Impact of extruded feed ingredient on meat quality of broiler chickens: A meta analysis

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Abstract. Extruded-fed broilers can improve their performance by improving their digestibility, although its effect on meat quality has not been clarified. This study aims to evaluate the effects of extruded feed on broiler meat quality using meta-analysis. Literature was searched and screened using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol. Data from seven articles with publication time between 2013 and 2024 were calculated using OpenMEE software to determine the hedges-D of the meta-analysis and interpreted using forest plot images. The results showed that extruded feed did not negatively influence meat quality parameters, such as UFA, SFA, TBARS, Omega-3, pH, drip loss, freshness, and yellowness ($P>0.05$). It can also improve quality by decreasing WHC and reducing total lipids ($P<0.05$). These results indicate that extruded feed can improve meat quality.

1 Introduction

Poultry production is less profitable owing to the rising cost of traditional raw materials such as corn and soybeans. Thus, finding feedstuffs that can either wholly or partially replace soybean meal in poultry nutrition is essential. Feed costs account for 70% of poultry production expenses. Flaxseeds and faba beans are substitute sources of protein for broilers. The seeds of this legume have moderately high protein content and amino acid profiles that resemble those of soybean meal [1]. However, because of their high resistant starch content and anti-nutritional components, these seeds should only be used sparingly in poultry diets. One technological method that can boost the use of seeds for poultry nutrition is extrusion. By extrusion, feedstuff must flow under carefully regulated heating and shearing circumstances through a die. Over the past two decades, extrusion processing of feed ingredients has grown in popularity. The main advantages of extrusion cooking are its adaptable product qualities, high energy efficiency, small operating space requirements, new feed product formulations, automated control system, high productivity, and effluent-free, environmentally friendly technology.

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Extruded feed ingredients can improve the performance and digestibility of broiler chickens [2]. However, its effects on meat quality remain unclear. Some studies have shown that meat from extruded chickens can improve the nutrient quality of meat, as shown by the enhanced omega-3 fatty acids content and oxidative stability [3]. Some studies have demonstrated no differences in breast and leg muscle pH and water-holding capacity (WHC) between broiler chickens fed raw or extruded feed [4]. WHC is an important variable as a measure of chicken meat quality because it shows the ability of meat to retain moisture in the muscle tissue and any liquids that may be supplementary to the meat processing—the WHC typically links to meat juiciness and tenderness. Omega-3 and omega-6 fatty acid composition, total lipids, oxidative stability, pH, and drip loss are also the main parameters of meat quality.

Although many studies have reported the effect of extrusion on meat quality, as shown in Table 1, there is no work to summarise these research results quantitatively. This study used meta-analysis to investigate the effects of extruded feed ingredients on broiler meat quality, including physical and nutritional meat quality. These methods have been used to synthesize quantitative data from several studies. Using this approach, the total effect size of all studies was calculated. Statistical power can resolve uncertainties or discrepancies in individual studies on the effect of extruded feed on meat quality by combining these effect sizes.

2 Materials and methods

A literature search for meta-analysis was conducted using Scopus from 2013 to 2024. The keywords used were "extrusion," "feed," and "broiler meat quality." They resulted in 5 to 14 studies from seven articles using the Preferred Reporting Item for Systematic Reviews and Meta-Analysis (PRISMA) protocol [5]. The results of the seven articles included in the meta-analysis are presented in Table 1, and the number of studies for each variable varies from 5 to 18 studies. The inclusion criteria were completeness of data, including the number of samples, availability of standard error or standard deviation, and direct comparison between extruded and unextruded feeds. The data were analyzed using a random-effects model with the standardized mean difference of Hedges, where the mean value of unextruded feed was grouped into the control group (X^C), and the mean value of extruded feed was grouped into the experimental group (X^E). The calculation is as follows [6].

$$d = \frac{(X^E - X^C)}{S} J \tag{1}$$

J is the correction factor for the small sample size and S is the pooled standard deviation.

$$J = 1 - \frac{3}{(4(N^C + N^E - 2) - 1)} \tag{2}$$

$$S = \sqrt{\frac{(N^E - 1)(s^E)^2 + (N^C - 1)((s^C)^2)}{(N^E + N^C - 2)}} \tag{3}$$

