

Averrhoa carambola L. leaf as a source of phytobiotic feed additive for broilers: A review

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ABSTRACT

The sweet starfruit (*Averrhoa carambola* L.), a plant widely cultivated in Indonesia and other tropical regions, has long been recognized for its medical properties. Its leaves are rich in bioactive compounds including polyphenols, flavonoids, and essential fatty acids. These compounds exhibit strong antioxidant, antibacterial, and anti-inflammatory activities, making sweet starfruit leaves a promising candidate for phytobiotic feed additive in poultry nutrition. Antioxidants play an important role in preventing the oxidation of long-chain unsaturated fatty acids. Tannins are polyphenols that reduce free radicals by inhibiting the enzymatic system. Flavonoids can stabilize free radicals by adding electrons from free radicals and preventing ring reactions that form new free radicals. Flavonoids function in the prevention and treatment of oxidative pathologies such as atherosclerosis and inflammation. Flavonoids can function as drugs because they have a role in regulating enzymes and receptors in the brain that produce significant effects on the central nervous system. The active compound content of sweet starfruit leaves makes this plant useful as a phytobiotic feed additive. This study explored the potential of sweet starfruit leaf extract as a natural feed additive to improve broiler performance and the finding support as a sustainable and effective alternative to synthetic growth promotor.

Introduction

In the quest for sustainable and health enhancing poultry feed solution, nature offer a powerful alternative like sweet starfruit plant. The sweet starfruit plant (*Averrhoa carambola* L.) is a plant that grows widely in Indonesia. This plant grows widely in rural and urban areas. In China, Malaysia, Brazil, and India, sweet starfruit leaves are widely used for medicine, because they have antibacterial and anti-inflammatory properties. Sweet starfruit leaves are also widely used as a medicine to reduce fever (Yang *et al.*, 2020). Wei *et al.* (2014) stated that sweet starfruit leaves have high antioxidant activity, are rich in polyphenols (742.58 mg/g) especially proanthocyanins; high in flavonoids (624.79 mg/g) especially apigenin and quercetin, high unsaturated fatty acids (PUFA) (72.13%), the highest fatty acid content is linolenic acid (62.04%) and linoleic acid (9.84%), where these two fatty acids are essential fatty acids that are very much needed by the body but the body cannot produce them itself. Feeding with high content of essential fatty acids will be reflected in tissue fatty acids. The active compound content of sweet starfruit leaves makes this plant can be used as a phytobiotic feed additive. Feed additives are additional ingredients that are specifically added to feed to improve feed quality (Paraskeuas., 2017). The integration of sweet starfruit leaf extract into broiler feed as a phytobiotic feed additive present a promising strategy to enhance metabolism, improve gut health. Boost immunity, and elevate meat quality. Phytobiotic feed additives from herbal plants can be increased in availability through further processing, including extraction and encapsulation. Extraction of green plants serves to increase the content of active compounds or bioactive substances contained in the greens.

The application of encapsulation technology can be applied to plant extracts to increase stability, palatability, and bioavailability so that it can increase the efficacy or benefits of herbal plants (Sugiharto and Ayasan, 2023). Encapsulation can protect active compounds and ensure product

quality and benefits for broiler chickens. The synergy of several active compounds from starfruit leaf extract encapsulated with maltodextrin makes this plant can be used as a feed additive. The high antioxidant and fatty acid content in sweet starfruit leaves is the reason for using the leaves of this plant as a feed additive in compiling poultry rations. The high content of antioxidants and essential fatty acids in sweet starfruit leaves is expected to improve metabolism so that the digestive tract profile improves, health status improves, performance and productivity improve, and meat quality improves. According to Hossain *et al.* (2024), giving 500 mg/kg of herbal mixture in ration can increase breast weight, improve water holding capacity (WHC), and reduce abdominal fat. According to Dokou *et al.* (2023a), encapsulation of plant extracts can reduce meat fat and increase fatty acids of chains 3 and 6, where the composition of fatty acids and meat color are better in the treatment with plant extracts. According to Orlowski *et al.* (2018), giving phytobiotic feed additives at a level of 550 mg/kg can improve the quality of broiler chicken meat compared to the control. This review focused on *Averrhoa carambola* L. leaf extract as a source of phytobiotic feed additive for broiler chicken to support animal health and production.

