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Effects of poultry offal meals produced by adding dissolved air flotation sludge to feeds on broiler field performance

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ABSTRACT - In this study, we investigated the effects of using poultry offal meal (POM) produced in rendering plants by adding dissolved air flotation sludge (DAFS) at set ratios into broiler grower and finisher feeds. The experiment conducted within the scope of the study lasted six weeks and involved 12,000 broiler chicks from Ross 308 strain middle-aged (36 weeks) breeders. Twelve different treatments were used in grower feed with 2 or 3% POM and finisher and pre-slaughter feeds with 4 or 5% POM produced by adding DAFS at 0, 11, and 22%, respectively. A downward trend was observed in average live weight (ALW), daily weight gain (DWG), feed conversion ratio (FCR), and European production efficiency factor (EPEF) values among the treatment groups, some of which were significant (P<0.05), as the usage rates of POM and DAFS increased. The treatment groups fed POM without DAFS in 2% grower and 5% finisher feeds had significantly higher ALW and EPEF values and significantly lower FCR values than the group fed POM at 22.0% in 3% grower and 5% finisher feeds (P<0.05). However, the mortality value remained unchanged according to the POM and DAFS usage rates (P>0.05). As a result, POM may be used in broiler feeds without significantly affecting ALW, DWG, FC, FCR, EPEF, and mortality values. However, if DAFS is used in POM production, attention should be paid to DAFS content, since exceeding certain levels may cause a downgrade in ALW, FCR, and EPEF values.

Keywords: broiler, byproduct, nutrition, poultry

1. Introduction

The rendering process is among the most important recycling processes in the meat industry. The most practical and safest way of value-added healthy byproducts in processing plants without causing environmental contamination or disease outbreaks is processing the animal byproducts (fat, blood, and feather meal etc.) in rendering plants (Fransen et al., 1995; Fransen et al., 1998; El Boushy and Van Der Poel, 2000).

Dissolved air flotation sludge (DAFS) is one of the byproducts added to the mixture processed in rendering plants from time to time. Many studies have been carried out to imply scientific conditions and study the nutritional value of DAFS (De Vries and Mudler, 1986; Fransen et al., 1995). The nutrient composition of DAFS was found as 15-50% protein, 40-80% fat, and 7-15% dry matter (Fransen et al., 1995; Lee, 2002).

Markham and Reid (1988) reported that dried DAFS can be used as a feed additive when it is thoroughly ground and patented. After the studies conducted, DAFS and POM started to be widely used in facilities in the USA (Fransen et al., 1995; Fransen et al., 1998). However, specific rules and prohibitions on the use of rendering products in animal feeds have put these facilities into big trouble with the EU and EU candidate countries, including Turkey (EC 2004a,b,c; EFSA, 2007).

In a broiler field study, when the secondary protein nutrient (SPN or biosolids, a product meal derived from DAFS) was added to broiler feeds at 20% and analysed, the following were found: 1.50% insoluble ash, 1727.97±320.63 kcal/kg apparent metabolizable energy corrected for nitrogen retention (AMEn), 28.24±14.09% apparent nitrogen retention (ANR), and 19.50±8.26% apparent fat digestibility (AFD) (Sungwarapon et al., 2004).

In another broiler field study, dried DAFS was added to broiler feeds at 7 and 15%, and no negative effects on the meat taste and palatability and histopathological changes in organs (liver, heart etc.) were found (De Vries and Mudler, 1986). When El Boushy et al. (1984) used poultry feed with 2, 3, 4, 5, 6, and 7% pure dehydrated DAFS with a ferrous compound in the production process, the growth rate decreased at the 4th and 7th weeks. In a pig study, it was found that flocculated poultry sludge mixed with 3% molasses, pasteurised at 95 °C for 5 min, then rapidly cooled to 20-25 °C, and fermented with *Lacbacillus plantarum* had a slightly negative effect on feed intake (FI), health, and performance when used at 19-28% dry matter basis in feeds, but this was not significant (Fransen et al., 1995).

Therefore, this study aimed to evaluate pressed and dewatered poultry DAFS and their suitability for use in poultry diets. In this context, this study investigated the effects of using poultry offal meal (POM) produced in rendering plants by adding DAFS in different ratios into broiler feeds and determine the most suitable ratio and duration under field conditions.

2. Material and methods

Research on animals was conducted according to the institutional committee on animal use (case number: 2023/35).

2.1. Test house

This research was carried out under real field conditions at an altitude of 822 m at the coordinates 40°42'53.62" N, 31°31'29.82", in modern R&D test house with capacity for 12,000 broilers/period from a company located in Bolu, Turkey, this being one of the most important aspects of the research. There were 60 ground pens in the house, and each of the pens measured 13.0 m^2 (6.5 m × 2.0 m) and were equipped with two nipple drinker line kits (SPARKcup, Roxell NV, Belgium), a pan feeder (MINIMAXline, Roxell NV, Belgium), and a ceramic radiant heater (Rd 3 FA, SBM Int., France). In addition, a digital scale connected to the central computer was set in each of the pens to monitor the live weight of the broilers throughout the study.

