Sauropus androgynus* (using *Neurospora crassa*, *Lactobacillus* sp. or *Saccharomyces cerevisiae* as fermentation starter) increased the numbers of erythrocytes and packed cell volume, which may indicate improved physiological conditions of broilers. It is not clear on how the fermented leaves affected the blood profile of broilers, but the improvement in nutrient digestibility due to feeding of fermented leaves (Mirnawati et al., 2013) may account for the increased nutrition available for hematopoietic activity in broilers. The increased antioxidant capacity in birds which are fed fermented leaves (Cao et al., 2012) may also be attributed to the decreased hematopoietic cells damage owing to the free radicals. Santoso et al. (2015b) also reported that feeding fermented *Sauropus androgynus* increased the number of leukocytes and thrombocytes, suggesting an improved response of broilers towards incoming disease agents. Likewise, Kim et al. (2017) reported that dietary inclusion of 5 and 10% fermented *Ginkgo biloba* leaves increased the serum concentration of immunoglobulin (Ig) G of broiler chickens. The increased levels of flavones and terpenes in the leaves due to microbial fermentation may be associated with the increased lymphocyte production, cytokine release, and B-cell proliferation (Kim et al., 2017). The latter condition was attributed to the increased Ig production in broilers. Indeed, the improved antioxidant capacity of birds due to feeding of fermented leaves seemed to alleviate immunosuppression due to oxidative stress; hence, improved the immune response of broilers. Moreover, the capacity of fermented leaves in improving the intestinal bacterial ecology (Zhang et al., 2015) may modify both local (intestinal immune system) and systemic immune systems of broilers (Sugiharto and Ranjitkar, 2019). In agreement, the synergistic cooperation between polysaccharides and bacteria used as fermentation starter may improve the ecology of intestine and consequently improve the immune development of broilers (Kim et al., 2017). In contrast to the results of the above study, Santoso et al. (2018) did not find any effect of fermented *Sauropus androgynus* plus bay leaf (up to 5% of diets) on erythrocytes and leukocytes profiles of broilers. The differences in the nature of plant leaves, the levels of incorporation of fermented leaves, and the conditions during studies may explain the discrepancy in the results of different studies.

Feeding fermented leaves has been reported to affect the lipid metabolism in broilers. Cao et al. (2012) found that dietary inclusion of *A. niger*-fermented *Ginkgo biloba* leaves up to 1% improved lipid metabolism as indicated by the reduced total cholesterol, triglycerides, and low-density lipoprotein (LDL)-cholesterol and the increased high-density lipoprotein (HDL)-cholesterol in blood. In accordance with this, Zhang et al. (2020) noticed the decreased total cholesterol in serum with feeding diet containing *Radix astragalus-ginkgo* leaves to broilers. In addition, feeding fermented *Sauropus androgynus* plus bay leaf decreased concentrations of triglycerides, cholesterol, LDL and very-low-density lipoprotein (VLDL) and LDL to HDL ratio in serum of broilers (Santoso et al., 2018). The feeding treatment, in contrast, increased the levels of HDL in serum. In the previous study, Sugiharto et al. (2019) suggested that fermentation could increase the contents of phenolic compounds and flavonoids in the substrate or medium. Cao et al. (2012) and Zhang et al. (2020) suggested that flavonoids in the fermented *Ginkgo biloba* leaves showed lipolytic activity as indicated by the reduction of lipid and cholesterol in the serum of broilers. The latter investigators also suggested that flavonoids in the fermented leaves may establish insoluble binding with cholesterol in digesta and inhibit the absorption of cholesterol by the intestine. Moreover, flavonoids may upregulate hepatic β-oxidation and downregulate lipid synthesis. However, it should be taken into consideration that the effects of fermented leaves on the physiological conditions may not be consistent in different broilers. In contrast to the above-mentioned studies, Santoso et al. (2015c) did not find any significant impact of feeding fermented *Sauropus androgynus* leaves on the concentrations of cholesterol and triglycerides in the serum of broilers. The different natures of leaves, microbial starter used for fermentation, and the conditions during the *in vivo* trials seemed to account for the divergent data above.

