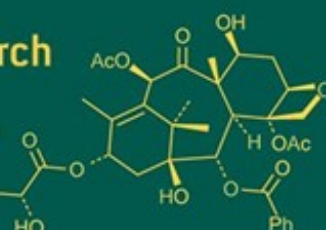
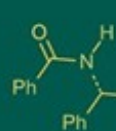


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Effect of medium chain fatty acid supplementation on poultry production: A review

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ABSTRACT

Medium chain fatty acids (MCFAs) are organic acids that are more efficiently absorbed and metabolized compared to saturated long-chain fatty acids. They are recognized for their unique nutritional, physiological, and antimicrobial properties. In this review, we summarize comprehensive evidence supporting the role of MCFAs in enhancing the performance, gut health, nutrient digestibility, egg production, carcass characteristics, immunity and biochemical status of poultry. We also elaborated the effect of medium chain fatty acid supplementation on performance of broiler in heat stress. The use of sub-therapeutic doses of antibiotics as growth promoters (AGPs) has been widespread in the poultry industry to maintain gut ecosystem balance and improve overall chicken performance. However, due to growing concerns about antibiotic resistance, the European Union has banned the use of AGPs in poultry diets. As a result, researchers are exploring alternative solutions such as prebiotics, probiotics, essential oils, and organic acids to enhance poultry production and growth performance. MCFAs demonstrate antibacterial, antifungal, and *anti-coccidial* properties, inhibiting the growth of pathogenic organisms and improving nutrient digestibility. When administered at appropriate doses, MCFAs can enhance growth, improve health status, reduce mortality rates and heat stress in poultry. In this review, we have enlightened the advances in utilization of organic acids in poultry production such as encapsulation for sustainable production.

Keywords: Broiler, Growth performance, Nutrient digestibility, Egg production, Carcass characteristics

1. Introduction

The global demand of protein for human consumption is increasing, which shows that poultry production has a bright future. The modern poultry have reached high production with efficient feed conversion due to impressive progress in the genetic potential of the birds, feed quality, and strict biosecurity. Similarly, efforts are being made to enhance gut health to improve digestion and utilization of nutrients as gut function and health are important for optimum performance of birds through crucial feed additives. Generally, antibiotic growth promoter as feed additives has been widely used in poultry production; this may results into development of antibiotic resistance and residue in poultry products (Guo *et al.*, 2018; Montoro-Dasi *et al.*, 2020) [1, 2]. Many countries have banned the use of antibiotics as growth promoters to safeguard human health. As food safety is incomplete without including safety of agricultural production, which must be provided despite the growing challenges associated with it. Replacing antibiotics with alternative antimicrobial substances is essential for achieving more sustainable poultry meat production (Daghio *et al.*, 2024) [3]. Fatty acids are commonly categorized as short chain (SCFA; up to 4 C), medium chain (MCFA; from 6 to 12 C) and long chain (LCFA; more than 12 C).

The rapidly increasing cost and fluctuating availability of conventional fat sources, such as palm and soybean oils, highlight the need to explore alternative fat sources that promote resource efficiency and the reuse of agro-industrial by-products, thereby reducing environmental impact. Medium-chain fatty acids (MCFAs) consisting of 6–12 carbon atoms ($C_6:0$ – $C_{12:0}$), have attained the attraction in poultry nutrition because they are easily digested and quickly converted into energy. Furthermore, MCFAs exhibit antimicrobial properties that may improve gut health, helping to enhance the growth performance and overall health of broiler chickens, particularly during the early stages of life for which fulfil the precise feeding attempt for poultry production (De Los Monteros-Peñafiel *et al.*, 2026) [4].

