

# **Surface Area and Envelope Volume of Growing Broilers from 35 d to 63 d of Age**

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## **SUMMARY**

Poultry is Mississippi's most valuable agricultural commodity valued at \$2.3 billion and produced on 1,478 farms in 2012. 3D models of broilers are needed to find ways to increase heat removal, thus be able to increase bird performance (better feed conversion ratios) or use fewer fans (less energy) or a combination of both. 3D models can be utilized in a broiler house computational fluid dynamics (CFD) model to improve our understanding of the bird-airflow interface. Therefore, the objective of this study was to characterize surface area and envelope volume of growing broiler birds from 35d to 63 d of age. Live broiler chickens were successfully scanned at 35, 49, 63 days of age with a commercially available 3D digitizer system. Adjustments were made to accommodate live broilers such as cameras angles and placement, light intensity, and bird movement. 3D surface models were successfully rendered however, issues arose with the calculation of surface area thus affecting volume and S/V ratio for both male and female birds. Models can currently be used to gather physical measurements but the study must be repeated to improve the model surface area measurements.

## **INTRODUCTION**

Poultry is Mississippi's most valuable agricultural commodity valued at \$2.3 billion and produced on 1,478 farms in 2012. Mississippi is home to the fourth largest broiler integrator, Sanderson Farms. 3D models of broilers are needed to find a way to increase heat removal, thus be able to increase bird performance (better feed conversion ratios) or use fewer fans (less energy) or a combination of both. The objective of this study was to characterize surface area and envelope volume of growing broiler birds to improve estimates of convective heat loss coefficients during tunnel ventilation (35d to 63d).

Moiré and phase shifted moiré have been used by many researchers to non-invasively measure contours. Junior et al. (2011) used moiré with traditional cameras and compared images to the chickens' skin with the feathers laid out on a flat surface. Koury (2014) developed a 3D scanning methodology using a commercially available Creaform MegaCapturor 3D Digitizer and a commercially available software package to determine surface area and envelope volume with full-scale fiberglass models of farm animals (chicken, pig, dairy cow and horse). He had a system error of less than 1% for standard test cylinders and was successfully able to develop a 3D surface model of a live broiler chicken. This system was used for this project.

## **MATERIALS AND METHODS**

### **Animals and Husbandry**

Thirty Ross x Ross 708 broilers (15 male, 15 female) were housed at the USDA ARS Poultry Research Unit in a 3.43 m x 2.90 m (3 bird/m<sup>2</sup>) environmentally controlled room. The birds were fed a commercial diet. Images were taken of the birds in the sitting position every two weeks at 35, 49, and 63 d of age. Birds were individually taken from the pen and placed on a metal perch (22.86 cm width x 22.86 cm length x 64.77 cm height) to begin the scanning

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process. After each scan, the birds were placed back into the pen until the next scanning period. Scanning was attempted at 21 d of age but the birds were too small for the system to register.

### **Image Acquisition System**

Birds were scanned with a 3D Digitizer (MegaCapturor, Creaform, Quebec City, Canada). The digitizer system consisted of four cameras mounted on adjustable stands that stood 1.6 m (fig. 1). The cameras were connected to a desktop computer and operated by an acquisition software package (InSpeck Fringe Acquisition and Processing Software (FAPS) v7.5, Creaform, Newark, DE). Communication was managed through serial cables that were connected from each digitizer to a multiplexer that was linked to the control computer. FireWire cables were connected from each camera into a FireWire hub for image transfer. The megacapturor was able to acquire texture and geometry from any given model by the use of an optical measurement system. This optical system combines phase shifted moiré and active optical triangulation. A 3D image was taken in less than a second with an image resolution of 7.7 megapixels.

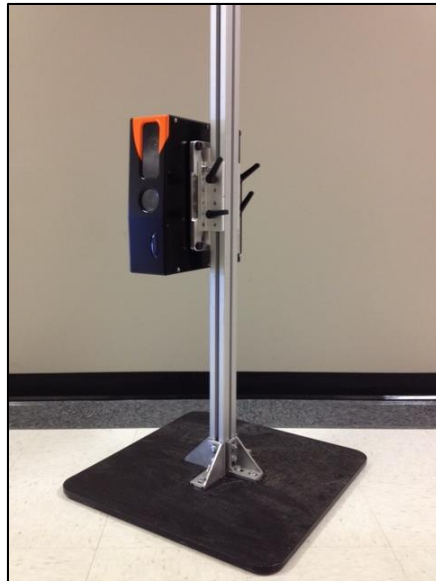


Figure 1 Basic setup with digitizer on adjustable stand.