Numerous concerns were considered during the study design. To begin, the primary limiting factor is the number of replicates required and the number of compartments in the test house in which the broilers were reared. The rearing phase of the study was conducted in a test house with 60 compartments measuring 13 m^2, each capable of housing 200 broilers at a standard stocking density.

2.2. Dissolved air flotation sludge and poultry offal meal production

Dissolved air floatation sludge was produced by dewatering it in a belt press following physical, chemical, and biological treatment processes in the water treatment unit of a poultry slaughterhouse plant located where the experiment was conducted. The average dry matter content of DAFS increased from 5 to 25% during the process using a belt press, and this value was recorded as 21.54% during the experiment. The obtained DAFS was then added at the determined ratios into the trial design with other slaughterhouse byproducts (head, blood, feather etc.) to batch-cookers (HM 5000, HAARSLEV A/S, Denmark) at the rendering plant for POM production. All the byproducts were processed in these batch-cookers according to a process that takes approximately 4 h, in which a high temperature of

135 °C and a high pressure of 2.5 bars are used to completely deactivate viruses, spore-forming bacteria, and microorganisms (Fransen et al., 1998; El Boushy and Van Der Poel, 2000), and consists of cooking, hydrolysing, and drying stages. All the processes in POM production, such as cooking, pressing, and loading, are carried out in accordance with the regulations set for EU and EU candidate countries (EC, 2004a,b,c; EFSA, 2007). The poultry offal meals with/without DAFS produced in this way were put through an oil press and sent to the feed plant.

Chemical (moisture, crude protein, crude oil, crude ash, calcium, magnesium, potassium, iron, manganese, copper, mercury, lead, nickel, and potassium permanganate) analyses of DAFS used in POM production and POM with/without DAFS used in feed production were carried out using classical methods (the method numbers are, respectively: 930.15, 988.05, 920.39, 942.05, 968.08, AOAC (2000); atomic absorption method; and TSE 8336 based on Walckley and Black method, Anonymous, 2023) (Tables 1 and 2).

Table 1 - Content of dissolved air flotation sludge (DAFS) used for poultry offal meal production

Content	DAFS	
Moisture (%)	21.54	0.00
Crude protein (%)	7.38	34.24
Crude fat (%)	1.92	6.12
Crude ash (%)	2.04	9.46
Calcium (mg/kg)	1842.00	8546.88
Magnesium (mg/kg)	167.00	774.88
Potassium (mg/kg)	46.00	213.44
Ferrous (mg/kg)	6217.00	28846.88
Manganese (mg/kg)	26.82	124.44
Copper (mg/kg)	10.58	49.09
Mercury (mg/kg)	0.01	0.046
Lead (mg/kg)	4.20	19.489
Nickel (mg/kg)	1.06	4.91
Potassium permanganate (mg/kg)	94.58	438.85

Table 2 - Nutrition value of poultry offal meal (POM) with added dissolved air flotation sludge (DAFS) used in the study[1]

	DAFS usage rate in POM[1] (%)		
	0.00	11.00	22.00
Dry matter (%)	96.28	96.28*	96.28*
Crude protein (%)	62.09	60.12	58.02
Crude fat (%)	20.72	19.94	19.07
Crude ash (%)	9.62	9.80	10.00

[1] These values are revised for the dry matter content of POM without DAFS.

The analysis results are consistent with those reported by other researchers (Lee, 2002) and fell within the specified limits. This shows that DAFS has an average content of 78.46% total solids, 21.54% total moisture, and 9.46% ash of total solids. These findings from the current research are consistent with previous studies that have shown that poultry DAFS content has a high density of organic matter consisting of soluble proteins, carbohydrates, and fibres (Ghaly and MacDonald, 2012; Hu et al., 2017; Cui et al., 2019; Ozdemir et al., 2020). However, some of these values differ from the values reported in previous studies (Ferreira et al., 2018; Irshaid et al., 2021). It is thought that the differences in sludge compositions and properties are attributable to differences in poultry type, production process, feed, age of the poultry, and the cleaning process applied at the facility.

In addition, the most abundant component in DAFS samples is crude protein, accounting for approximately 34.24% of the dry weight of DAFS. Crude fat is the second most common component of DAFS, accounting for approximately 6.12% of its dry weight. Recent studies on the nutritional values and chemical composition of poultry DAFS have revealed that sludge is a good source of protein, fat, and minerals that can be incorporated into animal diets in agricultural practices (Ghaly and MacDonald, 2012; Hu et al., 2017; Adhikari et al., 2018).