Shilling *et al.* (2013) [5] reported that lauric acids disrupted the cytoplasm structure of bacterial cells using coconut oil and it's most active individual fatty acids. Lauric acid was the most inhibitory to *Clostridium* growth. Additionally, the anticoccidial properties of MCFAs have been proven by studying high quality coconut oil that contains MCFAs and their proper monoglycerides. The medium chain fatty acids are also utilized faster than long-chain fatty acids (LCFA) due to difference reflected in the biological processes of uti

Antibacterial activity of medium chain fatty acid

As MCFA have ability to cross semi-permeable membrane of bacteria in un-dissociated and fat soluble form which enter cytoplasm of bacterial cell. At neutral pH of the cell cytoplasm, the un-dissociated MCFAs get dissociated by releasing H^+ and anions. This generation of H^+ cation creates acidic environment inside the bacterial cell, the problems for bacteria is that it must maintain a near-neutral cytoplasmic pH. The pH sensitive bacteria are unable to tolerate a large spread of ions between the internal and the external pH. A specific H^+ -ATPase pump acts to bring the pH inside the bacteria to a normal level. This phenomenon consumes energy and stops the growth of the bacteria or even kills it due to suppression of cytoplasmic enzymes and nutrient transport causes cellular energy depletion that resulting in cellular death (Bergsson *et al.*, 2001) [13]. Along with this, MCFA inhibits the production of lipases by the bacteria. As lipases are needed to allow the bacteria to attach to the intestinal wall, this process will be prohibited and the bacteria will be washed out (Dierick *et al.*, 2002) [10]. Moreover, the anionic part of dissociated MCFAs intercalate with the bacterial DNA, thereby inhibiting DNA replication and accordingly bacterial growth. Thus, medium chain fatty acid has better effect on growth and bactericidal property.

2. Systematic review analysis

A systematic search of literature related to Medium chain fatty acid supplementation for sustainable poultry production- A review cited from first authors research. All the parameters mentioned in review article is referred from that research only.

3. Effect of MCFAs on performance

High production and better FCR is a key to develop the poultry industry. Many studies were done to achieve it. Antimicrobial activity of MCFAs lowers the load of pathogenic bacteria leading to the reduced metabolic needs of nutrients, thereby increasing the availability of nutrients for growth. Reduced bacterial load in gut eventually decreases the concentrations of toxic metabolites from the bacteria, reduces bacterial fermentation of essential nutrients like protein and energy. Thus, improved nutrient retention observed with MCFA supplementation might have contributed to higher weight gain.

A few early studies suggested that MCFA have improved body weight (3.6 %) due to inclusion of mixture of MCFA like caproic acid, caprylic acid, capric acid and lauric acid at 1.2 g/kg feed (Deschepper *et al.*, 2013). Huang *et al.* (2024) [14] found that 200 mg/kg microencapsulated essential oil and organic acid supplemented group of broiler has increased average daily gain (ADG) and average body weight (ABW) as compared to control group. Studies show that body weight gain and FCR was improved in 400 mg/kg organic acid of diet supplemented group of broiler birds as compared to control group. Reddy *et al.*, (2022) [15] described that FCR and body weight found to be best in MonoBlok-ECS, a commercial product containing medium-chain fatty acid derivatives with synergistic components (MCFA-SC) @ 500g/ton of feed supplemented group of broiler. Broilers with an encapsulated blend of organic acid in drinking water had higher body weight, ADG and lower FCR than the negative control group (Rahnama *et al.*, 2021) [16]. Ma *et al.* (2021) described that broilers supplemented with low medium chain fatty acid (LMOA, 3000 mg/kg) and HMOA (high medium chain fatty acid, 6000 mg/kg) exhibited significantly higher ($p < 0.05$) final body weight and average daily gain during both the grower and overall phases. Additionally, broilers received LMOA showed a notable improvement ($p < 0.05$) in feed conversion ratio in both the grower and overall phases. Jadhav *et al.* (2021) [17] reported birds fed diet containing 0.25% lauric acid, 0.25% capric acid or their combination recorded significantly higher ($P < 0.01$) body weight compared to control group. The increase in live weight in birds fed lauric acid over control was 4.37%. Del Alamo *et al.* (2007) [18] observed that inclusion of the MCFA (C6-C₁₂) @ 0.20% in the starter (0-7days), 0.15% grower (8-21d) and 0.10% finisher (22-42 d) diets improved the reported im-

