

The Economic Viability of Alternative Rabbit and Tilapia Feed in Puerto Rico



Juan Torres Betancur

Craig Teed

Daniel Youkana

The Economic Viability of Alternative Rabbit and Tilapia Feed in Puerto Rico

An Interactive Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
degree of Bachelor of Science



By:
Juan Torres Betancur
Craig Teed
Daniel Youkana



Submission Date: December 18, 2014

Report Submitted to:

Joylin Guzmán
Principal Researcher and Investigator of Alternative Forage
AgroInnova

Ana Rodríguez
Special Assistant to the Mayor of Caguas, Puerto Rico
Municipality of Caguas

Professor Tina-Marie Ranalli
Adjunct Teaching Professor, Humanities and Arts
Worcester Polytechnic Institute

Professor Lauren Mathews
Associate Professor, Biology and Biotechnology
Worcester Polytechnic Institute

This report is representative of the work produced by the aforementioned undergraduate students, and submitted to the faculty of WPI as evidence of a degree requirement. WPI publishes these reports on its web site without editorial or peer review. For more information about the IQP and MQP projects program at WPI, refer to <http://www.wpi.edu/Academics/Projects>.

ABSTRACT

Our project goal was to aid AgroInnova in efforts to increase local food production from rabbit and tilapia rearing in Puerto Rico. We obtained knowledge on effective local farming strategies and alternative plant options in Puerto Rico. We then developed our feed prototypes to be nutritionally equivalent to commercial feed options. Next, we evaluated the economic viability of our feed prototypes and compared the unit cost of the commercial and alternative options. We then developed testing strategies that could be performed to determine the feed efficiency of our prototypes compared to commercial feed. Lastly, we created outreach materials to enable AgroInnova to promote a continued focus on alternative feeds and other economically sensible farming strategies.

ACKNOWLEDGEMENTS

We would like to recognize the following individuals who helped us complete our project to the best of our abilities. The hospitality and support we received from all parties was greatly appreciated. We know that without the help of all the following individuals we would not have been able to reach the level of success that we did.

Thank you to our sponsor, AgroInnova, for the opportunity to work alongside company employees and utilize resources that greatly assisted us throughout the process. We would like to thank our liaisons, Joylin Guzmán and Ana Rodríguez, for their availability and willingness to guide us whenever we needed it.

We also greatly appreciated the time and assistance provided to us by various local farmers. Roberto Delgado, Edgardo Ramírez, and Michael McGee provided us with insight into their business ventures and farming strategies, which proved invaluable for our project. Local experts Doctor Yamil Quijano and Patrick Reyes also provided us with pertinent knowledge on alternative feed and factors to consider when determining the economic viability of farming practices.

In addition to thanking those from Puerto Rico who helped us achieve our goal, we would like to thank several members of the Worcester Polytechnic Institute community. We would like to thank our advisors, Professor Tina-Marie Ranalli and Professor Lauren Mathews, for their continued support during both our proposal phase and project phase. We would like to extend our gratitude to our ID2050 professor, Professor Stephen McCauley, for his help in our proposal phase as we developed our project. Lastly, we would like to thank Worcester Polytechnic Institute for making this experience possible.

EXECUTIVE SUMMARY

Puerto Rico is heavily reliant on importation for food. Various sources have confirmed this, publishing that up to 85% of the island's food supply is currently imported (Latin American Herald Tribune, 2014). Importation dependence can result in a weakened economy, higher unemployment rates, fewer jobs, higher poverty rate, and other factors. This problem can be traced back to the steady decline of the agricultural sector in Puerto Rico during the late 20th century. Over the past few decades, there have been many factors that have contributed to the weakness and slow development of the rabbit and tilapia industries in Puerto Rico relative to other locations around the world. One of the main driving forces was the apparent lack of profitability of the industry based on the need to import feed for the animals, which raised the farming expenses, particularly the cost of animal feed. As a result, the cost of locally grown meat products rose and cheaper imports were utilized.

Rabbit and tilapia meat are both healthful and palatable sources of lean protein for human consumption. Both species are known for being easily farmed in multiple dimensions including the minimal prior experience needed for farmers to start a business and the capability of developing the industries in places with limited land (J. Guzmán, personal communication). The nutritional requirements for these two herbivores are well known, but the same cannot be said for the nutritional composition of many kinds of forage that are found in Puerto Rico.

Our project goal was to aid AgroInnova, our sponsor, in efforts to increase local food production from rabbit and tilapia rearing in Puerto Rico. We explored options for increasing the profitability of rabbit and tilapia farming in Puerto Rico and provided strategies and resources that could further improve the growth potential of these industries. We worked with AgroInnova for seven weeks, and we planned to accomplish our goal by completing several objectives.

We began our project by acquiring knowledge from rabbit and tilapia farmers, as well as experts in the field of alternative forage. The interviews we performed and the data we recorded from our visits to farms aided us in the development of our alternative feed options and allowed us to fully explore cost-efficient farming strategies that are currently being utilized by farmers. From aquaponics to the utilization of recycled materials, we learned that there are farmers on the island who utilize strategies to make their business more cost-effective and self-sustainable. Once we gathered knowledge on this subject from various farmers in Puerto Rico, we needed to employ this knowledge to develop cost-effective feeds containing alternative plant ingredients

and to assist AgroInnova in promoting further growth of these industries.

We used background research we performed and the insight we gained from local experts to generate several theoretical feed prototypes that contained alternative plant ingredients. These prototypes were created to match the nutritional content of the most popular commercial feeds in Puerto Rico (J. Guzmán, personal communication). The alternative tilapia feed prototypes were designed with varying levels of protein to meet the requirements of the different life stages, while the rabbit feed prototype was created with 17% protein content by mass to match the provided nutrition of the popular commercial brand on the island (*Federación*). Each of our rabbit feed prototypes included the following, in varying percentages: *Morus alba*, *Pennisetum purpureum*, *Pueraria lobata*, *Moringa oleifera*, and *Federación* commercial feed. Each of our tilapia feed prototypes included some of the following in different percentages: *Morus alba*, *Lemna minor*, *Azolla caroliniana*, *Mid-South 36% Fish Food*, and *Rise Floating Fish Diet*. After creating the prototypes in AgroInnova's facility in Caguas with the outlined ingredients, we aimed to support the economic sensibility of our alternative feed prototypes.

Based on information provided to our team by both tilapia and rabbit farmers, we were informed that animal feed is accountable for 50-80% of farming expenses (R. Delgado and M. McGee, personal communication). By applying the knowledge and data we previously gathered, we produced economic viability reports for creating alternative feed. We projected that our feed prototypes would be less expensive per kilogram by creating an economic viability report that analyzed all of the expenses that would be involved in the production of the feeds by farmers to be used on their own farms. Specifically, one of our rabbit feed prototypes was projected to save almost 30% when compared to the unit price of the commercial option that was equivalent in nutritional content.

Commercial feeds for tilapia and rabbits have a feed-efficiency ratio of 2:1. This means that for every 2 kilograms of feed consumed by the animals, 1 kilogram of salable meat is produced. We quantified this through a report provided to us by Roberto Delgado, a rabbit farmer that projected how much feed would be consumed in kilograms, based on the number of rabbits reared. Michael McGee, a tilapia farmer, also reported that this feed-efficiency ratio was consistent with the commercial feed for tilapia. We created guidelines for experimental testing of our alternative feed prototypes that would yield results to determine the feed-efficiency ratio. Our purpose for doing this was to have another mode of comparing the economic viability of

alternative feed options relative to the commercial feeds. Based on our background research and knowledge gathered from experts, we expect that our alternative feeds will have efficiency ratios that are comparable to those of commercial feeds, providing additional support to the case for its economic feasibility.

In order to promote the concept of alternative feeds and other farming strategies that could save farmers money and increase the profitability of rabbit and tilapia farming, we created outreach materials for AgroInnova to utilize after we left the island. We created several modes of outreach to reach the largest portion of the target population possible. We created a video advertisement for AgroInnova to upload to the company's Facebook page. Although the page has over 1,400 "likes", which would make the information visible to many people, we discovered that fewer than 6% of farmers use the internet for their businesses (National Agricultural Statistics Service, 2007). It was for this reason that we choose not to rely solely on the internet for outreach. We created the script for a radio commercial to advertise AgroInnova's workshops. Finally, we created pamphlets to send to farmers whom might not have previously known about AgroInnova.

We also created materials for a workshop that AgroInnova will provide for farmers interested in alternative feeds and other financially-sensible farming strategies. We developed a PowerPoint presentation outlining the concepts of alternative feeds and economically-sensible farming strategies. This will be used as the primary tool to lead the workshops to help farmers become more informed on ways they can grow their business and save money. We also created handouts to serve as a way for the farmers to be able to take important information home. We created evaluation forms for the leader of the workshop to hand out to the participants before and after the workshop. The feedback provided from these evaluations will allow AgroInnova to continue to adapt and improve the workshop to meet the needs of farmers and more effectively promote the strengthening of the rabbit and tilapia industries on the island.

AUTHORSHIP PAGE

This project involved equal participation and contribution from all members of the team: Juan Torres Betancur, Craig Teed, and Daniel Youkana. We worked together to write and edit each section of the paper, and agree that this project was completed through teamwork.