Modern broiler strains are very susceptible to stress, which can lead to oxidative damage and disrupted physiological conditions. Fermented feed has been suggested to be a source of natural antioxidants (Sugiharto et al., 2019) that can substitute the role of synthetic or chemical-based antioxidants. In respect to fermented leaves, Cao et al. (2012) formerly reported that feeding *A. niger*-fermented *Ginkgo biloba* leaves improved the antioxidative status of broiler, as indicated by the increased serum concentration of α-tocopherol and total superoxide dismutase activity. Xie et al. (2016) also confirmed that feeding fermented olive leaf residues improved the health and antioxidative status of broilers. Moreover, Zhang et al. (2015) reported that feeding fermented *Ginkgo* leaves increased the antioxidant capacity of broilers, as indicated by the increased levels of serum and hepatic α-tocopherol, total superoxide dismutase, and glutathione activities in jejunum and ileum, and the decreased hepatic reactive oxygen species, hepatic protein carbonyls and malondialdehyde, and jejunal and ileal protein carbonyls. In agreement with the above-mentioned studies, a recent study by Zhang et al. (2020) reported that feeding fermented *Radix astragalus-ginkgo* leaves increased the antioxidant capacity of broilers, as indicated by the elevated concentrations of glutathione and α-tocopherol and total superoxide dismutase activity in serum, and the decreased malondialdehyde in serum and reactive oxygen species in liver compared to those in control. The improvement in the expression of antioxidant enzyme genes such nuclear factor erythroid 2-related factor 2 (Nrf2), heme oxygenase 1 (HO-1), superoxide dismutase, and glutathione peroxidase (GPx) were also noticed with feeding fermented leaves in the study of Zhang et al. (2020). Other study conducted by Niu et al. (2019) further documented that dietary supplementation of fermented *Ginkgo biloba* leaves resulted in improved antioxidant activity, as indicated by the increased total antioxidant capacity and catalase activity in duodenum and glutathione peroxidase in ileum of broilers. There are some explanation regarding the effects of fermented leaves on the antioxidative status of broilers. A very recent study by Zhang et al. (2020) suggested that polysaccharides and flavonoids contents in the fermented plant leaves are responsible for the improved antioxidant capacity of broilers. Sugiharto et al. (2019) further reported that polysaccharides and flavonoids could modulate the cellular production of free radicals and endogenous antioxidants leading to a balance between the free-radicals (pro-oxidants) and antioxidants. In addition, the presence of live microorganisms in the fermented leaves may also contribute to a balance between pro-oxidants and antioxidants as some microorganisms such as lactic acid bacteria and filamentous fungi showed antioxidant properties.

Intestine is one of the internal organs that functions not only to digest and absorb nutrients, but is also responsible for the immune defense of broilers. It is now being realized that intestinal immune system could modify both local and systemic immune system, and thus, it is very crucial for the body defense against incoming pathogens. In the chicken intestine, the increased populations of good bacteria and decreased pathogenic bacteria has been reported to improve immune development and positively modify the immune response of broilers on the incoming disease agents (Sugiharto, 2016). In the study of Zhang et al. (2015), increased populations of lactobacilli were observed in ileum, whereas decreased *E. coli* and *Salmonella* were noticed in ileum and caecum of broilers with feeding of fermented *Ginkgo biloba* leaves. It is reported that some beneficial properties in fermented feed (particularly organic acids and lactic acid bacteria) may be responsible for the antibacterial activities of fermented leaves resulting in reduced pathogenic bacteria populations in the intestine of broiler (Sugiharto and Ranjitkar, 2019). The latter condition as well as the acidifying effect of organic acids may promote the growth of commensal or good bacteria in the intestine of broilers (Sugiharto, 2016). However, there is still a lack of studies elucidating the effect of fermented plant leaves on the intestinal bacterial ecology and immune system of broilers.

Effects of fermented leaves on carcass and meat characteristics of broilers

Broiler meat is a major protein source for most people in the world. At present, consumers are increasingly conscious of the nutritional values of meats they eat. For this reason, broiler farmers are now advocated to produce meats with high protein, low fat and cholesterol, high levels of polyunsaturated fatty acids (PUFA), and low level of saturated fatty acids (SFA). These traits are usually attributed to healthy meats, which are safe for daily human consumption. Nutritional strategies have been developed to produce healthier and more nutritious broiler meats, one of which is through feeding fermented feed (Sugiharto and Ranjitkar, 2019). Besides use for improving the nutritional value of meats, nutritional strategies have been employed to increase the carcass proportion or dressing percentage of broilers, which may lead to an increase in the edible portion of chickens. As abdominal fat is usually considered as waste in broiler production, the reduction in abdominal fat content of broilers is another objective of dietary strategies.