provement in body weight gain (BWG) compared to the control group. Few studies on supplementation of medium chain fatty acids (C6, C8 and C₁₀) at 1:1,000 (in water) (Chotikatum *et al.*, 2009) [19], oil containing 0.3% capric acid and 2.7% lauric acid (van der Hoeven-Hangoor *et al.*, 2013) [20] reported improvement in body weight gain. The enhancement in the FCR with MCFA could be a result of higher BWG due better utilization of nutrients. Issac *et al.* (2013) [21] observed that MCFA at 0.8 to 1.7 g/kg feed yielded significantly better FCR. Correspondingly, MCFA in form of coconut fat (Kessler *et al.*, 2009) [22], 0.05% of lauric acid (Bhalsing, 2018) [23] recorded better feed conversion ratio in broilers. Moreover, Hejdysz *et al.* (2018) [24] observed improvement in FCR by 5 % on supplementation of MCFA in triglyceride form of capric and caprylic acids at 3 g/kg over control. Lamot *et al.* (2016) [25] reported that inclusion of MCFA (30g/kg feed) improved FCR. In contrast, K. Perz *et al.* (2022) [26] reported no significant effect was found on the BW, FCR and FI of green-legged partridge hen supplemented with medium chain fatty acids. Similarly, in the study, there was no significant difference was found in terms of mean live weight gain, feed consumption and feed conversion rate in medium-chain fatty acid supplemented group of broiler (Demirci *et al.*, 2021) [27].

The supplementation of dietary MCFA was reported to induce the secretion of cholecystokinin and perhaps other intestinal hormones, which are known to influence the feeling of satiety and therefore feed intake (Mabayo *et al.*, 1992) [28]. Reduced pH of the gut with medium chain fatty acid supplementation might have increased pancreatic secretion which increases appetite besides enhancing the palatability of the feed (Cave, 1982) [29]. It shows that feed intake may dependent on the influence of MCFA. In agreement with above statement, study reported by Kessler *et al.* (2009) [22] who replaced 2.67% corn oil with coconut fat (oil rich in MCFA) and found increased feed intake ($P < 0.05$). While, in another study of Khatibjoo *et al.* (2017) who observed that supplementation of medium chain fatty acid has no effect on feed intake. On other hand, significant reduction in feed intake was reported with supplementation of caprylic acid (De Los Santos *et al.*, 2008), capric acid at 0.080% (Zheng *et al.*, 2006) [30] of diet in broiler diets. Reduced feed intake with MCFA supplemented at higher levels compared to lowered doses might be due to fact that, the MCFAs in diet are absorbed through the portal system without resynthesizes of triacylglycerol in intestinal cells, and are predominantly subjected to β -oxidation in liver very rapidly (Leyton *et al.*, 1987) [31].

4. Effect of MCFAs on gut health

Gut microflora can directly interact with the lining of the gastrointestinal tract which may alter the physiology of the tract and immunological status of the bird (Klasing, 2007) [32]. The pathogenic gut microflora may be involved in localized or systemic infections, toxin formation and putrefaction of intestine that ultimately hamper productive performance of the bird. MCFAs produce a strong antibacterial effect due to the anionic part of the molecule, but effect is due to change of the bacterial pH and due to influence on the metabolic level of the bacteria is not yet understand. Because, inhibitory effect of different fatty acids on micro-organism is depend on minimum inhibitory concentrations (MIC), depending on the type of fatty acid, type of microorganism and environmental pH.

Studies show that incorporating 200 mg/kg and 400 mg/kg of the microencapsulated essential oils and organic acids preparation (EOA) to the diet could improve the intestinal microenvironment through improving intestinal morphology and gut health of birds (Haugh *et al.*, 2023). Rahnama *et al.* (2022) [33] reported that addition of an encapsulated blend of organic acids in drinking water of broiler birds resulted in a significantly lower ($p < 0.05$) pH in the jejunum compared to the negative control. Furthermore, these organic acids reduced the pH in various sections of the gastrointestinal tract of broilers relative to those on the control diet. In this study, the administration of 500 g of encapsulated organic acids or 1000 mL of non-encapsulated blend led to a lower count of *E. coli* compared to the negative control ($p < 0.05$). Additionally, a linear decrease ($p < 0.05$) in *E. coli*