### **Scanning Procedure**

To begin the scanning procedure all four cameras were turned on, FAPS opened, and room lights off. The light intensity levels for each digitizer were adjusted (fig 3). Each digitizer shot out eight parallax points within a fringe pattern. At least two of the eight parallax points needed to be on the surface of the object for correct acquisition. Digitizers were adjusted by hand before setting light intensity. Light intensities were typically set around 40%. Too much light or not enough light can cause a distortion within the grayscale images. Once all of the above has been executed then an acquisition can be shot. There are two ways to shoot a sequence. One is to shoot all digitizers at once by clicking the ALL function in the acquisition control center. Another way is to press the camera button of choice to only take one picture at a time.

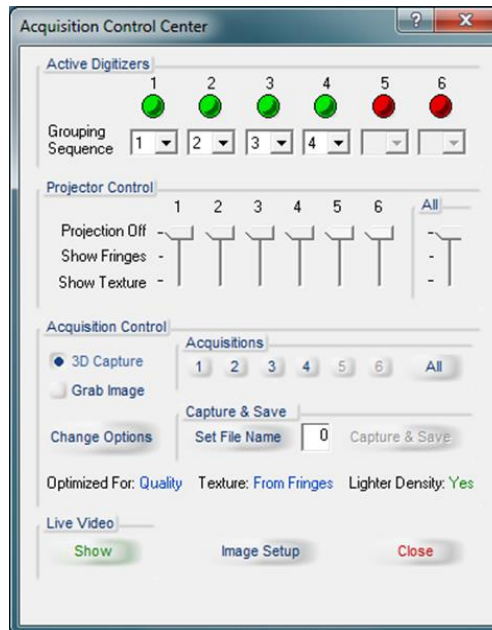


Figure 3 Image shows the acquisition control center where light intensities are set in the image setup (located at the bottom of the control center) and images are taken individually or using the ALL button.

### Pre-Processing

After acquisition, the first step in the processing phase of FAPs was to pre-process each image. FAPS would auto-detect the location of parallax points projected on the model (fig 4). This computed the phase function where the image data appeared in a grayscale that determined image quality. The grayscale showed any distortions that may have been caused by things such as movement and light intensity being off (fig 5). An example of a distortion due to the tail feathers is shown in fig 6. Next, the interest area was selected to determine the boundaries of the image that were needed before further processing (fig 7). The selection of the interest area was completed manually by tracing a line around the object and connected by a series of points. Vertices were added, modified, or deleted after the interest area had been selected. Then pseudo-color images were post-processed to determine continuity (fig 8). This allowed us to determine if the correct depth was analyzed by the digitizers and that there were no discontinuities within the depth perspective. Verifying a discontinuity was done by the comparison of the colored representation (red to blue) to the original image. The color red is warm and therefore closest to the digitizer, while blue is cool and furthest from the digitizer. Minor discontinuities were fixed if present. The post-processing tool then transformed the edited data into a 3D image. After post-processing had been completed you can view the image in a 3D wire plot on an XYZ axis to assure that the pseudo-colors were correct. The final step in the image processing was to define a sampling value for the export of the image. The sampling value determines the density of mesh. For example, 1 over 3 indicated a sampling of one point over every 3 acquired data points in each lateral axis. The smaller the number, the denser the mesh. The texture was always 1/1 when exported. The 3D images were then exported to a rendering software package Geomagic Wrap 12 OEM Edition (3D Systems, Rock Hill, SC).

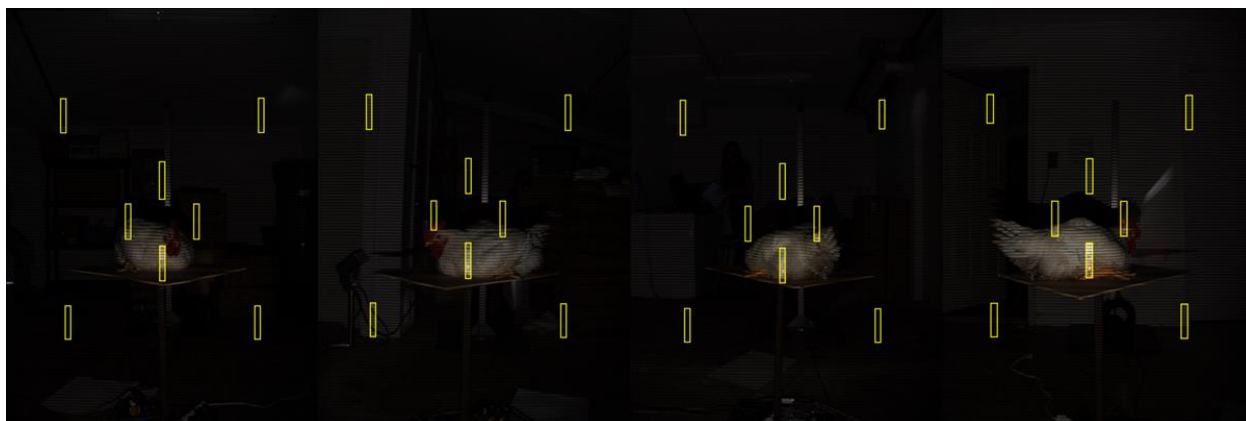


Figure 4 Four position image showing the parallax points that are shot out by the digitizer for a male bird at 63 d.