2.3. Experimental design

Accordingly, POM usage rates, which are generally recommended in diet formulas of integrated feed plants, were considered and, thus multiple control groups were created. Treatment groups, on the other hand, were simply generated by adding DAFS at two different rates to the control groups. As a result, the final trial plan was designed considering the above-mentioned poultry house conditions and possibilities, along with an attempt to consider all possible alternatives.

In this study, test diets were formulated by adding POM with/without the DAFS at determined proportions. This study included 12 treatment groups that were designed based on their diet contents (Table 3).

Table 3 - Trial design and treatment groups

Treatment group	Group code		DAFS in POM production (%)	POM (%)		
				Starter feed	Grower feed	Finisher and pre-slaughter feeds
Control	C	C24	0.0	0.0	2.0	4.0
		C25				5.0
		C34			3.0	4.0
		C35				5.0
Treatment	D1	D124	11.0	0.0	2.0	4.0
		D125				5.0
		D134			3.0	4.0
		D135				5.0
	D2	D224	22.0	0.0	2.0	4.0
		D225				5.0
		D234			3.0	4.0
		D235				5.0

POM - poultry offal meal; DAFS - dissolved air flotation sludge.

2.4. Diet preparation

The feeds were prepared with corn-soya and manufactured in the feed plant of a private company located where the experiment was carried out. Poultry offal meal with/without DAFS was added to the basal diet based on the trial design. Diets were formulated in accordance with international standards (NRC, 1994) and according to the recommendations of grandparent company ROSS (2.0-2.5 kg average live weight [ALW]) (Aviagen, 2014) were taken into consideration for the trial design. Diets were prepared in four periods (starter, grower, finisher, and pre-slaughter). The starter feeds were in crumble, while the other feeds were manufactured in pellet form (3.5 mm in diameter; Tables 4 and 5) and the prepared basal diets were analysed with AOAC (2000) (Table 6).

Table 4 - Feedstuff contents of starter and grower diets

	Starter[1]	Grower[2]					
DAFS[3] (%)	0.00	0.00	0.00	11.00	11.00	22.00	22.00
POM (%)	0.00	2.00	3.00	2.00	3.00	2.00	3.00
Anticoccidial[4]	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Bonkalite	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Broiler starter vitamin	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Broiler chick vitamin	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Canola meal-35	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Choline chloride-75	0.48	0.28	0.28	0.28	0.28	0.28	0.28
DCP-18[5]	6.30	4.40	4.20	4.40	4.20	4.40	4.20
Corn	559.32	573.66	583.18	573.66	583.18	573.66	583.18
Corn gluten-60	20.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish meal	25.00	20.00	20.00	20.00	20.00	20.00	20.00
Full fat soybean meal	167.96	144.94	135.32	144.94	135.32	144.94	135.32
Lysine-99[6]	3.36	1.64	1.82	1.64	1.82	1.64	1.82
Marble powder	11.90	9.10	8.80	9.10	8.80	9.10	8.80
MDCP[5]	6.00	4.50	4.20	4.50	4.20	4.50	4.20
Methionine (dry)[7]	3.30	2.52	2.44	2.52	2.44	2.52	2.44
Phytase enzyme[8]	0.30	0.30	0.30	0.30	0.30	0.30	0.30
POM	0.00	20.00	30.00	20.00	30.00	20.00	30.00
Poultry trace elements	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Sodium bicarbonate	2.20	1.80	1.80	1.80	1.80	1.80	1.80
Soybean meal-48	154.38	156.36	148.16	156.36	148.16	156.36	148.16
Vegetable oil (soybean)	0.00	21.00	20.00	21.00	20.00	21.00	20.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

POM - poultry offal meal; DAFS - dissolved air flotation sludge.
[1] Supplied per kg diet: vit. A, 13000 IU; vit. D3, 5000 IU; vit. E, 100 mg; vit. B1, 3 mg; vit. B2, 8 mg; biotin, 0.2 mg; vit. B6, 5 mg; vit. B12, 0.016 mg; vit. K3, 4 mg; niacin, 70 mg; folic acid, 2 mg; Ca pantothenate, 20 mg; Mn, 120 mg; Zn, 100 mg; Se, 0.3 mg; Cu, 16 mg; Fe, 50 mg; I, 2 mg; antioxidant 125 mg.
[2] Supplied per kg diet: vit. A, 11000 IU; vit. D3, 5000 IU; vit. E, 80 mg; vit. B1, 2 mg; vit. B2, 6 mg; biotin, 0.2 mg; vit. B6, 4 mg; vit. B12, 0.016 mg; vit. K3, 3 mg; niacin, 70 mg; folic acid, 1.75 mg; Ca pantothenate, 20 mg; Mn, 120 mg; Zn, 100 mg; Se, 0.3 mg; Cu, 16 mg; Fe, 50 mg; I, 2 mg; antioxidant, 125 mg.
[3] DAFS was added to poultry offal during production in the rendering plant.
[4] Clinacox, anticoccidial (Lily Ilac, Istanbul, Turkey).
[4] Salinomycin, anticoccidial (Lily Ilac, Istanbul, Turkey).
[5] DCP-18 and MDCP (Rotem Turkey, Istanbul, Turkey).
[6] Lysine-99; Lysine HCL 99 (Rotem Turkey, Istanbul, Turkey).
[7] Dry methionine; DL Methionine Feed Grade (Evonik Turkey, Istanbul, Turkey).
[8] Phytase enzyme; Phyzyme (Nutriline Feed and Food Additives L.L.C. Istanbul, Turkey).