counts was observed in the ileum of broilers with increasing levels of the non-encapsulated blend of organic acids. Evans *et al.* (2017) [34] reported that addition of medium chain fatty acids in turkey poult diet lowered the bacterial colonization such as *Salmonella* in early period of their life. Deschepper *et al.* (2013) showed that MCFA at 0.8 and 1.2 g/kg feed reduced the invasion of *Salmonella enteritidis* in the intestinal organ of broilers. Moreover, Jadhav *et al.* (2021) [17] observed birds fed diet containing 0.25% lauric acid, 0.25% capric acid or their combination noted numerically reduced coliform count, whereas, the total viable count in group fed MCFAs at 0.25% and their combination were significantly reduced.

In accordance with Skřivanová *et al.* (2007) [35] who observed that supplementation of 0.25 or 0.5 % caprylic acid in diets of broilers resulted in reduced ($P < 0.05$) $\log_{10}$ CFU of coliforms and salmonellas in the crop and cloacal contents compared to control group. Similarly replacement of the animal fat and soybean oil with broilers diet with MCFA (0.3% C₁₀ and 2.7% C₁₂) stimulate the the gram-positive bacteria belonging to the phylum of the *Firmicutes*, including *Lactobacillus* species, and species belonging to the family of the *Enterococcaceae* and *Micrococcaceae*, whereas the gram-negative bacteria belonging to the family of the *Enterobacteriaceae* were reduced (van der Hoeven-Hangoor *et al.*, 2013) [20]. The MCFA has antimicrobial properties *in vitro* and the gram-positive organisms found to be more sensitive to these acids (Kabara *et al.*, 1972) [36]. Gerwe *et al.* (2013) observed that *Campylobacter* colonization was reduced with supplementation of medium chain fatty acids. MCFA supplementation was equally effective with organic acids in decreasing the levels of colonization in ceca and improved growth performance. The MCFAs synergistically suppressed the expression of the genes regulating invasion and thereby decreased the numbers of bacteria and have potential to reduce colonization of bird and appear to be much more effective against *salmonella* than the short chain fatty acids. MCFAs specifically down-regulate the expression of *hilA*, a master regulatory gene within *Salmonella Pathogenicity Island 1* (SPI-1). The *hilA* gene is directly responsible for the bacteria's invasive capacity. By suppressing *hilA*, the bacteria lose their ability to invade intestinal epithelial cells, substantially lowering colonization in the gut and spread to internal organs. (Van Immersal *et al.*, 2007).

Good intestinal health in the poultry industry has great importance to achieve target growth rates and feed efficiency (Montagne *et al.*, 2003) [37]. The villus height and crypt depth could be considered as a common criteria measurement of gut health, as villi is area for most of the nutrients absorption consequently resulting in better utilization of nutrients and reflecting in higher performance (Awad *et al.*, 2008) [38]. MCFA supplementation might reduce total bacterial and *E. coli* count in gut that influence for higher villi height and crypt depth. MCFAs can be utilized directly by the enterocytes for energy production, resulting in better tissue development and supporting the integrity of the intestinal tissue and resulting in enhanced epithelial function (villus length, crypt depth) in the upper small intestine (Takase *et al.*, 1990; Dierick *et al.*, 2002) [39, 10]. A low pH in the gut is beneficial in several ways. It will increase the activity of the enzyme pepsin which enhances the utilization of the protein and hence is good both for the environment and economy of production. The pKa value is pH at which organic acids dissociate by 50%. The pKa of MCFA is between 4.88-5.13 (Hsiao *et al.*, 1999) [6] and pH of duodenum and jejunum ranged between 5 and 7 (Soerjadi *et al.*, 1982) [40] which is most suitable pH for dissociation of medium chain fatty acid. Thus, medium chain fatty acids have positive impact on the gut health in terms of gut microbial count, gut morphology and gut pH resulting in better digestive and absorptive capacities.