TABLE OF CONTENTS

ABSTRACT	III
ACKNOWLEDGEMENTS	IV
EXECUTIVE SUMMARY	V
AUTHORSHIP PAGE	VIII
LIST OF FIGURES	XI
LIST OF TABLES	XII
1.0 INTRODUCTION	1
2.0 BACKGROUND	3
2.1 AGRICULTURAL HISTORY OF PUERTO RICO	3
2.1.1 <i>Agricultural development before 1960</i>	3
2.1.2 <i>Agricultural development since 1960</i>	4
2.2 CHALLENGES TO AGRICULTURAL DEVELOPMENT IN PUERTO RICO	6
2.2.1 <i>Poverty</i>	6
2.2.2 <i>Physical environment</i>	7
2.2.3 <i>Rabbit and tilapia meat industries</i>	7
2.3 ALTERNATIVE PLANTS AS COMPONENTS OF ANIMAL FEED	8
2.4 ALTERNATIVE ANIMAL FEED AND FEED REQUIREMENTS	13
2.4.1 <i>Nutritional requirements for rabbits and tilapia</i>	13
2.4.2 <i>Case Studies Outside of Puerto Rico</i>	16
2.4.3 <i>Case studies in Puerto Rico</i>	19
2.5 STRATEGIES FOR AGRICULTURAL OUTREACH	19
2.5.1 <i>Agricultural extension</i>	20
2.5.2 <i>AgroInnova: a business incubator of Puerto Rico</i>	22
3.0 METHODOLOGY	25
3.1 OBJECTIVE 1: ACQUIRE KNOWLEDGE FROM FARMERS AND LOCAL EXPERTS	26
3.2 DEVELOP THE FORMULATIONS AND COORDINATE TESTING OF FEED	30
3.2.1 <i>Collecting information on the biochemical composition of the commercial rabbit and tilapia feed</i>	30
3.2.2 <i>Analyze economic viability</i>	32
3.2.3 <i>Create the feed formulations at the AgroInnova facility in Caguas</i>	34
3.2.4 <i>Farmer feedback on prototypes</i>	36
3.2.5 <i>Develop a plan for future experimental testing of the animal feed</i>	37
3.3 OBJECTIVE 3: DEVELOP AN OUTREACH PROGRAM FOR AGROINNOVA TO EMPLOY	38
4.0 RESULTS AND DISCUSSION	42
4.1 KNOWLEDGE ACQUIRED FROM FARMERS AND LOCAL EXPERTS.....	42
4.2 FEED FORMULATIONS AND STRATEGIES FOR EXPERIMENTAL TESTING OF FEED.....	46
4.2.1 <i>Analysis of biochemical testing results and development of feed prototypes</i>	47
4.2.2 <i>Template for economic viability</i>	50
4.2.3 <i>Creation of feed prototypes at AgroInnova facility in Caguas</i>	56
4.2.4 <i>Farmer feedback on feed prototypes</i>	57

4.2.5 <i>Plan for future experimental testing of feed prototypes</i>	58
4.3 DEVELOPMENT OF OUTREACH PROGRAM FOR AGROINNOVA TO UTILIZE	63
5.0 RECOMMENDATIONS AND CONCLUSION	86
5.1 RECOMMENDATIONS FOR RABBIT AND TILAPIA FARMERS.....	86
5.2 RECOMMENDATIONS FOR OUTREACH PROGRAM	89
5.3 RECOMMENDATIONS FOR FURTHER RESEARCH	91
5.4 CONCLUSION.....	93
REFERENCES.....	95
APPENDIX A: ROBERTO DELGADO INTERVIEW GUIDE.....	104
APPENDIX B: EDGARDO RAMÍREZ INTERVIEW QUESTIONS.....	105
APPENDIX C: MICHAEL MCGEE INTERVIEW QUESTIONS.....	107
APPENDIX D: DOCTOR YAMIL QUIJANO INTERVIEW GUIDE	109
APPENDIX E: JOYLIN GUZMÁN INTERVIEW QUESTIONS.....	111
APPENDIX F: ROBERTO DELGADO, SURVEY RESPONSES	112
APPENDIX G: EDGARDO RAMÍREZ INTERVIEW TRANSCRIPT	114
APPENDIX H: TRANSCRIPT FOR MICHAEL MCGEE INTERVIEW.....	120
APPENDIX I: TRANSCRIPT FOR JOYLIN GUZMÁN INTERVIEW	131
APPENDIX J: RABBIT TESTING, RECORDING TEMPLATE	136
APPENDIX K: TILAPIA TESTING, RECORDING TEMPLATE	137
APPENDIX L: FINANCIAL STRATEGIES FOR TILAPIA FARMS POWERPOINT	138
APPENDIX M: FINANCIAL STRATEGIES FOR RABBIT FARMS POWERPOINT.....	145

List of Figures

Figure 1: Pie chart of Puerto Rico's GDP by economic sector in 2012	6
Figure 2: Maralfalfa, an example of flora in Puerto Rico with Doctor Yamil Quijano.....	9
Figure 3: Cage method for rabbit husbandry	15
Figure 4: Small-fry tilapia tank.....	23
Figure 5: Map of Puerto Rico detailing work locations.....	25
Figure 6: Interview with Roberto Delgado (right)	27
Figure 7: <i>Federación</i> rabbit feed	32
Figure 8: Dehydration machine containing <i>Morus alba</i> leaves	35
Figure 9: Edgardo Ramírez showing the proper feeding technique, <i>ad libitum</i>	44
Figure 10: Rabbit feed prototype	57
Figure 11: Potential technique for separating fish into groups for testing.....	63
Figure 12: Front (right), back (center), and flap (left) of the outreach pamphlet.	64
Figure 13: Middle sections of the outreach pamphlet.....	65
Figure 14: Image from Facebook video, expressing collaboration.....	66
Figure 15: Image from outreach Facebook video, farming byproducts.....	67
Figure 16: Image from outreach Facebook video, <i>Azolla caroliniana</i>	67
Figure 17: Radio advertisement script for workshop outreach program.	68
Figure 18: Schedule for workshops.	71
Figure 19: The front of the handout for tilapia workshop..	75
Figure 20: The back of the handout for tilapia workshop.....	76
Figure 21: The front of the handout for rabbit workshop..	77
Figure 22: The back of the handout for rabbit workshop	78
Figure 23: The front of the prior knowledge workshop survey.....	80
Figure 24: The back of the prior knowledge workshop survey	81
Figure 25: The front of the workshop evaluation sheet..	82
Figure 26: The back of the workshop evaluation sheet	83

List of Tables

Table 1: Basic information of the six potential alternative plants for animal feed.....	10
Table 2: Plant growth requirements	12
Table 3: Chemical composition of recommended rabbit feed	14
Table 4: Tilapia feeding strategy based on weight	16
Table 5: Animal feed prototype survey for interested farmers	37
Table 6: Basic information of the six potential alternative plants for animal feed.....	47
Table 7: Nutritional content of rabbit feed prototypes.....	48
Table 8: Nutritional content of tilapia feed options	50
Table 9: Economic viability report	52
Table 10: Alternative plant annual yield projections	53
Table 11: Projections for producing alternative feed options	54
Table 12: Unit price of alternative feed options	54
Table 13: Comparing alternative and commercial feed unit prices	55
Table 14: Comparing alternative and commercial feed unit prices after one year	55
Table 15: Rabbit farming feed expenses.....	56

1.0 INTRODUCTION

In the mid-20th century, a movement known as the Green Revolution brought with it inventions such as the gas-powered tractor and chemical substitutes for soil, as well as farming processes that allowed regions worldwide to farm in more labor-efficient and cost-effective ways (Paarlberg, 2000). However, Puerto Rico currently imports 85% of its food supply due to a weak agricultural output (Latin American Herald Tribune, 2014). This weakness can be attributed to circumstances that limited the island's involvement in the Green Revolution. Sociopolitical barriers, such as land laws enacted by the region's government, limited the size of land devoted to individual farming businesses. This caused a swift decline in the area's agricultural output relative to other regions in the world that embraced expansion to increase production. The citizens of the island were subsequently driven towards other industries such as manufacturing. Only 3% of Puerto Rico's current workforce is dedicated to agriculture (Rivera, 2014), a major decline from an estimated 36% in 1950 (The New York Times, 1981). Likewise, less than 1% of the 2012 gross domestic product (GDP) was represented by agriculture (The World Bank, 2014).

Local food production from a region's agricultural sector is vital. Regions that lack a level of self-sustainability are vulnerable to food shortages. For example, until the start of the 21st century, Syria devoted 40% of its workforce to agriculture (IRIN, 2012). Extended droughts over the past decade have greatly diminished this industry, resulting in a strong dependence on importation. The unfavorable agricultural environment, coupled with recent wars that have limited the importation of food, has placed the country in a state of poverty and reliance on food packages from the United Nations for survival (IRIN, 2012). This country, like many others, has felt the detrimental impact of vulnerability caused by dependence on importation for food.

The integration of raising livestock in Puerto Rico has been a challenge. The food for livestock is composed of resources that need to be imported. This importation causes animal feed costs to be higher for farmers on the island compared to those in regions such as the mainland United States who can access the products locally. Animal feed accounts for 50-80% of animal-rearing production costs (FAO, 1980). This correlates to a rise in price for local animal products. Ultimately, this phenomenon puts farmers in a position where they are unable to compete with the lower prices of imported animal meat and byproducts, disabling the growth of the industry.

Several organizations have begun promoting ways to increase self-sustainability in Puerto

Rico. AgroInnova is an incubator company on the island that is committed to addressing agricultural weaknesses by offering educational and material resources that promote efficient farming methods (AgroInnova, 2013). Due to the importance of animal feed expenses in animal husbandry, AgroInnova has identified five local, alternative plants as possible components to less expensive feed formulas. The preliminary research for this initiative was performed in collaboration with the University of Puerto Rico in Mayagüez and the Municipality of Caguas, and included biochemical and nutritional analysis of each plant option. The process of utilizing this analysis to develop the alternative feed formulas had not been performed yet.

The goal of this project was to aid AgroInnova in efforts to increase local food production from rabbit and tilapia rearing in Caguas, Puerto Rico by providing less expensive feed options that contain alternative plant ingredients and a commercial feed component. We also developed an outreach program for AgroInnova to follow as the company will continue to promote alternative feed and other strategies to strengthen the island's agricultural sector and minimize the need for food importation. We created several objectives to accomplish this goal. Firstly, interviews helped us to understand the current perspectives of local farmers on animal feed. We gained insight pertaining to which aspects of animal husbandry and feed products are most important to them, and we addressed these criteria accordingly to create a product that served their needs. Secondly, we developed the most suitable animal feed options by analyzing the results from biochemical tests performed on the alternative plant species and executing a cost-benefit analysis on each potential formula. We communicated the ideal formulas for tilapia and rabbits to AgroInnova for production of the prototypes. Lastly, we presented the prototypes for testing and created an outreach program designed to communicate the economic benefits of the new feed options to local farmers.