2.5. Animal housing

Twelve thousand broiler chicks obtained from middle-aged (36 weeks) Ross 308 broiler breeders were used in the present study. The chicks were sexed, vaccinated, and transferred to the test house. They were then weighed using a scale (EC-130, Bizerba SE/Co. KG, Germany) and randomly distributed to the 60 pens as 200 chicks per pen (stocking density of 15.38 chicks/m^2) with each subgroup consisting of 50% female + 50% male. Five replications were used per treatment during the growing period.

The animals were fed in four phases namely starter, grower, finisher, and pre-slaughter, and these four phases were between 0-10th, 11-25th, 26-36th, 37-41th days, respectively. Water and feed and water were given *ad libitum* during the study.

The ALW of the broilers were determined for each subgroup at the end of the growing period before loading for transport and weighing all animals. The FI levels of the subgroup were determined by

Table 5 - Feedstuffs contents of finisher and pre-slaughter diets

	Finisher[1]						Pre-slaughter[1]					
DAFS[2] (%)	0.00	0.00	11.00	11.00	22.00	22.00	0.00	0.00	11.00	11.00	22.00	22.00
POM (%)	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00	4.00	5.00
Anticoccidial[3]	0.50	0.50	0.50	0.50	0.50	0.50	0.00	0.00	0.00	0.00	0.00	0.00
Bonkalite	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Broiler vitamin	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Canola meal-35	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Choline-75	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DCP-18[4]	3.90	3.20	3.90	3.20	3.90	3.20	3.90	3.20	3.90	3.20	3.90	3.20
Corn	638.98	649.42	638.98	649.42	638.98	649.42	639.48	649.92	639.48	649.92	639.48	649.92
Corn gluten-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fish meal	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Full fat soybean meal	99.40	88.08	99.40	88.08	99.40	88.08	99.40	88.08	99.40	88.08	99.40	88.08
Lysine-99[5]	1.88	2.06	1.88	2.06	1.88	2.06	1.88	2.06	1.88	2.06	1.88	2.06
Marble powder	8.40	8.20	8.40	8.20	8.40	8.20	8.40	8.20	8.40	8.20	8.40	8.20
MDCP[4]	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Methionine (dry)[6]	2.06	1.98	2.06	1.98	2.06	1.98	2.06	1.98	2.06	1.98	2.06	1.98
Phytase enzyme[7]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
POM	40.00	50.00	40.00	50.00	40.00	50.00	40.00	50.00	40.00	50.00	40.00	50.00
Poultry trace elements	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	2.00	1.80	2.00	1.80	2.00	1.80	2.00	1.80	2.00	1.80	2.00	1.80
Sodium bicarbonate	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60
Soybean meal-48	116.68	109.56	116.68	109.56	116.68	109.56	116.68	109.56	116.68	109.56	116.68	109.56
Vegetable oil	29.00	28.00	29.00	28.00	29.00	28.00	29.00	28.00	29.00	28.00	29.00	28.00
Total	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00	1000.00

POM - poultry offal meal; DAFS - dissolved air flotation sludge.
[1] Supplied per kg diet: vit. A, 11000 IU; vit. D3, 4000 IU; vit. E, 80 mg; vit. B1, 2 mg; vit. B2, 5 mg; biotin, 0.05 mg; vit. B6, 3 mg; vit. B12, 0.012 mg; vit. K3, 2 mg; niacin, 40 mg; folic acid, 1.5 mg; Ca pantothenate, 20 mg; Mn, 120 mg; Zn, 100 mg; Se, 0.3 mg; Cu, 16 mg; Fe, 50 mg; I, 2 mg; antioxidant, 125 mg.
[2] DAFS was added to poultry offal during production in the rendering plant.
[3] Salinomycin, anticoccidial (Lily Ilac, Istanbul, Turkey).
[4] DCP-18 and MDCP (Rotem Turkey, Istanbul, Turkey).
[5] Lysine-99; Lysine HCL 99 (Rotem Turkey, Istanbul, Turkey).
[6] Dry methionine; DL Methionine Feed Grade (Evonik Turkey, Istanbul, Turkey).
[7] Phytase enzyme; Phyzyme (Nutriline Feed and Food Additives L.L.C., Istanbul, Turkey).