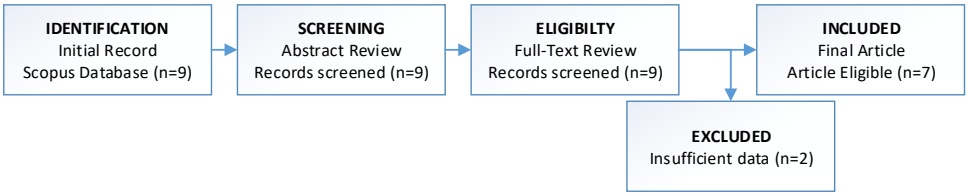
Where N^E is the sample size of the experimental set, N^c is the sample size of the control set, S^E is the standard deviation of the experimental set, and S^C is the standard deviation of the control set. Hedges'd (v_d) variance is defined as

$$V_d = \frac{(N^C + N^E)}{(N^C N^E)} + \frac{d^2}{(2(N^C + N^E))} \tag{4}$$

Cumulative effect size (d_{++}) is formulated as

$$d_{++} = \frac{(\sum_{i=1}^{n} W_i d_1)}{(\sum_{i=1}^{n} W_i)} \quad (5)$$

Where w_i is the inverse of sampling variance ($w_i = 1/v_d$). The accuracy of the effect magnitude was determined using the 95% confidence interval (CI), or $d \pm (1.96 \times sd)$. The equation was derived from [6] with a 95% confidence interval. The data were analysed using the OpenMEE application. The meat quality variables included in the database were meat colour, thiobarbituric acid reactive substances (TBARS), saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), pH, water-holding capacity (WHC), drip loss, omega-3, and omega-6.



Note: n: number of articles.

Fig.1: Literature screening for database meta-analysis

Table 1. The article included in the meta-analysis on impact of extruded feed ingredients on meat quality of broiler chickens

No	References	Broiler strain	Feed Ingredient	Meat Part	Extruder Machine	Temperature and Speed	Country
1	Anjum et al. 2013 [3]	Hubbard	Flaxseed	Breast and Leg	Single screw	80-120°C and 80-120rpm	Pakistan
2	Costa et al. 2024 [7]	Ross 308	Spirulina	Breast and thigh	Twins screw	118 °C, exposure time 5-7s	Portugal
3	Hejdysz et al. 2019 [8]	Ross 308	Faba Bean	Breast and thigh	Single Screw	135 ± 10°C, exporsure time 10s	Poland
4	Banaszak et al. 2021 [4]	Ross 308 Cobb 500	Soybean	Breast and thigh	NA	NA	Poland
5	Kim et al. 2022 [9]	Ross 308	Manganese	Breast and thigh	Hot-Melt screw	45-55oC, 150 rpm	Korea
6	Avazkhanloo et al. 2020 [10]	Ross 308	Flaxseed	Breast	Single screw	132 ± 2°C, 450rpm	Iran
7	Zhaleh et al. 2019 [11]	Ross 308	Flaxseed	Breast and Leg	Single screw	155°C, exposure time 5s	Iran

Note: NA: Not Available

3 Results and discussion

The ratio of polyunsaturated fatty acids (PUFA) to saturated fatty acids (SFA) influences nutritional value. Nutritionists and national health authorities often disparage meat to provide excessive amounts of SFA to the diet. However, meat is a substantial source of long-chain n-

3 fatty acids, which are currently thought to be consumed insufficiently [12]. Reducing saturated fat and increasing PUFA, especially n-3 PUFA, in the diet would improve the health and reputation of meat [13]. The detailed results of the meta-analysis are depicted in Fig 2. The variable intersecting the zero axis indicates no significant difference between the two treatments. SFA, MUFA, PUFA and omega-3 contents were not significantly affected. The extruded feed decreased omega-6 levels significantly. Usually, omega 3 is highly sensitive to high-temperature processes. The process did not change the omega-three content because the effectiveness of the extrusion process is not only affected by temperature but also the interaction with the process's duration and the material's water content. Usually, the extrusion process lasts only a few seconds. The optimal process variable among temperature, screw speed, and water content can inhibit degraded of omega-3. The duration and the temperature of extrusion are shown in Table 1.

The meta-analysis results show that extruded feed reduced the total fat content of meat. The variable did not intersect the zero axis, indicating a significant difference between the extruded and unextruded feed. According to [4], the extruded feed ingredients given to chickens can lower the fat in the meat of both Ross 308 and Cobb 500. In addition, there was a decrease in lipids from both 35-day-old and 42-day-old Broiler. This decrease is also in line with research [9].

On the other hand, according to [3] and [7], there is an increase in total meat lipids in chickens fed extruded feed. Although, based on aggregate meta-analysis, the extruded feed can reduce the total lipids of meat, there are differences in the results of this experimental research. Hence, the different ages of the chickens can cause the digestibility of fat nutrients to be different [2]. It has an impact on the total lipid content in chicken meat.

Lipid peroxidation is the primary cause of the degradation of meat quality. Meat lipid peroxidation can be measured using the thiobarbituric acid assay, but the TBARS values were not significantly different in the meta-analysis. This may be because there were no differences in the polyunsaturated fatty acid concentrations. Meanwhile, the TBARS values in breast meat were lower than those in leg meat, likely because of the reduced fat content of breast meat [8].

