IMPACT OF POULTRY PROCESSING BY-PRODUCTS ON WASTEWATER GENERATION, TREATMENT, AND DISCHARGES

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Abstract. In 2009, Georgia's poultry industry slaughtered and further processed more than 1.3 billion chickens, more than any other state, utilizing 7 gallons (26 L) of potable water per carcass and generating over 9 billion gallons of high-strength poultry processing wastewater (PPW). The conversion of a live chicken into safe and wholesome meat products suitable for human consumption takes place in a series of processing steps. Each step of the process utilizes potable water and generates by-products that combine to form the facility's wastewater stream. Research within the Poultry Science and Bio & Ag Engineering Departments at the University of Georgia is establishing both the variation individual birds have effecting PPW, as well as determining which by-products have the greatest PPW impact. Early experiments have shown that blood plays a major role impacting PPW. Results show that PPW scalder samples collected from groups of broilers bled for 60 seconds had average chemical oxygen demand (COD) and total solids (TS) levels of 9.86g and 8.12g, respectively. Conversely, carcasses bled for 120 seconds averaged COD and TS levels of 6.49g and 5.43g, respectively. Increasing bleed time to 120 sec from 60 sec resulted in mean percent reductions of COD 34%, TS 33%, TSS 34%, TVS 36%, and TKN 29% in scalder PPW.

INTRODUCTION

The average number of broilers slaughtered per day at a US poultry slaughter plant has increased in the past 30 years from 60,000 to over 200,000 (Ollinger et al., 2000). Today, US poultry processors produce about 3.75 billion pounds of ready-to-cook product each month (NASS, 2010). The slaughter of poultry can be divided into five major steps: 1) Transport and unloading, 2) Hanging and killing, 3) Bleed out, 4) Scalding, and 5) Evisceration. The steps of bleed out, scalding, and evisceration have the greatest impact on the poultry processing wastewater (PPW) stream and produces the majority of offal. Offal is a general term used to describe inedible poultry by-products that are normally not acceptable for human consumption. Today, offal typically includes blood, feathers, heads, viscera and their content (Romans et al., 1994). On average, offal accounts for 28% of the live weight of a broiler chicken. Thus, a typical processing plant slaughtering 200,000 broilers per day with a mean live weight of 5.0 lbs (2.3 kg) will produce 140 tons (127 MT) of offal (Boushy and Poel, 2000).

In 2009, Georgia's poultry industry slaughtered and further processed more than 1.3 billion chickens, more than any other state (NASS, 2010). Northcutt and Jones (2004) conducted a survey of US broiler slaughter plants and found out that the average amount of water used per bird was 7 gallons (26 L). In a processing plant water is primary used for scalding, bird washing before and after evisceration, chilling, cleaning and sanitizing of equipment and facilities. Water is also the primary means used to transport offal out of various processing areas of a slaughter plant where it is separated from the PPW stream (Kiepper et al., 2008).

Extensive research since the 1950s has analyzed the effect of poultry processing by-products on PPW. However, this body of research has been focused on the total PPW stream. Previous research has not looked at individual by-products and their effect on PPW. Research within the Poultry Science and Bio & Ag Engineering Departments at the University of Georgia is establishing both the variation individual birds have effecting PPW, as well as determining the effect of specific by-products on PPW.

POULTRY PROCESSING WASTEWATER (PPW)

PPW consists of various constituents in the forms of particulates, organics, and nutrients (Eremektar et al., 1999; Welch and Lindell, 1992). PPW is the cumulative wastewater that is generated by uncollected blood, feathers, eviscerations, and cleaning of the live haul area at a slaughter plant (Kiepper et al., 2008). Screens are the most popular form of preliminary physical treatment process used in on-site poultry wastewater treatment systems to remove PPW constituents (Kiepper, 2003). Screening systems typically consist of primary and secondary rotary screens that remove solids greater than 500 micron (μm) in size (Del Nary et al., 2007; Kiepper, 2003). Screens recover offal, which has substantial value as a raw material for the poultry rendering industry, and remove larger solid particles from PPW preparing the wastewater stream for advanced treatment systems (Pankratz, 1995).

