

Handling of by-products from the slaughter process

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Abbreviated title: Handling of slaughter by-products

Summary

In 2008 poultry processors slaughtered 40×10^9 broilers with a total live weight of 99.6×10^6 metric tons (MT) of Ready-to-Cook (RTC) product worldwide. The world's largest poultry processing nation, the United States, processed 9×10^9 broilers or approximately 23% of the 2008 total. Modern poultry processing methods result in an average broiler RTC yield of 72%. Thus, along with generating 71.7×10^6 MT of RTC edible product, poultry processors also generated 27.9×10^6 MT of poultry by-products worldwide. Traditionally in the U.S. these by-products (i.e., inedible offal) are transported from the production floor in water-filled flumes where mechanical screens separate larger solids from the wastewater stream prior to subsequent treatment processes that produce additional solid waste by-products (e.g., DAF skimmings, sludges). In the U.S. the vast majority of the recovered offal serves as raw material for conversion to high-grade pet food ingredients by the rendering industry. However, due to demands for more efficient water use and the emergence of value-added poultry by-product components (e.g., oil for biofuels), U.S. poultry processors have begun exploring innovative by-product recovery/transfer (e.g., dry-handling vacuum systems) and separation technologies (e.g., tricanter centrifugation). These systems result in wastewater stream improvement by increasing stream quality while decreasing stream quantity.

Keywords: poultry slaughter, poultry processing by-products, wastewater treatment, screening

Introduction

In 2008 poultry processors slaughtered 40×10^9 broilers with a total live weight of 99.6×10^6 metric tons (MT) of Ready-to-Cook (RTC) product worldwide (USDA, 2009a). The world's largest poultry processing nation, the United States, processed 9×10^9 broilers or approximately 23% of the 2008 global total. Young chickens or "broilers" represent 95% of the total number of all types of poultry slaughtered annually in the U.S. (USDA, 2009b).

Products produced from the slaughter of poultry fall into two basic categories: edible and inedible (Ockerman and Hansen, 2000). The maximum percent yield of edible or 'dressed' product from the various poultry species ranges from a high of 77% for turkeys to a low of 58% for ducks. Young chickens or 'broilers' processed in the United States average a 72% edible yield (Barbut, 2002; Hedrick et al., 1994; Mountney and Parkhurst, 1995). Thus in 2008 along with generating 71.7×10^6 MT of RTC product, poultry processors also generated 27.9×10^6 MT of poultry by-products worldwide. Poultry processing plants produce inedible by-products in the form of blood, feathers and offal. By definition, offal can be separated as edible (i.e., liver, hearts, gizzards) and inedible (i.e., viscera). However here the term offal will be used to describe the inedible viscera removed from the poultry carcass after USDA inspection.

Broiler processing

The operations of the poultry meat industry can be divided into two major categories: production and processing. Poultry production includes all the functions involved in raising flocks of live birds. Poultry processing can be defined as the functions involved in converting a live bird into meat products and by-products: harvesting, slaughtering, further processing, rendering, and processing waste handling (Northcutt, 2001; Sams, 2001a).

The basic automated poultry slaughtering process in use today was established in the late 1960s (Bugos, 1992). The processing of broilers can be divided into three major categories: First Processing (slaughter through chilling), Second Processing (cut-up parts, deboning and portion control), and Third Processing (marination, coating, formed products). In the U.S. today, the vast majority of poultry slaughter plants include one or more of the additional operations of second, third processing.

First Processing in the U.S. begins when live birds enter the plant and are electrically stunned, killed and bled. Feathers and viscera are then removed. The carcasses are chilled, washed, and either packaged or sent to further processing (Barbut, 2002; Barker et al., 2004; Sams, 2001b). Once birds have been stunned, mechanical devices cut through the jugular veins and carotid arteries on one or both sides of the neck. Once the neck cut is completed, the blood is allowed to drain from the bird for 2 to 3 minutes. During bleed out, 30 to 50% of the blood drains from the bird (Barbut, 2002, Barker et al., 2004; Sams, 2001b).

