

HOW COMPOSTING CAN REVOLUTIONIZE POULTRY WASTE MANAGEMENT: A COMPREHENSIVE GUIDE

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Poultry waste

Due to the development of environmentally controlled housing technology during the past three decades, the poultry industry has experienced tremendous expansion. However, the chicken industry's quick expansion has led to some environmental issues. Several hundred tonnes of chicken waste are created every day, including dead birds, litter, and manure (Bolan et al. 2010). This trash must be regularly and promptly disposed of during a typical production cycle. Any delay in taking action to address these poultry wastes will increase costs and might have an adverse impact on the environment (Coufal et al. 2006; CAST, 2008).

Traditional disposal methods

The most common means of carcass disposal over the past few decades have been burial, incineration, landfills, rendering, on-farm freezers, or other preservation methods (CAST, 2008). On-farm burial, in which chicken carcasses are placed in an open trench or pit made in the ground and then covered with soil, is acknowledged as the most practical and affordable method of handling mortality losses (Wilkinson, 2011). However, nuisance complaints are raised when carcasses are buried (CAST, 2008; Bonhotal et al. 2014). The safest way to dispose of corpses is via incineration, and handling poultry carcasses won't affect the water quality. Additionally, this practice reduces the possibility of human exposure to pathogenic bacteria. Organic waste is burned in incinerators at high temperatures, producing carbon dioxide, carbon monoxide, nitrous oxide, calcium oxide, and water (CAST, 2008; Favoino and Hogg 2008). Although, the end product of burning or incineration is relatively bio-secure, there are several logistical and environmental problems with this option (Malone, 2006), most notably with regard to emissions (Bonhotal et al. 2014). Municipal landfills have been used extensively to dispose of poultry carcasses. However, disposal by landfill may pose a potential hazard to animal, poultry, and human health (Wilkinson, 2011). There may be an additional charge (tipping fee) if infected carcasses are bagged before shipment or immediately covered at the dump site (CAST, 2008).

Recycling chicken carcasses through rendering is environmentally friendly (NABC, 2004). A safe animal feed ingredient is created during the cooking stage of the rendering process, which also kills pathogenic bacteria (Nutsch and Spire 2004; NRA, 2006). The risks of disease transmission during routine pickup and the investment and operation costs of the rendering plants, however, are significant concerns with this disposal option (CAST, 2008; Bonhotal et al., 2014). For short-term storage of poultry carcasses, on-farm freezers or other preservation techniques have been utilized. Carcasses are kept in the freezers until they are picked up by the integrator and brought to a rendering factory. It is a great strategy for guaranteeing surface and ground water protection. It is an excellent method to ensure protection of surface and ground water. However, costs associated with the on-farm refrigeration and transportation need careful consideration (CAST, 2008). According to Crews et al. (1994), on-farm refrigeration is significantly more expensive than composting, burial, or incineration. Therefore, alternative carcass disposal methods with potential benefits are crucial to the running of any chicken farm. The logical solution to this issue is composting of litter and dead birds (Kelleher et al. 2002; Kumar et al. 2007).

Composting

According to Wilkinson (2011), composting is an aerobic biodegradation process in which helpful aerobic microorganisms that are naturally present in poultry litter decrease and turn organic waste (dead birds and litter) into a valuable end product. Composting has become the most common method of carcass disposal (CAST, 2008). Many of the issues with air and water quality related to incineration and burial are addressed by on-farm composting (Ahmed et al. 2012). Additionally, this procedure eliminates the expense of routine carcass pick-up and delivery to rendering facilities (CAST, 2008). Pathogenic bacteria, fungi, viruses, and parasites are also killed by the heat produced during the process (Lu et al. 2003; Kumar et al. 2007; Seekins, 2011; Wilkinson et al. 2011; Ahmed et al. 2012; Bonhotal et al. 2014; Miller et al. 2016). According to earlier studies (Murphy, 1990; Senne et al. 1994), two-stage composting eliminates poultry-related bacterial pathogens, viruses linked to egg drop syndrome (EDS-76), and highly pathogenic avian influenza (HPAI). Conner et al. (1991) did not detect any enteric bacteria in poultry waste after a two-stage (primary and secondary) composting process was finished. These findings suggest that two-stage composting has the ability to efficiently remove possible pathogens from chicken waste (Imbeah, 1998; Vinodkumar et al. 2014) and to reduce disease outbreaks (Bonhotal et al. 2008).

