Researchers Use Magnetic Nanoparticles to Extract Free Fatty Acids from Rendered Oil

The rendering industry as a whole is focused on capturing and processing poultry and other protein byproducts for conversion into valuable product streams like animal feed. The byproducts, called secondary protein nutrients, have a high oil content, but also contain large amounts of free fatty acids (FFAs). In bulk, FFAs accelerate the oxidative process, resulting in a lower overall oil quality defined by shortened shelf life, malodor, and decreased nutritional value.

To address this challenge, researchers with the Georgia Tech Research Institute (GTRI) endeavored to develop a low-cost and efficient way to remove FFAs from the rendered oil. The result — a novel extraction method based on the principle of chemisorption and the use of magnetic nanoparticles (MNPs).

Chemisorption produces a chemical reaction between a surface and any substance on that surface. In this case, the surface of the MNPs exhibits a high affinity for free fatty acids. Researchers are exploiting this phenomenon to remove FFAs from a range of oil systems. Once the particles are removed from the oil using a magnet or centrifugation, the FFAs attached to the surface will also be removed, thus lowering the overall FFA level of the oil.

“At rendering plants, the quality of the raw materials dictates the quality of the oil that is produced. Removing FFAs from rendered oil would provide renderers with more product mix flexibility,” explains Dr. Daniel Sabo, GTRI research scientist and project director. “At the same time, poultry processors would receive better quality animal feed while also having a byproduct material with a high dollar value.”

The team is currently testing FFA adsorption on MNPs in various oils, and comparing the adsorption levels to those achieved using best available technologies (BATs). These BATs include chitosan, activated carbon, and ion exchange resins. BAT materials remove FFAs using the same principle as the MNPs (chemisorption), but the MNPs show a distinct advantage.

Dr. Daniel Sabo, GTRI research scientist, uses magnetic nanoparticles to test free fatty acid removal from a sample of rendered oil.
“MNPs are an improvement on these materials due to the high surface area to volume ratio and the ease of manipulation. This means, that for a given amount of material, MNPs will have more surface for the FFAs to attach, and thus will result in more FFAs being removed compared to current BATs,” says Sabo.

In recent experiments, the adsorption capacity (defined as the amount of FFAs captured per amount of MNPs) was 880 mg-FFAs/g-MNPs in yellow grease. This was achieved with temperature and conditions similar to rendering industry standards, and according to Sabo, is five to 10 times larger than currently used adsorbent materials.

In addition, the team has tested the removal of attached FFAs from the MNPs to enable reuse of the MNPs. To accomplish this, aggressive regeneration conditions, including application of extremely caustic solutions over an extended duration, was investigated. These conditions allowed for the full removal of FFAs attached to the surface of the MNPs and showed that the particles are robust enough to withstand the harsh operating conditions.

“The MNPs continue to withstand harsh recycling conditions that allow for repeated use without any loss in adsorption capacity. All of this together adds up to a reduction in FFA removal costs,” notes Sabo.

Researchers believe further optimization of these recycling conditions is possible, and they plan to use a less caustic solution (an order of magnitude lower) for a shorter duration. This will help reduce the cost of particle regeneration, further driving down the cost of using MNPs to remove free fatty acids.

Researchers successfully used magnetic nanoparticles to reduce free fatty acid levels and improve oil quality.

Researchers also explored existing separation technologies — magnets versus centrifuge — for cost-reduction opportunities. To date, there was no observed difference in MNP separation using magnets or centrifugation; however, centrifugation allows for faster separation.

“Before (left) and after (right) photos of yellow grease sample testing. Researchers successfully used magnetic nanoparticles to reduce free fatty acid levels and improve oil quality.

“We are also investigating the removal of the FFAs from the surface of the MNP in such a way that preserves the FFAs. Each type of free fatty acid that is removed using this technique has some inherent value either as an additive to animal feed or in other areas in the chemical industry. The preservation of these FFAs offers an additional revenue stream to the renderers,” says Sabo.