Blood volume in broilers has a curvilinear relationship with body weight. As body weight increases the percent of blood decreases. Blood will constitute over 11% of the body weight of a 1.0 kg (2.2 lb) broiler, while blood will only represent 7% of the body weight of a 3.0 kg (6.6 lb) broiler (Kotula and Helbacka, 1966; Raj, 2004). The USDA (2009b) reported that the average live weight of broilers processed in the U.S. during 2008 was 5.5 pounds, of which 8% was blood. Thus a typical U.S. plant processing 200,000 birds per day will collect 12,000 - 20,000 kg (26,500 - 44,000 lb) of blood. Blood is typically collected in troughs or rooms dedicated for blood collection, and then pumped as a congealing liquid to sealed tanks in the by-product recovery area of each plant.

Following bleed out, broilers in the U.S. are scalded in hot water to ease the removal of feathers. Scalded carcasses are then defeathered. Feathers account for approximately 7% of a broiler's live weight and a typical U.S. plant processing 200,000 birds per day will collect approximately 35,000 kg (77,000 lb) of feathers (Barbut, 2002). Once defeathered, head and feet are removed (Barbut, 2002; Sams, 2001b). Feathers, heads and feet (or "paws" as they are commonly referred to as in the U.S. and if not recovered as edible product) travel in a common water-filled flume for transport from the processing area.

Using various mechanical devices, the viscera of each carcass is then removed. Once the viscera are inspected, many plants remove the heart, gizzard, liver, and neck as edible giblets (Barbut, 2002; Barker et al., 2004; Sams, 2001b). The remaining viscera is removed from the carcass and conveyed by water-filled flume to the offal recovery area. Offal accounts for 17.5% of a broiler's live weight, thus a typical plant processing 200,000 birds per day will collect about 87,000 kg (192,500 lb) of offal (Barbut, 2002). This area of U.S. processing plants most often include the use of vacuum systems to remove lungs and other attached viscera not previously detached from the carcass. This material either enters an adjacent water-filled flume or is directly conveyed under vacuum to the by-product recovery area. As

a result of the slaughter process a typical U.S. poultry plant processing 200,000 birds will collect approximately 138,000 kg (300,000 lb) of by-product made up of 63% offal, 25% feathers and 12% blood.

Second Processing is defined here as any process in which a chilled poultry carcass is cut up into parts and meat is separated from bone. Operations in this category include cut-up, tray packing, deboning, MSC (mechanically separated chicken), MDM (mechanically deboned meat), and portion control (Barbut, 2002; Barker et al., 2004; Sams, 2001c). The waste stream from second processing operations is made up almost exclusively of bone, meat, fat and skin. Second processing operations and volumes vary dramatically within individual U.S. processing plants and thus there is no 'typical' volume of by-products generated. However, by-products generated during second processing are typically significantly less volume than in first processing. The recovered by-products from second processing are typically conveyed by water-filled flume; however some U.S. plants utilized vacuum systems.

Third Processing is defined to include all the processes that manipulate poultry meat into value-added, convenience foods for consumers (Hedrick et al., 1994). This category includes batter and breading, curing and smoking, marination, par-frying, RTE, and IQF (instant quick frozen) (Fletcher, 2004; Keeton, 2001, Owens, 2001). Due to the inclusion of non-poultry meat ingredients in third processing, the wastewater generated by plants is similar to bakery wastewater, with large volumes of highly water soluble carbohydrate materials such as flour, sugar and spices (Kiepper, 2003; Merka, 2001).