Figure 5 Four position image showing the grayscale pre-processing of a male bird at 63 d.

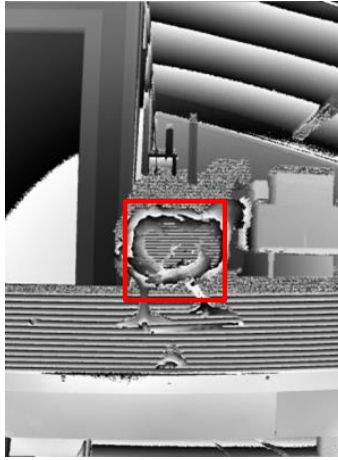


Figure 6 Grayscale image showing bird posterior with a 90° angle shot and what a distortion looks like.



Figure 7 Four position image showing a white line representing the interest area that has been selected. Not all of the chicken is selected, because not all is needed.

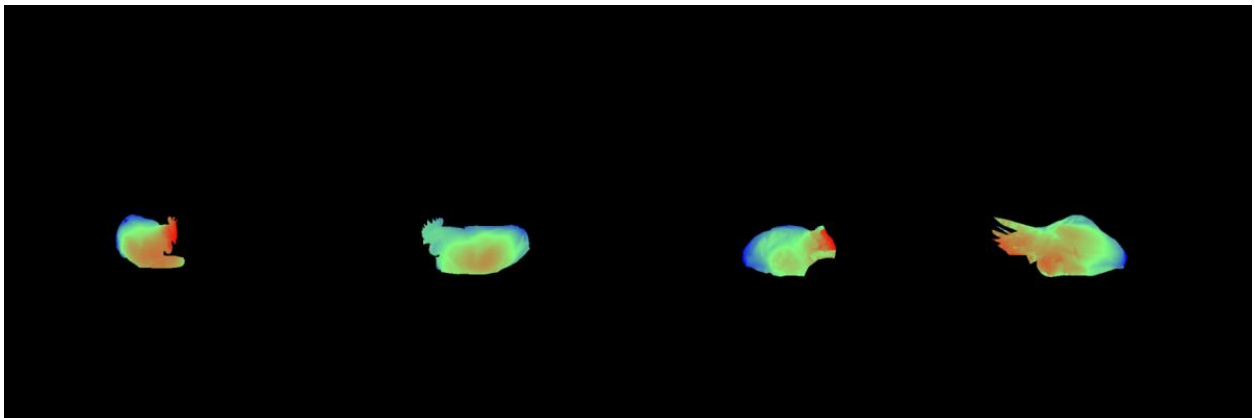


Figure 8 Four position image showing the Pseudo-color that analyzes depth perspective.

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## Post-Processing of 3D Image

The imported surface images were processed for final assembly and surface analysis. To begin, the 3D mesh images from FAPs were imported and a manual registration was completed (fig 9). At least three overlapping points were selected from each image to successfully stitch together (fig 10). After all four images have been manually registered, the surfaces were combined to create a single object (fig 11). Then the object is wrapped to convert it into a single polygon surface that can now be edited (fig 12). Models were typically edited by first deleting any overlapping areas that would cause problems later and then by using a Fill Single Bridge. A flat, tangent, or curvature bridge was used to fill in areas that were too large to fill all at once. Flat was used on the bottom of the model, because the broiler was in a sitting position. Then tangent or curvature was used on the top of the broiler to connect the open space seen in figure 12. Before moving to the finished model, it was important to open up each model from the bottom to make sure that no overlaps caused an additional object to form on the inside of the main model (fig 13). If an overlap was missed then it could throw off the final surface analysis. For instance, this internal object increased the surface area and volume measurements by 27.9% and 6.1%, respectively. A completed broiler male model is shown in figure 14. The smoother areas represent areas that have been filled in by Geomagic and were not seen by the digitizers. The completed flat bottom is represented well in figure 14. Figure 15 shows a female broiler at 63 d. She did not have as much hiding from the digitizers, therefore she had fewer areas that needed to be filled in and showed fewer areas that needed to be smooth.