In addition to optimizing MNP recycling conditions, the team also plans to optimize loading conditions and explore characterizing the removed FFAs.

Sabo says the team has currently used only one loading amount of MNPs. More work is needed to optimize that loading condition in order to remove the most FFAs at one time. This optimization, he explains, is required to eventually move the technology from the benchtop and pilot scale to the industrial scale. The team will also attempt to identify exactly the FFAs removed, which will help determine how to best use the recovered free fatty acids.

“So far, we have seen great strides in the use of our MNPs in the removal of FFAs. These particles have far exceeded my expectations on FFA removal, and not only in ideal solutions to boot. In fact, we have seen much higher removal efficiencies in a true rendered oil system than we did in an ideal oil system. This is a truly fun and intriguing project to work on,” says Sabo.
Researchers developing the Georgia Tech Research Institute’s (GTRI) Dynamic Filtration System have successfully increased the device’s processing capacity by enlarging its filter area. Recent tests show a high-rate filtration yielding both water recycling and value-added material recovery down to 50 microns. As a result, increased food safety with decreased intervention chemistries can be achieved.

Over the last year, researchers examined a variety of cartridge filter types and spiral wound membrane products. They determined that a critical aspect of selecting the separation surface (e.g., sieve, filter, or membrane) is balancing how to consistently change the pressure across the entire membrane. The team refers to their method for achieving this as a dynamic pressure gradient.

“Moving to a larger filter area outside of a flat plate setup is a significant achievement for us,” says John Pierson, GTRI principal research engineer and project director. “Moving from a flat plate filter or membrane setup to a cylinder also keeps the overall footprint smaller.”

The team also examined layering different separation surfaces to achieve a depth of filters. Here, larger particles are removed at the filter surface. Finer particles pass and are separated at the appropriate pore-size opening. Because of the dynamic pressure gradient, a range of particle sizes are concentrated in the filter chamber and can be removed based on time or process feedback.

“We have had success with operating the system with two to three deep flat filters and membranes. Our most recent work shows that when the system is operated as a dead-end filter versus a dynamic filter system, ripening of the membrane occurs. While finer materials pass, the average flux rates remain significantly higher for extended periods. Backwashing occurs once the pressure across the separation surface increases to a predetermined level. We record the pressure across the filter. We also record weight of water processed and backwashed using load cells. The transmembrane pressure is related to the flux or water processed through the membrane resistance,” explains Pierson.

Researchers are working to correlate this data given the fluctuating pressure resulting from the dynamic filtration process. That relationship will provide a means of automating the backwash cycle. If multiple units are operating across the length of a chiller, these can be coordinated to provide effective cleaning throughout its length as the processing day evolves.

Researchers have conducted a preliminary assessment of layered flat plate membranes combining 30-micron (0.0012-inch) and 100-micron (0.0039-inch) openings, which yielded 36% and 46% open areas on the respective membranes. With an effective membrane area of 5.36-square inches, about 1.4 gallons per minute of chiller water (1000 mg/L of TSS, total suspended solids) was processed. The overall TSS removal efficiency was 83%, and the overall throughput efficiency or filtrate accounting for any water used in backwashing ranged from 70% to 81%.

Currently, the team is finalizing the design of a pilot-scale system for on-site testing at a poultry processing facility. The on-site testing will probably begin by capturing a side stream of a chiller or other process where the overflow water is otherwise discharged to wastewater, notes Pierson. This will help ensure there are no food safety concerns. Researchers will also characterize the filtrate or filtered water and determine the amount of solids captured.

“We are excited about the progress we have made. I really believe that we can also use the operational data to demonstrate the daily progress made towards environmental sustainability during poultry processing,” says Pierson.