2.0 BACKGROUND

The agricultural output in Puerto Rico based on yearly gross income is one of the lowest worldwide. This results in as little as 15% of the region's food supply being produced on the island (Latin American Herald, 2014). This dependence on importation resulted in the Asociación de Agricultores de Puerto Rico estimating that the island's supply of fresh food would be depleted within 10 days and canned foods would be exhausted within 4 weeks if imports were stopped for any reason (Govardhan, 2007). In order to better understand how Puerto Rico became this dependent on imports and how this problem can be addressed, the history of agriculture in Puerto Rico should be investigated.

2.1 Agricultural history of Puerto Rico

Puerto Rico was characterized in the early 20th century by a strong agricultural sector. A study found that sugar cane was the predominant source of land use in 1936, as about one third of the area was used for sugar cane cultivation (Thomlinson, 1996). Likewise, the livestock industry was developing during this time, occupying the widespread mountain regions of the island that were previously unused (The World Bank, 2014). However, major sociopolitical changes in Puerto Rico during the mid-20th century led to a widespread shift from agriculture to other industries such as manufacturing. By 1988, no land was being used for sugar cultivation (Thomlinson, 1996). Urban development on lands previously suitable for agriculture increased by 41.6% in the 1980s (Del Mar Lopez, 2000).

2.1.1 Agricultural development before 1960

Prior to the mid-20th century, Puerto Rico prioritized the maintenance of a strong agricultural industry. In the early 1800s, revolutions in present-day Haiti and South America created an opportunity for Puerto Rico to become a regional power in the sugar cane industry. The production of sugar cane increased as the number of slaves on the island continued to grow. However, slave-owning farmers were reluctant to merge with other individual settlements. In 1873, slaves were freed from their settlements and new technologies began developing for the agricultural industry (Mintz, 1953). New technologies, such as grinding mills, allowed regional areas like the West Indies to produce larger quantities of sugar cane. The mills allowed for the

small-scale farms to send what was produced to a single location, where sugar was produced in bulk. There were attempts to implement these mills in Puerto Rico, but the results were futile due to insufficient funds. This caused a major decline in Puerto Rico's agricultural industry. In 1899, 81 of the 289 sugar plantations on the island were not cultivated (Mintz, 1953). This downward trend was quickly addressed when the United States (U.S.) began its occupation of the territory in 1898 (America's Library, n.d.).

The U.S. federal government provided the funds needed in Puerto Rico to create large mills, and introduced other agricultural innovations. The initiative to increase output of the newly acquired territory led to a change in farming on the island, as the concept of large-scale farming was introduced as a solution to limitations in development. There was a movement from small, individual farms to large plantations. From 1909-1919, the number of individually owned farms on the island decreased from 51 to 12, while the amount of arable land used for growing sugar cane nearly doubled (Mintz, 1953). The newly introduced ways of farming assisted in the maintenance and growth of other aspects of the agricultural industry, such as local food production. In 1938, the island produced approximately 65% of the total food that the population consumed. The region's production remained high even until 1951, when local farms produced about 59% of the territory's food (Febles, 1992).

2.1.2 Agricultural development since 1960

Influenced by several factors, the sugar cane industry in Puerto Rico almost completely collapsed during the 1960s, along with the island's agricultural industry. While the world was adapting to new farming technology, Puerto Rico remained stagnant. A scientist named Norman Borlaug performed research during the 1940s on varieties of wheat in Mexico. His main focus was on the implementation of different fertilizers and their effects on growth and production. His results led to the implementation of various new strategies for crop cultivation and changed agricultural industries throughout the world (Lobb, 2003). By the 1960s, food production per acre vastly increased in many countries such as Mexico, India, Pakistan, and the Philippines. This time period became known as the "Green Revolution" (Briney, 2007).

Although this movement led to nations becoming more self-sufficient, one major downfall of the change was that regions such as Puerto Rico were unable to adopt the new methods. The island's inability to join the "revolution" was caused by a lack of proper regional

leadership and usable land (Briney, 2007). As other countries around the world moved in the direction of large, factory-style farms that utilized new agricultural technologies and fertilizers, Puerto Rico did not embrace the idea of “big business” farming that allowed for maximum output and efficient labor. In 1941, the Senate President and Governor Guy J. Swope of Puerto Rico reenacted a law introduced by the US Congress known as the 500-Acre Law. It imposed a tax on any corporation that did not comply with owning 500 acres of land or less (Ayala, 1996; Caraballo, 2014). From 1935-1955, the number of farms in Puerto Rico greater than 500 acres decreased by over 50% (Bridgman *et al.*, 2012). This movement was contradictory to the one occurring in areas around the world that were experiencing significant agricultural growth. Although this decrease in large farms on the island did not affect the region’s ability to produce its own food immediately, the resulting decline in the profitability of the industry became quite problematic.

As the island moved away from large farms, Louisiana reaped the benefits of the Green Revolution. The mechanization of farming operation led to surpassing Puerto Rico in productivity of sugar cane. As investigated in Bridgeman (2012), the labor productivity of Louisiana had become over double that of Puerto Rico’s by the mid-1960s after being roughly equivalent two decades prior. The island’s output from sugar production dropped by nearly 70% from 1965 to 1970 as a result of other regions outcompeting Puerto Rico in productivity and efficiency (Bridgman *et al.*, 2012). The negative effect on the economy of Puerto Rico was exacerbated by the development of corn syrup as an alternative to sugar cane in the 1970s. This replacement for sugar became one of the most successful food ingredients in modern history (White, 2008).

The extreme drop in the demand for sugar in Puerto Rico’s exporting market forced the island economy to essentially abandon agriculture in search of other sources of revenue. Farming began to be viewed as an outdated profession. Most of the local population moved to urban environments or to the mainland U.S., leaving very few farmers in the rural areas. Today, Puerto Rico imports about 85% of the food that its citizens consume (Latin American Herald, 2014). Only 3% of the island’s labor force is currently devoted to agriculture, and less than 1% of the island’s GDP is represented by this sector (The World Bank, 2014). Figure 1 shows the GDP contribution by sector in Puerto Rico.

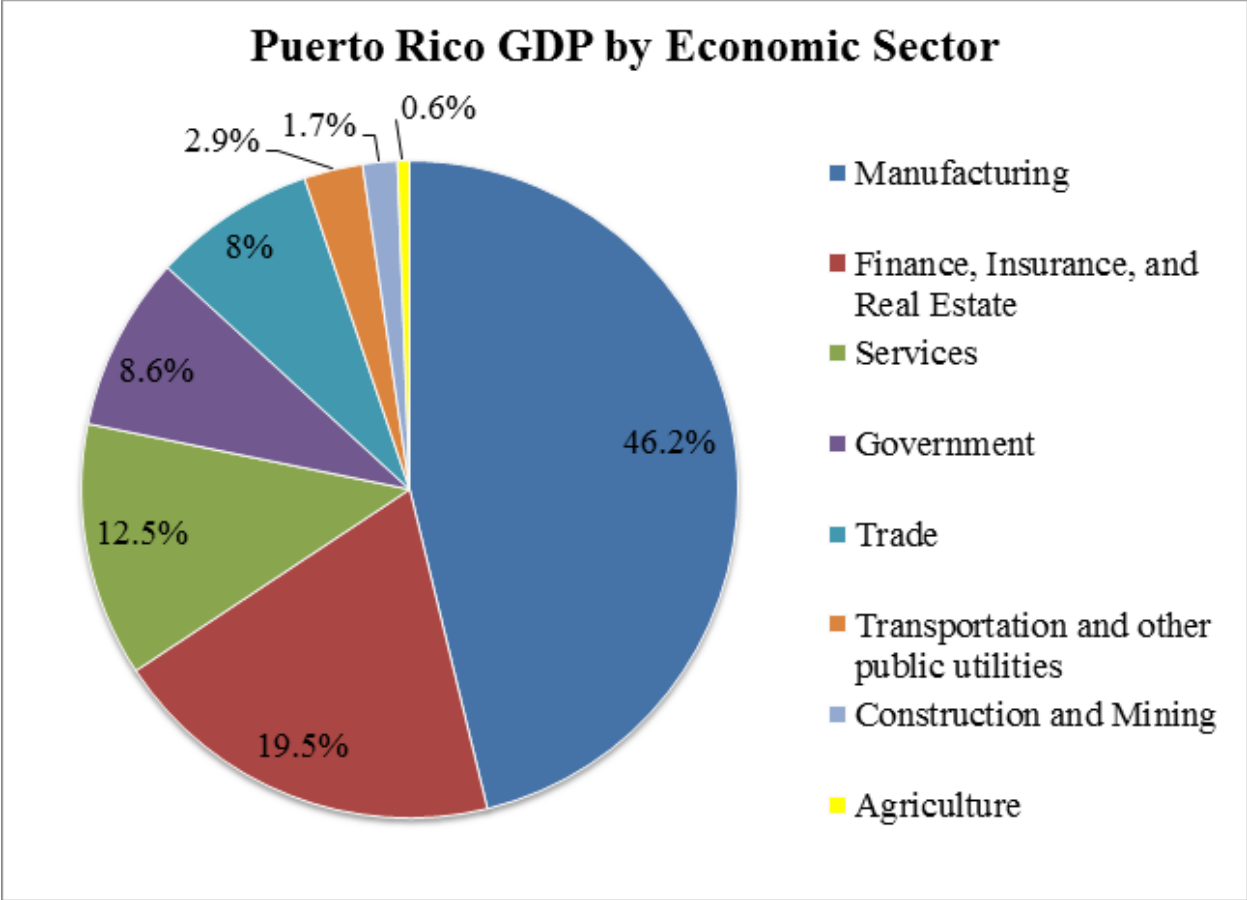


Figure 1: Pie chart of Puerto Rico's GDP by economic sector in 2012 (The World Bank, 2014)

2.2 Challenges to agricultural development in Puerto Rico

Puerto Rico faces difficult challenges that hinder agricultural development and production. The poverty level, divide of urban and rural communities, and ecological factors of the region all present problems that impact the effort to develop this sector. These issues must be overcome to revive the industry of agriculture on the island.