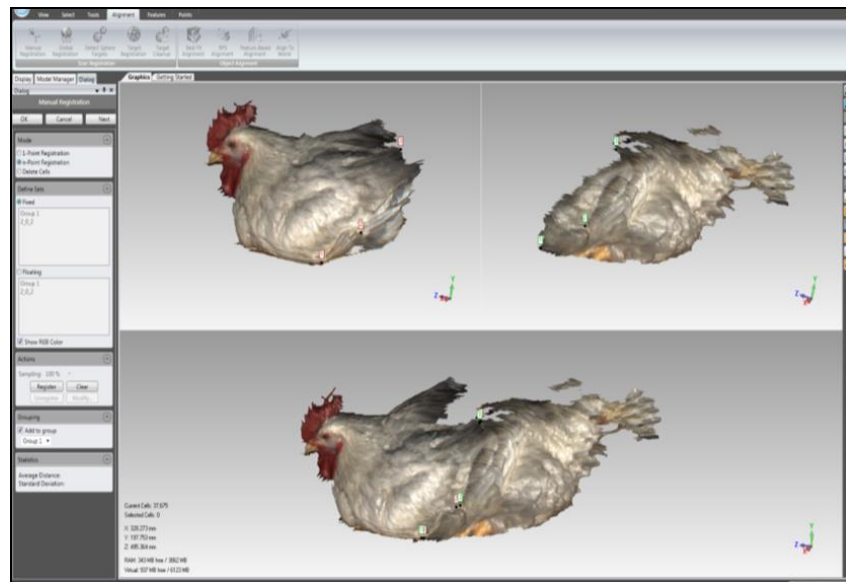


Figure 9 Image showing manual registration in process.



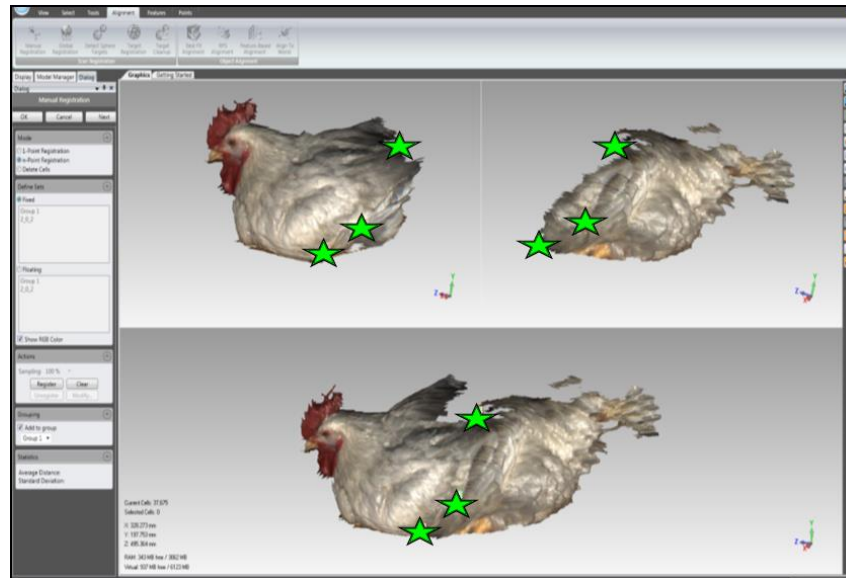


Figure 10 Image showing three overlapping points needed in manual registration.



Figure 11 Image showing the refined points that create a single object.

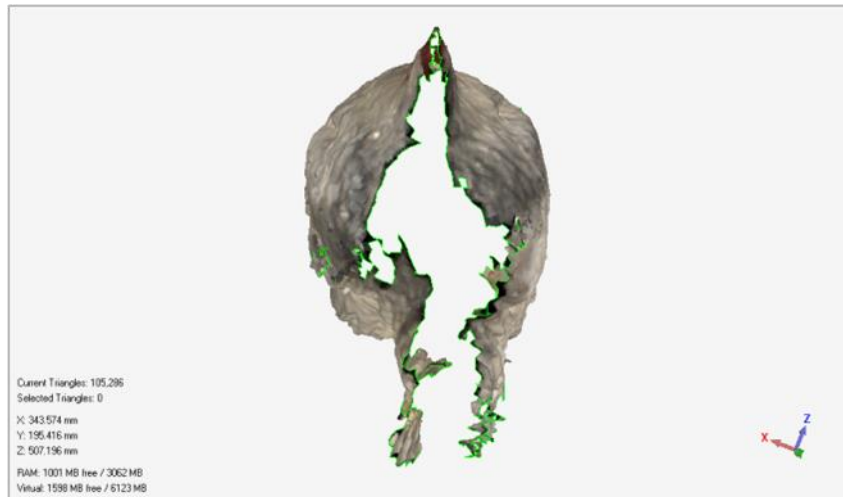


Figure 12 Image showing the points converted into a polygon surface that has been wrapped and is ready to be edited.