Moving forward, the team will continue to explore finer pore openings to capture smaller particles that affect water recovery and food safety chemical usage.
Robots are coming. It is not a matter of if, but a matter of when. Several companies have already thrown their hat in the ring introducing robotic systems for operation in commercial chicken farms, and others are on the way. The lower cost of entry and enhanced computing capabilities have made these systems viable for the first time in commercial production houses. So what does that look like today? And what will it look like tomorrow?

There are a handful of commercially available robotic systems on the market right now. These include a mix of ground robots, gantry robots that hang from the ceiling, and robotic solutions for specific modern house designs. These robots carry out tasks ranging from simply moving birds around to monitoring the environment and even automatically disinfecting houses.

Tibot Technologies (tibot.fr), a French company, has made available a ground robot called the Spoutnic. This robot is designed for early adopters, being both low-cost and serving a simple role. Spoutnic has no cameras or other advanced sensors. It navigates through the houses by bumping into chicken and equipment and changing direction, much like a Roomba vacuum cleaner robot. Its goal is to roam among the flock and encourage the birds to move. The company claims that this simple interaction is able to reduce floor eggs in breeder facilities by encouraging hens to lay eggs in the nest boxes. In broilers, the claim is that the robot is able to keep the birds moving, which promotes natural activity and weight gain.

Faromatics (faromatics.com) has a gantry robot, called the ChickenBoy, which hangs from the ceiling of houses and rides along rails. This system is primarily a sensing system that can monitor air quality, health and welfare, and equipment operation. It then relays this information back to the farmers. In addition to environmental sensors, it also employs a thermal camera for identifying mortality and wet spots in the litter. It also uses cutting-edge artificial intelligence algorithms for characterizing litter quality and disease.

The Octopus Poultry Safe robot (octopusrobots.com) is a fully autonomous ground robot that has been designed to sanitize poultry farms, specifically the litter. This robot aerates the litter by stirring it, inhibiting fermentation and reducing ammonia levels. It also actively sanitizes litter with an aerosolized spray. It uses artificial intelligence to identify birds and move autonomously through the house.

On a larger-scale, Charoen Pokphand Group (cpgroupglobal.com) has developed a humanoid robot “nanny” that roams coops, recording temperature and bird movement. This robot has been designed for caged chicken in Chinese facilities, roaming the hallways in between the cages and determining the welfare of the chickens inside. If a sick chicken is detected, the farmer is notified to remove the bird. In these facilities, the robot assistants allow a single human to operate a barn with up to 168,000 hens.

Each of the above described robots are currently available on the market today. So what about tomorrow?

Researchers at the Georgia Tech Research Institute’s (GTRI) Food Processing Technology Division have spent the last several years developing, testing, and proving a smart ground robot for augmenting and replacing the need for farmers to manage poultry houses. The goal is to do everything possible to reduce and even eliminate the need for farmers and farm-hands to enter the houses and perform tasks. To do this, the robot must be able to not only sense, but also manipulate the environment.

Colin Usher is a senior research scientist in the Georgia Tech Research Institute’s Food Processing Technology Division.
The GTRI robot is capable of fully autonomous navigation in houses, interacting with the chickens to allow it to traverse the entire floor area. See it in action at tinyurl.com/grohbot. As the robot drives around, it is constantly searching for floor eggs (in breeder houses) and mortality, tracking where it has and has not been, to ensure that it covers 100 percent of the floor area. Once detected, the robot can pick up and remove the eggs completely autonomously. In addition, this robot utilizes cutting-edge artificial intelligence and deep learning to identify chickens and make high-level characterizations of their welfare. It contains a suite of sensors for mapping the micro-climate and 3D sensors for estimating size and size distribution throughout the entire house. Future plans include microphones for listening to the chickens.

Finally, the system has remote control capability. Using a 360-degree camera mounted on the robot, the farmer can “dial-in” to the robot from their couch and take over control. In this mode, the operator is able to view around the robot as though they were sitting in the driver’s seat. Using a cell phone, tablet, or even a virtual reality system, they would be able to see what is around the robot on all sides. They can manually control the robot to drive wherever they want, activate egg picking or mortality removal manually, and inspect equipment with the high-resolution cameras. When they are finished, they can simply close the application and the robot will continue on autonomously with what it was doing before it was interrupted. How cool is that?