Rendering of inedible animal products consists of cooking raw by-product materials (blood, feathers and offal) to remove moisture and collect fat, protein and bone (Barbut, 2002; Grummer, 1992). The vast majority of by-products recovered from the slaughter and further processing of U.S. broilers is rendered. Cooking significantly increases the stability or 'shelf life' of the fat and protein by reducing the moisture content and killing the bacteria present in the raw offal (Barbut, 2002; Romans et al., 1994). In general, raw offal contains 50% moisture, 25% fat, and 25% protein and bone (John, 1991). In 1987, poultry processors supplied U.S. renderers with 3.2×10^6 MT (7.0×10^9 lb) of raw by-products, which represented 20% of the industry's total raw material (John, 1991).

Poultry processing by-product recovery

The majority of poultry processing by-products in wastewater must be removed prior to discharge in order to achieve compliance with established U.S. environmental regulations (USEPA, 1975). Initially, the principle of physically removing by-products (solids) from wastewater (liquid) appears simple. However in practice this principle becomes a complex function of interactions between the properties of the by-products, wastewater, and the separation method being utilized. Most poultry processing by-products in the U.S. are recovered using the physical separation process of screening in combination with the physical/chemical process of dissolved air flotation (DAF) (Kiepper, 2003; Torrens, 2001). Alternative separation methods such as electro-flotation have been investigated, but inherent technical difficulties or unfavorable economics have prevented widespread use (Bull et al., 1982; Johns, 1995).

Screening is the placement of a perforated surface in a wastewater stream designed to retain particulate matter greater in size than the surface gap openings (Pankantz, 1995). Screens are the most popular form of primary physical treatment used in U.S. poultry processing plants (Kiepper, 2003). Screening is often the first, simplest and most inexpensive form of by-product recovery. Screens come two main forms: rotary and shaker. Screens are often classified as Coarse, with gaps <6.0 mm (0.25 in) Fine, with gaps 1.5 to 6.0 mm (0.059 in to 0.25 in), Very Fine, with gaps 0.2 – 1.5 mm (0.008 in – 0.059 in), and Microscreens, with gaps < 0.2 mm (0.008 in) (WEF, 1998). Screens can be utilized as stand-alone units or in series, which allows coarser screens to remove larger particles before further screening by finer mesh units (Laughlin and Roming, 1993). Rotary screens are the most common form utilized by the U.S. poultry processors. Rotary or drum screens come in two basic forms: internally-fed and externally-fed. Shaker screens are also used in poultry processing plants, but are less common than rotary screens. Shaker screens utilize a flat perforated platform that is vibrated at a relatively low rate, allowing solids to be retained on the platform while water flows by gravity through the perforated plate (Walsh, 1993).

Vibratory Microscreening also referred to as rotating or vibro-energy screening, has been investigated by UGA researchers as an additional physical treatment step. Vibratory microscreening (< 0.2 mm) is defined as the use of countercurrent weights, rotated at a high speed to create a vibrating screen surface that allows the pass through of liquid, while retaining and transporting solids along the screen surface for recovery (Ngoddy, 1974).

DAF refers to the process of water-solid separation by the introduction of fine gas (usually air) bubbles to the wastewater stream. Although there are a variety of chemical wastewater treatment processes available for use in the poultry processing industry, DAF is by far the most popular form utilized in the U.S. (Kiepper, 2003). The efficiency of the system is enhanced by the addition of chemicals to adjust pH and improve the flocculation of particulate matter. The use of DAF technology has seen widespread application in the U.S. since the mid-1960s (WEF, 1998).

Alternative uses of poultry processing by-products

Waste fat, oil and grease (FOG) is a major component of poultry processing wastewater streams. In 2008 Georgia (USA) poultry processors slaughtered 1.3×10^9 broilers (~14% of U.S. production) with a live weight of 3.15×10^6 MT (6.95×10^9 lb) and generated approximately 34.0×10^6 million liters (ML) (9.0×10^9 gallons) of highly concentrated FOG wastewater in the process. Presently, most waste chicken fat from U.S. poultry processing plants is sold to rendering facilities at relatively low prices. This current method provides an easy way of handling the disposal of waste FOG, but neglects the fact that animal fat is a valuable by-product and has great potential as a source of alternative fuel.