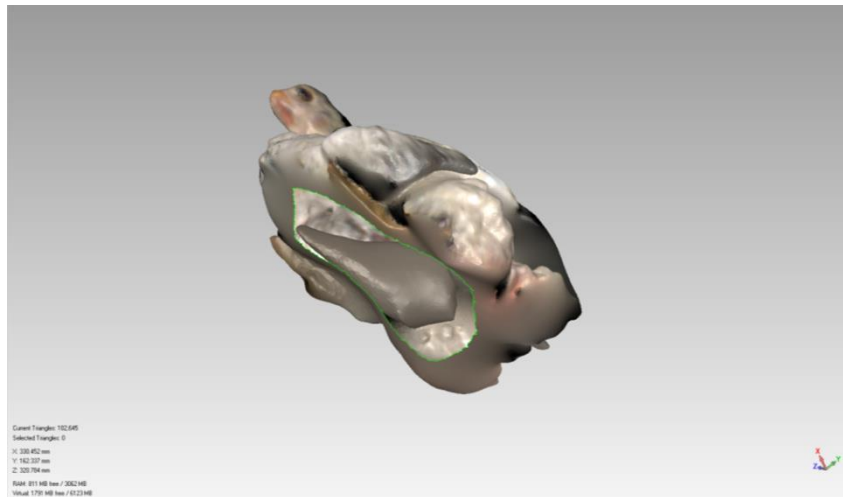


Figure 13 Image showing the importance of opening up the bottom of every model to make sure that the surface area and volume are not compromised.





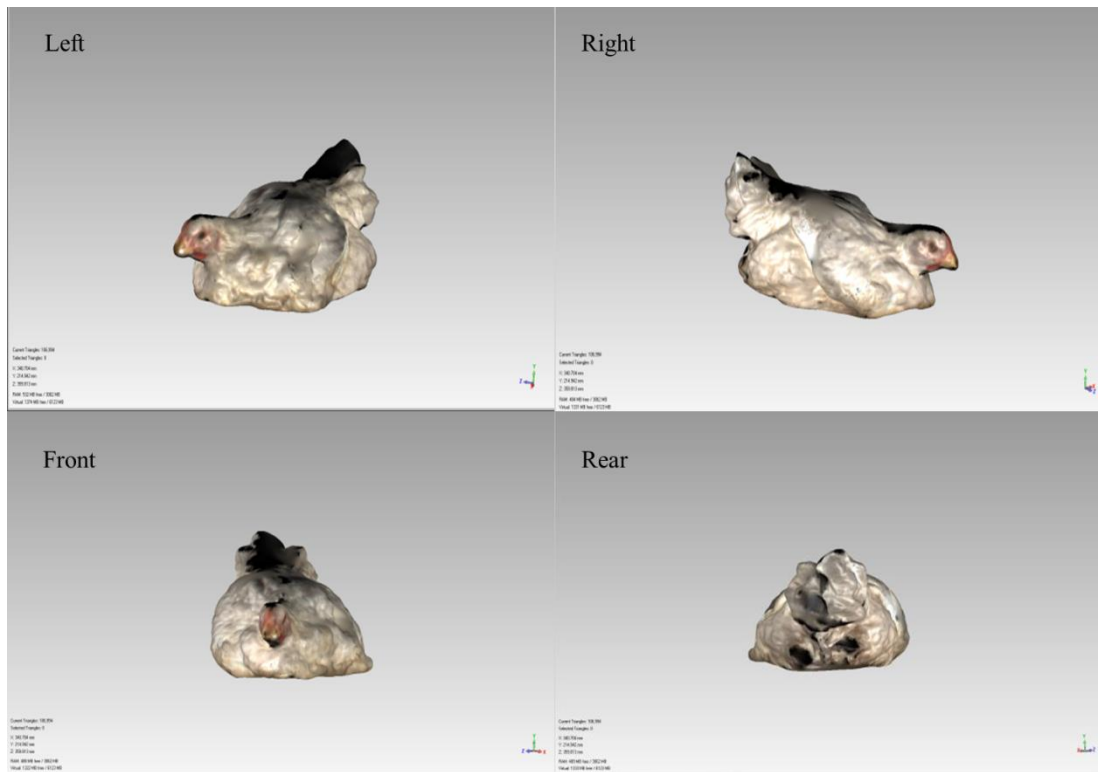


Figure 15 A finished female broiler model at 63 d.