Factors affecting composting

Moisture, carbon to nitrogen ratio (C:N), temperature, oxygen, porosity, and bulking agent all have an impact on the composting of carcasses. For composting to be successful, these components must be present in the proper quantity or ratio (Ritz and Worley, 2005).

Moisture

The most important element in determining whether a carcass composting process will be anaerobic or aerobic is the moisture content (Ritz and Worley 2005; Collins, 2009). To assist the formation of necessary enzymes in the composting process, an ideal moisture content is crucial (Kalbasi et al. 2005). In actuality, these enzymes hasten the composting process by dissolving big organic molecules into smaller ones (Mukhtar et al. 2004). The optimal aerobic moisture content, according to Keener et al. (2000) and Franco (2002), is between 50 and 60% (Collins, 2009; Seekins, 2011; Wilkinson, 2011). A moisture content of less than 40% will slow down the process due to reduced microbial activity (Morse *et al.* 2001; Ritz and Worley 2005). By adding a calculated amount of water to the compost pile, low moisture issues can be fixed (Collins, 2009). In contrast, if the moisture content is close to or above 70%, a compost pile may not heat up or may start to smell (Mukhtar et al. 2004), which can lead to problems, most notably with emissions (Kube, 2002; Looper, 2002). Turning the piles while adding more dry litter, straw, or other bulking agents to absorb the extra moisture can solve high moisture problems (Mukhtar et al. 2004; Kalbasi et al. 2005; Collins, 2009). A hand-squeeze method is typically used to roughly estimate the moisture content of the compost pile (Seekins, 2011). According to Ritz and Worley (2005), a tiny amount of well-watered compost will not drip water when compressed into a ball and will maintain its shape when released (Looper, 2002).

Carbon and nitrogen

The rate of biological (microbial) activity within the compost pile will be significantly influenced by the carbon to nitrogen ratio (C: N) (Collins, 2009). According to Kalbasi et al. (2005), a correct C:N ratio is essential for effective composting (Keener and Elwell 2000), as it provides enough energy and emits little

odor (Bagley, 2002; Franco, 2002). According to Collins (2009) and Franco (2002), appropriate C:N ratios should be between 15:1 to 35:1, While the C:N ratio of 25:1 seems to function best (Morse et al. 2001; Wilkinson, 2011). Insufficiently used nitrogen is released as ammonia from piles with a C:N ratio of less than 25:1 (Collins, 2009), which causes an unpleasant odor and air pollution (Morse et al. 2001). By adding a high-carbon co-compost material, such as sawdust, to the pile, the low C:N ratio issue can be solved (Morse et al. 2001). According to Seekins (2011), a C:N ratio more than 30:1 will slow down the composting process. Morse et al. (2001) found that all composting piles with very high C:N ratios have a tendency to heat more slowly than piles with a lower C:N ratio. By adding inorganic nitrogen to the pile, such as urea or ammonium nitrate, the high C:N ratio issue can be resolved (Collins, 2009).

Temperature

According to Mukhtar et al. (2004), temperature is also essential to the composting process. According to Keener and Elwell (2000), Mukhtar et al. (2004), and Seekins (2011), the action of the microorganisms inside the compost pile produces heat energy, which drives the rapid growth of thermophilic bacteria and encourages degradation (Harper et al. 2001; Langston et al. 2002; Ritz and Worley 2005; Ahmed et al. 2012). Additionally, exposure to high temperatures (135 to 160°F) for one to two days (Mukhtar et al. 2004; Kalbasi et al. 2005; Kumar et al. 2007) helps kill fly larvae and disease-causing microorganisms (e.g., bacteria, fungi and viruses), improving the safety of the finished product (Ritz and Worley 2005; Bonhotal et al. 2008; Collins, 2009; Seekins, 2011; Wilkinson et al. 2011; Bonhotal et al. 2014). Collins (2009) claims that unfavorable compost circumstances, such as a change in the C:N ratio, a reduction in oxygen supply, or an unfavorable moisture content, might lower the temperature inside the compost and cause the microbial community to return to a regime of lower temperature microorganisms. According to Glanville (1999), compost bins should be designed large enough to generate adequate internal heat and retain it for a longer period of time during cold weather.