Previous studies conducted by the Department of Biological & Agricultural Engineering (BAE) at the University of Georgia (UGA) examined the use of waste FOG recovered from various sources within poultry processing plants as possible fuel oil replacements (Adams et al., 2002; 2005; Goodrum et al., 2002; 2003). Although the FOG isolated from the offal had high fuel value, these studies concluded that the thermal recovery of this potential fuel source would be extremely difficult due to the amount of energy and storage that would be necessary. However at the same time other UGA researchers in the Department of Poultry Science and BAE were developing innovative methods to increase the recovery of fine particulates from poultry processing wastewater to increase industry revenues through enhanced offal recovery while simultaneously reducing costs associated with downstream wastewater treatment systems (Kiepper et al., 2005). It was proposed that these new recovery methods would eliminate the energy intensive processing required to remove the water from waste FOG suspended in wastewater streams as found in the previous biofuels studies.

The potential to recover FOG from poultry processing wastewater without the intensive use of heat energy has the potential to recover a major portion of the estimated 170×10^6 ML (45×10^9 gallons) of waste FOG leaving poultry processing facilities in the state of Georgia annually. Adams et al. (2005) reported that recovered poultry fat can be used as a heating fuel substitute or extender with minimal processing.

Offal generated by U.S. poultry processing plants is generally sold to rendering facilities at approximately \$0.014/kg (\$.03/lb) (USD). This gives fat a value of approximately \$0.22/gal (USD) as it is presently handled in the U.S. Purified fat from food processing wastewater can be used as a boiler fuel on-site displacing fuel oil, which is currently valued in excess of \$0.53/L (\$2.00/gal) (USD) (Adams et al., 2002; 2005; Goodrum et al., 2002; 2003). Using the conservative estimate of only recovering 10% of the 170×10^6 ML (45×10^9 gallons) of waste fat produced in the state each year by this method would result in an estimated savings to U.S. poultry processors of nearly \$9 million/year (USD).

In 2006, UGA researchers evaluated three (3) poultry wastewater by-product streams as potential alternative fuel sources (float fat after primary screens, secondary screen offal, and tertiary microscreen offal) at three (3) southeastern U.S. broiler slaughter plants. Results showed post-primary screen float fat and secondary screen offal have the greatest potential as alternative fuels based on ease of extraction and recovery efficiency. Currently in most U.S. poultry processing plants, secondary screen offal is collected and belt or screw conveyed to offal trucks. Thus, modification to existing collection systems in which secondary screen offal could be diverted to a FOG extraction/purification system is readily feasible. On the other hand, float fat tends to accumulate in equalization pits or transfer troughs that currently do not allow for easy collection.

The average volume of purified fat recovered from float fat and secondary screen offal by plant is shown in Figure 1 (next page). The volumes shown indicate the average kilograms and liters of purified fat recovered based on 100 kg of raw material. The float fat (28 L) and secondary screen offal (22 L) from Plant 2 produced the highest volume of purified fat for fuel testing. Average fat recovery for three plants ranged from 12.3 - 20.3 kg (14 – 28 L). Fat recovered as float fat and secondary screen offal was subjected to standard fuel and combustion analysis. Results comparing sample averages to #2 diesel fuel (D2) are summarized in Tables 1 and 2 (Kiepper and Geller, 2007).

Figure 1. Average kg and L of purified fat recovered from 100 kg of raw by-product.