5. Effect of MCFAs on nutrient retention

MCFAs reduces the gastric pH which activates pepsinogen and other zymogens by adjusting gastric acidity closer to that required for optimal digestion activity (Jongbloed *et al.*, 2000) [41]. Beside this MCFAs, stimulates cholecystokinin secretion in the small intestine which in turn, stimulates the secretion of pancreatic protease (Stubbs

et al., 1985) [42] and this increased enzyme activity which have improved the digestion of proteins and possibly other nutrients. Furthermore, acidic digesta may decrease gastric emptying, and therefore provide more time for nutrient digestion in the GIT (Kidder *et al.*, 1978; Mayer, 1994) [43, 44]. Apart from these MCFAs has a strong antimicrobial effect on the intestinal morphometry (Dierick *et al.*, 2002) [10] which decreases competition between host and microbes thereby ultimately increasing the availability of nutrients for absorption and utilization. It was also hypothesized that greater intestinal villi height and crypt depth provides a more surface area for nutrients absorption and consequently, improved digestibility (Awad *et al.*, 2008) [38].

Huang *et al.* (2023) described increased digestive enzymes activity and cecal lactic acid bacteria and butyric acid content in microencapsulated essential oils and organic acids preparation (EOA) supplemented group of broilers. Similarly, Chotikatum *et al.*, (2009) [19] reported significantly ($P < 0.05$) higher digestibility of protein in broilers with supplementation of medium chain fatty acids (C₆, C₈ and C₁₀) at 1:1,000 in water than those given normal tap water. According to Van Der Sluis (2002) [45], the positive effect of MCFA on digestion was related to a slower passage of feed in the intestinal tract resulting in better absorption of the nutrient. While, few authors reported no effect on nutrient retention with organic or MCFA supplementation. In contrast, supplementation of broiler diets with specific structured triacylglycerides consisting of medium chain fatty acids at sn-1, 3 position and capric acid (C_{10:0}) @ 20, 40, 60 and 80 g/kg diet did not affect DM, CP and EE digestibility (Zheng *et al.*, 2006) [30]. No effect on nutrient digestibility of dietary medium chain fatty acids acid supplementation by above workers could be attributed to fact that insufficient dose or form used that required for produced the desire antimicrobial activity against gut pathogenic organism. The sources and amounts of dietary protein and minerals may affect the buffering capacity of diets, which can influence the degree of acidification that occurs with the inclusion of medium chain fatty acids.

6. Effect of MCFAs on carcass characteristics

The antimicrobial activity of MCFAs results in better utilization of nutrient for muscle development in broilers (Deschepper *et al.*, 2003) [9]. Antimicrobial activity, higher nutrient utilization and higher body weight gains with MCFA supplementation could have attributed to higher dressing percentages. Possible higher dressing percentage in some studies could be attributed to the fact that MCFA or organic acids supplementation stimulates the insulin and improves glucose uptake in body muscle that is used for muscle protein synthesis. Also most often mentioned characteristic of MCFA is their ability to reduce obesity and fat tissue that well proven in broiler along with rat and pig. Demirci *et al.* (2023) [46] found carcass weight, dressing percentage and gizzard weight and other visceral organ weight was similar among all groups of broiler whereas heart and liver weights were significantly lower in ($P < 0.05$) in 0.4% free capric acid (CA) supplemented group and higher in lauric acid (LA) supplemented group of broiler. Demirci *et al.*, (2021) [27] reported total n-3 levels was increased and total n-6 and n-6/n-3 levels was decreased in medium chain fatty acid supplemented groups of broilers. Ma *et al.* (2021) [16] described the pH levels of breast and thigh muscles at 24 hours post-slaughter were significantly higher ($p < 0.05$) in broilers fed with HMOA, and there was also a notable improvement in the redness of thigh meat ($p < 0.05$). Furthermore, the supplementation of LMOA significantly increased ($p < 0.05$) the levels of saturated fatty acids, unsaturated fatty acids, and the ratio of polyunsaturated fatty acids to saturated fatty acids in breast meat. Isaac *et al.* (2013) [21] observed higher dressing percentage in broilers supplemented with balanced mixture of 60 % MCFA (C₆, C₈, C₁₀, C₁₂) @ 0.8 g/kg and 1.2 g/kg compared to control. While, Shokrollahi *et al.*, (2014) [47] reported that dressing percentage of broilers was not affected with dietary supplementation of 0.1, 0.2 and 0.3% MCFA (balance mixture of C₈-10) compared to those fed with control. However, breast yield percentage was significantly increased in the 0.3% MCFA treatment and 0.2% &