Table 6 - Diet specifications (starter, grower, finisher, and pre-slaughter)

	Starter (0-10th day)	Grower (11-25th day)		Finisher and pre-slaughter (26-36th and 37-41st day)	
Poultry offal meal (%)	0.00	2.00	3.00	4.00	5.00
Dry matter (%)	88.30	88.40	88.39	88.38	88.37
Metabolic energy (kcal/kg)	3035.00	3170.00	3170.00	3250.00	3250.00
Crude protein (%)	22.00	21.10	21.10	19.10	19.10
Crude fat (%)	5.62	7.55	7.46	8.00	7.88
Dry fibre (%)	3.16	3.06	3.02	2.87	2.83
Dry ash (%)	6.03	5.46	5.42	5.00	4.93
Calcium (%)	1.05	0.90	0.90	0.85	0.85
Phosphorus (%)	0.76	0.70	0.70	0.65	0.65
Phosphorus (available) (%)	0.50	0.45	0.45	0.42	0.42
Sodium (%)	0.17	0.17	0.17	0.17	0.17
Chlorine (%)	0.19	0.19	0.19	0.19	0.19
Methionine (%)	0.70	0.58	0.58	0.51	0.50
Met + cyst (%)	1.07	0.95	0.95	0.86	0.86
Lysine (%)	1.43	1.26	1.26	1.11	1.11
Choline (%)	1.62	1.51	1.51	1.42	1.43

weighing the feed left in the feeders at the beginning and end of the growing period. Feed conversion ratio (FCR) values were determined using the equation given below (Aviagen, 2018):

$$FCR = \frac{\text{Total feed consumed (kg)}}{\text{Total live weight (kg)}}$$

The number of chicks that died in the subgroups was daily recorded and the mortality and liveability rates were calculated. European Production Efficiency Factor (EPEF) values were calculated by using liveability, live weight, age and FCR as follows (Aviagen, 2018):

$$EPEF = \frac{\text{Liveability (\%)} \times \text{Live weight (kg)}}{\text{Age (day)} \times \text{FCR}}$$

2.6. Statistical analyses

The DAFS usage rate (control/0, 11, and 22%) in POM production; and the POM usage rate in grower (2 and 3%), finisher and pre-slaughter feeds (4 and 5%) were used in a 3 × 2 × 2 factorial arrangement. The quantity of replicates was calculated via power analysis with PASS 11 (Hintze, 2011), and the replication quantity for each group was determined as four. However, the repetition number was finally determined as five to improve trial reliability and to account for deviations that may occur due to field conditions considering that the test house contained 60 pens. Additionally, the available treatment number could have been increased by re-dividing the compartments in the test house. However, considering the potential difficulties throughout the rearing period, it was preferred to work with 200 birds in total.

The results were based on actual data since the differences were not significant (P>0.05) between the data with and without arc sinus transformation. The statistical analyses of the results were performed using IBM SPSS 22 (SPSS, 2013), by first obtaining the skewness and kurtosis values, and subsequently confirming the normal distribution by Shapiro-Wilk test. After this process, an analysis of variance (ANOVA) was conducted for the experiment using the GLM procedure of SPSS (2013) suitable for two-way designs.

The two-way ANOVA model is as follows:

$$Y_{ijkl} = \mu + DAFS_i + POMg_j + POMf_k + DAFSPOMgPOMf_{ijk} + e_{ijkl} \qquad (1)$$

in which Y_{ijkl} is the dependent variable; μ denotes the overall mean; $DAFS_i$ is the effect of the DAFS usage rate in POM (i = control/0, 11 or 22% in the experiment); $POMg_j$ is the effect of the POM usage rate in grower diets (j = 2 and 3% in the experiment); $POMf_k$ is the effect of the POM usage rate in finisher and pre-slaughter diets (k = 4 and 5% in the experiment); $DAFSPOMgPOMf_{ijk}$ is the effect of the interaction between DAFS, POMg, and POMf; and e_{ijkl} is the random error term. The two-way ANOVA and post-hoc Tukey test were employed to analyse the differences in the investigated parameters in relation to the DAFS usage rate in POM, POM usage rate in grower, finisher, and pre-slaughter feed, as well as their interaction (Kocabas et al., 2013).

3. Results

Average live weight, FCR, EPEF, and mortality were determined as the basic performance criteria in the study, and the results were analysed (Table 7).