Synthetic antibiotics and antioxidants use for broiler chickens

The application of synthetic antibiotics in broiler chicken farming has sparked significant debate due to its effects on both animal and human health. Traditionally, antibiotics have been employed to boost growth and prevent diseases in poultry, thereby greatly improving feed conversion rates and minimizing intestinal issues in broilers (Zhu *et al.*, 2021). Nonetheless, the ongoing and often improper use of antibiotics in animal agriculture has resulted in the emergence of antibiotic-resistant bacteria, which poses a grave risk to public health by causing treatment failures and potentially spreading these resistant strains through the food supply

(Alabi *et al.*, 2024; Turcotte *et al.*, 2020). In response to these challenges, numerous countries have implemented bans or limitations on antibiotic use in livestock production. These measures are designed to combat antimicrobial resistance (AMR), a critical global health concern (Azizi *et al.*, 2024). For example, the European Union has long banned the routine use of antibiotics as growth enhancers in animal feed, and recent policies in countries like Canada aim to eliminate the preventive use of medically important antibiotics in poultry farming (Turcotte *et al.*, 2020). The prohibition of synthetic antibiotics compels the poultry industry to seek alternative methods to sustain health and productivity on farms. Recent research has investigated non-antibiotic options, such as probiotics, prebiotics, organic acids, enzymes, essential oils, and plant-based compounds like curcumin, which have shown potential in promoting growth and disease resistance in poultry (Azizi *et al.*, 2024; Sureshbabu *et al.*, 2023). These alternatives are viewed as more sustainable and less likely to contribute to AMR, though challenges persist in assessing and applying them practically on a large scale (Nechitailo *et al.* 2024). Despite these developments, the shift from antibiotics has been gradual in certain areas. In countries like Bangladesh, antibiotics remain widely used due to factors such as limited microbial diagnostic facilities, lack of awareness, and economic pressures (Chowdhary *et al.*, 2022). Efforts to address this issue include educating producers on the responsible use of antibiotics and implementing good farming practices and biosecurity measures (Chowdhary *et al.*, 2022). The routine use of antibiotics in animal production has sparked concerns about antimicrobial resistance. Several countries have moved to prohibit the use of antibiotics as growth promoters in broiler chickens. While antibiotics can enhance feed conversion efficiency and alleviate intestinal issues, their excessive use leads to increased antibiotic resistance (Alabi *et al.*, 2024).

Researchers are exploring various alternatives to antibiotics, such as prebiotics, probiotics, organic acids, and plant-based compounds like Aloe vera, which possess antibacterial properties and can enhance chicken performance and immune function (Zhu *et al.*, 2021; Babak and Nahashon, 2014). Additionally, yeast and its derivatives have been found to serve as feed additives that boost immunity and gut health (Bilal *et al.*, 2021). However, reducing antibiotic use presents new challenges for chicken productivity. Short-term cessation of antibiotics can disrupt gut microbiota composition, decrease production efficiency, and increase the prevalence of *Clostridium perfringens*, a common chicken gut pathogen (Turcotte *et al.*, 2020). Furthermore, a decrease in antioxidants in broiler diets significantly affects chicken health. Antioxidants play a crucial role in mitigating oxidative stress, which can negatively impact chicken health, performance, and meat quality (Salami *et al.*, 2015). Legislative restrictions on synthetic antioxidants can adversely affect poultry health and performance, as high levels are often necessary to achieve the desired outcomes, particularly under high oxidative stress conditions. Careful dosage selection and further research can help optimize the benefits of antioxidant supplements (Salami *et al.*, 2015).

Natural alternative of antibiotics and antioxidants for broiler chicken

Due to rising concerns about antibiotic resistance and the demand for safer poultry products, the quest for natural substitutes for antibiotics and antioxidants in broiler chicken production has intensified. Researchers have investigated various strategies and natural substances to replace antibiotics and boost antioxidant activity in broilers. *Moringa oleifera*, a plant with promising potential, has emerged as a natural alternative to antibiotics. It exhibits antimicrobial, antioxidant, and anti-inflammatory properties, and its addition to broiler feed is linked to enhanced gut health, better nutritional digestibility, improved biochemical profiles, and stronger immune responses (Khan *et al.*, 2021). Similarly, phytobiotics, which are plant-derived compounds, have been acknowledged for their antimicrobial and antioxidant capabilities. These compounds improve gut