0.3% MCFA treatments had a lower abdominal fat percentage compared to control or 0.1% MCFA treatments ($P < 0.01$). These findings were similar to those reported by Chiang *et al.* (1990) [48], who suggested that dietary MCT decreased abdominal fat percentage in broiler chickens. Experiments in other animal species and human subjects also showed that MCT reduces body fat deposition (Seaton *et al.*, 1986; Scafì *et al.*, 1991) [49, 50]. The reason for decrease in abdominal fat content with MCFA supplementation could be that it suppress lipid absorption (Nakai *et al.*, 2005) [51] which reduces calorie intake (Van Gaal *et al.* 2005), reduces the biosynthesis of fatty acids and enhances fatty acid oxidation (Murase *et al.*, 2001) [52] of extra body fat. In another characteristic of carcass traits, relative weight of liver and gizzard were not alerted with dietary mixture of formic, propionic and acetic acid along with caproic and capric acid (Świątkiewicz *et al.*, 2012) [53]. Similarly, in other studies, relative weight of liver, pancreas and gizzard were not alerted with dietary supplementation of MCFA (balance mixture of C8-10) (Shokrollahi *et al.*, 2014) [47].

The MCFAs and SCFAs have a different metabolic fate than long chain fatty acids, and they are rapidly absorbed in the small intestine, transported to the liver as FFAs via hepatic portal circulation, and then enter into the mitochondria independent of fatty acyl-CoA-carnitine transferases (Ode *et al.*, 1991) [54]. Acetyl-CoA formed by β -oxidation can be further oxidised via the Krebs cycle to carbon dioxide and water and can be used for the synthesis of LCFA and cholesterol. The complete oxidation of MCFAs in the liver, citric acid cycle increases energy loss as heat and reduces energy accessibility and by fat storage. Two molecules of acetyl-CoA condense to form ketones and this ketone bodies can be used for synthesis of LCFAs. The thermal effect of MCFAs and subsequent reduction in body fat deposition could be related to the production and oxidation of ketone bodies (Bach *et al.* 1996).

7. Effect of MCFAs on immunity

Measurement of immune organ weight is a common method for assessment of immune status in chickens (Heckert *et al.*, 2002) [55]. Immune organs constitute the immune system of the body together with lymphoid tissue and immune cells. Generation, proliferation, differentiation, and maturation of immune cells usually take place in the thymus, spleen, and bursa. Therefore, the immune organ index is an important indicator reflecting immune competence. A trend of increased development of the bursa of Fabricius was observed by Nguyen *et al.*, (2018) [56] indicated that broiler supplemented with the blend of organic acid and MCFAs presented better immunity than in control group. It is shown that there is an important relationship between the weight of bursa of fabricius and immune response, which indicated that antibody production in a breed with large bursa was higher than that of small bursa (Ammar, 2008) [57]. Therefore, it is hypothesize that the increase in the IgG concentration could be due to the increased development of the bursa of Fabricius.

In medium chain fatty acid supplemented chickens, there is possibility of increasing the antibody due to vaccination might be due to speeding up of differentiation of lymphoid organs by increasing the activity of the hexose monophosphate pathway, thus increasing the circulating antibody. These findings are well supported by Lohakare *et al.* (2005) [58] who opined that increasing antibody titers to vaccination in organic acid supplemented chickens might be due to speeding up of differentiation of lymphoid organs by increasing the activity of the hexose monophosphate pathway, thus better development of lymphoid organs which enhances circulating antibodies. Organic acids create an optimal gut environment and supply the metabolic precursors required for active cellular function. The accelerated cellular turnover and energy boost speed up the development and maturation of lymphoid organs. Better developed lymphoid tissues respond more robustly to vaccinations, resulting in higher circulating antibody titers and stronger overall flock immunity. The reports on effect of MCFA on immune response in broilers available in the literature are scanty. Lamot *et al.* (2015) reported that MCFA improved immune

response in terms of immunoglobulin, agglutination titers, interferon gamma (IFN- γ) and complementary activities. However, Saeidi *et al.* (2016) [59] reported that medium-chain fatty acids showed non-significant difference on immune response in Japanese quail. They also observed that immune response determined in terms of SRBC antibody titers did not differ significantly among the different treatment groups in quails.