Oxygen

Because carcass composting is an aerobic biodegradation process (Morse et al. 2001), oxygen is necessary for the microorganisms in the mixture (Ritz and Worley 2005; Seekins, 2011) to function at their peak and create an environmentally friendly product (Charnay, 2005; Collins, 2009; Turan, 2009; Wilkinson, 2011; Ahmed et al. 2012; Miller et al. 2016). Insufficient oxygen in the compost pile causes the process to turn anaerobic, which produces extremely odorous chemicals such ammonia, organic acids, and hydrogen sulphide (Henry, 2003). According to Glanville (1999), a compost pile must have a minimum of 5% oxygen concentration to maintain a process reasonably aerobic. This means that the compost pile must be mechanically stirred frequently. Mukhtar et al. (2004) claim that aeration significantly affects the final product's quality. The quality and kind of bulking material utilized have a significant impact on the oxygen supply to the compost pile. Mixtures containing too fine a bulking component (such as sawdust or litter) will restrict the oxygen supply to the microbes, slowing their growth. Reduced microbial growth results in composting temperatures that may not be high enough to kill pathogens, which lengthens the composting process (Ritz and Worley, 2005).

Porosity

According to Mukhtar et al. (2004) and Kalbasi et al. (2005), the porosity of the pile has an impact on the amount of oxygen available, the aeration process, temperature, microbial development, and the amount of time needed to finish

composting. According to Keener et al. (2001), the compost media should be sufficiently porous (between 35 and 45 percent) to ease the oxygen supply and optimize microbial growth, but not too porous to cause excessive cooling or drying (Harper et al. 2002; Looper, 2002; Wilkinson, 2011). Due to a deficiency in oxygen, piles with extremely low porosity or a predominance of very fine textures cannot heat up, whereas heaps with very high porosity can heat up quickly but cannot maintain high temperatures (Seekins, 2011). Keener et al. (2000) claimed that particle size controls the pile's porosity (Looper, 2002). A mixture should have a significant number of particles with a diameter of between 1/8 inch and one inch to achieve the best results (Kalbasi et al. 2005).

Bulking agent

Sawdust, shavings, wood chips and grill litter are all co-compost materials or bulking agents that have a variety of important uses (Wilkinson, 2011). They surround the carcasses, reducing their accessibility and attractiveness to mice, insects, and other wild animals (Mukhtar et al. 2004), and they offer additional carbon to microbes (Kalbasi et al. 2005). As an added benefit, adding co-compost material or bulking agents to the pile helps the pile maintain the correct ratio of carbon to nitrogen (C: N) for optimum composting (Mukhtar et al. 2004) and traps leachate and odors generated by decaying carcasses (Sander et al. 2002). By keeping the compost porous and maintaining the oxygen concentration within the pile, using somewhat coarse co-composting materials can help prevent odor and fly issues (Kalbasi et al. 2005; Ritz and Worley 2005).

To achieve a C:N ratio of 23:1 and a moisture content of about 55%, the compost recipe for composting poultry carcasses must contain 1 part by weight of carcasses, 2 parts by weight of used litter, 0.1 parts by weight of straw, and 0.25 parts by weight of water.