3.1. Chick weight

The chick weight (CW) values of the treatment groups (C024, C025, C034, C035, T124, T125, T134, T135, T224, T225, T234, and T235) were 42.3 g (CV_{CW} = 1.51), 41.9 g (CV_{CW} = 2.76), 42.0 g (CV_{CW} = 1.28), 41.8 g (CV_{CW} = 1.67), 42.0 g (CV_{CW} = 1.15), 41.6 g (CV_{CW} = 0.62), 42.3 g (CV_{CW} = 0.78), 42.2 g (CV_{CW} = 0.42), 41.8 g (CV_{CW} = 0.46), 41.9 g (CV_{CW} = 1.01), 42.1 g (CV_{CW} = 2.08), and 41.9 g (CV_{CW} = 1.92), respectively (Table 7).

Table 7 - Effects of using poultry offal meal (POM) produced by adding dissolved air flotation sludge (DAFS) at different rates on broilers' performance

Treatment group	DAFS in POM (%)	POM in grower diets (%)	POM in finisher and pre-slaughter diets (%)	CW (g)** (1st day)	ALW (g)** (41st day)	DWG (g)** (41st day)	FCR** (41st day)	EPEF** (41st day)	Mortality (%)** (41st day)
C024	0.00	2.00	4.00	42.3±0.4	2419±7	59.0±0.2b	1.768±0.005bcd	326.18±0.98ab	2.25±0.14
C025			5.00	41.9±0.6	2472±12a	60.3±0.3a	1.757±0.010d	329.46±8.16a	3.99±0.86
C034		3.00	4.00	42.0±0.3	2429±12	59.3±0.3	1.800±0.005abc	316.37±1.01	3.88±0.24
C035			5.00	41.8±0.3	2443±11ab	59.6±0.3	1.785±0.005	319.27±3.72	4.38±0.80
T124	11.00	2.00	4.00	42.0±0.2	2412±18	58.8±0.4	1.762±0.005d	320.02±2.08	4.13±0.32
T125			5.00	41.6±0.1	2433±35	59.3±0.8	1.758±0.017d	323.97±8.40	4.13±0.94
T134		3.00	4.00	42.3±0.2	2429±23	59.2±0.6	1.765±0.008cd	325.60±4.76ab	3.00±0.35
T135			5.00	42.2±0.1	2394±21bc	58.4±0.5b	1.805±0.006ab	308.87±0.46c	4.50±0.54
T224	22.00	2.00	4.00	41.9±0.1	2415±11	58.9±0.3b	1.808±0.008a	314.92±3.38	3.38±0.24
T225			5.00	41.9±0.2	2383±19ab	58.1±0.5b	1.816±0.018a	308.97±4.98bc	3.50±0.74
T234		3.00	4.00	42.1±0.4	2403±16bc	58.6±0.4b	1.804±0.020ab	315.45±6.74	3.00±0.65
T235			5.00	41.9±0.4	2377±26c	58.0±0.6b	1.814±0.015a	311.39±7.08bc	2.63±0.43
P-value				0.915	0.031	0.028	0.031	0.040	0.061

C- control; T - treatment; first digit after the letter (0, 1, and 2) - DAFS usage percentage in POM; second digit after the letter (2 and 3) - POM usage percentage in grower diets; third digit after the letter (4 and 5) - POM usage rate in finisher and pre-slaughter diets; CW - chick weight; ALW - average live weight; DWG - daily weight gain; FCR - feed conversion ratio; EPEF - European production efficiency factor.
a-d - The difference between the averages indicated by different letters in the same column are statistically significant ($P<0.05$).

The uniformity of the chicks utilised in the research was high, and the variations between the CW values of the treatment groups were not statistically significant (P>0.05).

3.2. Feed intake

A decrease in FI was found when POM was administered with DAFS as opposed to POM alone (Table 8). This is particularly evident in grower FI, in which the difference between some treatment groups was significant (P<0.05). Depending on the grower FI, the difference between the total FI of some groups was also found to be statistically significant (P<0.05).

Table 8 - Effects of using poultry offal meal (POM) produced by adding dissolved air flotation sludge (DAFS) at different rates on the feed intake of broilers (M±SEM)

Treatment group	DAFS in POM (%)	POM in starter and grower diets (%)	POM in finisher and pre-slaughter diets (%)	Feed intake (g/broiler)				
				Starter (0-10th day)	Grower (11-25th day)	Finisher (26-36th day)	Pre-slaughter (37-41st day)	Total
C024	0.00	2.00	4.00	324±4	1090±1ab	2185±24	542±2	4141±21
C025			5.00	325±5	1093±2ab	2220±18	544±3	4182±11
C034		3.00	4.00	344±4	1102±2ab	2235±24	541±1	4222±28a
C035			5.00	325±1	1100±1ab	2235±14	528±13	4188±27
T124	11.00	2.00	4.00	325±2	1013±17cd	2231±26	527±16	4096±26c
T125			5.00	331±4	987±21d	2251±7	531±14	4099±26bc
T134		3.00	4.00	327±4	1051±14bc	2238±4	514±17	4130±25
T135			5.00	330±5	1056±14abc	2208±23	546±4	4141±35
T224	22.00	2.00	4.00	339±6	1084±14ab	2255±19	543±1	4221±15ab
T225			5.00	333±4	1105±4a	2226±125	499±16	4163±19
T234		3.00	4.00	332±4	1109±4a	2225±25	527±15	4193±23
T235			5.00	331±6	1105±2a	2191±22	530±14	4157±32
P-value				0.151	0.000	0.276	0.196	0.009