MCFA (especially lauric acid; C_{12:0}) were found to increase IL-1 α expression in vitro in a dose response manner through toll-like receptor (TRL-4) activation (Lee *et al.*, 2001). Although effects of nutrition on immune function in poultry have been extensively reviewed, most studies do not focus on effects of nutrition. Moreover, mostly general effects of feed and water access on immune function and function are studied, ignoring effects of diet composition (Walstra, 2011; Simon *et al.*, 2014) [60, 61].

8. Effect of MCFAs on biochemical studies

Most MCFAs are weakly bound to albumin in the blood and free MCFAs cause stimulation of insulin secretion which lead to reducing the concentration of blood glucose. Demirci *et al.*, (2021) [27] reported that triglyceride levels were found to be significantly lower in the medium chain fatty acid supplemented group of broiler as compared to control group. Shokrollahi *et al.*, (2014) [47] observed the serum concentration of glucose tended to decrease as the levels of MCFA in the diet were increased and it was significantly reduced in 0.2 or 0.3% MCFA treatments. Balanced mixture of (C8-10) MCFAs supplemented either at 0.1 or 0.2 % butyrate or combination of butyrate and MCFAs significantly decreased ($P < 0.01$) serum glucose and cholesterol level (Khatibjoo *et al.*, 2017). However, Bhalasing (2019) found that dietary supplementation of lauric acid ranging from 0.05 to 0.2% or AGP had no effect on serum glucose and cholesterol. Powell (2000) [62] reported that the reduction in cholesterol levels may be the result of the increased breakdown of cholesterol by bile acids and inhibitory effect of organic acids on micelle formation in the low pH of digesta content but such inhibitory on serum cholesterol with MCFAs supplementation @0.05 to 0.2% on micelle formation did not occur as evident from fat retention. Replacement of corn oil in diet with 25, 50, 75 and 100 % of coconut oil (rich in MCFA) resulted in linear ($p < 0.01$) decrease in serum total cholesterol, LDL cholesterol, and LDL/HDL cholesterol level (Wang *et al.*, 2015) [63]. Similarly, effect of 0.1, 0.2 and 0.3 % dietary supplementation of MCFA in broiler (Shokrollahi *et al.*, 2014) [47] and 0.1, 0.2 and 0.4 % dietary MCFA in quail (Saeidi *et al.*, 2016) [59] on blood parameters are significantly decreased the concentration of triglyceride, total cholesterol and LDL- cholesterol and increased HDL-cholesterol ($P < 0.05$). These findings were partly similar to those reported by Asakura *et al.* (2000) [64], who reported that dietary medium chain triglycerides (MCT) had no influence on serum concentration of triacylglycerol as compared to maize oil in primary hypertriglyceridaemic subjects. Furthermore, they implied that the MCT treatment induced significantly higher fasting total cholesterol and non-HDL-cholesterol concentrations than maize oil. Contrarily, MCT lead to an increased amount of LDL-cholesterol and total cholesterol, but a decrease in HDL cholesterol in humans (Cater *et al.*, 1997) [65]. The different results may be attributed to differences in species and/or composition of MCFA.

In contrast, Demirci *et al.* (2023) [46] Indicated that the admixture of free capric acid, lauric acid, at the rate of 0.4% in diet did not cause any significant difference in broiler serum biochemical parameters. Demirci *et al.*, (2021) [27] reported there was no significant difference between the groups in terms of serum glucose, total cholesterol, total protein and albumin ($P > 0.05$).