2.2.1 Poverty

The financial weakness of many of the citizens of the island makes it difficult to address the importation dependency because the less expensive products that are imported are a necessary choice over those that are produced locally. The average annual income for citizens of Puerto Rico in 2013 was \$22,730, compared to \$33,073 in Mississippi. The U.S. average was nearly double that of Puerto Rico, at \$42,693 (Branch, 2013). The poverty rate (measured as the percentage of residents who earn less than half of the average household income of that country)

in Puerto Rico in 2012 was 45.6% according to the U.S. Census Bureau. Mississippi, the poorest state in the U.S., had a 2012 poverty rate of 22.6%, according to the same report. There are also a large and growing number of homeless citizens. The size of the homeless population on the island is speculated to have grown as much as 70% from 2011 to 2013 alone (Branch, 2013).

The state of poverty on the island has affected the living conditions of many citizens. Citizens that lack sufficient funds to house themselves, as well as those within the 13.5% of the population that are currently unemployed (BLS, 2004), do not have the option to eat more expensive local food over more affordable imports that are available. This pattern has led to the rise in the prices of imported products, as the demand remains high so long as it is a less expensive option relative to locally developed food.

2.2.2 Physical environment

The environment in Puerto Rico is not ideal for agriculture. Factors spanning from the unpredictable weather to the dehydrated and nutrient-poor soil make it difficult to produce food on the island. The island suffers from extended droughts, hurricanes, and the difficulty of cultivating tropical soil. The weathering of soil in tropical regions such as Puerto Rico causes an increase of weathered rock contents and decreases the capability of the plants to absorb the necessary nutrients (Horn, n.d.). Less than 7% of the land on the island is arable according to the CIA, and less than 5% of the total land is utilized for permanent crops (CIA, 2014). Additionally, 1,616 square kilometers of the island, or 18% of the total region, is occupied by the Luquillo Mountains (Gould, 2007). Mountainous regions are considered to be unfavorable for agriculture due to the low soil quality, variable weather, and other environmental inhibitions.

2.2.3 Rabbit and tilapia meat industries

The rabbit and tilapia meat industries in Puerto Rico have steadily decreased in production over the last decade (E. Ramírez & R. Delgado, personal communication). We discuss these two industries together because of the similarities in their respective decline and the similarity in possible solutions for improving the profitability of each industry. According to Roberto Delgado and Edgardo Ramírez, who are both farmers in Puerto Rico, both industries lack consistent production and this has been the main cause of their decline. The profitability of the industries decreased as the cost involved in animal husbandry of tilapia and rabbits rose.

According to them, this rise was caused by higher costs of imported animal feed. Thus, fewer farmers pursued either of the industries, whether it is increasing production or getting involved on any level. They also informed us that, in both the tilapia and rabbit meat industries, grocery stores are unwilling to stock the meat due to the inconsistent production (R. Delgado & E. Ramírez, personal communication).

According to Roberto Delgado and Edgardo Ramírez, a change in the eating habits of the residents of Puerto Rico also negatively impacted the rabbit and tilapia farming industries. A rise in the amount of fast food chains on the island at the start of the 21st century resulted in a new generation of people that ate at restaurants more and cooked at home less often. Many meat industries in Puerto Rico have seen a decline in sales during this time period, including those for rabbit and tilapia (E. Ramírez, personal communication).

2.3 Alternative plants as components of animal feed

Alternative plants are plants that are not typically grown for agricultural purposes in a region, but can be utilized for agriculture (Moncada, n.d.). Plants are very valuable for their nutritional content and their ability to perform a variety of processes, as growth and reproduction can be easily regulated. Although the difference in nutritional value varies greatly between species, many plants have been domesticated to be excellent sources of fiber, protein, and carbohydrates for organism consumption (Abaye, 2009). Other flora, such as weeds and “less useful” plants, can be referred to as “alternative.” Utilization of alternative plants as ingredients in animal feed could prove economically feasible, depending on a number of factors.

There are a number of potential uses for alternative plants in agriculture as an industry, including being utilized as animal feed ingredients. The supplying of feed accounts for 50-80% of the cost involved in animal husbandry (FAO, 1980). As a result, growing alternative plants as an inexpensive filler ingredient in locally sourced feed could strengthen the region’s ability to produce food locally.

AgroInnova composed a preliminary list of alternative plant sources. These were chosen because they are commonly found on the island, are known to have a high nutritional content, and can be grown with low maintenance. AgroInnova began researching alternative plants in 2010 and had an extensive list of over 20 plant species before deciding on five species. Some plants were removed from the larger list because tests showed the plants had harmful effects on

the animals. In addition, the five plants could potentially be used in animal feed. The five plant species are *Pennisetum purpureum* (maralfalfa, Figure 2), *Morus alba* (morera), *Moringa oleifera*, *Lemna minor*, and *Azolla caroliniana* (J. Guzmán, personal communication). An additional plant species that we were informed of during an interview with Roberto Delgado was *Pueraria lobata* (kudzu). This plant was found to have nutritional content that could be used for animal feed, and this led to the addition of this plant to our pool of alternative plant species, making a total of six.



Figure 2: Maralfalfa, an example of flora in Puerto Rico with Doctor Yamil Quijano on the right

We performed extensive research involving the biochemical composition of the available alternative plants. We did this to determine the nutritional contents of each potential plant option. The data are included in Table 1. Since these alternative plants grow in the region without being tended to by farmers, these species can grow in the environment with minimal requirements for cultivation and growth. This leads to a lower expense for farmers that grow plants for feed (J. Guzmán, personal communication).

Table 1: Basic information of the six potential alternative plants for animal feed

Species	Dry Matter (% fresh mass)	Crude Protein (%DM)	Crude Fat (%DM)	Crude Fiber (%DM)	Calcium (%DM)	Sodium (%DM)	Phosphorus (%DM)	Vitamin A (IU/kg DM)
<i>Pennisetum purpureum</i> (maralfalfa)[1,2]	18.67[1]	16.6[1]	13.0[1]	36.1[2]	0.36[2]	0.40[1]	0.29[2]	0[1]
<i>Morus alba</i> [3]	33.6	22.13	11.0	5.90	3.30	0	1.43	250
<i>Azolla caroliniana</i> [4,5]	5.3[4]	21.6[5]	4.5[4]	15.0[4]	0.6[5]	0[4]	1.3[5]	0[4]
<i>Lemna minor</i> [6]	7.0	20	5.0	22.5	0	0	0	0
<i>Moringa oleifera</i> [7]	42.7	20.9	2.3	18.5	2.64	0.50	0.26	75640
<i>Pueraria lobata</i> (kudzu)[8]	26.5	15.1	0.67	33.1	1.23	0	0.24	0

Sources: [1] Y. Quijano, personal communication; [2] FAO. (2010); [3] Deshmukh *et al.* (1993); [4] Huggins (2007); [5] Hasan (2009a); [6] Leng *et al.* (1995); [7] FAO, (2012b); [8] FAO, (2012a).

Table 2 shows basic information necessary to know if farmers are to grow and harvest any or all of the six alternative plants previously mentioned. The table indicates how each plant is successfully grown, harvested, and replanted. Information is also included on the ideal growing environments for each of the species. We included this information in our background research so that we could be better equipped to relay the necessary information of how to produce these plants as crops in large volumes for animal feed. We also decided to include this information because these plants have not been previously harvested as crops in Puerto Rico. This in itself is an experimental venture, and the information below is not readily accessible to farmers. Although these plants can be grown in many different ways, we wanted to create a table that outlined the recommended growing conditions for the plants. It was important to use the recommended information in this table because these conditions produced plants with the needed nutritional values for the alternative animal feeds that we created.

Table 2: Plant growth requirements

Species	Light	Water	Harvest	Processing	Temperature
<i>Pennisetum purpureum</i> (maralfalfa)[1]	Full	Prefers areas with high level of rainfall, but maintains growth with minimal irrigation during dry season	Every 40-60 days; cut 4 inches away from the base to maximize product and allow for regrowth	Grinding of the dried radial plant (not roots) allows for use in livestock feed	Higher growth rate in hot, tropical environments
<i>Morus alba</i> [2]	Full	Drought tolerant, fruit does not ripen fully; prefers moist areas	Every 90-120 days (tropical); cut away from trunk base (time needed to heal)	Grinding of the dried plant forage allows for use in livestock feed	>= 10C average temperature required; optimal growth in hot, tropical weather
<i>Azolla caroliniana</i> [3]	25-50% is ideal (out of this range results in lower growth rate)	Absorbs nutrients available in aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Can grow in temperatures ranging from freezing to arid; Optimal growth at 20-30C
<i>Lemna minor</i> [4]	Full results in optimal growth, able to grow with moderate sunlight	Absorbs nutrients available in the aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Tolerant in range of temperatures; normal growth observed at as low as 7C, but hot temperatures are ideal
<i>Moringa oleifera</i> [5]	Full results in optimal growth, able to grow with moderate sunlight	Dependent on irrigation during severely dry seasons or extended droughts	Entire plant can be harvested from every two weeks to every 50-60 days; cut at the stem, leaving >0.5m out of the ground.	Grinding of entire radial plant allows for use in livestock feed	Can survive lower temperature, prefers semi-arid or tropical environments with high temperatures
<i>Pueraria lobata</i> (kudzu) [6]	Does not need full sunlight, but will grow towards the sun if more light is needed	Highly durable/tolerant to drought; grows at a higher rate with available moisture	Can be harvested at any time, grows freely in various areas. Entire vine achieved by various methods	Grinding of entire plant material allows for use in livestock feed; can be fed directly from harvest	Is found in a variety of environments, but grows rapidly in hot, humid environments

Sources: [1] Y. Quijano, personal communication; [2] Cook *et al.* (2005); [3] Luto (2014); [4] Rook (2006); [5] J. Guzmán, personal communication; [6] R. Delgado, personal communication.