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## RESULTS

Live broiler chickens were successfully scanned at 35, 49, 63 days of age with a commercially available 3D digitizer system. Figure 16 displays weight by age of both male and female broilers from 35-63 d of age. Good uniform weights were shown throughout all three measurements. However, issues arose with surface area (SA) measurements. Figure 17 shows surface area by weight by male and female broilers. These surface areas should be trending upwards with body weights. But as seen at 35 and 49 d SAs are highly variable. Better measurements were taken at 63 d of age. Figure 18 helps explain what we think may be happening. By looking at the male broiler on the left at 35 d, a lack of complete plumage created these irregular surfaces. So, that when the images are stitched together it causes more surface area to be measured compared to the female bird on the right at 63 d that had very little that needed to be filled in. Improvements can be made by installing a digitizer overhead to improve the model surface. Figure 19 shows volume (VOL) by weight of the growing broilers. The VOL trends are similar to the surface areas, because the volumes are calculated from the same surfaces. Again there is a lot of variability at 35 and 49 d of age. Although there are still issues with how the software calculates the surface areas from these broilers due to the variations in the feather plumage, figure 20 shows that we can still gather physical dimensions from the models. The dimensions are reasonable and can be used to update the ASABE Standard with the models that have already been created. Surface to Volume ratio was not calculated nor was a statistical analysis because of the issues experienced with surface area determination.

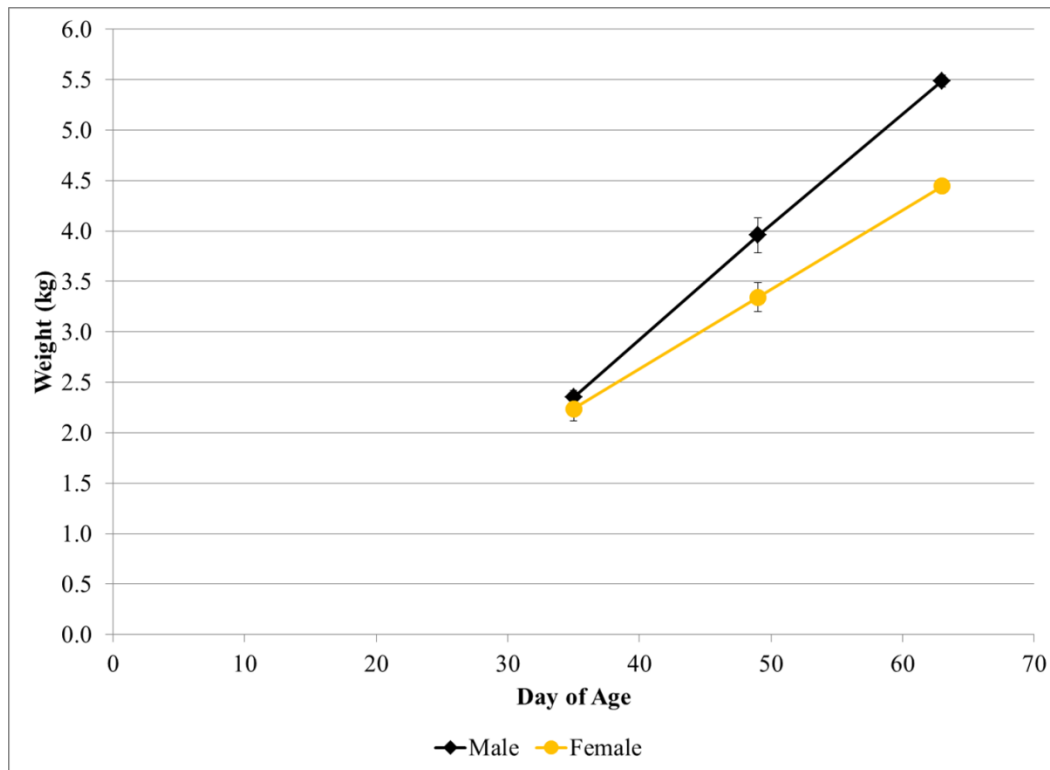


Figure 16 Graph of weight by day of age for male and female broiler birds.