9. Effect of MCFA in laying hen

It is well accepted that dietary supplementation of an organic acid mixture significantly increases egg production in laying hens, as compared with hens that were not given such supplementation. MCFAs are also used as alternatives to antibiotics due to their similar effects

as those of organic acids on antimicrobial activities outside the intestinal tract and on reducing pH leads to a change in the spectrum of the intestinal microbiota. So, MCFAs had positive effects on laying hens' productivity including egg production and egg quality, and faecal microbiota content. Also, the positive effect on calcium absorption may have enhanced the eggshell strength in laying hens. Study show that hatchability and fertility rate were ($P \leq 0.05$) higher in caprylic acid (CA) and butyric acid (BA) with or without cinnamon essential oil (CEO) treated groups as compared to the control group (Abd El-Maged *et al.*, 2024) [66]. Klementavičiūtė *et al.* (2016) [67] reported feeds supplemented with medium-length fatty acids improved egg yolk color and feeds supplemented with MCFAs +emulsifier Lipidol significantly reduced egg weight 1.12 % ($P < 0.05$) as compared to control group. In a study with laying hens fed diet supplemented of caprylic acid positive effects on egg weight and feed efficiency decreased the serum and yolk cholesterol concentration and reduced the proliferation of *Escherichia coli* (Wang, 2010). Lee *et al.* (2015) [68] reported that dietary supplementation of a microencapsulated organic acid blend with MCFAs can have positive effects on egg production, egg strength, Haugh units, calcium concentration, and faecal Lactobacillus and E. Coli contents in laying hens. However, Swiatkiewicz *et al.*, (2010) found that the addition of MCFA had a positive influence on eggshell characteristics, i.e. eggshell percent, density and breaking strength.

10. Effect of MCFA in heat stress

Impairment of the intestinal barrier occurs due to disturbances in the tight junction network, which can lead to reduced nutrient absorption, increased risk of bacterial translocation, and activation of the inflammatory cascade (Dokladny *et al.*, 2006) [69]. One strategy to manage intestinal health is feed supplementation with organic acids notably medium chain fatty acids, which inhibit bacterial growth by modulating pH and microbiota in the intestinal tract. Additionally, medium-chain fatty acids (MCFA) can decrease the host's inflammatory response (Carlson *et al.*, 2015) [70] and are promising candidates for use as supplements in feed to mitigate the effects of heat stress. Feed enriched with a blend of medium-chain fatty acids (MCFA), organic acids, and plant polyphenols has been shown to effectively prevent disturbances caused by heat stress in redox balance, villus morphology, and morphometry. Furthermore, it enhances the integrity of tight junctions and improves nutrient transport (Santos *et al.*, 2019) [71]. Ding *et al.* (2020) [72] observed that heat stress (HS) impaired growth performance; however, the addition of fumaric acids (FA) resulted in higher final body weight, increased average daily gain, and improved European broiler index compared to the HS group. Santos *et al.* (2019) [71] stated that heat stress in broiler birds was alleviated by supplementation of medium chain fatty acids blend.

11. Conclusion

Medium chain fatty acids (MCFAs) present a promising alternative to traditional antibiotics in poultry production, particularly in light of the recent ban on growth promoters in the European Union. Their unique properties not only enhance nutrient digestibility but also provide significant antimicrobial benefits, contributing to improved gut health, overall performance and reduce heat stress in poultry. MCFAs have been shown to positively influence various factors, including growth rates, egg production, and immunity, while also reducing mortality rates. As the industry seeks sustainable and effective solutions to enhance poultry production, further research on optimal dosages and applications of MCFAs in heat stressed birds could lead to significant advancements in poultry health and productivity, paving the way for safer, antibiotic-free farming practices.

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Ethics statement

Since the current study is a review article and involves no live animals, ethical approval was not sought.

CRediT authorship contribution statement

Pratik Jadhav: Writing – review & editing, Writing – original draft, Conceptualization. Ashvini Bansod: Writing – review & editing. Rajeshwar Khandare: Supervision. Abhilash Jadhao: Writing – review & editing.

Declaration of competing interest

All persons listed as authors have read and contributed to preparing the manuscript attest to the validity and legitimacy of the data and its interpretation, and agree to its submission to Aquaculture. The manuscript has not been published nor is being considered for publication elsewhere. We have read and understood your journal's policies, and we believe that neither the manuscript nor the study violates any of these. There are no conflicts of interest to declare.

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Data availability

Data sharing is not applicable to this article as no data were created or analysed in this study.

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