2.4 Alternative animal feed and feed requirements

Animals need amino acids, vitamins, fat, fiber, protein and other nutrients to develop and survive (Erdmann & Jones, 1989). The purpose of animal feed is to meet those nutritional requirements. Different species of animals and their different life stages may need varying ratios of nutritional components. We presume that commercial animal feeds are designed to meet the individual needs of the species for which they are created. However, to our knowledge, commercial feed manufacturers do not release to the public any research they may carry out to create their feed formulas.

Rabbits and tilapia are categorized as herbivores. This term refers to their feeding patterns, as they rely solely on the consumption of plants to meet their nutritional demands (Northwestern University, 2014). For these two animal species, feed formulas can be created using only plant ingredients. The difficulty with formulating animal feed arises from the challenges to simultaneously deliver high-quality nutritional content and still be cost-effective for farmers. The cost effectiveness is especially crucial for farmers in Puerto Rico because animal feed accounts for 50-80% of both tilapia and rabbit production costs (FAO, 1980). Many high quality feeds are too expensive to be an option for small-scale farmers. Cost effective strategies are not only needed to increase profit but also to make this type of farming a feasible option. The following factors are the likely reasons that cost effective feed is so crucial to the farmers in Puerto Rico: all animal feed is imported (this leaves the farmers with limited choices on feed for their animals), the rabbit and tilapia meat industries are small, and the farmers rearing these animals have low income.

2.4.1 Nutritional requirements for rabbits and tilapia

Rabbits

The major nutrients that are required for rabbits are protein, amino acids, carbohydrates, fats, vitamins and minerals, and water. Commercially produced rabbit feed generally includes the following relative amounts of protein (14-20%), fiber (12-22%), and fat (1-3%) (Tamsin, 2014). However, not all commercial rabbit feed options meet the required nutritional values (R. Delgado, personal communication). Those that meet the requirements have the following nutritional constituents: fiber (18%), protein (12%), calcium (0.5%), fat (2.4%), vitamin D, vitamin E, and vitamin A (Tamsin, 2014). These components are vital for general health,

effective tissue and bone growth, and reproductive capabilities of the animals (University of Minnesota, 2014). Although proper nutrition is available with commercial pellets, providing food with sufficient nutritional content might be achieved in a more affordable way by using resources that are produced inexpensively and available locally. Table 3, below, illustrates the different recommended chemical compositions for rabbit feed according to the stage of development of the rabbit. The four categories are: young rabbits, lactating does, peri-weaning rabbits, and mix of maternity and fattening rabbits. The life stage of “young rabbits” ranges from 4 to 9 weeks of age. The lactating doe is a rabbit with nursing pups. Peri-weaning rabbits are those that are still nursing. The mix of maternity and fattening rabbits include those that are pregnant and being fattened for sale.

Table 3: Chemical composition of recommended rabbit feed (statistical information taken from Lebas, 1989)

Component of Diet	Young Rabbit (4 to 12 weeks)	Lactating Doe	Peri-weaning	Mixed (maternity+fattening)
<i>Crude Protein (%)</i>	16	18	15	17
<i>Crude Fiber (%)</i>	12	10	14	12
<i>Fats (%)</i>	3-5	4-5	3	3-4
<i>Calcium (%)</i>	0.40	1.20	1.00	1.10
<i>Phosphorus (%)</i>	0.30	0.50	0.50	0.60
<i>Sodium (%)</i>	0.30	0.30	0.30	0.30
<i>Vitamin A (IU/kg)</i>	6000	10000	10000	10000

Rabbits are known to have a high rate of food consumption, usually ranging from 65-80 g/kg of body weight per day (Halls, 2010). Due to the organism’s efficient digestive system, rabbits can be fed a lower quality grain diet with high roughage and still grow and reproduce (Irlbeck, 2001). This is important because the alternative plant options previously indicated by AgroInnova might be able to meet the rabbits’ nutritional requirements without significant

complication. For these animals, there are various ways of monitoring food consumption. Roberto Delgado monitors food consumption by giving a certain amount of feed per cage (Figure 3).



Figure 3: Containment to monitor food consumption, Roberto Delgado's farm

In order to maximize population growth and general health, the animals are separated by sex during all times except when being bred (R. Delgado, personal communication). Further separation can be done based on age and size to ensure that proper nutritional intake is maintained and supplied with more than enough food to feed the entire population.

Tilapia

Tilapia have a stricter diet that has been studied at length due to the fact that tilapia farming has expanded worldwide and the enterprise accounts for nearly 5% of farmed finfish (Conrad, 2004). A diet consisting of a high percentage of plant protein has been noted as being effective food for the growth of individual fish, as well as the growth of the population. Similar to rabbits, tilapia have been observed to grow in size and number most effectively when fed a diet that is properly balanced in protein, carbohydrates, fats, and vitamins and minerals. However, tilapia require more specific ratios of different nutritional components depending on the stage of development. Table 4, below, provides a particular example of differing feeding regimens that can be implemented based on the development of the organisms.

Table 4: Tilapia feeding strategy based on weight (FAO, 2014a)

Component of Diet	Larvae	Small Fry	Fingerlings	Juveniles	Adults
<i>Crude Protein (%)</i>	45-50	40	35-40	30-35	28-32
<i>Crude Fats/Lipids (%)</i>	10-15	10-15	10-15	10-15	10-15
<i>Crude Fiber (%)</i>	8-10	8-10	8-10	8-10	8-10
<i>Phosphorus (%)</i>	0.90	0.90	0.90	0.90	0.90

Tilapia that are in the first (larval) stage of development, considered to be from birth until a weight of 0.2 grams, require a 40-45% protein diet. Once the tilapia weighs 0.2 grams until it weighs 1 gram, it is considered a small fry and requires a 40% protein diet. The fingerlings weigh between 1 and 10 grams, and the juveniles weigh between 10 and 25 grams. During the adult stage of development, tilapia grow from 25 grams to harvest size (potentially over 2 kg). This latter stage requires a diet consisting of 30-32% protein (Fitzsimmons, 2013). In contrast to the decrease of protein intake over time, the presence of carbohydrates should increase as the organisms' develop from premature to harvest size. It is recommended to feed a younger population, weighing less than 1g each, formula that contains less than 25% carbohydrates. It should then be increased to 25-30% once the fish have grown larger (Fitzsimmons, 2013). These factors, along with traces of certain vitamins and minerals, should be considered when producing a successful formula for tilapia feed.

2.4.2 Case Studies Outside of Puerto Rico

To our knowledge, few studies have been published on the use of our alternative plants and the biochemical analysis of them. Here, we review the most relevant studies that we identified, focusing on case studies carried out in the tropics that tested alternative plants as feed components for tilapia and rabbits.

Tilapia

In June 2005, a study was conducted in Guácimo, Costa Rica on the effectiveness of *Morus alba* as an animal feed for tilapia. The study was designed to determine if a feed that was

made up of a combination of *Morus alba* and commercial feed could deliver similar growth results of tilapia compared to a diet of 100% commercial feed. The purpose of the study was to attempt to lower the cost of tilapia feed. The tilapia were divided into four groups of 75 fish, each weighing 112 grams. One group was fed given 100% commercial feed; a second was fed given a feed made up of 12.5% *Morus alba* and 87.5% commercial feed pellets feed; another was given a feed made up of fed 25% *Morus alba* and 75% commercial pellets; the final group was given a feed made up of 50% of *Morus alba* and 50% commercial pellets of both feeds. Every fifteen days, the experimenters measured the length and weight of the tilapia. At the end of the study, they determined that there was no significant difference in the development of the fish between the four treatments, and that a feed made of up to 50% *Morus alba* could be used as an effective tilapia feed. In addition, the group determined that using *Morus alba* as a supplement to the commercial feed could also reduce the cost of the feed by almost 7% (Medina & García, 2005).

Rabbits

Nuhu (2010) conducted a study in Ghana on the use of *Moringa oleifera* as animal feed for rabbits. The study determined the biochemical breakdown of *Moringa oleifera*, including its crude protein level, crude lipid level, and crude fiber levels. The study also provided the nutritional requirements for the growth of healthy rabbits. The *Moringa oleifera* plants used in the experiment were cultivated in July of 2008, and the exact procedure for planting, harvesting, and processing the plants was provided in the study. The experiment separated thirty weaner rabbits into five groups of six. One group was fed with 100% commercial rabbit feed; a second group was fed 95% commercial feed and 5% *Moringa oleifera* meal; a third group was fed 90% commercial feed and 10% *Moringa oleifera* meal; a fourth group was fed 85% commercial feed and 15% *Moringa oleifera* meal; the final group was fed 80% commercial feed and 20% *Moringa oleifera* meal. The rabbits were fed these meals for twelve weeks. The blood of the rabbits was then tested to find the protein concentration in the rabbit's blood. The reason for testing this was to determine how much of the protein in the feed was actually being absorbed into the bloodstream. Even if there is adequate protein in the diet, you cannot assume that it will all be absorbed, there is a chance that some of it will be excreted out. Mora-Valverde (2010) found that the rabbit's digestive system will excrete indigestible fiber along with low quality protein in order to obtain approximately 40% of the maintenance energy required to digest the

feed.

The economic expense of the feeds, the digestibility of the feeds, and the growth and development of the rabbits were also tested. The economic expense of the feed was calculated by taking the market unit cost of each ingredient and adding the subtotals to find the total unit cost of the experimental feed. This test showed that the experimental feed with 20% *Moringa oleifera* cost 0.37 Ghana cendi per kilogram while the commercial feed cost 0.28 Ghana cendi per kilogram. Although the experimental feed was more expensive, the rabbits' growth rate of 15.01 grams was significantly larger than the 11.71 grams from the commercial feed. Even more significant was the total weight gain for the rabbits. The experimental feed had a total weight gain of 1260.84 grams while the commercial feed only had a total weight gain of 983.64 grams. The digestibility of the feed was calculated by gathering the feces daily, oven drying the feces, having the remaining material tested for biochemical analysis, and comparing the nutritional content to the expected amount from food intake. The growth and development of the rabbits was tested by documenting feed intake and average body weight gain per day. The study found that there was no significant difference in the development of the rabbits between the feeds, and that *Moringa oleifera* could be used to improve daily weight gain, and dry matter and crude protein digestibility of rabbits. The study determined that *Moringa oleifera* could supplement up to 20% of rabbit feed without negative impact on the development of the rabbit (Nuhu, 2010).