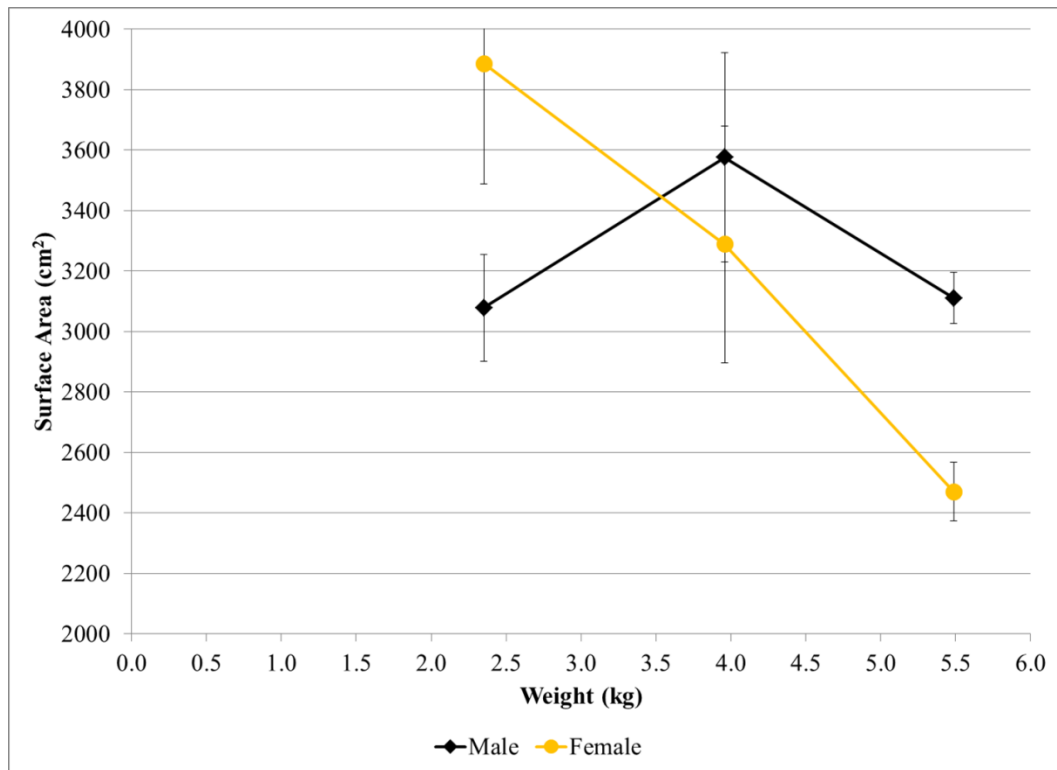


Figure 17 Graph of surface area and weight for both male and female birds.