In most studies, feeding fermented plant leaves resulted in no impact on the carcass weight of broilers. Formerly, Syahruddin et al. (2011) noticed that dietary inclusion of fermented *Morinda citrifolia* L. leaves had no influence on carcass proportion of broilers. In line with this, Manihuruk et al. (2018) documented that feeding fermented *Moringa oleifera* leaves did not alter the weight and proportions of carcass of broilers. Feeding fermented *Sauropus androgynus* leaves was also shown not to affect the carcass weight of broiler chickens in the study of Santoso et al. (2015a). In the above studies, carcass weight was presented as the percentage/relative to live body weight of broilers. Hence, any increase in the absolute carcass weight would not result in significant statistical values as the increased carcass weight was parallel with the increase in final body weight of broilers. With regard to fat content, study by Cao et al. (2012) showed that feeding fermented *Ginkgo biloba* leaves reduced abdominal fat content of broilers. Furthermore, feeding fermented *Radix* astragali-*ginkgo* leaves decreased the deposition of abdominal fat of broiler chickens in the study of Zhang et al. (2020). Moreover, Santoso et al. (2015a) documented that dietary inclusion of fermented *Sauropus androgynus* leaves reduced fat, cholesterol, and total fatty acids contents of broiler meats. In the recent study, we also showed that feeding *Chrysonilia crassa*-fermented mixture of cassava pulp and *Moringa oleifera* leaf meal resulted in the reduction in abdominal fat content of broilers (Sugiharto et al., 2020). Feeding fermented leaves has also been reported to reduce cholesterol content of meat, as reported by Syahruddin et al. (2011) when feeding fermented *Morinda citrifolia* L. leaf meal to broilers. In agreement with this, feeding fermented *Sauropus androgynus* L. Merr leaf resulted in reduced cholesterol contents in broiler meats (Syahruddin et al., 2013). As discussed in the previous section, the flavonoids content in the fermented plant leaves may act as a lipolytic agent leading to the reduction in fat deposition and cholesterol synthesis (Cao et al., 2012; Zhang et al., 2020).

SFA have commonly been associated with the arteriosclerosis disease, whereas unsaturated fatty acids have health-promoting effects on humans. For these reasons, consumers are now pursuing meats with high PUFA and low SFA. It was apparent in the study of Cao et al. (2012) that dietary incorporation of fermented *Ginkgo biloba* leaves reduced C16:0 and C18:0 levels and increased the levels of C18:2, C18:3, and C20:4 in broiler meats. Further, Kim et al. (2017) reported that dietary incorporation of 5 and 10% fermented *Ginkgo biloba* leaves (using *L. plantarum* KCTC 3099, *L. acidophilus* KCTC 3111 and *S. cerevisiae* KCTC 7904 as fermentation starter) decreased the contents of SFA and monounsaturated fatty acids (MUFA), whereas it increased n-3 PUFA contents in the breast and thigh muscles of broilers. Our recent study reported that feeding fermented mixture of cassava pulp and *Moringa oleifera* leaf meal using *Ch. crassa* as fermentation starter increased PUFA content, reduced MUFA, and had no effect on SFA content of broiler meats (Sugiharto et al., 2020). It was most likely that polyphenol content in the fermented plant leaves increased the activity of peroxide-scavenging enzyme, which consequently reduced the oxidation of unsaturated fatty acids in meats (Cao et al., 2012). In accordance with this, Santoso et al. (2015b) revealed that fermented *Sauropus androgynus* leaves increased vitamin A, β-carotene, and vitamin E, which decreased oxidation of meat PUFA. With regard to MUFA, the activity of flavonoids and organic acids derived from the fermented leaves could modify the function of Δ-9-desaturase enzyme (key enzyme responsible for the conversion of SFA to MUFA), resulting in the reduction of MUFA in broiler meats (Kim et al., 2017). In contrast to the reported studies above, Santoso et al. (2015b) showed that feeding fermented *Sauropus androgynus* leaves increased the ratio of saturated to unsaturated fatty acids in broiler meats. The variations in nature of plant leaves, the microorganisms used as fermentation starter, and the conditions of broiler during study (e.g., feed composition, gender, age, etc.) may explain the conflicting data above.

Conclusion

Fermented plant leaves may be used as protein-rich feed ingredients in broiler rations. Besides, fermented leaves may also be exploited as alternatives to antibiotic growth promoters and synthetic antioxidants for broiler chickens. However, fermented leaves should be incorporated with care as their excessive levels in diets may negatively affect broiler performance.

Ethics Committee Approval: This is a review paper, and we therefore did not conduct a trial using animals, therefore we did not ask the approval from the Ethic committee in our faculty.

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