Another study conducted by Bamikole *et al.* (2005) in Nigeria focused on the nutritive value of *Morus alba* leaves for the growing of rabbits. This study investigated the nutritive value of *Morus alba* with experimental diets consisting of 100% commercial feed, 75% commercial feed with 25% *Morus alba* leaves, 50% commercial feed with 50% *Morus alba* leaves, 25% commercial feed with 75% *Morus alba* leaves, and 0% commercial feed with 100% *Morus alba* leaves. The *Morus alba* leaves contained a higher content of crude protein and crude fiber than the concentrate. This study found that there were no significant changes in daily weight gain by the rabbits when the diets were of less than 50% *Morus alba*. In respect to the palatability, the dry matter intake for the rabbits given the diet of 100% *Morus alba* was only 3.9% lower than that of the 100% concentrate. The study concluded that because of its high nutritive value, feeding rabbits with the *Morus alba* supplement can lower costs while maintaining good health in rabbits.

2.4.3 Case studies in Puerto Rico

Goats

Santana *et al.* (2011) conducted several studies on different alternative plants and the possible use of these plants as animal feed. One of the studies focused on evaluating the potential use of *Morus alba* as a supplement to commercial animal feed for Nubian goats in Puerto Rico. The researchers divided the goats into two groups, one that was fed with just commercial feed and one that was fed with a *Morus alba* supplement equivalent to 4% of the animal's weight. Every day the amount of feed that the goats consumed was measured and every two weeks the weight of the goats was taken to assess their growth. Although the time frame of the experiment was not disclosed, the researchers determined that there was no significant difference in growth or consumption between the two feeds at the conclusion of the study (Santana *et al.*, 2011).

Cows

A second study by Dr. Rafael Ramos Santana and Dr. Yamil Quijano, a forage specialist from the University of Puerto Rico Mayagüez, investigated the use of maralfalfa as an alternative plant ingredient for cow feed. The study focused on the nutritional value of maralfalfa and how it varied depending on when the plant was harvested. They analyzed the crude protein values, the digestibility, estimated annual yield, number of harvests per year, and the dry matter percentage of the maralfalfa. The harvest time intervals tested were 40 days, 50 days, 60 days, 70 days, 80 days, and 90 days. The study determined that maralfalfa was highest in crude protein levels when it was harvested between 50 and 60 days after being planted. The study also determined that maralfalfa could be used as a successful supplement for commercial cow feed. This was based on the biochemical composition of maralfalfa (Y. Quijano, personal communication).

2.5 Strategies for agricultural outreach

During the mid-20th century, in addition to advancements in agriculture that the “Green Revolution” provided, many developing countries also formed agricultural extension programs (Birkhaeuser, 1991). Agricultural extensions are companies or government agencies that focus on communicating new technological advancements and systems to farmers. The extensions complement science-based information with local knowledge to create higher crop yields. The

success of these companies has been pivotal to the growth of farms in many countries around the world. Countries such as Ethiopia, Pakistan, Bangladesh, Egypt, Indonesia, The Philippines, Thailand, and Ghana have all benefitted from agricultural extension programs (Umrani & Jain, 2010).

2.5.1 Agricultural extension

Agricultural extension programs apply new knowledge and technology to the industry through education of farmers. Extension programs can work for private organizations as well as government agencies (Birkhaeuser, 1991). In the past 50 years, it has become more common for government and private organizations to create extension programs for their respective countries. However, in recent years, economic hardship of countries around the world has caused agricultural extension programs to rely increasingly on the private sector for funding (Ameur, 1995). Extension programs in developing countries receive a large amount of support from the Food and Agriculture Organization (FAO) of the United Nations and the World Bank (Umrani & Jain, 2010).

Umrani *et al.* (2010) explore some of the specific services in detail that are provided by the Food and Agriculture Organization. The FAO is actively involved in “organizing world conferences, exchanging external sources, and undertaking field activities” (Umrani & Jain, 2010). It devotes many of its farming strategies to encourage the participation of the farming community. The processes created by the FAO include the Farmer Field School (FFS) and the Farming Systems Development (FSD). The FFS focuses on giving farmers the control of the extension program to better address their needs. Alternatively, the FSD focuses on “on-farm research”, linking farmers, research, and the extension. This approach is most commonly considered a team approach rather than a production approach because the ties are more closely created between the team of farmers and researchers rather than the scientific methods.

Agricultural extension programs allow for the sharing and collecting of information. These extensions provide farmers with a platform to express their concerns to public agencies. Typically, farmers fail to understand how advancements in technology can increase their productivity. By reducing the confusion, overall productivity of the agricultural industry improves (Birkhaeuser, 1991). The main desired outcome of most extension programs is to increase the productivity of farms, while decreasing their financial burden by implementing

alternative farming strategies (Ameur, 1995).

Land-grant universities were established under the Morrill Land-Grant Act of 1862. Over 17 million acres of land was committed to finance universities that were made to help society. Land-grant universities function under the idea that all parts of life or labor are good enough for the university. The universities are mandated to help spread useful and practical knowledge throughout society. They provide help in many fields, one of which is agriculture. Land-grant universities work very closely with agricultural extensions. In fact, a large number of faculty members at the schools also have responsibilities with agricultural extension programs. The University of Puerto Rico Mayaguez was established in 1911 as a Land-grant university (McDowell, 2001).

Although each extension serves the purpose of creating a viable system to enhance the production or yield of the farm, each program is different in the methodology used to reach its goal. Dercon (2009) explored the successes that areas in Ethiopia experienced when agricultural extension programs were introduced. It included the account of an initial study performed in 1999 on the impact of agricultural extension programs in Ethiopia. Farmers were educated on new technological advancements and farming strategies. The extension programs encouraged 56% of farmers to use new fertilizers. Five years later, a follow-up study revealed that the new fertilizer helped to increase the agricultural production of the community. On average, the poverty rate was reduced by 9.8% and the rate of food consumption increased by 7.1% in regions where at least one agricultural extension program was introduced (Dercon, 2009). Overall, the experts conducting the study determined that the agricultural extension programs helped to reduce the agricultural production inefficiencies of the region in Ethiopia.

In Ghana, agricultural extension programs used communication as the main strategy to increase the production and knowledge of local farmers. The Department for International Development (DFID) supplied farmers from 18 villages and towns with an hour-long radio program. During the hour, community farmers discussed different farming methods for the conservation of soil and water. This radio program allowed local farmers to communicate with one another and spread farming techniques and experiences. The program was broadcasted three separate times and in many different languages. The farmers that listened to the broadcast were interviewed before and after the radio programs. This was done to investigate how much the farmers learned from the programs. After the implementation of this agricultural extension

program in 2001, farmers were asked about the benefits of the new form of communication. They replied that conservation practices, the use of animal manure, and how to make compost, are all things that they learned that they would use in the future (Chapman, 2003). This agricultural extension program, like many others, promoted the communication and spreading of knowledge amongst farming communities. From 2001 to 2002, there was an increase of 11.58% in Ghana's food production (FAO, 2014b).

2.5.2 AgroInnova: a business incubator of Puerto Rico

AgroInnova is a business incubator company that was started in 2013. A business incubator can be defined as an organization that is designed to promote the growth of different businesses by providing the necessary resources and services that are suitable for success (Small Business Encyclopedia, n.d.). AgroInnova focuses on the agricultural industry, particularly on ways to improve local food production in Puerto Rico. The organization's main target companies are the start-up farms in the region. AgroInnova lends its equipment and educates the farmers on new technology. The programs provided by AgroInnova function similarly to other agricultural extension programs around the world, as they work closely with the farming community by educating the target audience on relevant technology and process strategies. By doing this, these programs assist the farmers in efforts to increase productivity and lower expenses (AgroInnova, 2013). Also, AgroInnova works together with members of the University of Puerto Rico Mayagüez (a land-grant university), to obtain research and analyze data.

Due to Puerto Rico's extreme dependence on importation, a growing focus has been placed on the region to become more self-sustainable. The progress currently being made can be attributed to companies such as AgroInnova. It has been estimated that if 90% of previously imported food products were grown locally in Puerto Rico, it would save the local economy \$3.15 billion and generate almost 90,000 additional jobs in the agricultural sector (Santiago, 2012). AgroInnova has prioritized the spreading of regional awareness of what this projection means; the island has the potential to achieve a high level of self-sustainability and significantly improve the economy.

AgroInnova's experimental stations and facilities

On November 4th, we visited AgroInnova's experimental station in Hormigas. Our

liaison, Joylin Guzmán provided us with a tour of part of the 32-acre farm. Although the land and facilities were still under construction, she described to us what the farm would look like once completed. Even though the farm was under construction, we investigated the plan for the farm. We found that it will serve demonstrative purposes. Farmers will be able to see the farming strategies being implemented by AgroInnova. We visited the location where the tilapia would be raised, some plants would be grown, and where the plants would be dehydrated and formed into pellets. In this area, AgroInnova had tanks to house small-fry tilapia. They also had ground prepared for two additional tanks, one for breeding tilapia and another for raising tilapia. The tanks for the small-fry can be seen in Figure 4 below.



Figure 4: Small-fry tilapia tank

We also saw where they planned to place an outdoor dehydrator. This dehydrator uses heat from the sun to increase the temperature of the system; the plants are heated, and this causes an increase in the rate of evaporation. This increase causes the plant to lose water faster and dry out. AgroInnova also plans to place the pellet-forming machine near the dehydrator (J. Guzmán, personal communication). We then travelled to another location on the farm, where they planned to raise rabbits and process various products. A building at this location would work as a place

where farmers could bring their different products to be cleaned, peeled, prepared, and froze.