health by enhancing gut morphology, integrity, and microflora composition, which in turn leads to better growth performance (Obianwuna *et al.*, 2024). Probiotics, such as specific strains of *Lactobacillus salivarius*, have been shown to effectively boost the performance and health of broiler chickens. These probiotics enhance body weight, improve feed conversion ratios, and reduce harmful bacteria while fostering beneficial bacteria in the gut, creating a healthier intestinal environment (Shokryazdan *et al.*, 2017). Prebiotics also support the growth of beneficial gut flora, aid digestion, and strengthen the overall immune response (Zhu *et al.* 2021). Natural alternatives to antibiotics, such as essential oils and organic acids, show promise. Administering essential oils through various methods has demonstrated potential in enhancing antioxidant levels and possibly substituting antibiotics in broiler diets, though further research is necessary to fully assess their effectiveness and refine application techniques (Oladokun *et al.*, 2021). Nutrigenomics and natural antioxidants play a vital role in managing oxidative stress, which impacts the health and performance of broilers. Antioxidants sourced from fruits, vegetables, and spices help regulate genes related to oxidative stress and improve health indicators like inflammatory response and intestinal barrier integrity (Kouvedaki *et al.*, 2024). Some natural feed additives possess immunomodulatory effects, potentially strengthening the immune system of broiler chickens under stress like described in Figure 1. Additives such as flavonoids and resveratrol have been recognized for enhancing immune responses, although determining the correct dosage is essential (Phillips *et al.*, 2023). While natural alternatives to antibiotics and antioxidants are available, ongoing research is vital to optimize their application, establish accurate dosages, and fully incorporate these substances into sustainable poultry production systems (Thirumeignanam *et al.*, 2024).

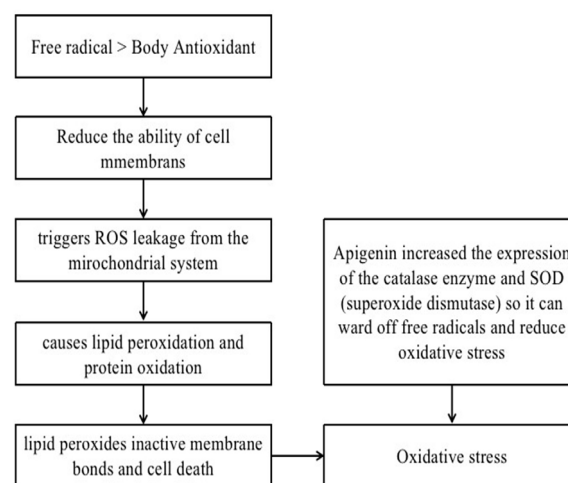


Fig.1. Schematic diagram of phytobiotic feed additives effect.

Phytobiotic feed additive for broiler chicken

Poultry meat, especially those fed with a variety of feeds, is a supplier of essential unsaturated fatty acids, especially 3-chain fatty acids (Farrell, 2013). The type and composition of feed play an important role. Feed supplemented with grains, vitamins, minerals, and certain additives such as prebiotics or probiotics can improve meat quality by increasing protein content and sensory qualities such as color and texture. The content of certain feed ingredients, such as amino acids and unsaturated fatty acids, is very important for improving meat quality such as pH, color and tenderness. According to Mancini and Hunt (2005), meat quality is closely related to genetics and nutrition given during maintenance. Nutrition that is in accordance with livestock needs can increase productivity and the quality of meat produced. Feed with high content of essential fatty acids can also reduce abdominal fat in poultry. In addition to fatty acid content, feed with high antioxidant content can also produce meat prod-

ucts with high antioxidant content. Antioxidants contained in feed will affect metabolism in the body so that it has an impact on meat quality. Antioxidants can prevent oxidation of long-chain unsaturated fatty acids (LC-PUFA / Long Chain-Polyunsaturated Fatty Acid) and enrich poultry meat products with 3-chain fatty acids (Mir *et al.*, 2017).

