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Providing Proteins to Belizean Residents Through Poultry Products

Ellis Freel
University of Arkansas, Fayetteville

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Abstract

Belize is a food insecure, developing country. Although Belize has plenty of nutritious food in-country, the exportation of that food to generate income contributed to a distribution issue of that nutritious food. More impoverished areas of Belize do not have access to nutritious food because of the lack of affordability and high export rates. Diets with a lack of food, or lack of balanced, nutritious food can negatively impact growth and cognitive development, especially in children. Poultry is one of the only products in Belize not able to be exported. Implementing poultry into Belizean diets would affordably alleviate food insecurity and contribute to more balanced, nutritious meals to bolster growth and cognitive development. The University of Arkansas partnered with St. Matthew's Anglican School in Pomona, Belize to implement a poultry complex to stock their school canteen with meat and eggs. Based on the school's population of 200 students and 100 faculty, and the need for both meat and eggs, background research suggested 100 broilers and 100 layers would be the target number of chickens. Two poultry houses (one for broilers, one for layers) were designed prior to arriving to Belize and then altered due to local availability of materials and management practices. A brief handbook was written to outline the steps taken to build the poultry complex at St. Matthew's Anglican School with the purpose of allowing other local schools to build the same type of complex to have access to affordable, nutritious protein. Follow-up communication has revealed successful meat and egg rearing for St. Matthew's school and integration of poultry rearing into school curriculum.

Introduction

Background and Need

Nearly 89.5 percent (116.7 million) of households in the United States were food secure throughout 2020, according to the United States Department of Agriculture (USDA) (USDA, 2021). Food secure means households had access, at all times, to enough food for an active, healthy life for all household members. This includes the right balance of food for nutritious meals. Contrarily, 10.5 percent (13.8 million) of U.S. households were food insecure at some time during 2020 (USDA, 2020). The Food and Agriculture Organization (FAO) of the United Nations defines food insecurity in a population as the lack of access to enough safe and nutritious food for normal growth and development (FAO, 2022). Globally, the United Nations estimates that between 720 and 811 million people faced hunger in 2020 (UN, 2021).

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Food insecurity comes in different severities, so the level of food insecurity is popularly measured based on the Food Insecurity Experience Scale (FIES), which asks questions about the availability of food and frequency of food consumption. The FIES has four main levels of food insecurity: uncertainty regarding ability to obtain food, compromising on food quality and variety, reducing food quantity or skipping meals, and no food for a day or more. There is a separate measurement for food security referred to as the four dimensions of food security, which attempts to determine the cause of food insecurity if food insecurity is present. The four dimensions of food security are availability, access, stability, and utilization. In 2016, the FAO reported a moderate or severe food insecurity for Belize at 28% and severe food insecurity at 9% based on the FIES measurement (Stevenson, 2021).

Belizean residents spend their money similarly to Americans, but the income level is much lower (Anonymous, 2018). After breaking down allocation, about BZ$7.92 or less is spent on food each day in Belize, which equates to about US$15.84 (Anonymous, 2018). Children are specifically vulnerable to undernourishment because children are reliant on what their parents can provide. Extensive research has outlined the long-term consequences of early-childhood malnourishment (Black, 2013). Significant consequences included increased vulnerability to disease, decreased cognitive, motor, and emotional development, decreased school performance and learning capacity, decreased adult stature, and decreased work capacity and productivity (Black, 2013). These compounding consequences are significantly reduced when children have consistent access to affordable, nutritious food. To analyze the reasons for insecurity, the dimensions of food security must be analyzed.

Availability of nutritious food in Belize is plentiful. Belize had a 100.02 food production index, as compared to the world average of 103.12 (USAID, 2021). The food production index is based on the sum of price-weighted quantities of different agricultural commodities produced after deductions of quantities used as seed and feed weighted in a similar manner. The commodities included are considered edible and contain nutrients, with coffee and tea being excluded because neither have any nutritional value. Therefore, Belize produces enough food to feed the country of Belize, but the utilization and access to the food is lacking. Belize imported 25.65% of their food and merchandise while 93.61% of exported goods was food (USAID, 2021). These numbers demonstrate Belize is exporting more food than importing, reducing the amount of food available to residents. The frequent exportation of food is estimated to be due to the decreased income level and the need for more money in Belize. This creates a cycle of exporting food in exchange for money without the extra money being spent on food for residents,

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but rather increased agricultural practices to keep up with exportation demands. The nutrition country profile written by FAO's Agriculture and Consumer Protection Department estimates that 25% of Belizean households live in poverty (FAO, 2022). Poverty could be attributed to Belize being prone to natural disasters and those natural disasters destroying areas of employment for Belizeans. Therefore, for Belize, much of the food insecurity originates from poverty and lack of diet variability rather than food availability.

Furthermore, a more recent study found that a contributing factor to food insecurity is lack of education (Stevenson, 2021). Lack of education leads to lack of employment, which also contributes to the high poverty rate in Belize. An analysis of agricultural policies in Belize reported approximately 23,000 people in Belize, which is one fifth of the employed population, were employed in farming and livestock production (Foster, 2017). The U.S. Agency for International Development reported that more than half of the children employed in Belize are employed in agriculture-related activities (USAID, 2021). Of all agricultural exports in Belize, poultry is the only major product that is not an export product (Foster, 2017). Belizeans need a sustainable, nutrient dense, and affordable food.

Problem Statement

Constructing and implementing a sustainable poultry house in Stann Creek, Belize would produce a non-exportable good to provide high-quality, affordable protein for families in the Stann Creek district. Chickens can provide protein in two different sources: eggs and meat. The meat and its derived products provide enough essential nutrients for satiation in higher quantities when compared with the common low-income diet of rice and beans (Marangoni, 2015). With a poultry house on school property, different math, science, and English curriculum can be

implemented in the school, and the farm can provide supplemental employment for people in the area.

Purpose Statement

The purpose of this study was to implement two sustainable poultry houses in the Stann Creek District Pomona, Belize for the St. Matthew's Anglican school to provide readily accessible, nutritious, affordable protein; to create a balanced diet; to employ people in the area; and to intertwine poultry curriculum into the school for experiential learning and education.