Composter construction and layout

The design and layout of composters have a big impact on how quickly materials decompose (Mukhtar et al. 2004). A dead bird composter should be carefully designed to prevent any operating issues down the road. Efficiency gains can be achieved through improved management and a well-designed composter. Based on the local climate, composter designs might differ from operation to operation, however all effective composters share a few characteristics (Collins, 2009). According to Mukhtar et al. (2004), a compost site should be situated in an area that is well-graded, well-drained, and elevated in order to achieve the best outcomes. This will prevent ground water and surface runoff from entering the facility (Ritz and Worley 2005; Seekins, 2011). The composter should also be placed and graded such that it is reachable all year round. According to Collins (2009), the size of a composter should be in line with the size of the poultry operation since, according to Ritz and Worley (2005), one cubic foot of primary compost space is needed for every pound of mortality. The primary composting capacity (number of primary bins) and the secondary composting capacity (number of secondary bins) will be equal. According to Ritz and Worley (2005), Collins (2009), and Seekins (2011), small bin composters are typically 6-8 feet wide by 5 feet tall, and 5-6 feet deep. Collins (2009) claims that the quantity of bins in a system relies on the size of each bin and the overall volume of bins needed (Morse *et al.* 2001).

The compost bins are often made of treated timber (Morse et al. 2001; Mukhtar et al. 2004) and placed on an impervious base or hard stand (Ritz and Worley 2005; Seekins, 2011; Wilkinson 2011). The bins should have a roof over them to protect the

contents from the elements (Morse et al. 2001), as well as to maintain the pile's proper moisture content (Ritz and Worley 2005; Collins 2009; Seekins 2011). On the other hand, bins without a roof are more susceptible to precipitation and weather changes (Mukhtar et al. 2004). An all-weather impermeable base helps reduce nutrient leaking into the soil, which reduces surface and groundwater contamination and stops pests and rodents from tunneling under the compost (Mukhtar *et al.* 2004; Bonhotal *et al.* 2008; Collins, 2009). Additionally, it facilitates facility cleanup (Ritz and Worley 2005). Similar to this, filling the bin will be simpler using a system of detachable drop-boards that slide into an upright channel at each end of the bin.

Composter operation and management

In the beginning, a primary bin should have a base layer of fresh litter that is 8 to 12 inches thick (Morse et al. 2001; Wilkinson, 2011). Fresh litter will start the process by supplying the necessary bacteria (Ritz and Worley, 2005), and it will also assist keep leachate from releasing its pungent odor (Wilkinson, 2011). The next step is to add a thin coating of bulking material, such as straw, coarse shavings, or peanut hulls. The bulking agent helps maintain ideal porosity for efficient composting as well as provides the carbon required for a microbial energy source. After the layer of bulking agent, to avoid heat loss and putrefaction, the bird corpses are positioned side by side in rows at least 6 inches away from the bin walls (Ritz and Worley 2005; Seekins, 2011). Each layer of the carcass can have a small amount of water added to it if necessary to get the moisture level up to the desired level; however, water usage should be moderate to prevent overly moist circumstances. In contrast, excessive moisture prevents the flow of oxygen, which anaerobically ends the process (Mukhtar et al. 2004). Then, a layer of 6 to 8 inches of litter must be spread over the carcasses (Ritz and Worley 2005; Wilkinson 2011). Problems with odor and flies will result from incomplete coverage. Dead birds, bulking material, and litter should be added in successive layers once the first layer is finished, up to a maximum height of 5 to 6 feet. Higher compost temperatures (over 170°F) brought on by excessive height can increase the likelihood of spontaneous combustion (Ritz and Worley 2005). To prevent exposed pieces or odors that draw vermin, flies, or rodents to the pile, the last layer of carcasses must be covered with a thick (8 to 10 inch) layer of litter (Morse et al. 2001; Mukhtar et al. 2004).

Within five to seven days after a bin is fully stocked, the temperature at the centre of the pile should increase to 135 to 160°F (Morse et al. 2001; CAST, 2008; Collins, 2009; Wilkinson, 2011). The decomposition process will be accelerated by the high temperature, which will also aid in the destruction of any harmful bacteria that may be present in the raw waste (Ritz and Worley 2005; Keener and Elwell 2006). A 36 inch probe-type compost thermometer can be used to measure the temperatures in the centre of the pile to ensure a thermophilic temperature range throughout the composting bin (Collins, 2009; Wilkinson, 2011). Make sure to probe the bin at several points to get the fullest image possible of its internal state (Mukhtar et al. 2004). A single temperature reading can be deceiving because it is common to detect hot and cold regions within the same bin.