Maintenance management plays an important role in optimizing results in livestock farming. One of the maintenance management that needs to be considered is feed management. Quality feed will provide maximum benefits. Broiler chickens require feed with high nutrition because the maintenance period is relatively short between 5 to 6 weeks. Feed with sufficient protein and energy content is needed, where protein is used for growth, while energy is used for survival. Complete and balanced feed quality during the starter period is something that needs to be considered because it is the foundation for achieving maximum genetic potential, while the quality of grower and finisher feed will affect the amount of consumption and achievement of harvest weight. Maintenance management, especially feeding management, greatly influences the quality of meat produced (Mir *et al.*, 2017). According to Mancini and Hunt (2005), meat quality is closely related to the nutrition provided during maintenance. The response of livestock to the feed given is closely related to the growth of the skeleton, muscle, and fat deposition. Feed with low fat content does not affect sensory characteristics but can reduce carcass fat. To obtain a balance of nutrients, it can be done by adding feed additives to the ration so that it can affect metabolism. Feed additives added to the ration can be enzymes, drugs, probiotics, prebiotics, feed preservatives, antibiotics and so on.

The provision of feed additives such as probiotics, organic substances, enzymes, phytobiotics in animal feed aims to stimulate growth. Many studies have examined the use of feed additives in rations or animal feed, especially feed additives from natural sources that can come from leaves, roots, seeds, fruits, and so on. Phytobiotic feed additives can be classified based on their botanical origin, namely leaves, roots, seeds, fruits, or

by-products; based on the composition of their bioactive content, namely saponins, flavonoids, terpenes, phytoestrogens, phenylpropanoids; based on the process, namely extracts, essential oils, and isolation of active substances; based on the type of action or function consisting of its function to increase absorption, as a fermentation modulator, its function as an agent that stimulates digestion and nutrient absorption; and acts as a direct and indirect anabolic on target organs (Ramadan *et al.*, 2022). In choosing feed additives that come from nature, it is necessary to pay attention to the bioactive substances contained in them and the right process for application, this aims to optimize the content of bioactive materials so that they are right on target according to the goals to be achieved. Several studies about feed additive in broiler chicken was shown in Table 1.

***Averrhoa carambola* L. as phytobiotic feed additive**

The starfruit plant (*Averrhoa carambola* L.) is a very popular plant in almost the entire world because it has high nutritional value and can be used for medicine (Lakmal *et al.*, 2021). This plant is found in America, Brazil, Australia, and Southeast Asia such as Malaysia, China, Taiwan, and India (Aladaileh *et al.*, 2019). This plant belongs to the *Oxalidaceae* family and is a plant that originates from tropical areas and is widely domesticated in other areas (Ramadan *et al.*, 2022). Other names for *Averrhoa carambola* are starfruit, Carambola, Belimbing, Chinese star fruit, Five Angled Fruit, Star Apple. According to the USDA (2024), the taxonomy and images of the starfruit plant are Kingdom: Plantae; Sub kingdom: Tracheophytes; Super Division: Angiosperms; Division: Magnoliophyta; Class: Magnoliopsida; Sub class: Rosidae; Order: Geraniales; Family: *Oxalidaceae*; Genus: *Averrhoa*; Species: *A. carambola*; Binomial name: *Averrhoa carambola* L.

Phytochemically and pharmacologically, each part of the starfruit

Table 1. Research on plant extract as feed additives in broiler chickens.