Project Objectives

The following objectives guided this project:

- Following the manual and conceptual plan for the poultry project created by another honors student, discern what materials are necessary for construction of the poultry house(s) in Stann Creek Belize, and whether those materials need to be acquired in country or brought from the United States.
- Implement and oversee construction of the poultry house(s) in accordance with sustainable poultry house processes in Stann Creek, Belize (methods and materials).
- Educate locals on how to properly grow both broilers and layers and safely harvest chickens as a protein source.

Definitions

Poikilothermic – unable to self-regulate body temperature

Dual Purpose – a single breed of chicken that can be raised for both meat and eggs

Broiler – chicken raised for meat

Layer – chicken raised for eggs

Canteen – cafeteria for St. Matthews Anglican School

Literature Review

Although Belize has a poultry association, there is little to no research available online about efficient practices for raising broilers or layers in Belize. An absence of documentation about raising poultry in Belize leaves gaps in literature and in practice for growing an affordable protein source. Therefore, success for constructing the poultry house in Stann Creek will be based on research conducted in the United States in conjunction with other records and resources for raising chickens in tropical environments. To adequately prepare for the steps of establishing a poultry house, the literature is categorized chronologically for what needs to be understood first before further steps can be implemented.

Malnutrition and Food Insecurity in Belize

The amount of nutritious food in Belize is enough to sustain the people in Belize. Belize had a 100.02 food production index, as compared to the world average of 103.12 (USAID, 2021). The food production index measures how much of the crop grown in the country is nutritious and usable. According to USAID, the food production index is based on the sum of price-weighted quantities of different agricultural commodities produced after deductions of quantities used as seed and feed weighted in a similar manner. The commodities included are considered edible and contain nutrients, with coffee and tea being excluded because neither have any nutritional value. Belize produces enough food to feed the country of Belize, but the utilization and access to the food is lacking. Belize imported 25.65% of their food and

merchandise while 93.61% of exported goods was food (USAID, 2021). These numbers demonstrate Belize is exporting more food than importing, reducing the amount of food available to residents. The nutrition country profile written by FAO's Agriculture and Consumer Protection Department estimates that 25% of Belizean households live in poverty (FAO, 2022). Poverty prevents people in Belize from purchasing enough food to feed whole families. Furthermore, a recent study found that a contributing factor to food insecurity is lack of education (Stevenson, 2021). Lack of education leads to lack of employment, which also contributes to the high poverty rate in Belize. Therefore, for Belize, much of the food insecurity originates from poverty and lack of diet variability rather than a lack of food. Of all agricultural exports in Belize, poultry is the only major product that is not an export product (Foster, 2017). Implementing poultry production in Belize will provide Belizeans with a necessary sustainable, nutrient dense, and affordable food. Establishing a poultry complex will also allow for employment experience and opportunities to learn how to grow chickens in a backyard flock if a family has the resources to do so.

Poultry Production in Belize

The Belize Poultry Association (BPA) was established on May 3, 1996 (BPA, 2012). The BPA represents the commercial sector of growing poultry in Belize. Commercial poultry production exists in three of the six districts in Belize. The other districts are more rural, so they have mainly backyard flocks to fulfill the demand for chicken in villages that are too far from town to maintain a regular inventory of chicken. Before commercialized poultry was established in Belize, Belize imported all poultry meats from the United States in the form of frozen thighs and breasts. Chicken is no longer imported, and all chicken consumed is from local sources in

Belize. Some turkey and duck are still imported from the United States, but chicken was the focus of this project (BPA, 2012).

In an agricultural policy review, of all agricultural exports in Belize, poultry is the only major product that is not an export product (Foster, 2017). This will grant higher access to chicken for the Belizean population and will incentivize biosecurity efforts and food safety to prevent sickness among the population of chickens and humans. The main concern that could destroy all efforts toward a poultry complex is disease. If the birds become infected with a disease, they will not produce protein effectively or will cease all production because their bodies will prioritize fighting off infection (Hargis, 2022). Backyard flocks in Belize will be the main source of pathogens due to inaccessibility to veterinarians and expense for vaccinations.

Housing Construction Considerations and Ventilation

Materials and design of the poultry houses must align with a sustainable, cost-effective system that will last long-term. Materials should be locally sourced to ensure no foreign pests or diseases are introduced, and for ease of transportation. If this is not possible, then materials may be shipped for the construction phase of the poultry houses. Production systems in large-scale commercial farms implement housing systems that enable complete control over the climate provided for the birds, however these houses are expensive to both build and operate, making them unreasonable for developing countries without significant support (Glatz & Pym, 2013). Constructing the houses with a tropical climate and minimal energy usage in mind yields a functional house based on the natural environment. The goal is to protect chickens from their natural enemies (Halpin & Ocock, 1911).

Materials for poultry houses are the same for any other simple structure designed for sheltering. Wood, concrete, tin, cinder blocks, nails, bolts, and chicken wire will be the main materials for the poultry house. Direct access to these materials in Belize locally would be ideal, however some materials may need to come from elsewhere. This poultry project aligns with the medium-scale commercial discussion in Glatz & Pym's (2013) article on management in developing countries. Most medium-scale commercial layer and chicken meat houses rely on natural airflow through the structure for ventilation (Spatz, 2022).

The design of the houses will be conducive to maintaining a proper environment for the birds. The roof will be the hardest to construct, but most are made of tin. A gable roof will be the coolest option, which is a prime consideration in the tropical environment of Belize (Halpin & Ocock, 1911). Utilization of chicken wire on the walls will allow for air to get in while keeping predators out. Since a fully insulated, walled house with complete darkness is not feasible, a house that allows for natural ventilation using open walls and wind is necessary. All doors should be raised six inches so that the bottom of the door clears the litter (Upton, 1920). A good floor must be dry and durable, with a good hard surface (Upton, 1920). A cooler, dry house can be more easily operated than an undesirable wet, damp house (Upton, 1920).

The chickens should have an ample amount of room to stretch their wings in the poultry house. If the chickens are placed in the house and their food and water is in the house, they are unlikely to venture outside of the house. The amount of square footage allotted for a chicken is measured in pounds per square foot. Chickens should be allotted about 7.5 lbs/sq ft (Espinosa, 2014). Since chickens grown for meat usually grow to about 7.5 pounds per bird, this can be simplified to a minimum of one square foot per bird, but the more room you can give them the better. Increasing the space between them lessens the transmission of disease, allows them to

move around more, enables them to reach the food and water easier, and helps the workers walk around and investigate birds easier (Hargis, 2022).