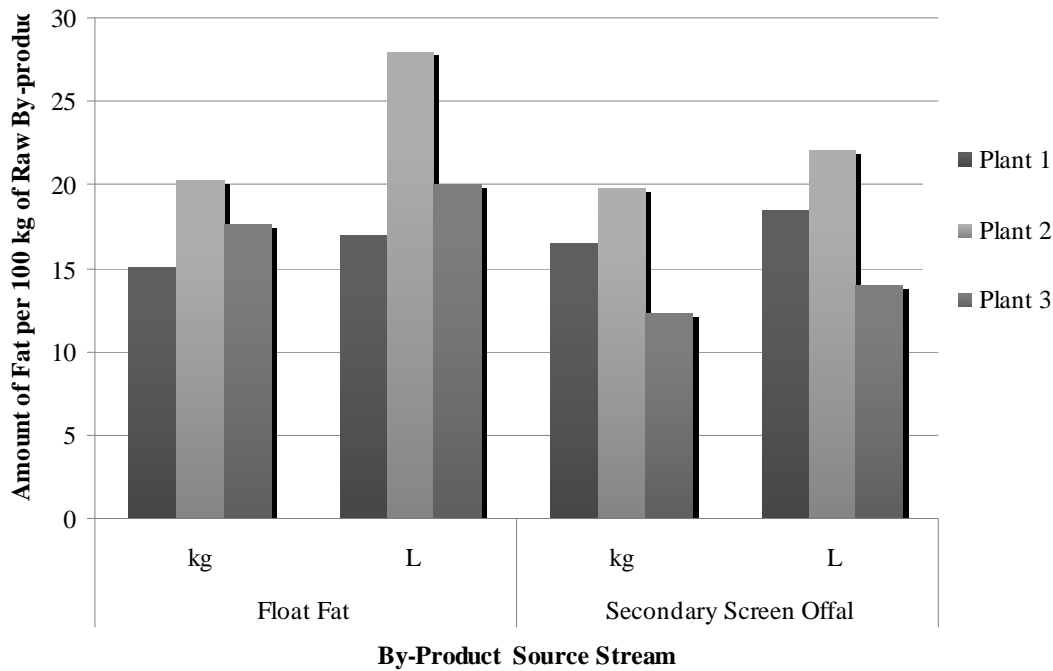


Table 1. Average fuel quality of poultry fat samples versus #2 diesel (D2).

| Sample Series | Poultry Fat | versus |
|-------------------------|-------------|--------|
| Plant/Sample | Average | D2 |
| Carbon (%) | 73.11 | 85.06 |
| Hydrogen (%) | 11.47 | 13.68 |
| Nitrogen (%) | 0.03 | 0.01 |
| Sulfur (%) | 0.05 | 0.02 |
| MIU (%) | 2.48 | n/a |
| Moisture (%) | 1.11 | n/a |
| Insoluble (%) | 0.25 | n/a |
| Unsaponifiable (%) | 1.12 | n/a |
| Energy Content (BTU/lb) | 16557 | 20313 |
| FFA (%) | 3.30 | n/a |
| Dynamic Viscosity (cP) | 15.80 | 5.60 |
| Specific Gravity (g/mL) | 0.89 | 0.84 |

Table 2. Average emissions properties of poultry fat samples versus #2 diesel (D2).

| Sample Series | Poultry Fat | versus |
|--------------------------|-------------|--------|
| Plant/Sample | Average | D2 |
| Efficiency (%) | 78 | 79 |
| Ambient Temp (F) | 84 | 80 |
| Stack Temp (F) | 367 | 354 |
| Oxygen (%) | 8.82 | 8.24 |
| Carbon Monoxide (PPM) | 601.97 | 343.39 |
| Carbon Dioxide (%) | 6.70 | 7.03 |
| Combustibles (%) | 0.1362 | 0.1022 |
| Excess Air (%) | 67.73 | 65.72 |
| Nitric Oxide (PPM) | 17.14 | 17.22 |
| Nitrogen Dioxide (PPM) | 29.22 | 23.48 |
| Oxides of Nitrogen (PPM) | 46.84 | 41.18 |
| Sulfur Dioxide (PPM) | 0.00 | 0.07 |
| Consumption (gal/hr) | 2.22 | 2.17 |
| ΔT (°F) | 22.78 | 20.88 |

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