Treatment	Results	Reference
Administration of a mixture of ginseng and artichock herbs at a rate of 0.05% or 500 mg/kg to Hanhy-up-3-ho chickens	Administration of 0.05% herbal mixture can increase the average weight gain and feed conversion, increase blood albumin and SOD levels and reduce ammonia and H ₂ S emissions in excreta. Administration of herbal mixture can also increase chest weight, improve WHC (water holding capacity) and reduce abdominal fat.	(Hossain <i>et al.</i> , 2024)
Extraction of herbal plants with water and encapsulation using cyclodextrin at a level of 0.1% (1000 mg/kg) in broiler chickens aged 1-35 days	Encapsulation of herbal plants with cyclodextrin can increase the final weight of broiler chickens, have a positive effect on the composition of meat protein, reduce meat fat, increase fatty acids chain 3 and chain 6. The composition of fatty acids and meat color are significantly better in extracts encapsulated with cyclodextrin.	(Dokou <i>et al.</i> , 2023a)
Administration of a mixture of herbal plants (0.1% or 1000 mg/kg) to broiler chickens aged 1-35 days	Herbal plant extracts encapsulated with cyclodextrin at a level of 1000 mg/kg can delay fat oxidation in meat and increase the number of lactic acid bacteria in the cecum.	(Dokou <i>et al.</i> , 2023b)
Administration of a mixture of Punica granatum and Allium cepa with water extraction and extract encapsulated with cyclodextrin at a level of 1000 mg/kg to broiler chickens	The administration of a mixture of Punica granatum and Allium cepa with water extraction and extract encapsulated with cyclodextrin at a level of 0.1% affected the composition of meat, meat color, TBARS and protein carbonyl. Supplementation of the extract also increased the content of omega 3 and 6 fatty acids in thigh meat. The fatty acid content in breast meat was higher in water extract, while the fatty acid content in thigh meat was higher in extract encapsulated with cyclodextrin.	(Vasilopoulou <i>et al.</i> , 2022)
Cosmos caudatus leaf extract encapsulated with maltodextrin and given as an additive at levels of 0.5 g/kg; 1 g/kg; 1.5 g/kg in broiler chickens aged 15-42 days	Encapsulation of plant extracts can increase daily body weight gain at doses of 0.5 g/kg (0.05%) and 1 g/kg (0.1%)	(Agusetyaningsih <i>et al.</i> , 2022)
Extracts from the plant mixture were given to broiler chickens at levels of 0, 250, 500, 1000, 2000 mg/kg.	Plant extract supplementation improves the performance and health of the digestive tract (increases the length of villi in the duodenum, jejunum, ileum); reduces coliform bacteria and increases lactic acid bacteria.	(Farahat <i>et al.</i> , 2021)
Administration of plant extracts at a level of 200 mg/kg; and 400 mg/kg in broiler chickens up to 28 days of age	Administration of 400 mg/kg plant extract can increase body weight gain. Administration of plant extract increases microbiota in the duodenum and ileum, and this increase is predicted to be related to protein absorption, amino acid metabolism, resulting in increased growth performance.	(Zhu <i>et al.</i> , 2019)
Supplementation of herbal feed additive phytogetic at the level of 550 mg/kg (0.55 g/kg)	Supplementation of phytogetic feed additives at the level of 550 mg/kg can improve the quality of broiler chicken meat compared to the control.	(Orlowski <i>et al.</i> , 2018)

plant is rich in flavonoids, saponins, alkaloids, tannins, proanthocyanins, vitamin C, and gallic acid (Aladaileh *et al.*, 2019). Extracts from starfruit leaves can lower blood pressure, insoluble fiber content can help excrete cholesterol in feces thereby reducing blood fat, beta sitosterol content can function as an antimicrobial, phenol, flavonoid, proanthocyanin, ascorbic acid and gallic acid content function as antioxidants, and apigenin content can function as an anti-inflammatory (Lakmal *et al.*, 2021). The starfruit plant is reported as a plant that has the potential to be used as a medicine, including for the treatment of diabetes sufferers because it has a hypoglycemic effect and has an effect of inhibiting the lipase enzyme in the pancreas like show in Figure 2.. Biological studies state that the hypoglycemic effect comes from the leaves and the active compounds contained therein. The hypoglycemic properties of this plant are due to the high fiber content. Fiber plays an important role in glucose homeostasis. The hypoglycemic potential of sweet starfruit leaf extract is shown by decreasing blood sugar levels in experimental mice (Ferreira *et al.*, 2008). Sweet starfruit leaves are also widely used to treat diabetes, cancer, and inflammation (Wei *et al.*, 2014). The mechanism of sweet starfruit leaf extract as a phytobiotic feed additive is related to its function in increasing nutrient absorption in the digestive tract, so that health improves, performance and productivity increase, nutrient intake increases and meat quality increases. This mechanism is related to the role of active compounds contained in sweet starfruit leaves which function to inhibit dyslipidemia and reduce hyperlipidemia (Abduh *et al.*, 2023). The flavonoid content in sweet starfruit leaf extract (apigenin) can inhibit the enzyme 3-hydroxy-3-methylglutaryl CoA (HMG-CoA) reductase and pancreatic lipase, where inhibition of HMG-CoA will reduce endogenous cholesterol synthesis and cholesterol will be secreted through bile as free sterols by the Adenosine Triphosphate (ATP) transporter, thereby reducing cholesterol in the liver and increasing cholesterol secretion in the excreta. Pancreatic lipase plays a role in the absorption of triglycerides in the small intestine. The apigenin compound in sweet starfruit leaf extract can inhibit pancreatic lipase so that it can prevent digestion and absorption of triglycerides, reduce endogenous triglyceride synthesis in the liver and increase triglyceride secretion in excreta (Aladaileh *et al.*, 2019).