Biosecurity

Preserving the health of the chickens being grown is the most important factor in efficient, cost-effective production. Biosecurity means doing everything possible to prevent diseases from infecting the flock (USDA, 2014). In the US, chickens are vaccinated for infectious bronchitis, Marek's disease, and Newcastle disease in the hatchery. Infectious Coryza, Fowl Pox, Fowl Cholera, and other diseases can be vaccinated for at about three weeks of age if they pose a threat of infection (Hargis, 2022). All people encountering the birds, including workers and students, should exercise biosecurity protocols to minimize the risk of infection. Personal protective equipment is the main action for pathogen prevention. All people coming in direct contact with the flock should utilize personal protective equipment, which consists of a hair net, gloves, disposable coveralls, and booties to cover shoes. This will limit the number of pathogens that could be transmitted from body to bird. Before entering the house, people should step in disinfectant with booties on, ensuring that no wild fowl feces are on the bottoms of people's feet. A study conducted in Bangladesh revealed the most effective biosecurity practices to observe are movement of people, birds, other poultry, and animals into and out of the shed, cleaning of the shed, cleaning of the equipment, personal hygiene, use of disinfectants, waste management, and vaccinations (Rimi, 2017).

To minimize the risk of infections, the poultry house should exercise an all-in, all-out production method. This will allow down-time between flocks for sanitization, disinfection, and cleaning of all equipment. Down time is also important for the reduction of pathogens and natural fermentation of good bacteria in the litter. Pathogens decrease by a function of their

respective half-life, so the longer the downtime, the less pathogens that will be present when placing the next flock.

Biosecurity affects the placing of different types of flocks. Broilers may be more at-risk for obtaining a disease that layers are less likely to catch. Therefore, all chickens with different purposes should be separated by space. The space placed between the chickens will influence the design for the house. The two most concerning diseases that could potentially result in the eradication of the flock and all surrounding flocks are Highly Pathogenic Avian Influenza and Exotic New Castle Disease. Both are so virulent that the USDA requires that all imported birds are quarantined and tested for the viruses that cause these two diseases before those birds can enter the country (USDA, 2014).

Types of Chickens

Cost, needs, and resources of the Stann Creek district in Belize will dictate the types of birds the community can support. Breeders are worth much more than just broilers and layers because they are selectively bred to hatch chickens with preferred genetics to maximize products. There are two types of chickens in Belize, the Factory Chicken and the Local Chicken (Anonymous, 2010). The Factory Chicken in Belize are those that come from a commercial chicken supplier, such as the Belize Poultry Association. Those chickens are much more productive and are raised commercially. Factory Chickens are also known as Mennonite chickens. Local chickens are equivalent to backyard flocks. The difference is not in the nature of the chicken, but in the management style. Mennonite chickens are raised commercially with scientifically developed feeding, modern poultry housing, and under modern conditions. Contrarily, local chickens are raised casually in the traditional Mestizo style. There is also a distinction between Creole and Garifuna poultry management styles (Anonymous, 2014). Creole

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management style has much more emphasis on the poultry with the Creole following a much more intensive program. Creole management accepts raising poultry as a way of life. So much so that chickens are allowed to roam freely throughout the city, especially on the outskirts. The Garifuna management style is Laissez-Faire because the Garifuna culture does not place an emphasis on raising chickens. The owners change frequently, and no specific programs are followed. Even if modern poultry systems came into the Garifuna area, most households would likely not be able to afford the chicken for consumption. Those who live in cities in Belize have much less reliance on backyard poultry than those in rural areas (Mallia, 1999).

For the poultry house in Stann Creek, a mix of Mennonite and local raising styles is desired. The chickens will be more productive if they are raised Mennonite chickens with modern production management. However, a dual-purpose breed is not typically raised in a Mennonite style yet will provide the most flexibility and provides both eggs and meat as an available protein source with less space needed.

Equipment

Installation of modern poultry equipment is expensive because the automatic feeders must be accompanied by a feed mill, which can not be filled manually and requires an electronically controlled auger. This model is not feasible in developing countries like Belize, so a manual approach that allows for locals to gain employment experience will be preferred. Bell drinkers for water, bell feeders for feed, and shovels for moving litter will be the biggest equipment expense and the most important equipment necessary for chick viability. Square shovels in conjunction with large concrete flat brooms make manual litter cleanout easier. In developing countries, the optimum performance from birds is difficult to achieve due to less-than-optimal programs, including those for feed and water.

A manual feed program will be followed as closely as possible using a manual feeding system with bell feeders and human labor. A concern with bell drinkers is difficulty keeping the water clean and controlling the temperature of the water for the chicks at different life stages. Water quality is important for preventing growth of potential pathogenic organisms and increasing production potential (Watkins, 2010). When the flock is just looking generally sick, but not showing specific clinical signs, always check the water. Bacteria are often overlooked as a health threat (Watkins, 2010). Unsanitary water causes biofilms, which can protect pathogenic organisms, so cleaning and sanitizing the bell drinkers often is crucial to maintaining water quality (Watkins, 2010). Water quality is best when the pH level is between 6.5-7.5 (Watkins, 2010).

Enough bell feeders and drinkers must be purchased for the birds to ensure a proper amount of eating and drinking. Water and food should be plentiful in every part of the house. If the food and water is not introduced to the chicks right as they are placed, then the chickens will not eat or drink and will starve themselves to death (de Barros, 2021).

Monitoring

Chickens must be checked daily and monitored to catch any issues that may arise. When walking into the house, check the humidity, litter, and temperature. Then, stand there for a few minutes to let the birds calm down and watch for any abnormalities in behavior. Different clinical signs in the birds can emerge to indicate an issue or infection. Clinical signs in birds are the equivalent to symptoms in humans. Birds can get a runny nose, which will present as dirty patches on their shoulders where they have rubbed their mucus and dirt from the litter has stuck to their shoulders. Birds will also cough and sneeze. A bird's sneezing is called snicking. These are simple clinical signs of most viral pathogens found in poultry, but certain clinical signs may

indicate a more serious infection warranting a specific diagnosis. Treatment plans will be advised by the veterinarian and a lab sample with autopsy can confirm a diagnosis.