Even after screening, PPW has relatively high concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), nitrogen and phosphorus. Significant identified constituents leading to these high concentrations include uncollected blood, solubilized fat, urine and feces (USEPA, 2002).

One of the most important analytical characteristics of PPW is total solids (TS), which is composed of floating, settleable, and colloidal matter (Metcalf and Eddy, 2003). TS are defined as the residual material remaining in a vessel after evaporating a sample and then drying it at a specific temperature (APHA, 1992). TS can be categorized by particle size as total suspended solids (TSS) plus total dissolved solids (TDS), or by organic content as total volatile solids (TVS) plus total fixed solids (TFS) (CSUS, 1993). TSS is defined as the portion the TS retained on a filter with a specific pore size (2.0μm or smaller) (Metcalf and Eddy, 2003). TVS is the weight loss after TS is ignited (APHA, 1992). Solids are an environmental concern because its impact can increase turbidity which can clog fish gills and reduce oxygen transport upon entering water bodies (Mittal, 2004).

POULTRY BLOOD

USEPA (1975) establishes blood as the strongest single pollutant in a poultry processing plant. Blood makes up approximately 8% of the live weight of a broiler (Duke, 1973). During the process of bleeding a broiler, 40-60% of the total blood present in the body exits the carcass (Wilson, 1998). In 1950, Porges reported a BOD of 92,000 mg/L for chicken blood. This value was similar to the BOD of chicken blood reported by Bates in 1948 at 100,000 mg/L. In 1992, Hansen and West reported a COD of raw blood from an animal rendering plant at 150,000 mg/L.

After killing, broilers are allowed to bleed out for a period of 1-2 minutes prior to entering a scalder tank designed to loosen feather follicles to aid in picking. In the scalder, any remaining draining blood along with manure and external dirt on the carcass washes into the scalder, substantially increasing the pollutant load of the PPW stream (Porges, 1950). The effectiveness of blood collection in processing plants has great impact on the PPW stream due to the heavy organic load which can elevate BOD and COD levels (Weakly et al., 1972). Elevated organic levels in PPW not only pose challenges in wastewater treatment, but also are a major economic concern for plants discharging to municipal sewers. Most municipalities that receive high-strength industrial wastewater have a surcharge fee structure in place that charge industries additional fees based on their specific wastewater discharge (USEPA, 1975).

Georgia's poultry industry would receive substantial economic and environmental benefits by reducing the amount of uncollected blood allowed to enter the PPW stream (Kiepper et al., 2008). When blood is effectively collected, a processing plant's sewage strength can be reduced by 35-50% (which represents a reduction of 17-18 lbs of BOD per 1000 chickens) (USEPA, 1973). One method of reducing the amount of blood entering PPW is to extend the time that blood is allowed to drain from a carcass during slaughter.

BLEED TIME EXPERIMENT

Twenty-four (24) male Cobb 700 White Leghorn broilers reared at the University of Georgia Poultry Research Center (UGAPRC) as part of an independent litter treatment study flock were utilized for this experiment. The broiler flock was reared in six 32-bird pens on pine shavings, and was fed a commercial broiler diet and water ad libitum. Randomly selected broilers were assigned to one of two treatment groups, those bled for a period of 60 sec (n=12) and those bled for 120 sec (n=12).

On the day of processing, the birds were 8 weeks and 2 days old. To best simulate commercial transport conditions, feed was withdrawn from the flock at 12:00 am the day of processing. At 6:00 am, 24 birds were randomly selected from the flock, leg banded and cooped. All male birds were selected to minimize variations in body weights. Pieces of cardboard box were placed at the bottom on each open-bottom crate to simulate solid-bottom coops (i.e., industry standard). Birds were processed at the UGA Poultry Processing Laboratory starting at 10:00 am (i.e., 10 hours minimum hold time in coops).