C - control; T - treatment; first digit after the letter (0, 1, and 2) - DAFS usage percentage in POM; second digit after the letter (2 and 3): POM usage percentage in grower diets; third digit after the letter (4 and 5) - POM usage rate in finisher and pre-slaughter diets.
a-c - The difference between the averages indicated by different letters in the same column are statistically significant (P<0.05).

3.3. Average live weight

When ALW results were analysed, it was found that there were numerical differences between the treatment groups, and ALW decreased as the DAFS rate increased, being more evident among various groups (Table 7) and significant in certain groups (P<0.05). For example, the ALW in the treatment group fed POM without DAFS in 2% grower and 5% finisher feeds were significantly higher than the group fed POM with the highest level (22.0%) in 3% grower and 5% finisher feeds (2472±12 g and 2377±26 g, respectively).

3.4. Daily weight gain (DWG)

When DWG results were analysed (Table 7), we found numerical variations across the treatment groups, and the DWG decreased as the DAFS rate increased, with this effect being more evident in some groups and significant (P<0.05).

3.5. Feed conversion ratio

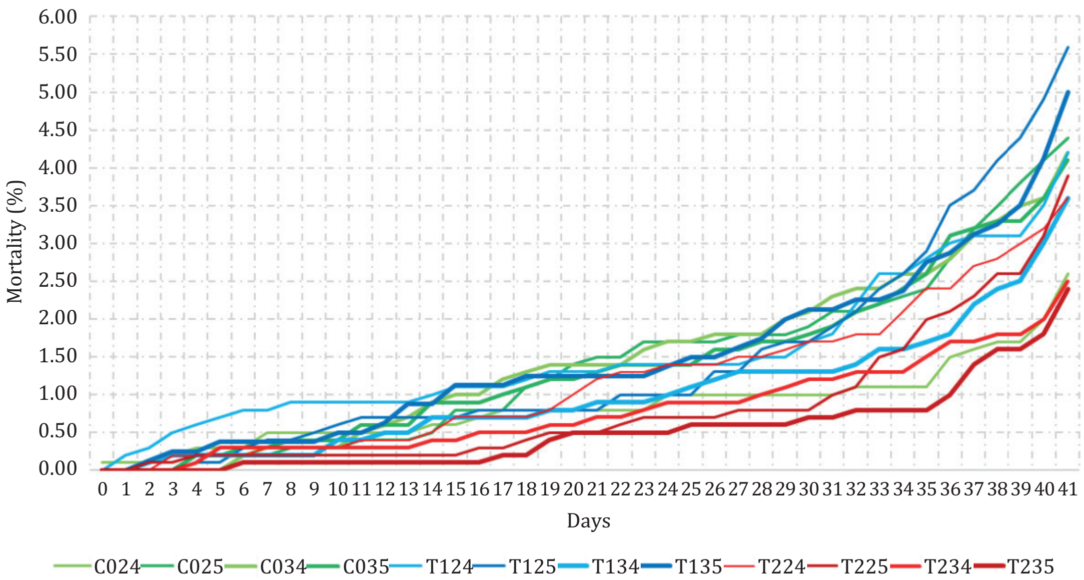
There were numerical differences among the treatment groups (Table 7). These numerical differences among some of the groups were more evident, and the differences between these groups were statistically significant (P<0.05). For example, the FCR in the treatment group fed POM without DAFS in 2% of grower and 5% of finisher feeds was significantly higher than in the group fed POM with level of 22.0% in 3% of grower and 5% finisher feeds (1.757±0.010 and 1.814±0.015, respectively).

3.6. European production efficiency factor

Numerical differences were found between EPEF values (Table 7). These numerical differences were more evident in some groups and some were found to be statistically significant (P<0.05). For example, the EPEF values in the treatment group fed POM without DAFS in 2% of grower and 5% finisher feeds were significantly higher than in the group fed POM with highest level (22.0%) in 3% grower and 5% finisher feeds (329.46±8.162 versus 308.87±0.46 and 311.39±7.08, respectively).