Aside from clinical signs for infection, the behavior of the birds can indicate possible temperature problems. Since chickens lack sweat glands, the chickens resort to sweating with their tongues by opening their mouths and panting. This action is called glular fluttering. All chicken behavior is adaptive. The chickens will respond to environmental stimuli to respond, find shelter, mate, and rear offspring, therefore, social gathering of the chickens can reveal specific location of temperature issues (Mauldin, 1991). If a certain part of the house is hot, then the birds tend to migrate to the cooler part of the house, lay out flat near the ground, and spread their wings. If a certain part of the house is too cool, then the birds will huddle together in the warmer part of the house.

Humidity in the house should remain around 70%. If the humidity is not in this range, the temperature is harder to control, the litter will get clumpy and hurt their feet, the air may become too dusty if the humidity is too low, and ammonia levels will not remain under control (Ellen et al. 2000). Square shovels in conjunction with large concrete flat brooms make manual litter cleanout easier.

If any birds are displaying signs of suffering, then they should be culled to prevent long-term suffering and to preserve animal welfare. Culling is quick and painless for the birds because the proper form is a cervical dislocation. Cervical dislocation severs the brain stem of the chicken, so the death may be agonal. An agonal death is when a chicken still moves around after being killed, and this is a normal nervous system response. The bird can not feel or respond to any outside stimuli, so the procedure is ethical (Aviagen, 2014).

Mortality disposal in a chicken house must be performed every day to ensure biosecurity and prevent cannibalism from other chickens. Each day, all carcasses must be removed and placed in a proper waste disposal area. If birds are not removed daily the carcasses decompose more and make disposal more difficult.

Bell drinkers and feeders should be checked at least twice daily, depending on the size of the bell drinkers and feeders. They should be refilled each time the birds are checked and should be cleaned when found empty. The amount of food and water consumed by the chickens should be calculated so that the Feed Conversion Ratio can be calculated at the end of each week.

Everything mentioned before should be recorded on sheets of paper. The mortality, food, water, pH of the water, relative humidity, temperature should all be recorded to be able to determine any changes in the production. A change in any of these could indicate an issue with the chickens and could warrant further investigation.

Property Signage

Signage and fences are implemented around all poultry complexes in the United States to prevent uninvited guest from coming in direct contact with the chickens. The reason for this is biosecurity. Not knowing who is coming in direct contact with the chickens risks the transmission of diseases because guests often do not exercise proper biosecurity protocols and may have been in contact with other wild birds that are vectors for disease.

Placing signs around the premises will help deter guests from entering the area and will raise awareness for the poultry house. A guest log should be placed outside the poultry complex for guests to sign. If the flock is infected, then the guests can be notified and questioned to figure out the source of the disease and prevent further transmission.

A material that is long-lasting will benefit the people of Belize best since they have little access to printers. Laminated signs will not last as long as a wood sign. However, wood rots and decays over time, and could be hard to read due to the single tone of the wood. A metal sign seems to be the solution with the option to color the sign and the only deterioration coming from rust. A galvanized metal sign will be rust resistant, easy to read, and will be cost-effective for a long period of time. Custom metal signs can be made with SmartSign, which has a high rating and has been referred by others.

Construction of a poultry house incorporates many people and many factors for maintaining a productive chicken. A proper foundation is the first thing the complex needs, then a well-constructed house followed by proper equipment, placed chicks, and monitoring the chicks, and advertisement for the house. Prioritizing these steps will keep costs down and create more protein available for consumption. Incorporating biosecurity into each piece of production and maintaining a proper shelter for the chickens are the most important factors for a healthy chicken.

Development Plan

Prevalence of food insecurity in Belize is due mainly to the high amount of exportation of available food supply. However, poultry is the one of the only agricultural products that is not exported, which makes poultry a solution for preventing exportation and increasing food availability (Foster, 2017). This project will help alleviate the food insecurity by establishing a high-quality, affordable protein that is satiating and nutrient-dense for Belizean residents. Poultry fits all the criteria and provides a solution not at risk of exportation, making poultry a reliable and sustainable source of food as well. Because there is only a foundation, the development will include budgeting, construction, acquiring equipment, placement of chicks, production cycle,

and then education. Educating Belizean residents to sustain the operation after our team leaves will determine the success and sustainability of the complex.

1. Determine the entire budget and cost allocations for the project.
    a. Since some grants are only allowed to be spent on certain items, there were different subsets of allocations from different monetary grants.
    b. The money not specific to certain items was factored into the total budget to be spent as needed.
2. Collect Information
    a. Information will be collected on construction materials, biosecurity protocols, sustainable waste removal and disposal, equipment, proper monitoring, and long-term signage. This information will be included in future steps of the development plan before implementation.
    b. Research confirmed the poultry production methods in the U.S. that were most effective in raising a productive chicken, however these methods must be adapted to the resources available in Belize.
    c. There are production manuals for small-flocks in Belize and for raising poultry in developing countries, but none that align specifically with commercial-sized poultry in a tropical area with limited resources. These are referenced to understand the two aspects of lack of resources and chickens in tropical climates, but these are combined to elicit an expectation of issues that may be encountered.
3. Design House and Placement

a. Following biosecurity protocols and factoring in the amount of people benefiting from the poultry house, a design will be drawn for the layout and construction of the poultry house. This will consider the area we have to work with and the amount of space each bird needs among themselves and between the differing flocks.
b. The type of chickens we want to house will be considered with respect to broilers, layers, breeders, or dual-purpose. For this project, we want to incorporate both sex dual purpose chickens that will both produce meat and eggs as protein sources.
c. 100 male broilers will be placed in one 200 square foot house and 100 female layers will be placed in another 200 square foot house. Both houses will be 10’ x 20’. Only the female layer house will have a run for the chickens to roam free range.

4. Determine Equipment Needs
    a. The bell drinkers and bell feeders were determined to be the best option for food and drink given the available resources.
    b. During the brooding period of the birds, about two weeks after hatching, the birds are poikilothermic. Cardboard will be placed into a circle as big as the area of a heat lamp as a brooder pen with the bell drinkers and feeders placed inside. The birds will be contained in this area until they can regulate their own body temperature.
    c. After the birds are old enough to regulate their own temperature of around 106 degrees Fahrenheit (41 degrees Celsius), the main concern is preventing heat

stress. Fans are needed to prevent heat stress and is coupled with insulation and sprinklers or cool cells to keep the birds cool.