Birds were processed in eight (8) batches with each batch consisting of 3 birds. Birds were removed from coops by hand, weighed and then hung from shackles. Birds were electrically stunned using a 25-volt DC high frequency stunner (12-15 mA per bird) followed by a 25-volt AC post-stunner. Working in three 2-man teams the 3 birds were simultaneously decapitated, to minimize variation in neck cuts, within 30 seconds of exiting the stunning tunnel. Killing via decapitation is considered an acceptable means of killing (AVMA, 2007). Previous research has shown that there is no significant difference in blood loss volume between broilers exsanguinated via neck cut versus decapitation (McNeal et al., 2003).

The birds were bled for either 60 sec or 120 sec. Draining blood was collected in plastic bags and weighed. After blood collection for the specified time period, additional blood was allowed to drip into an individual metal container of 4.2 gal (16L) heated scalder water set below each bird. Make-up water for each scalding container was taken from the commercial scalding tank.

A 0.5 gal (2L) background control sample of source scalder make-up water was collected and placed on ice. The carcasses were then simultaneously dipped into the scalding container and agitated for 2 minutes. After agitation, carcasses were removed and re-hung on the shackle line. Following scalding, 0.5 gal (2L) samples of well-mixed scalder water were collected from each of the three scald containers and placed on ice.

DATA TREATMENT AND ANALYSIS

Blood Loss: Each blood collection bag was weighed prior to processing. After blood was collected from each carcass, the weight of the empty sample bags was subtracted from weight of collected blood and sample bag to determine total weight of blood collected. Total weight of blood was then divided by the live weight of the broiler and multiplied by 100 to determine the % of blood loss based on live weight.

Scalder Wastewater: Regardless of the analytical test performed, all data points received similar treatment. If the background control sample concentration (mg/L) was at a detectable level, that background concentration value was subtracted from the data point. On the other hand, if the background control sample concentration was below detectable limit (BDL), the concentration data point remained as reported. A load value in grams per bird (g/b) was determined for each data point by multiplying the volume of scalder water (16L) by the concentration (mg/L) of that parameter. The result (mg) was divided by 1000 to determine the load in g/b.

The scalder background and 24 scalder wastewater samples were analyzed for COD (chemical oxygen demand method 5220D), TS (total solids method 2540B), TSS (total suspended solids method 2540D), TVS (total volatile solids 2540E), and TKN (total Kjeldahl nitrogen method 4500-NorgD) (APHA, 1992).

STATISTICAL ANALYSIS

Data were subjected to statistical analysis by the SAS JMP 8.0.2 program (SAS Institute, 2009). Data from the 2 bleed times (60 sec and 120 sec) with 12 replications were analyzed by 1-way ANOVA procedures for a completely randomized design with time as the main effect. Means were separated using the Tukey-HSD procedure (SAS Institute, 2009). Differences in means were regarded as significant at $P < 0.05$. Coefficient of variation (CV) was determined by dividing the data set standard deviation (σ by the mean (μ) and reported as a percentage ($CV = \sigma/\mu*100$).

RESULTS

Blood Loss: Experimental data showed that the 24 male broilers averaged 9.02 lbs (4.09 kg) with no significant difference in mean live weight between treatment groups (*P*=0.5208). Blood loss was compared at bleed times of 60 (n=12) and 120 (n=12) seconds, and was measured in mass (grams) recovered and calculated as percent (%) of live weight as shown in Table 1.

Analysis of blood loss data summarized in Table 1 shows that the mean mass recovered (*P*=0.0383) and mean percent of live weight (*P*=0.0155) blood loss at 120 seconds (101.4g and 2.51%) was significantly greater than at 60 seconds (82.7g and 2.00%).

The coefficient of variation (COV) was used to analyze the variation of individual carcasses in blood loss. Data showed that birds bled for 60 sec varied twice as much as birds bled 120 seconds in both blood loss as % live weight (i.e., 31% v. 12%) and grams (i.e., 32% v. 13%).