3.7. Mortality

There were numerical differences between the mortality values of the treatment groups. The mortality values increased numerically as the DAFS rate increased, but the differences were statistically significant (Table 7 and Figure 1).



C - control; T - treatment; first digit after the letter (0, 1, and 2) - DAFS usage percentage in POM; second digit after the letter (2 and 3) - POM usage percentage in grower diets; third digit after the letter (4 and 5) - POM usage rate in finisher and pre-slaughter diets.

Figure 1 - Effects of using poultry offal meal (POM) fat with or without dissolved air flotation sludge (DAFS) in feed on the mortality of broilers.

4. Discussion

The results of this study were evaluated, discussed, and interpreted separately according to analysed criteria (Table 7).

4.1. Chick weight

The uniformity of the chicks utilised in the research was high, and the measured CW were found to be slightly lighter (42.0 < 43.0 g) compared with the specs (Aviagen, 2019). The variations between the CW values of the treatment groups were not statistically significant (P>0.05). It is thought that this is an expected result, that it is due to the fact that the chicks were placed in each replication pen as 50% male and 50% female at the beginning of the trial, so that the chick weights, or in other words the starting weight, would not affect subsequent performance, and that the trial was planned correctly in this respect.

4.2. Feed intake

Feed intake decreased when POM was added to DAFS as opposite to POM alone (Table 8). The FI values were slightly different (>304 g, <1369 g, >1807 g, and <1009 g for starter, grower, finisher, and pre-slaughter, respectively) compared with the specs (Aviagen, 2019), and this is thought to be due to diet specifications and their changes due to the addition of DAFS. Also, it was observed that the colour of POM and feed with DAFS darkened slightly, probably due to the chemicals used in DAFS production, and this darkening became more evident as the amount of DAFS added increased, consistent with Fransen et al. (1995).

4.3. Average live weight

Average live weight values achieved in the trials (Table 7) were slightly lighter (<2821 g) compared with the specs (Aviagen, 2019), and this is thought to be due to diet specifications and growing conditions. The ALW decreased as the DAFS rate increased, being more evident among various groups. While the results of the study were not consistent with the findings of De Vries and Mudler (1986), who stated that there was no negative effect when using 7% or even 15% DAFS, they were consistent with the results of El Boushy et al. (1984), who reported a decrease in growth rate when DAFS was used at 2-7%. It is thought that the differences between the results are due to differences in the DAFS production system and DAFS content.

4.4. Daily weight gain

The DWG of the treatment groups (Table 7) was numerically lower than the specified values (Aviagen, 2019). Similar to the findings for ALW, the DWG showed a more pronounced decrease as the DAFS rate increased. This result is likely attributable to the feed content and growing conditions. However, the results of the present study were consistent with those of some authors in the literature (El Boushy et al., 1984), who reported a decrease in growth rate when DAFS was used at a concentration of 2-7%, but not with others (De Vries and Mudler, 1986), who stated that there was no negative effect when DAFS was incorporated at 7% or even 15%. It is thought that the differences between the results obtained in similar studies and our samples are due to differences in POM and DAF contents as well as diet specifications.

4.5. Feed conversion ratio

The FCR value increased extremely as the DAFS rate increased (Table 7). The results were supported by the findings of El Boushy et al. (1984), who reported that growth rate decreased when 2% DAFS was used. However, the results were not supported by the study of De Vries and Mudler (1986), who found no negative effect when using 7% or even 15% DAFS. It is thought that the differences between the results obtained in similar studies and our samples are due to differences in DAF contents and DAF usage levels.

4.6. European production efficiency factor

The EPEF values, which were used to evaluate the total performance obtained at the end of the experiment period, decreased as the DAFS rate increased (Table 7). It is thought that the differences between the results are due to differences in the DAF production system and DAFS content. In addition, since the EPEF value is calculated using ALW and FCR data, a similar result is obtained as in these criteria.

4.7. Mortality

The results were compatible with the results of De Vries and Mudler (1986), although they were not consistent with other research (El Boushy et al., 1984) results. This result is thought to be due to differences in the production and processing of DAFS and the elimination of possible harmful organisms that may be present in the DAFS through thermal processes similar to our process, especially sterilization.

5. Conclusions

It was determined that POM with or without DAFS at 22% can be used up to 3.0% in grower and 4.0% in finisher and in pre-slaughter feeds, with no decrease in feed intake; there may be a slight decrease in the survival rate when POM is used with DAFS in particular, but this is not at significant levels. A decrease in performance values may occur depending on the deteriorated feed conversion ratio when DAFS is administered during the rearing period. However, it should be noted that these results may vary depending on the DAF production technology.

Data availability

The data that support the results of this study are available from the corresponding author upon reasonable request.

Author contributions

Conceptualization: Okur, N. **Resources:** Okur, N.

Conflict of interest

The author declares no conflict of interest.

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