5. Make a list
    a. After thinking about issues that could be encountered, a list will be compiled with the materials and equipment needed to construct and carry out at least the first production period.
    b. There will be multiple lists outlining when and where the different materials and equipment need to be purchased. There will be one for the items we will purchase locally in Belize and one for the items we need to bring from the United States.
    c. The cumulative list will be compared to the monetary allocations to ensure a proper amount of funding is available for all aspects of production. If there was not enough, we would look for more outside grants from other entities.
6. Source & Gather Materials
    a. From the list, all the materials will be priced and determined to be sourced in-country or foreign. The materials needed immediately to begin construction will be the first to be gathered, and the projects further out will be put on a timeline to gather materials later.
7. Create Timeline
    a. A timeline for generalized deadlines will be made to create goals for the team in Belize. This is to estimate when certain items need to be gathered and organized, and when the chickens need to be delivered after construction is complete and the equipment is set up for brooding.

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8. Construct the Poultry Houses
    a. The construction of the poultry houses will be the most labor-intensive and time-consuming portion of the project. The houses will need to be structurally sound to protect both humans and chickens, and last without significant repairs for a long period of time.
    b. If large beams, or significant construction needs to be performed there will be a local man present for reference and knowledge. Another difficult part of the construction that will require outside help is the pulley system for the sides of the poultry house. This will be a do-it-yourself project attempted with the help of the local construction reference.
    c. Cinder block walls are manageable on our own, but since the structure will need reinforcement for hurricanes, rebar and a concrete and pea gravel mix will need to be poured into the voids of the concrete.
    d. The roof will need to be reinforced with hurricane straps to enforce wind resistance, which has been incorporated in most structures since the 1960's. Gable roofs are most preferred in tropical countries due to high rainfall. The overhang should not be less than 3.5 feet to prevent entry of rainwater into the shed. Using metal sheeting for the roof and sides, thickness should be "0.0145 average thickness or better" when discussing thickness with the builder. This is consistent with the higher end of the 29-gauge thickness ranges (0.014-0.015 inches). The thickness can be measured with a set of digital calipers. Make sure an anticorrosion coating is applied to the metal. Brand does not really have an effect, but G90 galvanized coating is the minimum amount of

coating. G90 galvanized metal has a coating thickness of 0.90 oz per square foot total (both sides). Any less than a G90 will not yield good long-term protection and higher levels could be cost-prohibitive.

e. Light should be 7-8 feet above ground level after the heat lamp brooding period. Due to lack of reliable energy resources in developing countries, the lights for brooding should consist of regular heat lamps, and the other lights should be the best lights available. Chickens are produced best under a photoperiod of 20 hours light period and 4 hours dark period. Lights with a dimmer switch are ideal; however, due to unreliable electricity most developing countries just use natural light to illuminate the chicken house. Therefore, since electricity is unreliable, we will be dependent on natural light for the light photoperiods and night time for the dark photoperiods.

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9. Place Equipment and Chicks & Conduct Measurements

   a. After the poultry house is constructed and the equipment is prepared for brooding, the chicks will arrive at the complex and will be placed. Chicks can be sourced from Quality Poultry Hatchery, which provides both broiler and layer chicks directly in Belize City. Another option for sourcing is Cackle Hatchery and having the birds shipped to Dangriga. White Leghorns are dual-purpose birds that have heat-resistance in their genes. The cost for 100 male and 100 female leghorns sourced from Cackle Hatchery with the Marek's vaccine and delivered to Belize is $600.12 (U.S.).

   b. Chicks will reside on locally sourced litter and will immediately be presented with food and water in brooding pens to prevent starvation and maintain

regular body temperature. Chicken feed can be sourced from Reimers Feed Mill in Dangriga, and the cost will be offset by the $1,000 grant acquired by the previous honors student.

c. All water, temperature, humidity, and other measurements will be conducted before and after placement for adjustments.

10. Create Signage

a. Trespassers will be deterred with biosecurity signs that inform bystanders of the poultry complex. These signs must last for a long period of time due to lack of resources at the St. Matthews school in Belize. Biosecurity signs were customized by Ellis Freel and purchased online for $163.12 to be taken to Belize.

b. Record keeping is also a part of signage. A record of all possible measurements must be taken about birds while in production in the house. Prior production periods can be compared against more recent flocks to see if production is consistent or if adjustments need to be made to improve production. Record keeping logs are included in the St. Matthews broiler manual for this project and were designed by Emily Spatz, another honors student working on the Dangriga poultry project (Spatz, 2022).

c. Another record that must be kept is a guest log for people who enter and exit the complex. This eases the contact tracing process if the complex becomes infected with a disease.

11. Proper Disposal & Resale Possibilities

Commented [LSW6]: Record-keeping logs were included in the manual prepared by Emily. You might want to state and cite that. Technically, that is not a part of your development plan.

a. Determine a place for mortality disposal. The disposal spot should be far from the actual house for biosecurity purposes. The mortality disposal spot could attract beetles or other animals, which are vectors for disease and will interfere with biosecurity protocols.
b. If the whole house must be eradicated for Avian Influenza or Exotic Newcastle Disease, then in house composting will be utilized.
c. Can collect chicken manure to resell as fertilizer for other farms or gardens in Belize. Eggs can be sold if there are excess. Eggs can be kept without refrigeration for about two weeks after collection.
d. Profits should be used to reinvest in the project and purchase more chicks and supplies.

12. Educate Locals
    a. The sustainability of the complex will depend on the ability of the locals to effectively produce chicken. Education of the locals and students in Belize will ensure they know how to manage the poultry facility, and what to do in case an issue arises. The ministry of agriculture is a resource for the school if there are any questions or concerns.
13. Evaluate and Adjust
    a. During each step, unexpected consequences, beneficial or harmful, may arise that cause an adjustment to the timeline. This is anticipated because of the large scope of this project.
    b. The first production period will be carefully monitored to ensure the chickens are comfortable and that animal welfare is abided.

c. Records from previous flocks in Belize will be referenced to see what can be improved. If the chickens seem to be hot by presenting clinical signs of glular fluttering, then more sprinklers and fans may be placed on them to mitigate the issue.

Success for this project relies directly on the poultry management technique. If the birds are comfortable and free from stress, then the birds will perform well and serve their purpose of providing protein to the school children in Belize. Following the plan, and then adjusting to what is not working is the best way to create success for raising a poultry flock. Monitoring the chickens each day and providing a comfortable environment where the chickens are not worried and are being sustainably raised is the most important piece with the other details falling into place.