During our tour of the Hormigas farm, we asked many questions of Joylin Guzmán, which helped us to get a better understanding of how AgroInnova operated and how farmers would work with AgroInnova. We also asked about the cost for both AgroInnova to run the farm and the cost that individual farmers would have to pay to use the equipment and location.

Later on that day, we travelled to AgroInnova's facilities in Caguas. Both of our liaisons, Joylin Guzmán and Ana Rodríguez, showed us the various machines, and we gained insight into how the food processing systems work at AgroInnova. At this location was an indoor dehydrator, along with other equipment that is used to process and package the products of any farmer that works with AgroInnova. This visit allowed us to see how farmers who wanted to work with AgroInnova would process their products.

3.0 METHODOLOGY

The goal of this project was to aid AgroInnova in promoting agriculture as a means to increase local food production in Caguas, Puerto Rico. We accomplished this by providing less expensive animal feed options that contain alternative plant ingredients. We also developed an outreach program for AgroInnova to communicate the best practices of the animal feed to local agricultural enterprises.

We worked from October 27, 2014 until December 18, 2014, and the majority of our time was spent in Caguas, Puerto Rico where our sponsor was located. We also performed field research in Corozal and Gurabo. Experimental stations for various plant species are located in both of these cities. The map below (Figure 5) shows the location of these specific areas.



Figure 5: Map of Puerto Rico detailing work locations

We achieved our goal by the following objectives:

- Acquire knowledge from farmers and local experts on different rabbit and tilapia farming strategies, and gather their current perspectives on alternative animal feed options.
- Develop our alternative feed formulations, evaluate the economic viability of each, and coordinate future testing of the feeds for feed efficiency
- Develop an outreach program for AgroInnova to employ

3.1 Objective 1: Acquire knowledge from farmers and local experts

The opinions and information provided by local farmers helped us complete our other objectives and reach the desired final outcome of the project. Our sponsor set up three trips to local tilapia and rabbit farms. These farmers were not in business with AgroInnova. However, they did agree to have us visit their farm. This willingness might have been caused by the relationship between AgroInnova and the farmers. Thus, there may have been some bias. However, we wanted to interview farmers that owned small-scale rabbit or tilapia farms so these farmers met our target population. We wanted to target this audience because these farmers would have experience with the start-up costs and maintenance costs of a small-scale farm. This information would help us identify the needs for any farmer that would be interested in rearing rabbits or tilapia. In respect to the farmers we interviewed, we concluded that their relationship with AgroInnova could have proved their eagerness to investigate innovative and cost-effective methods for rearing rabbits and tilapia.

During our visits we talked about their perspective on animal feed. We asked the farmers about their current animal feed, current animal-rearing expenses, alternative options, and farming strategies. We took photographs at each farm to document various animal-rearing techniques. All of the information that we obtained during these farm visits and interviews was used to develop our animal feed formula and create an outreach program.

For each week of November and the first week of December, our sponsor set up one trip to a local farm and another trip to one of their experimental stations. We were unable to visit more than one farm per week due to the concern of the local farmers, such as the possibility of spreading germs from animals of one farm to another.

Visits to farms

We visited one rabbit farm and two tilapia farms. On November 5th, we traveled to Yabucoa to interview a rabbit farmer, Roberto Delgado. On November 12th, we went to Barrio Beatriz to visit a small-scale tilapia farm and to interview Edgardo Ramírez. Finally, on December 4th, we visited a large-scale tilapia farmer, Michael McGee, located in Lajas. Prior to visiting each farm, we conducted research on the facility and the farmers that were operating at each location. With the information that we gathered through our research we formulated interview questions to ask during our visits. In addition to asking interview questions, we asked ad-hoc questions based on our observations and the responses that we received from the

farmers. Our interviews with Michael McGee and Edgardo Ramírez were formal, so they were recorded. Our interview with Roberto Delgado, at his farm, was informal. We were walking around the farm and were unable to record his responses to our questions. All three members of our team participated in asking questions, and one team member wrote detailed notes on the answers.

The first farmer that we visited was Roberto Delgado. He owns a small-scale rabbit farm, which is similar in size to a large majority of rabbit farms in Puerto Rico (R. Delgado, personal communication). The interview questions that we developed through our research prior to the visit can be found in Appendix A. Some of the additional ad-hoc questions we asked inquired about what material he uses for his cages, how strong the rabbit meat industry was in Puerto Rico, and how he thought a less expensive animal feed would both affect his individual farm and the entire rabbit-breeding industry. Finally, we obtained a label from the current rabbit feed that Roberto Delgado uses. This tag provided the nutritional facts for the feed, and we also obtained its unit cost. Shown below in Figure 6 is our team interviewing Roberto Delgado.



Figure 6: Interview with Roberto Delgado (right)

We visited and interviewed a tilapia farmer named Edgardo Ramírez at his farm in Caguas, Barrio Beatriz on November 18th. Our liaison, Joylin Guzmán, described this farmer as a small-scale tilapia producer. The interview questions that we developed through our research prior to the visit are located in Appendix B. Similarly to our interview with Roberto Delgado, we wanted to attain a more in-depth understanding of tilapia farming in general and the specific strategies utilized on the island to farm these animals.

We explained to him that it was our goal to analyze the economic viability of tilapia farming in Puerto Rico, as we would be performing extensive research on the biochemical breakdown of alternative plants on the island that could be utilized as components of a less expensive feed. We discovered that he was planning to begin testing the effects of feeding tilapia a diet composed of 40% fresh, chopped *Azolla caroliniana*.

We asked him ad-hoc questions based on observations and additional topics of conversation during our visit. This included inquiring about his plans for how he would test the effects of feeding the fish a diet of fresh *Azolla caroliniana* compared to only commercial feed. We also asked him further questions about the self-sustainability of his farm. We determined that this information would be valuable for our research, as he talked to us about how he utilized recycled materials for the construction of his farming system and how he collected the waste from the tilapia to use as a form of fertilizer.

The final farmer that we visited and interviewed was a tilapia farmer named Michael McGee. His farm was located in Lajas, where we travelled on December 4th for the interview. Joylin Guzmán described the farmer as a large-scale tilapia producer. The interview questions that we developed through our research prior to the visit can be found in Appendix C. We asked these questions to find out the economic breakdown of his farm, to determine what animal feed he currently used, and to determine if he implemented any money saving strategies on his farm. We also were interested in his opinion on alternative animal feeds and if he was interested in testing our prototype once it was created.

As we did with the prior farmers we interviewed, we asked Michael McGee additional questions based on what we encountered during our visit to his farm. For example, we asked him to estimate the ratio of kilograms of feed per kilogram of saleable tilapia meat (feed-efficiency ratio) for his commercial feed. We also asked him to whom he sells his tilapia, and how strong he thinks the tilapia market is. In addition, we asked him many questions on his

facility. Some of these questions were about what plants he was growing, how he was using aquaponics, and how he knew if his ponds were healthy. Aquaponics is the integration of hydroponics and aquaculture, promoting sustainability by utilizing fish-rearing byproducts to fertilize soil for plant growth (Diver, 2010). All of these ad-hoc questions were asked with the intention of finding out how Michael McGee ran his tilapia farm and to determine his opinion of the current tilapia meat industry in Puerto Rico.

Expert Interviews

We interviewed Doctor Yamil Quijano on November 13th at the experimental station in Gurabo. The questions that we created prior to the interview are located in Appendix D. We created these questions with the understanding that Doctor Quijano is an expert on maralfalfa. We wanted to gather as much knowledge as possible from Doctor Quijano on the effects of supplementing animal feed with alternative ingredients. His knowledge only pertained to his experiences with feeding cows a diet consisting of maralfalfa (*Pennisetum purpureum*). Since this plant was one of the potential alternative components that we could use for our tilapia and/or rabbit feed formulas, we gathered as much information as we could from Doctor Quijano pertaining to the successes and challenges he faced surrounding feeding this plant to his cows. This included his qualitative analysis, as well as the strategies he employed to create the new diet and the results that were seen from feeding maralfalfa to his animals.

The ad-hoc questions that we asked Doctor Quijano focused on the study that he conducted on cows. Examples of these questions include how his study could be interpreted as it relates to tilapia and rabbits, how the investigators decided on the ideal harvesting period for maralfalfa, and what was the most productive way to plant maralfalfa. The reason we asked these questions was to gain a better understanding of his study, and to gain as much knowledge from him about maralfalfa as we could. We also wanted to assess how viable it was to use the findings of his study on cows to make assumptions for tilapia and rabbits.

We conducted an interview with Joylin Guzmán, an expert in alternative forage and one of our liaisons, on December 4th. The questions that we prepared for this interview can be found in Appendix E. The main reason for this interview was to determine AgroInnova's plan for growing the alternative plants and how they expected the farmers to grow them and produce the feed. Some of the questions that we asked Joylin Guzmán included whether or not AgroInnova planned to produce the feed and sell it to the farmers, whether she thought that farmers in Puerto

Rico had enough available land on their farm to grow the plants, and if she thought that farmers on the island could afford all of the equipment needed to harvest the plants and produce the animal feed. We planned to use this information for our economic viability report and for our outreach program for the farmers.

3.2 Develop the formulations and coordinate testing of feed

Based on AgroInnova's previous research, shown in section 2.4.2 of the background chapter, Joylin Guzmán recommended that we create an animal feed formula composed of 80% alternative plants and 20% commercial pellets. Our challenge was to determine the ratio of the alternative plant component in feed for both tilapia and rabbits. In order to effectively satisfy the rabbit and tilapia dietary standards through these feed formulas, we analyzed the current animal feed formulas fed to these animals on the island. The alternative feed must contain the same nutritional components. We investigated the commercial feed nutritional composition in order to determine which alternative plant species could be used to achieve this goal of producing a less expensive tilapia and rabbit feed. Because commercial feed has the amount of essential vitamin supplements needed for the diet of rabbits and tilapia while the alternative plants do not, a feed of 100% alternative plants could not be created.