**RESEARCHER PROFILE**

**Stephanie Richter**

*Job title:* Research Scientist I  
*Education:* M.S., Biology, Georgia Institute of Technology; B.S., Biology, Georgia Southern University  
*Areas of research expertise:* Microbiology, Food Safety, Poultry Science, Health and Safety  
*List of any poultry industry projects you’re working on and your research role:* Ice Slurry Chilling – microbiology and carcass chilling technologies, PAA stability, and salt uptake tendencies  
Novel Separations – microbiology and wastewater characterization  
Virtual Reality Cutting Trajectory – Understanding poultry physiology for automation/robotic relationships  
*What I find most rewarding about working on poultry industry projects:* My research has made me an informed consumer. I appreciate what packaging labels mean and how you can infer the history and processing of the product. I love to answer the question people ask me the most. “Stephanie, do you still eat chicken?” You bet I do!  
*A talent I wish I had:* I want to learn to play the guitar  
*Another occupation I’d like to try:* Paleontology  
*My first job:* Lifeguarding at my local pool and mowing lawns around my neighborhood  
*If I could meet someone famous, who would it be and why:* “The winner ain’t the one with the fastest car, it’s the one who refuses to lose.” – Dale Earnhardt Sr.  
Dale Earnhardt Sr., The Intimidator, was my hero growing up. I had all his fan gear. I cheered for him with my dad from the grandstands and from our couch. This quote of Senior’s has resonated with me. It inspires me to never be complacent. I’ve got to put in the time and effort to conquer my goals, and once I achieve them, I will never stop giving it my all. #DaleYeah  
*One thing people may not know about me:* My Mama is Chinese and my Grandma was my “day-care” in my younger days. I can speak fluent Mandarin!  
*My day would not be complete without:* Iced coffee with toffee nut syrup  
*The last book I read:* Dinosaurs in the Attic by Douglas Preston  
*The last movie I saw:* Escape Plan starring Sylvester Stallone  
*My favorite song:* “Mary Jane’s Last Dance” by Tom Petty and the Heart Breakers  
*My motto:* “Know yourself, know your worth” –Drake  
*My hobbies:* Camping, cooking, watercolor painting  

**Technical Assistance Is Just a Phone Call Away**

ATRP provides no-cost technical assistance to Georgia-based firms and individuals in the poultry industry. These assists range from simple inquiries regarding information or help needed to address a problem to extensive on-site consultations in which researchers collect data and provide a report on their findings and recommendations. In-plant energy usage/cost assessments and workplace safety evaluations are also offered.

ATRP uses input from all assists to gauge situations calling for new research initiatives in energy, environmental, safety, and other areas.

To inquire about the program or to schedule an assist, call ATRP Program Manager Doug Britton at (404) 407-8829 or email him at doug.britton@gtri.gatech.edu.
Recycled Phosphorus in Broiler Diets

Dr. Jie Xu, principal research scientist, discusses her work on using recycled phosphorus in broiler diets. Researchers recovered the phosphorus from poultry processing wastewater using functionalized magnetic nanoparticles (MNP).

Q: PoultryTech – What role does phosphorus play in broiler production?
A: Xu – Phosphorus is one of the essential minerals that is required for normal muscle growth and egg formation. More than 85% of the body’s total phosphorus is stored in bone. Phosphorus also plays a vital role in cellular metabolism and regulatory mechanisms. Through its involvement in these metabolic and structural processes, phosphorus is essential for animals to reach their optimum genetic potential in growth and feed efficiency as well as skeletal development. Because of the key role of phosphorus in bone development and mineralization, inorganic phosphorus must be added into the diet to meet the requirements of the animal.