Design Process and Creative Works

Upon arrival and discussion with local Belizean residents, the plan for the poultry houses were altered drastically from the literature review and development plan. This was expected, as we did not know the availability of materials or special climate considerations for Belize. Using the literature review and development plan as research, we tailored the poultry houses to the Dangriga community and climate. Because of these new considerations, many of the previous honors student's plans were abandoned. The biggest construction change was elevating the entire blueprint two feet off of the ground to accommodate potential flooding. With this new requirement, we changed floor materials from concrete or wood to chicken wire, which enables the school to utilize droppings from the broiler and layer houses as fertilizer for nearby plants. Sustainability became a focus for the remainder of planning. During the first tour of the school property to decide where the poultry houses would be placed, the school principal expressed

concern with the use of wood because of termite issues. Wood was the most affordable and local material for construction of the poultry houses, so we asked other locals how to deter termites in the area. Multiple locals recommended painting burnt oil on the posts to deter termites, so that was implemented into the plan as well.

With the help and assistance of many community partners, two 200 square foot poultry houses and one 25 square foot holding pen were constructed at St. Matthew's Anglican School in Belize. One of the 200 square foot houses was a layer house, and the other 200 square foot house was a broiler house. Between the two houses, a pen where the layer hens can run around for increased welfare and foraging abilities was established. On the outskirts of the two connected layer and broiler houses, a small holding pen was constructed for new birds that arrived to be held for 2-3 weeks to prevent disease contamination. Around the outside of the entire poultry complex, a chain-link perimeter fence was constructed to increase biosecurity and prevent predators from entering the poultry complex. Pine, a local contractor from Dangriga, was the primary source of information for acquiring local materials. Pine helped calculate and source the number of necessary materials, as well as figure design mechanics for the functionality of the houses, pen, and perimeter fence. Differences in the development plan and finished product are due to access to local materials, equipment, and amendments made by Marvin Blades, the lead for the Minister of Agriculture for the Stann Creek District of Belize.

Marvin Blades gave tours of the complex to other schools in the area, and some want to replicate the poultry system from St. Matthews. A handbook with required materials, instructions, and biosecurity practices will be produced so other schools in Belize can have access to affordable, nutritious protein, to continue to help alleviate food insecurity.

Handbook

1. Choose Poultry Products

St. Matthews Anglican School expressed interest in both meat and egg products for the canteen to fight food insecurity. Broilers (chickens raised for meat) and layers (chickens raised for eggs) should never be raised together because they have different production cycles. Meat and eggs are both poultry products with high-quality and affordable protein availability.

2. Size

The size of the poultry complex depends on whether both meat and eggs are desired and how much space is available at the location. Thinking about the goals for the complex and how many people the products are designed to feed can aid in figuring out what size of a complex needs to be established. St. Matthews Anglican school has around 300 mouths to feed each day, so having enough chickens to supply meat and eggs for that many students and faculty determined the size of the complex. Each house was designed to hold 100 birds with two square feet of space per bird. Two square feet per bird is a generous allotment that will aid in higher animal welfare. In the 200 square foot houses, 100 birds can be cycled every 6-8 weeks for meat in one house and 100 birds will be in egg production in the other, which would provide about 90 eggs per day for the canteen.

3. Location

The poultry complex should be constructed on open, flat ground free from debris or overgrown trees. Wind could cause overgrown trees or debris to fall on the structure, damaging the infrastructure and potentially harming the chickens. Foundational support from the ground is imperative because the houses will have to be built two feet above the

surface to prevent chickens from drowning if a flood were to occur. Access to water, light, and a moisture-free storage building for feed is required.

4. Materials

Pine, the local contractor, listened to the vision for the poultry complex and helped plan the construction and materials for the project. All materials for this project were acquired from local hardware stores in the surrounding areas of Pomona, Belize. Most frequented was Hummingbird Distributors, which delivered the materials for free to St. Matthews School. Materials will vary depending on the project and team. A list of estimated materials for the two main poultry houses and accompanying pen and perimeter fence is below:

15 - 4 x 4 x 10 wood posts (12 for main chicken houses, 1 for holding house, 2 for pen)

25 - 2 x 10 lumber (stairs, nesting boxes,

50 - 2 x 4 lumber

15 - 12 ft sheets standard zinc roofing

2 - 150 ft rolls of thick gauge chicken wire

Screws and fasteners

Staples

25 metal fence posts (perimeter fence)

3 packages door hardware (2 main pens and holding house)

1 package gate hardware (pen)

2 lock hardware sets (egg doors)

1 gate (perimeter fence)

5. Construction

Pine is a local contractor in Dangriga, Belize who directed the team on how to build the poultry houses and fixed any issues that occurred during construction. Construction for all three houses took about 22 half-days of labor with a group of about 5-8 working on the houses at once. Construction would occur in the morning and run until lunch time. This can be expressed as around 88 hours of labor for the construction and set-up of two poultry houses, a pen, a perimeter fence, and a smaller holding house at St. Matthew's Anglican School. The first house constructed was the broiler house, but the layer house is slightly different to accommodate for egg doors and nesting boxes. Relevant pictures are placed beneath each respective step. The order for construction of the poultry complex is outlined below:

1. Dig four holes for 4 x 4 foundation posts in a 10 foot by 20-foot rectangle. Posts should be roughly 2 feet below ground, secured in concrete, and 10 feet above ground. Backfill the post holes with the dirt removed when digging the holes after the posts are placed and concrete is dry.

2. Drill 2 x 4 boards to the posts two feet above ground level to establish floor joist height. A piece of the 4 x 4 posts should be cut out to create a joint and make the 2 x 4s flush with the posts.

3. Drill 2 x 4 boards evenly spaced parallel with the shorter side of the house and flush with boards in step 2 to make floor joists. Make sure to run two of the floor joists 4 feet apart adjacent to the middle foundation post to create a walkway in the center of the houses.

4. Drill 2 x 4 boards around the perimeter of the top of the posts to connect the structure.
5. Cut a couple of inches off two of the posts to establish a slant for the pitch of the roof.
6. Drill six 2 x 4 boards evenly across the top as rafters for the roof.