Table 1. Blood loss for esanguinated 8 wk old broilers electrically-stunned and bled for 60 sec and 120 sec

Bleed Time	Mean ± SEM	COV(%)*
60 sec (%)	$2.00^b \pm 0.18$	31
120 sec (%)	$2.51^a \pm 0.09$	12
60 sec (g)	$82.7^b \pm 7.6$	32
120 sec (g)	$101.4^a \pm 3.8$	13

[a,b] – differing superscripts within a column indicate statistically significant differences (*P<0.05*)
* COV – coefficient of variation

Scalder Wastewater: The 60 sec bleed time treatment produced significantly larger mean COD (9.86 g, 616 mg/L), TS (8.12 g, 510 mg/L), TVS (6.80 g, 425 mg/L), and TKN (1.12 g, 70 mg/L) PPW loads and concentrations. There was no significant difference in TSS load or concentration between the 2 bleed times (Table 2). Increasing bleed time to 120 sec from 60 sec resulted in mean percent reductions of COD by 34%, TS by 33%, TSS by 34%, TVS by 36%, and TKN by 29%.

CONCLUSIONS AND ECONOMIC IMPACT

It is logical to assume that allowing birds to bleed out for a longer period of time during the slaughter process would result in greater blood recovery for rendering and less blood entering the scalder and other processing wastewater streams. However the potential economic impact of increasing bleed times in poultry processing has not been established, until now.

Because a known volume of water was used in each scalder (16 L), the concentration (mg/L) of each parameter of the 24 scalder wastewater samples could be converted to a gram load by simply multiplying the COD mg/L concentration result by the scalder water volume (i.e., 16 L) and then dividing the result by 1000.

From Table 2:

- The COD mean load for 60 sec was 9.85g
- The COD mean load for 120 sec was 6.49g

Therefore, an additional 3.36 grams/bird of COD is added when the birds are bled for 60 sec. With a 60 second increase in bleed time, an economic impact based on surcharge fee can be calculated.

For a typical broiler slaughter plant processing 250,000 birds per day (bpd), 260 processing days per year, and paying $0.30 per lb of COD in surcharges:

(250,000 bpd) (3.36g) = 840,000g/d or 840 kg/d

840 kg/d = 1852 lbs/d

(1852 lbs/d) ($0.30/lb) = $ 555.60 / day

($ 555.60/d) (260 processing days/year)

= $ 144,456.00 /year

Table 2. Mean load (grams) and concentration (mg/L) values for scalder wastewater samples collected after carcass bleed out times of 60 sec and 120 sec (n=12)

Bleed Time	60 sec	120 sec
COD		
g ± SEM	$9.86^{a} \pm 1.24$	$6.49^{b} \pm 0.37$
(mg/L ± SEM)	$(616^{a} \pm 78)$	$(406^{b} \pm 27)$
TS		
g ± SEM	$8.12^{a} \pm 0.96$	$5.43^{b} \pm 0.44$
(mg/L ± SEM)	$(510^{a} \pm 60)$	$(339^{b} \pm 27)$
TSS		
g ± SEM	2.05 ± 0.42	1.35 ± 0.17
(mg/L ± SEM)	(129 ± 27)	(85 ± 11)
TVS		
g ± SEM	$6.80^{a} \pm 0.88$	$4.32^{b} \pm 0.59$
(mg/L ± SEM)	$(425^{a} \pm 55)$	$(270^{b} \pm 37)$
TKN		
g ± SEM	$1.12^{a} \pm 0.13$	$0.79^{b} \pm 0.08$
(mg/L ± SEM)	$(70^{a} \pm 8)$	$(50^{b} \pm 3)$

^{a,b} - differing superscripts with a row indicates statistically significant differences ($P<0.05$)

The results of this experiment demonstrate that increasing bleed time has a direct economic impact on processing wastewater. Using this experimental data, an increase of bleed time from 1 to 2 minutes could potentially save a typical processing plant over $140,000 per year in reduced wastewater surcharges.

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