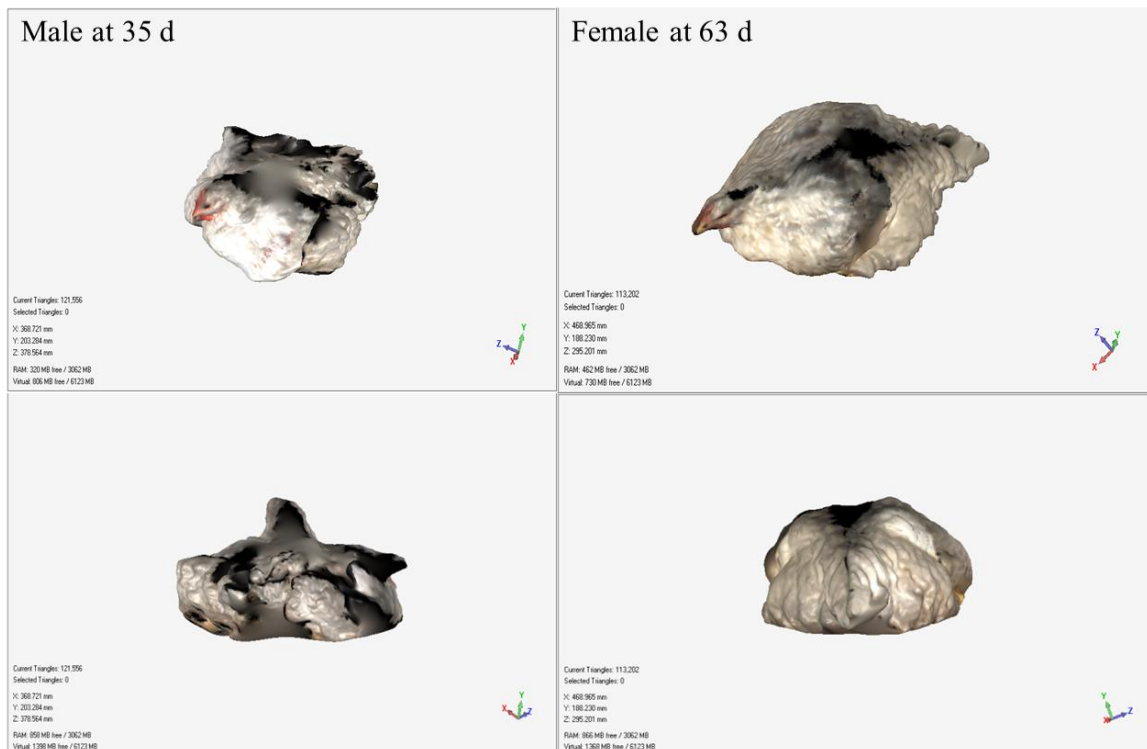


Figure 18 Illustration of model surface area issues

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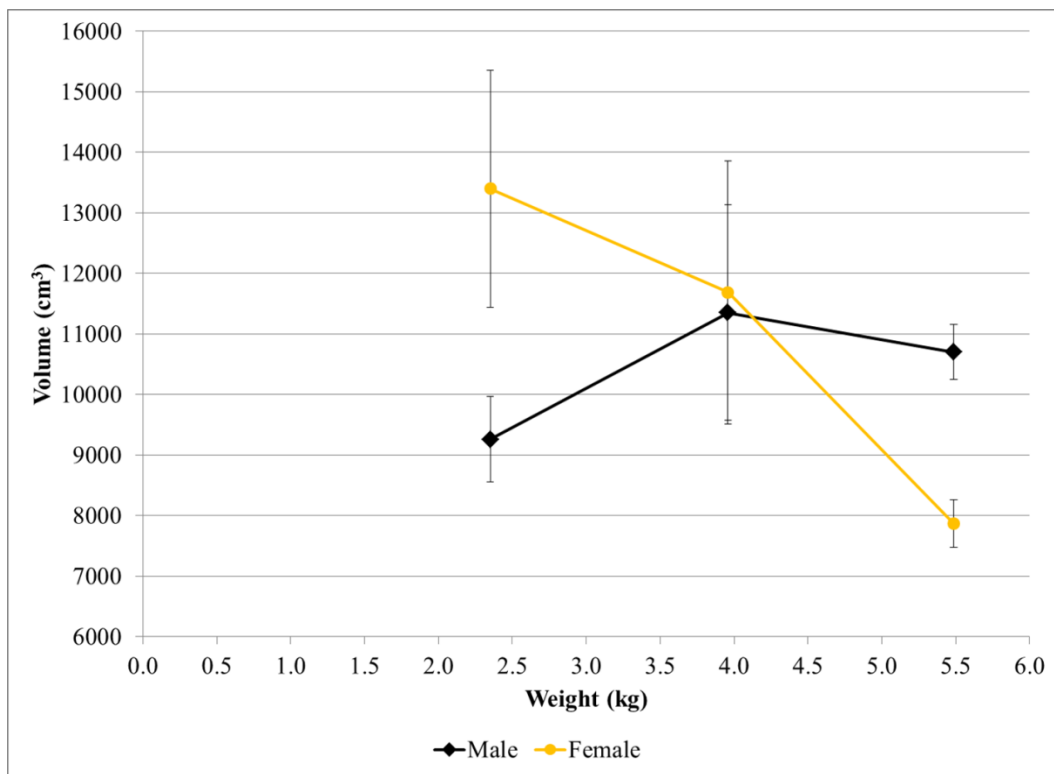


Figure 19 Graph of volume by weight of male and female broilers.

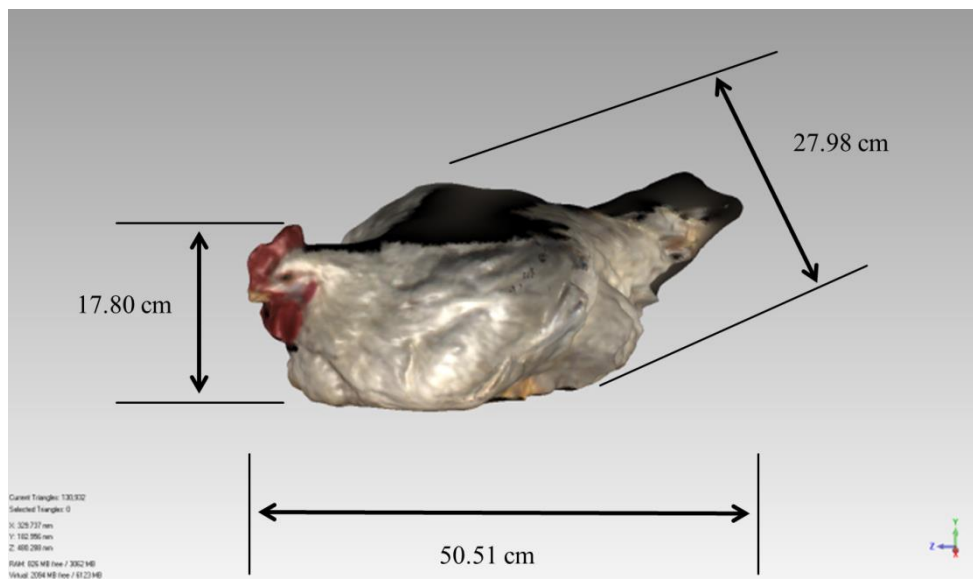


Figure 20 Physical dimensions can be gathered from each 3D model.

## **PRELIMINARY CONCLUSIONS**

Live broiler chickens were successfully scanned at 35, 49, 63 days of age with a commercially available 3D digitizer system. Adjustments were made to accommodate live broilers such as cameras angles and placement, light intensity, and bird movement. 3D surface models were successfully rendered however, issues arose with the calculation of surface area thus affecting volume and S/V ratio for both male and female birds. Models can currently be used to gather physical measurements but the study must be repeated to improve the measurements.

## **ACKNOWLEDGEMENTS**

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