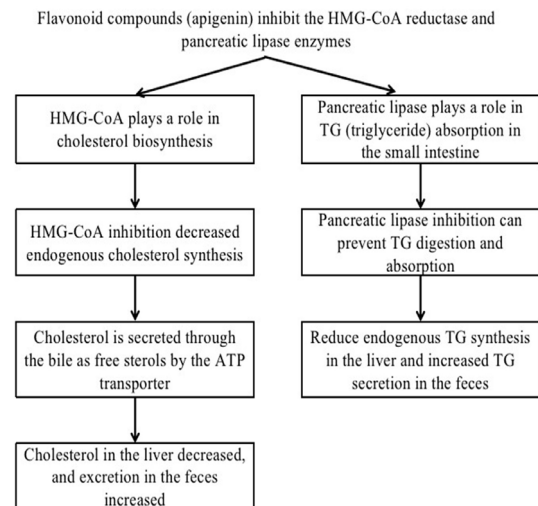


Fig 2. The mechanism of Apigenin (active compound of *Averrhoa carambola* L.)

In addition to active compounds, sweet starfruit leaves also contain a number of essential fatty acids omega 3 and omega 6. According to Wei *et al.* (2014), sweet starfruit leaves contain phenol as much as 742.58 mg/g, flavonoids 624.79 mg/g. There are more than 11 fatty acids from sweet starfruit leaves, alpha linolenic acid is in large quantities, namely 62.04%, linoleic acid 9.84%. The content of saponins, tannins, and flavonoids is a source of antioxidants and has a natural antibacterial effect (Masood *et al.*, 2013). Saponins are compounds found in several types of plants that can increase nutrient absorption through the intestinal epithelium and can be used as feed additives in poultry rations. Saponins can increase villus height and crypt depth (Alfaro *et al.*, 2007) so that they can increase nutrient digestibility. Tannin is a potential natural antioxidant and is widely used as a feed additive. Tannin can counteract free radicals and inhibit prooxidative enzymes (Masood *et al.*, 2013). Flavonoids have the ability as antioxidants by counteracting free radicals and stopping oxidative stress. Flavonoids can also be antifungal, where this compound is

Table 1. Research on plant extract as feed additives in broiler chickens.

Treatment	Results	Reference
The experimental rats were injected with poloxamer-407 as an acute hyperlipidemia condition, then injected with methanol extract of <i>Averrhoa carambola</i> leaves with several different fractions, and the parameters were measured at 0, 12, 24, and 48 hours.	Methanol extract of <i>Averrhoa carambola</i> leaves (1000 mg/kg) is able to reduce total cholesterol, triglycerides, LDL, and atherogenic index, and can prevent fat peroxidation and glutathione in experimental mice treated with acute hyperlipidemia.	(Abduh <i>et al.</i> , 2023)
The experimental mice were fed standard feed and high-fat feed for 4 weeks, the extract was given orally at a dose of 300 mg/kg. The parameters measured were physical and biochemical parameters.	Administration of sweet starfruit leaf extract has a significant effect on biochemical parameters: sweet starfruit leaf extract significantly reduces body weight; administration of the extract reduces oxidative stress compared to control	(Ramadan, N.S., <i>et al.</i> , 2022)
Exploratory research with sweet starfruit leaf maceration using methanol	In the methanol extract of sweet starfruit leaves, the most bioactive compounds found were butane, hexadecanoic acid, and methyl ester.	(Astiti and Ramona, 2021)
Administration of sweet starfruit leaf methanol extract at doses of 250, 500, 1000 mg/kg	Supplementation of sweet starfruit leaf methanol extract at levels of 500 and 1000 mg/kg can reduce serum fat, reduce body mass index, atherogenic index, reduce cholesterol and triglycerides in the liver, and increase cholesterol levels in excreta. Sweet starfruit leaf methanol extract improves hyperlipidemia and oxidative stress in experimental mice and also has the potential to reduce cell oxidation. A. cvarambola extract has the potential as an antihyperlipidemic and can be developed as a lipid-lowering agent.	(Aladaileh, <i>et al.</i> , 2019)
Extraction of sweet starfruit leaves using ethanol and water	The content of active compounds apigenin and quercetin in sweet starfruit leaf extract is greater in extraction using ethanol than in extraction using water.	(Yunarto dan Sulistyaningru, 2017)
Leaf extraction using ethanol and tested in vitro and in vivo using laboratory mice	Starfruit leaf extract contains steroids, glycosides, tannins, alkaloids, saponins, and flavonoids. Sweet starfruit leaf extract has the potential as an antioxidant. Starfruit leaf extract can inhibit the growth of <i>Streptococcus agalactiae</i> , <i>St pyogen</i> , <i>Pseudomonas</i> and <i>Shigella dysenteriae</i> microbes	(Hossain <i>et al.</i> , 2017)
Differences in extraction using acetone and water to test antioxidant activity, total phenols, and total flavonoids	The highest antioxidant, phenol, and flavonoid activities in extraction using acetone compared to water. Sweet starfruit leaf extract contains unsaturated fatty acids, especially linolenic fatty acids in large amounts (62.04%). Sweet starfruit leaf extract also contains a lot of PUFA (72.13%)	(Wei <i>et al.</i> , 2014)