According to Seekins (2011), the composting procedure typically involves two heating cycles and a curing stage. When the primary bin temperatures fall to 125 to 129°F (7 to 21 days later), the first heating cycle is finished (CAST, 2008). For a second heating cycle, the material is subsequently moved to the secondary treatment area (secondary bin) (Ritz and Worley 2005; Collins 2009; Wilkinson 2011). In order for another heat cycle to take place, the mixture needs to be aerated (Mukhtar et al. 2004; Ritz and Worley 2005; Seekins, 2011). Allow material to "cascade" from the

loader bucket as it is transferred to the second-stage area in order to ensure good turning and re-aeration (Collins, 2009). The harm to the environment will increase as a result of improper turning because it will cause odors and fly issues (Collins, 2009). When the secondary bin temperatures fall to or below 100°F, the second heating cycle is finished. After that, the material is moved to a storage area to finish the maturation process (Seekins, 2011; Wilkinson, 2011). When the compost's temperature drops to a level that is close to ambient or room temperature, the maturation period has ended. To ensure that the compost is fully stabilized, it should be stored in the storage yard for at least 30 days (Seekins, 2011).

Utilization of poultry waste

Land application

According to analysis, poultry waste, particularly litter, includes vital plant nutrients like potassium, nitrogen, and phosphorus (Martin and McCann 1998; Kelleher et al. 2002). Because of this, litter is utilized as an organic fertilizer in a number of countries (Bolan et al. 2010); nevertheless, due to issues with environmental degradation, its acceptance has been constrained (Stuven and Bock 2001). Unpleasant odors can be produced when ammonia and other volatile gases escape into the atmosphere (Tiquia, 2005). Furthermore, according to Boruadda et al. (2012), the dangerous greenhouse gases released by untreated litter are linked to ozone depletion, global warming, and climate change. Unprocessed litter applied in excess can cause eutrophication and degrade surface water resources (US EPA, 1996). To ensure the sustainability of the poultry business, it may be necessary to create a technique that offers a safer and more practical substitute for the land application of poultry waste (Kelleher et al. 2002; Szogi and Vanotti 2009).

Use in poultry feed

According to Fontenot et al. (1991), animal waste is more beneficial as feed than as fertilizer. Poultry waste, particularly litter, provides greater crude protein (Bhattachary and Fontenot 1966), accessible energy (Fontenot 1999), and nutrients that can be digested (Tadele 2015) than other animal wastes. In comparison to the TDN values discovered by Bhattachayra and Taylor (1975), Miron et al. (1990) revealed greater values for the organic matter digestibility in poultry litter. Only broiler litter, according to Muller (1975a), has a TDN value comparable to traditional feed additives. According to analysis, broiler litter has comparatively high protein content, with true protein making up around 45–67% of it, uric acid about 18–30%, and ammonia about 12–17%. Creatine (2–4%) and other nitrogen components make up a smaller portion. Additionally, according to Rankins et al. (2002), litter has a high concentration of various critical minerals that are crucial for animal nutrition. Feeding poultry manure has always been controversial and has led to a lot of research to support its safety.

Feeding to broilers

Numerous studies have been conducted to evaluate the feeding value of various types of chicken waste, including litter, manure, hatchery by-products, hen mortalities, rendered spent hens, and broiler offal. In this context, Elam et al. (1954) noticed a substantial improvement ($P < 0.05$) in chick growth after feeding young chicks filtered suspension of autoclaved litter. Similar to this, hydrolyzed broiler litter has the potential to be included in chick feeds, according to Wehunt et al. (1960). However, research by Flegal and Zindel (1970) revealed that dry poultry manure concentrations above 5% led to a significant reduction ($P < 0.05$) in chick growth. Later investigations by Fadika et al. (1975) fed developing Turkiyes dried layer manure at

doses of 5, 10, and 30% and discovered no significant change in weight increase or growth. The small decrease in feed efficiency coincided with the level of dietary manure rising. Similar findings were made by Lipstein and Bornstein (1971), who found that adding dry manure to the diet lowered the rate of growth and feed consumption in chicks. Additionally, it was suggested that broiler rations should include dried hatchery waste by Kempster (1945) and Wisman (1964). In their investigation, Ilian and Salman (1986) fed broiler chickens processed hatchery waste. When compared to birds fed 0% and 5%, broilers given 2.5% processed hatchery waste showed higher growth rates and feed efficiency ($P < 0.05$). In a similar vein, Deshmukh and Patterson (1997) found that employing hatchery by-products was equivalent to or superior to a standard poultry diet for broilers.