7. Drill four 2 x 10s across the rafters to act as a place to screw the zinc roofing sheets for stability.

8. Screw zinc sheets to the rafters to create the roof. Leave a couple inches of overhang on all sides.

9. Cut 2 x 4s to run perpendicular to the two joists in the center of the house. Ensure the perpendicular boards are flush with floor joists. Use scrap wood to wedge between boards and create a tight fit if 2 x 4s are too short.

10. Staple two layers of chicken wire across the floor of the whole house, except where the runway exists. For all stapling tasks, stretch out the chicken wire as much as possible and staple. Do not step on already stapled wire or it will stretch out and not be able to hold birds.

11. Run 2 x 10s down the center on top of the floor joists for the walkway.
12. After all floor joists are in place and wire is stapled, use 2 x 4s to make wall studs flush with the perimeter floor joists that established the floor height. Place

diagonal 2 x 4s from the perimeter floor joists to the foundational posts in between studs to provide support to the house.

13. Staple two layers of chicken wire around all the walls using wall studs except where the door will go in front of the walkway.
14. Fill in any gaps at the top of the house between rafters and at the bottom so layer chickens won't be able to escape when in the run.

15. Build wooden doors:

    a. Create a rectangle with 2 x 4s that fits in the opening where the walkway runs.

    b. Use 2 x 4s to run horizontally across the middle for support.

        c. Staple one layer of chicken wire across the entire door.

16. Put handles, locks, and hinges and hardware on door and attach to house facing where the other house will be:

17. Build stairs from the ground to the height of the walkway. Three stairs were enough for the 2-foot elevated house.

18. Repeat steps 1 – 17 for a layer house but leave one 10-foot side open for nesting boxes and egg doors. The broiler and layer houses were 15 feet apart with the long sides facing each other.
19. Establish the run:
    a. Place 4 x 4 posts evenly between the houses on both sides.
    b. Run 2 x 4s across the top and bottom of posts to connect the fence except for in between two posts on one side to leave room for a gate.
    c. Staple one layer of chicken wire along the length of the run on the posts and the 2x4s except where the opening for the gate is.

d. Build a gate by making a rectangle out of 2 x 4s and running 2 x 4s diagonally from one corner to the other for support. Attach hinges, locks, and handles and install.

20. Seal the run by stapling two layers of chicken wire below the chicken houses between the elevated floor and the ground.
21. Build nesting boxes.
    a. Use 2 x 10s as a base and cut 2 x 10s into ten one-foot pieces.
    b. Place one-foot pieces one foot apart and drill vertically onto the base board.
    c. Stack another 2 x 10 on top of the vertical 1 foot 2 x 10 boards.
    d. Repeat a-c until desired height of nesting boxes are reached.
    e. Place nesting boxes inside of the layer house on the 10-foot side that is open.

f. On the inside of the house, drill triangles to the sides of the nesting boxes to make a perch for the birds to access the boxes.

22. Build a roost:

a. Using scrap wood, cut two strips to run diagonally from the roof of the house to the floor joists in the layer house.

b. Screw thin boards perpendicular to the diagonal boards to create a ladder shape for laying hens to roost on.

23. Build egg doors:

a. Build two rectangles out of 2 x 4s that are two-thirds of the height and half width of the 10-foot side of the house.

b. Drill 2 x 10 boards as slats on top of the 2 x 4 rectangle.

c. Drill doors on the house using hinges and install locks on the egg doors.

24. Run electricity to the house with one light bulb, one light switch, and two outlets in each house. The light should be placed in the center of the house above the walkway for easy access. Outlets allow for brooding lamps when the chicks are young, and light is for human use when it is dark outside.
25. If needed, add a slanted roof extension to keep birds out of the rain when extreme winds and rain comes.

26. Build holding pen:
    a. Dig four post holes for 4 x 4 posts in a 5-foot by 5-foot square. Posts should be roughly 2 feet below ground and 7 feet out of the ground.
    b. Drill 2 x 4s 2 feet above ground level on the perimeter of the posts. There should be a cut made in the 4 x 4 posts at this level to create a joint for support.
    c. Drill 2 x 4s on top of the 4 x 4 posts to connect the structure.

d. Cut a couple of inches off two of the posts to establish a slant for the pitch of the roof.

e. Run three rafters evenly across the top of the house. Two should fall on the ends and one in the middle.

f. Run 2 floor joists evenly in the same direction as the rafters.

27. Build a perimeter fence:
    a. Dig holes for metal chain-link poles and pour concrete to stabilize poles.
    b. Ensure poles are perpendicular to the ground by measuring with a level before concrete is dry.
    c. After the concrete is dry, wrap chain-link fencing around posts and secure with metal ties except where the chain-link gate should be placed.
    d. Install chain-link gate.
28. Walk the outskirts of each piece of construction to ensure there are no gaps or holes the chickens can escape. Fill gaps as appropriate.
29. In Belize, termites were a pest of concern for the wood. Burned motor oil was painted on each post touching the ground to deter termites.
30. Hang biosecurity signage to keep unauthorized visitors away from the complex to minimize disease exposure.

An aerial blueprint of the poultry complex is provided in Figure 1 below with some essential measurements.

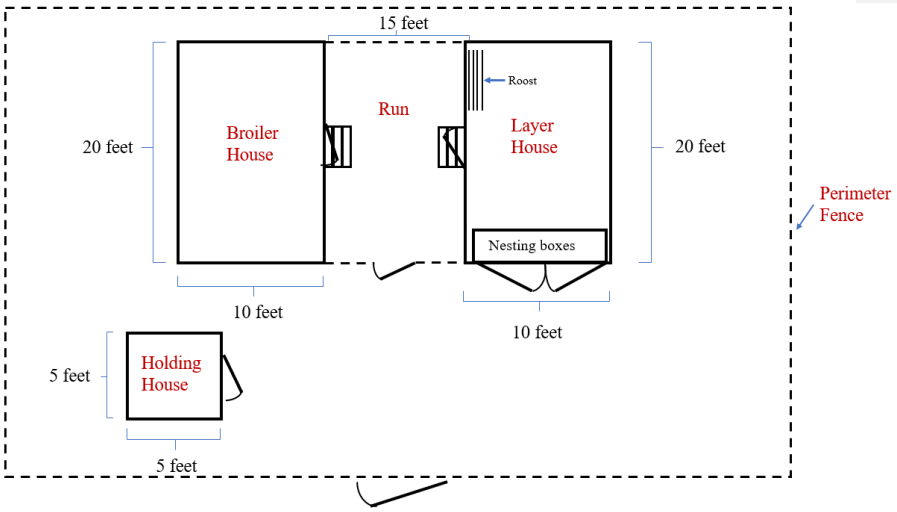

Figure 1. Aerial blueprint of poultry complex. Dashed lines represent fences.