However, greater dietary phosphorus concentrations increase the cost of poultry production and phosphorus excretion into manure. Excessive amounts of phosphorus in manure contribute to the pollution of lakes, streams, and wetlands leading to surface water eutrophication.

All these concerns have attracted global attention and stimulated the re-examination of the use of inorganic phosphorus in animal diets.

Q: PoultryTech – What is the source of the recycled phosphorus used in the study?
A: Xu – Poultry processing wastewater contains high levels of phosphorus, primarily from blood, bone, manure, detergents, and sanitizing compounds. The level of phosphorus has to be reduced from the wastewater before it can be discharged. We have developed a low-cost method to remove phosphorus species from wastewater using functionalized iron oxide-based MNP. Orthophosphate captured on the surface of the MNP has been used as a diet supplement to provide both needed phosphorus and iron in broiler diets.

Q: PoultryTech – Why is there an interest in using recycled phosphorus in broiler diets?
A: Xu – The majority of feed phosphorus is derived from phosphate rock. Because it is a non-renewable resource, phosphate rock is becoming increasingly scarce and expensive. Poultry accounts for approximately 50% of animal feed phosphate consumption worldwide, and phosphorus supplements have become the second most costly dietary component. In fact, the price of feed-grade phosphorus supplements for animal nutrition has increased over fourfold in the last few years, with future price increases expected.

In addition, it is common practice that extra phosphorus is present in formulated diets with substantial safety margins to guarantee that birds do not become phosphorus deficient.

Q: PoultryTech – How did you evaluate the recycled phosphorus for use in broiler feed?
A: Xu – In partnership with Dr. Woo Kim in the University of Georgia Department of Poultry Science, we conducted a preliminary study. A total of 240 one-day old male broiler chicks (Cobb 500™) were randomly assigned to 24 cages (one battery) with 10 per cage. Four types of diets were prepared, including positive control (industry standard), negative control (0.15% less phosphorus compared to positive control), negative control with 0.075% supplemented phosphorus-laden MNP, and negative control with 0.15% supplemented phosphorus-laden MNP.

The birds were fed the diets for 18 days, and the feed intake, body weight, body weight gain, and feed conversion ratio were measured on Days 7, 14, and 18. Test diets containing 0.3% chromium oxide as an indigestible marker were fed from Days 0 to 18. On Day 17, clean trays were placed under the cages, and at Day 18, the excreta and ileal digesta were collected to evaluate calcium and phosphorus digestibility (other mineral digestibility).

The body composition (total bone mineral content and density, fat%, lean muscle %) of three birds per cage was measured using a bone density scan. Samples of the small intestine were taken from three birds per cage to examine intestinal transport gene expression. In addition, bone samples of the femur, tibia, and left wing were collected and examined for structure and composition using scanning electron microscopy and energy dispersive x-ray spectroscopy. Tissue samples from the liver, spleen, and heart were also ashed for mineral analyses.

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Blockchain Technology for a More Transparent and Efficient Industry

BY RAFAEL RIVERA, MANAGER, FOOD SAFETY & PRODUCTION PROGRAMS, U.S. POULTRY & EGG ASSOCIATION
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Perhaps you are aware of all the news around Bitcoin and all other cryptocurrencies. I personally don’t understand much of it myself, but when talking about blockchain technology, you might have heard about it. The blockchain is an incorruptible digital ledger of economic transactions that can be programmed to record, not just financial transactions, but virtually anything of value. Specific data is set in blocks and then the blocks are connected to other blocks of relevant data creating a chain, hence the word, blockchain. This ledger is similar to what many companies do with office share point sites where employees have access to it and can keep track of any changes made to a document as a project moves along and communicate among themselves. This is a decentralized system where all participants receive the same information as it happens and that is what makes it incorruptible.

In a centralized system you would have a main information holder that distributes the information to other stakeholders. The data can get corrupted because all the stakeholders can’t communicate among themselves and whoever changes the data only communicates to the main information holder. Technically, every stakeholder can change the information in their copy of a ledger and there is no reliable way to verify who’s sharing the correct information. With blockchain you can set up a system where all stakeholders receive the same information and all changes are tracked and updated throughout the chain at the same time. All stakeholders can verify that they are receiving the same information because they are communicating among themselves.