an aromatic compound containing 15 carbon atoms with 2 aromatic rings (Lopez *et al.*, 2017). Examples of flavonoid derivatives are flavones (apigenin, luteolin), isoflavones, flavonols (kaempferol, quercetin), flavan-3-ols (catechin, gallate epicatechin), flavanol-3-ols, flavonones, and chalcones (Cushnie and Lamb, 2005).

Sweet starfruit leaves are rich in apigenin and quercetin, with concentrations of 6.37% and 4.49%, respectively, as noted by Yunarto and Sulistyningrum (2017). Apigenin is known for its antibacterial properties and serves as a potent natural antioxidant, while quercetin exhibits strong antioxidant activity (5.19 µg/mL) and holds potential as an anti-cancer agent (Salehi *et al.*, 2019). Astiti and Ramona (2021) found that the methanol extract of sweet starfruit leaves contains significant amounts of butane, 1,1-diethoxy-3-methyl, and hexadecanoic acid, at 35.76% and 26.93%, respectively. The compound butane, 1,1-diethoxy-3-methyl, is involved in the synthesis of organic acids and the production of ethylene, whereas hexadecanoic acid is an excellent antioxidant and anti-inflammatory agent, also acting as a hypocholesterolemic and antiandrogenic agent. Additionally, hexadecanoic acid works in synergy with other compounds to enhance antibacterial activity. According to Hossain *et al.* (2017), sweet starfruit leaf extract demonstrates antibacterial effects against *Streptococcus agalactiae*, *S. pyogenes*, *Shigella dysenteriae*, *Pseudomonas*, and *Staphylococcus saprophyticus*. Furthermore, the extract can serve as an analgesic, anti-diarrheal, antimicrobial, and antioxidant.

In research by Ramadan *et al.* (2022), it was found that sweet starfruit leaf extract enhanced anti-obesity effects in mice, leading to weight loss and a decrease in oxidative stress. This effect is closely linked to the phenolic compounds in the leaves, such as flavone glycosides and dihydrochalcone glycosides. Aladaileh *et al.* (2019) also reported that methanol extract from sweet starfruit leaves can lower serum fat levels in mice on high-fat diets, decrease body mass index, liver cholesterol, and triglycerides, while increasing cholesterol excretion, thereby improving hyperlipidemia and reducing cellular oxidation. According to Amata (2011), the antioxidant compounds in sweet starfruit leaves can enhance livestock productivity, and Wei *et al.* (2014) noted their strong antioxidant activity, suggesting significant potential for further development. Table 2 presents several studies on *Averrhoa carambola* as a phytobiotic feed additive.

Conclusion

The active compound content of sweet starfruit leaves makes this plant can be used as a phytobiotic feed additive. *Averrhoa carambola* L. leaf as a phytobiotic feed additive is related to its function in increasing nutrient absorption in the digestive tract, so that health improves, performance and productivity increase, nutrient intake increases and meat quality increases. This mechanism is related to the role of active compounds.

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Conflict of interest

The authors declare that they have no conflict of interest.

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