A side blueprint of one of the poultry houses from the long side is in Figure 2 Below. below to illustrate the height of the house and the stilts, as well as how many beams and posts were needed for house.

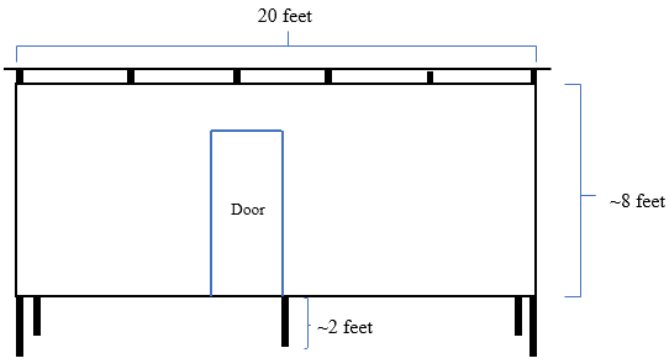

Figure 2. Side view of single large poultry house.

Figure 4. Entire poultry complex except chain link perimeter fence and door on holding pen.

6. Equipment

Equipment for the birds was sourced from Reimer's Feed Mill in Dangriga, Belize. Reimer's has an extensive catalog of items related to animals and pets. A list of equipment purchased for the chickens is below:

3 - 50-gallon stock tanks

5 small feeders

5 small waterers

10 big waterers

10 big feeders

2 feed scoops

4 light bulbs

2 bags of starter feed

Chain and hooks to hang feeders and waterers

The house should be completely sanitary with all equipment set up prior to the bird placement. Failure to prepare equipment could lead to diseases, which can cause lower production and flock issues.

As chicks, the birds are too small to run inside the houses, so 50-gallon stock tanks were purchased for the brooding phase. During brooding phase, the environment and temperature around the birds is critical to survival and future production potential. Feed and water should be immediately available to the chickens to minimize stress and prevent starve out. Starve out occurs when chicks refuse to eat and drink and end up starving themselves to death.

Figure 4. Chicks in 50-gallon stock tanks for the brooding phase.

7. Source Birds

Fifty-two birds were initially purchased from Wilhelm Dawson for BZE$200 (USD$100). Three University of Arkansas volunteers attempted sexing the chickens using the fast-feathering technique because the team was not trained to vent sex. The day-old chicks were sexed based on the length of their feathers. Longer feathers meant the chickens were females, and shorter feathers indicated males. The goal was to put only females in the layer house and males and females can be in the broiler house.

Guidance from Marvin Blades from the Ministry of Agriculture included vaccinating the chicks for Newcastle disease. Newcastle vaccination was acquired from the Ministry of Agriculture and delivered to birds after sexing via eye drops.

Local chickens are the best option for stocking any poultry complex because they will be bred to handle the specific geographical environment and food options. Importing chicks for placement can most notably create problems with heat stress, but also problems with nutrition. There is also a significantly lower cost associated with acquiring local chickens rather than purchasing and shipping chickens from elsewhere.

8. Biosecurity

Biosecurity should be top priority for the poultry houses. When biosecurity is compromised, flock performance decreases and the flock is at risk for termination. Ideally, everyone who comes near the birds shouldn't be exposed to any avian species or waterfowl 72 hours prior to contact. However, with St. Matthews implementing chicken production into the curriculum and some students having backyard flocks, this expectation is unreasonable.

To ensure the safety of the chickens, a simple bleach and water mixture should be prepared and placed in a footbath at the entrance of the complex. This mixture kills pathogens that can potentially be spread to the birds that may be on student or faculty footwear.

The holding pen was created as a biosecurity measure for when birds are donated to the complex. Donated birds should be housed in the holding pen for two to three weeks. During the two-to-three-week period, the birds should be monitored for any signs of disease. If the birds are diseased, do not introduce them to their respective flocks (broilers or layers). Diseased birds should be processed immediately (if they are of age) or humanely culled. If birds are not diseased, the birds should be introduced into the main flocks if they are the same age as that flock, or can be raised separately from the flock until processed.

9. Sustainability

Before building the infrastructure of the flock, knowing how the houses will continue to stay in production physically and financially is important. Birds, feed, and maintenance cost money, so knowing there are resources and monetary allocations available for maintaining the poultry houses is important. St. Matthews had a research grant from Emily Spatz for feed, and monetary allocations in the school budget, as well as support from the University of Arkansas for future use.

Conclusions and Discussion

Protein in the form of meat and eggs have been harvested, collected, and incorporated into the canteen at St. Matthew's Anglican school. This meets the purpose and objectives of building the poultry houses, training staff to care for and harvest chickens, and ultimately

alleviating food insecurity in Belize through poultry products. Broilers are being processed every 6-8 weeks and 90-100 eggs are being collected each day. The complex follows an all-in, all-out production cycle. August 25th, 2023 was the first date for chickens to be slaughtered, processed, and put in the freezer for the canteen. January 19th, 2023 was the first day eggs were collected from the nesting boxes and used in the canteen.

Future trips will monitor the wear and tear of the poultry houses, health of the chickens, and sustainability of the complex overall. St. Matthew's School administrators want to fund a hatchery for their next project so they can brood their own chicks for the broiler house instead of purchasing chicks from a supplier. Following the handbook, other schools in the surrounding areas of St. Matthew's School can implement their own poultry houses to further decrease food insecurity in impoverished areas of Belize. As discussed previously, implementing protein into diets provides essential nutrients for bolstering growth, cognitive development, and overall well-being.

The actual results of the project exceeded the original anticipated results. The three anticipated results included providing experience for future potential jobs, providing an affordable, nutrient dense protein, and establishing one poultry house at St. Matthew's school in Belize. These were met, but additional results include increased relationships between Belizean partnerships and the University of Arkansas, the potential for the school to sell meat or eggs for income to purchase more feed, implementing poultry care into school curriculum, having other schools interested in establishing poultry houses, and three houses being established on site at St. Matthews instead of only one.

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