Blockchain was created because we don’t trust. It is very difficult to have everyone adhere to rules and this allows third parties to verify accuracy and compliance. This can be an important tool to address challenges in food manufacturing such as: understanding demand, controlling inventory and cost, managing accounts, optimizing deliveries, creating collaborative solutions for food safety and quality, to name a few.

Blockchain technology has a lot of potential for the poultry business. It can allow seamless and rapid data sharing along the supply chain. It can establish more transparency by allowing customers and consumers to verify information. And it can improve trust. The challenge is that it is too costly at this point, and there are hurdles that will prevent people from trusting the data in the short term.

Food companies are testing the use of blockchain software to establish a product’s authenticity. In a food manufacturing setting you can have several blocks. Each block has a set of data specific to that segment of the distribution chain. For example, a poultry company might have a block where hatchery data like hatch dates and farm delivery times are stored. And these can communicate with the production block where you can then store farm information, feed conversion rates, and so on. The end user could possibly scan a product label and access specific data that can confirm where the food came from.

Since the different blocks are connected, the block from the processing plant can find where their product was shipped, when it was sold, and possibly where it was consumed. You can set these blocks and grant access to your customers so that they can also track the source of their products. The customers can also be connected among themselves to compare or share other useful information regarding specific types of ingredients or materials.

There are some challenges to get the technology to a level where the industry can rely on it. First, there is an enormous amount of data that would need to be stored that will possibly not be useful at all. So to get the data that you need, it would require a lot of data mining to obtain it. Establishing a blockchain will require energy and storage capability to achieve reliability as well. When it comes to communicating with stakeholders, how much would you want them to see? How much would a business like to share with a competitor? Who governs this and would everybody be willing to participate? These are some questions that will be coming along the way, and answers can be provided as the capabilities are built and tested.

Blockchain technology has a lot of potential for the poultry business. It can allow seamless and rapid data sharing along the supply chain. It can establish more transparency by allowing customers and consumers to verify information. And it can improve trust. The challenge is that it is too costly at this point, and there are hurdles that will prevent people from trusting the data in the short term.

We extend our appreciation to Cargill for discussing this topic at our recent Poultry Processor Workshop. The workshop covers relevant topics and innovations necessary to implement improvements in efficiency, quality, and safety of our products.
Q: PoultryTech – What were the results?
A: Xu – Results from the 18-day trial showed that the broiler birds fed the four different diets did not show a significant difference in some parameters, including body weight gain, feed intake, and feed conversion ratio. This is an indication that the growth performance is not sensitive to different calcium and phosphorus sources. As 85% of total body phosphorus is deposited in the skeleton of the bird, bone mineralization might be a better indicator for determining the dietary concentration of phosphorus. Preliminary bone density and mineral analyses indicated that the phosphorus-laden MNP supplemented diet is about equivalent to the industry standard. However, a larger more exhaustive study is required to conclusively assess the potential to recycle the phosphorus species from the poultry processing wastewater into animal feed.

Q: PoultryTech – What are the next steps?
A: Xu – We plan to continue testing wastewater-treated MNPs as part of broiler diets to better understand the overall contribution to bird health and nutrition. Other attached compounds, including fat and proteins, might also improve the overall feed conversion, so there is still a lot to learn on this front.

Q: PoultryTech – What are the potential benefits for the poultry industry?
A: Xu – The MNP-based phosphorus removal technologies being developed here at GTRI are effective in capturing phosphorus species from wastewater. This results in improved wastewater discharge quality and could have a significant impact in reducing the environmental effects in receiving surface waters. In addition, the ability to reuse the extracted phosphorus-laden MNP in the broiler diet is an elegant way to close the environmental loop while also potentially reducing feed costs.

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