The meat's water-holding capacity (WHC) affects its physical appearance and is a key criterion for evaluating meat quality. Deprived WHC results in high drip and impulse loss from meat, which can characterize significant weight loss from carcasses and may indicate the yield and quality of processed meat. The results also showed no differences in the pH or drip loss. In both extruded and unextruded feed, meat is prone to a rapid decrease in pH. Our meta-analysis showed that WHC decreased significantly, indicating a lower loss of water and, thus, higher suitability of meat for further processing. This may be because the digestibility of dry matter, crude protein, crude fat, and some amino acids is higher in extruded feeds [2]. These results support previous research [4] regarding the effect of extruded feed on WHC meat, which showed that WHC is lower in chickens fed extruded feed than in non-extruded feed for both Ross and Cobb broilers.

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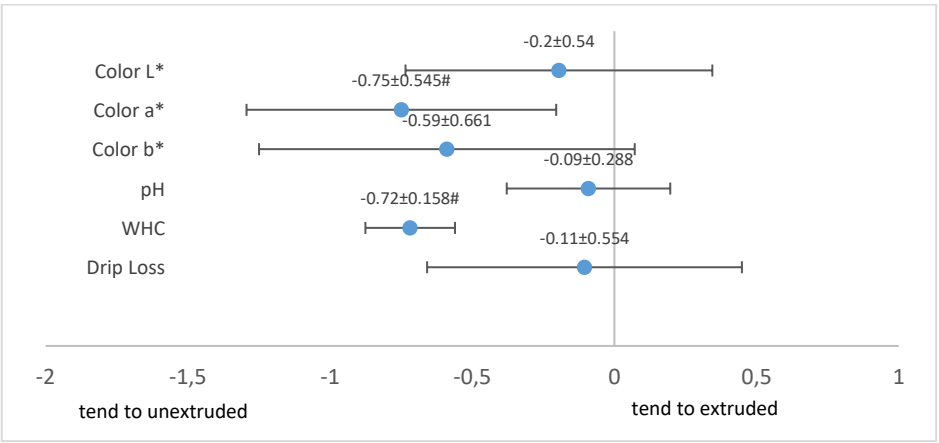

Fig. 2. Forest plot of the effect of extruded feed on meat color, pH, WHC and drip loss of broiler

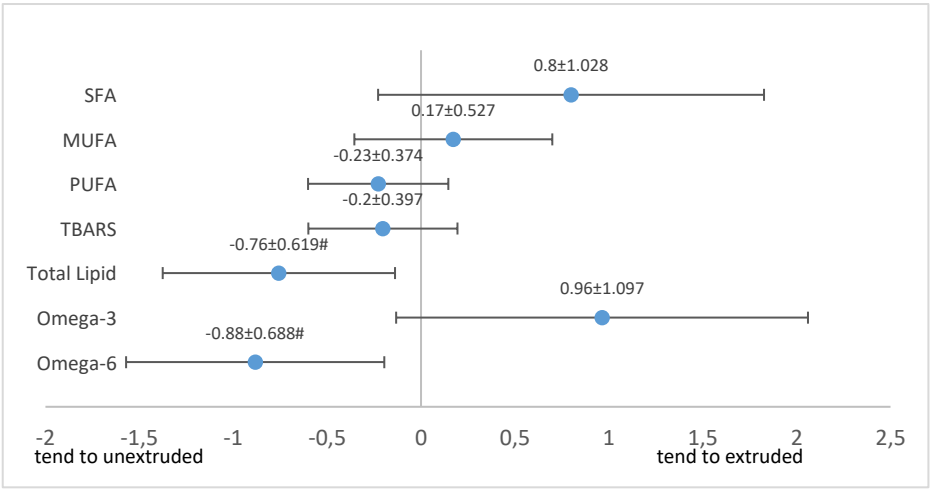

Fig. 3. Forest plot of the effect of extruded feed on meat fatty acid, TBARS, total lipid and omega-3 of broiler

Meat colour is affected by the mechanistic relationship between myoglobin and a combination of exogenous and endogenous factors. Improving colour stability and extending colour shelf life are key aspects of consumer acceptance of fresh meat and contribute to profitability in the poultry industry.

The extrusion process for each feed material had different process parameters. The lightness of the extrudate (L*) and redness (a*) primarily depended on barrel temperature, feed moisture, and feed rate. This may change the colour of the feed ingredients, affecting the meat's colour. The results showed that the L* and b* scores were not significantly different between the extruded and unextruded samples. In addition, the a* score was affected by the extruded feed. L* in meat is associated with denatured blood haemoglobin, storage duration, and pH levels, indicating freshness. b* denotes xanthophyll from feed deposited in broiler meat and is indicated by yellowness [14]. At the optimal temperature and time, xanthophyll or other active contents did not change. The value of a* indicates redness; although the a*value of extruded feed is significantly lower than that of unextruded feed, red pigment in poultry is not a preferred characteristic for consumers.

4 Conclusion

In this meta-analysis, extruded feed did not negatively influence meat quality parameters such as UFA, SFA, omega-3, TBARS, pH, drip loss, freshness, and yellowness. Meanwhile, it can improve quality by decreasing WHC and reducing total lipids. These findings suggest that extrusion technology can be applied to the feed industry to improve broiler meat quality**.**

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