Likewise, Rasool et al. (1999) discovered that adding hatchery waste meal to broiler diets at a level of 12% resulted in noticeably greater weight increase and feed efficiency. Similar to this, Kundu et al. (1986) found a significant ($P < 0.05$) improvement in feed efficiency in diets that substituted hatchery waste meal for the dietary fish meal. Escalona and Pesti (1987), however, discovered that adding processed hatchery by-product meal to broiler diets at 5% level did not significantly alter feed efficiency ($P > 0.05$). In subsequent studies, Agunbiade et al. (2007) found that diets in which hatchery waste meal completely replaced fish meal resulted in enhanced growth rate and feed efficiency ($P < 0.05$), indicating that hatchery by-products can be used successfully in poultry feeding (Reddy, 1988; Dhaliwal et al. 1996). Furthermore, when complete hatchery waste meal was added to broiler diets, Abiola et al. (2012) discovered a non-significant difference in carcass characteristics and haematological markers ($P > 0.05$). However, at 10% inclusion of whole hatchery waste meal in diet, feed consumption and growth rate increased ($P < 0.05$). As the amount of whole hatchery waste meal in the diet increased, the cost of production reduced ($P < 0.05$). Similar to this, numerous researchers have reported using hatchery waste in poultry diets as a way to cut feed costs (Babiker et al. 1991; Abiola, 1999; Abiola and Onunkwor 2004).

Processed chicks have also been used in poultry rations. Day old male chicks (cull) were autoclaved, dried, and then powdered before being added to poultry feed (Ravindra-Reddy and Rajasekhar-Reddy 1985). Similar to this, rendered fats and protein meals have been successfully introduced into animal feed (EPA, 2014), as demonstrated by Christmas et al. (1996), who fed broilers diets containing 0, 4, 8, or 12% rendered whole hen meal and observed no differences ($P > 0.05$) in performance at any level. For a period of six weeks, Aparna and Patterson (1997) gave extruded cockerel chicks (5 and 10%) and a combination of cockerel chicks and shell waste (2.5 and 5%, respectively) to broiler chickens. Weight gain, feed conversion, and carcass characteristic parameters did not differ between the diets in terms of growth performance ($P > 0.05$), but the group fed diets containing 5% cockerel chick shell waste had significantly higher ready-to-cook carcass and wing yield than the control group. Hossain et al. (2003) reported that live weight, feed conversion, profitability, and meat yield increased in broiler chickens with diets where broiler offal replaced the dietary fish meal, resulting in improved performance (Dafwang et al. 1986) at a reduced cost (Hamid, 1968). Similarly, Bulbul and Islam (1991) found that broiler chicken fed diets where broiler offal replaced fish meal had the lowest feed cost per kg weight ($P < 0.05$).

Both Orga et al. (1964) and Fraga et al. (1989) noted some enhancements in broiler performance as a result of broiler offal incorporation in the diet. However, Pesti (1987) discovered that dietary broiler offal had little to no impact on broiler performance ($P > 0.05$). Additionally, Kirkpinar et al. (2004) found that broiler

performance in terms of body weight, feed intake, and feed conversion efficiency were not significantly impacted ($P>0.05$) by the addition of chicken by-product meal to their diets. In terms of broiler performance, Bhargava and O'Neil (1975) also noted that poultry by-products and hydrolyzed feather meal were comparable to or superior to a wheat-soybean based control diet. In a similar vein, Mendonca and Jensen (1989) noted that 10% addition of poultry by-product meal in grill diet did not have a negative impact ($P>0.05$) on performance in terms of live weight gain, feed consumption, and feed conversion compared to control diet. Similar findings were made by Haque et al. (1991), who discovered that adding extruded poultry by-product meal (93 g/kg) to broiler diets had no negative effects ($P>0.05$) on body weight and feed utilization. Abiola (2001) revealed that values recorded for eviscerated weights, abdominal fat, and internal organs (liver, lungs, heart, and gizzard), across treatments, were not substantially different ($P>0.05$) from one another when cockerels were fed diets comprising hatchery waste meal.

Feeding to layers

Many researchers have documented the utilization of poultry waste as a feed resource. Flegal and Zindel (1969), Flegal (1971a), Flegal (1971b), and Flegal and Zindel (1972) fed laying hens diets including dried layer manure (10, 20, 30, and 40%). With the exception of layers given 10% manure, egg production, feed efficiency, and weight gain all declined as dietary manure level rose. However, as the amount of manure included in feed increased, the price of feed decreased. Similarly, Nesheim (1972) showed no significant difference ($P>0.05$) in the performance in terms of egg production and egg weight when feeding dry layer manure to laying hens at a level of 22.5%. The wheat-bran and dry layer manure diets' reduced calorie contents, however, were blamed for some variances in feed intake. Similarly, when dehydrated layer manure was fed to pullets at levels of 0, 12.5, or 25%, Flegal et al. (1972) observed no significant differences ($P>0.05$) in egg production and quality. In a similar vein, Quisenberry and Bradley (1968) discovered that layers fed diets including untreated litter and manure (10 and 20%, respectively) generally performed better than layers fed control diets. Wolford (1975), however, discovered that adding layer manure (10%) to the diets of caged Turkiye breeder hens did not significantly alter any performance metrics. Dry poultry waste was fed to laying hens at quantities up to 40% in 1971 by Flegal and Zindel, who reported no discernible differences in egg weight or eggshell thickness. For eggs from hens fed a diet containing 25% dried poultry waste, Biely et al. (1972) showed tendencies for lower percentages of large eggs and for lower Haugh unit scores.

Mahmud et al. (2015) fed laying hen diets comprising 4, 8, and 12% hatchery waste meal and found that when waste was fed at amounts as low as 4%, there were no appreciable variations ($P>0.05$) in egg quality metrics. Senkoylu et al. (2005) noted that adding feather meal or chicken by-product meal to layer feeds may cause Haugh unit values in eggs to decrease. Al-Harthi et al. (2009) discovered the opposite, demonstrating that the addition of hatchery waste meal to layer diets enhanced ($P<0.05$) shell quality. Abiola and Onunkwor (2004) discovered that completely substituting hatchery waste meal for fish meal in layer meals had no negative effects on the features of the eggs. Similar to this, Odunsi et al. (2013) found that substituting hatchery waste meal for fish meal in the diets of laying Japanese quail improved egg quality while costing less. Haematological variables weren't negatively impacted. Additionally, Ilian and Salman (1986) discovered that feeding processed hatchery waste to laying hens did not have a negative impact on their performance in terms of feed intake, body weight, egg production, feed conversion efficiency, or egg size.

Similar findings were made by Vande-Populiere et al. (1977), who discovered that the overall performance of laying hens on a diet supplemented with hatchery waste was on par with or superior to that of hens fed a control diet.

Chrappa et al. (1986) fed laying hens hatchery byproduct food at levels of 2 and 4%. In hens fed at a 2% level, egg production rose ($P < 0.05$), and a 4% level boosted eggshell strength. Hatchery by-product meal was added to the layer diet by Zohari (1975) at 3.6, 7.25, 10.5, or 14.1%. While egg weight did not vary ($P > 0.05$) at any level, egg production was significantly reduced ($P < 0.05$) at the 7.25 and 14.5% levels. Alaba and Ekeocha (2012) noted that poultry hatchery waste meal can successfully replace fish meal in layer diets without compromising performance or egg quality. According to Wisman and Beane (1964), laying hen performance in terms of feed intake, body weight, feed efficiency, and daily egg output was unaffected by feeding 15% hatchery by-product meal. According to Damron et al. (2001), rendered whole hen meal could be used well in layer diets up to 10% level. To our knowledge, there is no literature currently available that looks at the utilization of composted dead birds in poultry feed. However, efforts are required to investigate such affordable options in order to effectively utilize the several million tonnes of this waste.

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