3.2.1 Collecting information on the biochemical composition of the commercial rabbit and tilapia feed

We travelled to local agricultural stores and gathered data on the prices and nutritional components of the commercial rabbit feed brand in Puerto Rico. Roberto Delgado supplied us with the information pertaining to the *Federación* brand of rabbit feed (Figure 7). We gathered data on commercial tilapia feed biochemical composition and prices with the help of Edgardo Ramírez and Michael McGee. These two farmers shared with us which commercial brands they currently use to feed their fish and provided us with the price they pay for the feed.

In developing our alternative prototypes, we used the nutritional component of 1.0 kilograms of the commercial feeds as a standard. By utilizing the background research we performed on the biochemical composition of the alternative plant options (Table 1 in section 2.3), we determined the mass ratios of the components needed to achieve the same nutritional composition of the commercial feeds. We utilized the data we researched pertaining to the mass

percentage of the major nutritional components of each alternative plant option to calculate the nutrition of each feed prototype. As a theoretical example, Plant A contains 17% crude protein (indicating 0.17 grams of protein per gram of dry-matter weight). To determine the amount of crude protein this component provides to an alternative feed if it accounts for 10% of the formula, we first calculate how many grams of plant A (100 grams) would be present in 1.0 kg of feed. We then multiplied this by the protein content (per gram) of the plant (0.17 grams of protein per gram of dry matter) to yield the grams of protein per 100 grams of the dried plant material (17 grams of protein in this example).

We repeated this process for each plant component in each alternative feed mixture to validate its nutritional content as being comparable to that of the commercial options. We constructed tables to visually portray the composition of each prototype, indicating the percentage of each plant and the grams of all major nutritional components provided by that amount of the alternative plant ingredients. We developed our final options for both tilapia and rabbits, and organized them into tables to clearly represent the amount of each component and the nutritional composition of the feed (Table 7 and Table 8 in section 4.2.1).

We developed multiple theoretical prototypes for both rabbits and tilapia. By doing this, it allows for AgroInnova to initiate the testing of several options, increasing the likelihood that a successful alternative may be discovered. Having said this, there are many other possible combinations of the six alternative plants that we were considering to combine with the commercial components (but we did not include them in our report) to yield a diet similar to that provided by the 100% commercial option. We discovered that our final two rabbit feed prototypes and three tilapia feed prototypes most effectively met the correct amounts of each nutritional component compared to the nutrition of the commercial feed.



Figure 7: *Federación* rabbit feed

3.2.2 Analyze economic viability

We had previously discovered the importance of animal feed cost in farming; it accounts for 50-80% of animal rearing expenses (FAO, 1980). From this, we determined that a significant factor in minimizing the cost-to-benefit ratio of feed is the creation of a high quality formulation that is less expensive than the commercial option. In order to evaluate the economic viability of our alternative animal feed formulas, we needed to first determine the expenses involved in creating the feed and compare the overall expense with the price of the commercial feeds available.

Growing and processing alternative plants

We began this process by determining what assumptions could be reasonably made. The plant components of the alternative feed options are known for being versatile and hardy, as they are able to survive in a wide variety of climates. Both the aquatic and terrestrial species have low nutrient requirements, which is evident from the less than favorable environments they are found flourishing in. Various environmental limitations such as highly sedimentary soil, low nitrogen composition, and limited sunlight have been found to not affect the growth of these plants (Y. Quijano, personal communication). However, we assumed that these plants would be grown on a plot of land that has significant sun exposure and access to water to maximize yield.

Considering the hardiness of the plants involved, we determined that expenses such as irrigation and fertilization would not be necessary to consider. However, due to the lack of thorough understanding of the growth of these plants, it is yet to be seen if these expenses will need to be considered in future analysis. The expenses that we did include in evaluating the economic viability of this enterprise are those associated with the equipment for planting, harvesting, and processing, as well as opportunity costs and transportation. We combined critical thinking with the knowledge we obtained from local farmers and experts to draw further conclusions. The complete breakdown of expenses involved in determining the economic viability of growing these alternative plants can be found in section 4.2.2.

For the purpose of understanding the maximum possible production of the alternative feed prototypes, we considered a scenario in which each plant component is grown on 0.25-hectare plots. Each plant, in an environment similar to Puerto Rico (and with no fertilization or irrigation), has a known rate of production. We researched the annual production of each plant and found data in terms of dried short tons (2000 pounds, or 907.18 kilograms) of plant material per hectare per year (Table 10). Once we gathered this data, we divided each value by four to determine the annual yield of each plant per quarter-hectare of space.

After we gathered the data and utilized it in the aforementioned way, we considered which plants were in each formula. To identify the plant that would be the limiting component of each formula, we first determined how many dried kilograms of each plant would be produced from growing each plant on 0.25 hectares of land based on the quantity in dried short tons (907.18 kilograms per short ton). We then determined, based on the percentage in the formula of inspection that the plant accounted for, the amount of total feed that could be produced assuming that all other ingredients were available in excess (Table 11). The plant that yields the lowest projected total kilograms of feed produced is the limiting plant.

For example, plants A, B, C, and D are combined in specific percentages to create an alternative feed. Plant A accounts for 10% of the mixture, plant B accounts for 20%, plant C comprises 25% of the formula, and plant D is responsible for 30% of the overall feed. The production per 0.25 hectares of land for each plant are as follows: 300 kilograms (plant A), 200 kilograms (plant B), 500 kilograms (plant C), and 1000 kilograms (plant D). From this information, the maximum amount of the overall formula (100%) can be projected for each plant under the condition that all other ingredients are available in excess.

By performing these projections, it is found that 3000 kilograms of feed could be produced based solely on the production of plant A; the production of plant B projects an overall production of 1000 kilograms of feed; the production of plant C projects a production of 2000 kilograms of feed; and the production of plant D leads to a feed projection of 3333 kilograms. In this scenario, plant B would be the limiting plant due to its productivity projecting the lowest number of kilograms of feed producible. To validate this mathematical reasoning, one can analyze the contribution of this limiting plant in each theoretical projection. In the projection based on the production of plants A, C, and D, plant B would account for 20% of 3000, 2000, and 3333 kilograms of feed, respectively. These projections would require that plant B provide a productivity of 600, 400, and 667 kilograms. Given that the maximum production of plant B in 0.25 hectares of space is only 200 kilograms, these projections do not represent the actual amount of feed producible if each plant component was grown on 0.25 hectares of land (or water). This reasoning supports that the plant that yields the lowest feed production (if all ingredients are available in excess) dictates the amount of feed that will be produced under the outlined conditions. This logic was employed to draw the conclusions made in Table 11 in section 4.2.2.

We reasoned that the number of kilograms producible of “Tilapia Prototype #3”, under the given parameters, would be dictated by the aquatic plant with the lesser productivity for 0.25 hectares (rather than *Morus alba* which would be the “limiting” ingredient in the mixture). We drew this conclusion because we considered that a farmer could feasibly utilize more than 0.25 hectares of land to grow *Morus alba* on his or her farm. We concluded this because it is the only non-aquatic plant in the mixture. If he or she utilized 0.75 hectares of land to grow this plant, this flora’s productivity would exceed that of *Lemna minor*. Therefore, it is reasonable to calculate the unit price of “Tilapia Prototype #3” based on the productivity of the less productive pond plant. This conclusion can also be found in Table 11, along with the projected annual production for the other prototypes.

3.2.3 Create the feed formulations at the AgroInnova facility in Caguas

We created prototypes for our tilapia and rabbit alternative feed formulas using materials and resources available at our sponsor’s facility in Caguas. We were given access to the six fresh, alternative plant species (*Morus alba*, *Moringa oleifera*, *Pueraria lobata*, *Pennisetum*

purpureum, *Azolla caroliniana*, and *Lemna minor*) from farmers that we met during our time in Puerto Rico. We received these plants from the following people: Roberto Delgado, Joylin Guzmán, Edgardo Ramírez, and Michael McGee. We used the dehydration apparatus at the AgroInnova facility in Caguas (Figure 8) to dehydrate each.



Figure 8: Dehydration machine containing *Morus alba* leaves

We traveled to Caguas to create our alternative feed prototype on December 9th. We accounted for each of the plants that were generously supplied to us by either local farmers or our liaisons to confirm that all necessary alternative plants were available. The only plant that we were responsible for dehydrating was *Morus alba*. We dehydrated *Morus alba* leaves with the assistance of Joylin Guzmán. From the *Morus alba* plant, only the leaves were used because the rest of the plant does not contribute much nutrition (J. Guzmán, personal communication). The rest of the plants were used in their entirety (except for the roots) because the nutritional components are found throughout the aerial parts of the plants (J. Guzmán, personal communication). The leaves were dehydrated for approximately 3 hours, until they were very brittle in form. The same qualitative assessment of dehydration was performed by Joylin Guzmán on samples of the other five plants.

Once all of the available plant material was dehydrated, we weighed the samples on a

digital scale at the facility, and combined each component (80% plant material and 20% crushed, commercial pellets) in the correct ratios by mass. Due to a limited supply of *Azolla caroliniana*, *Lemna minor*, and *Pueraria lobata*, we only developed one prototype to be pelleted for our final presentation to local farmers and the mayor of Caguas. This pelleted mixture would only serve as a visual aid for our presentation, not for animal consumption. We adjusted the ratios of “Rabbit Feed Prototype #2” (Table 7 in section 4.2.1) to consist of 40% *Pennisetum purpureum*, 20% *Moringa oleifera*, 20% *Morus alba*, and 20% *Federación* rabbit feed. This mixture contains 40% *Pennisetum purpureum* (instead of 25%) due to the lack of *Pueraria lobata* availability at the time that we created the prototype. Therefore, our sample prototype is not an exact match to any of our recommended formulas. We gave the mixture to Joylin Guzmán, and she delivered it to a pelleting mill in Ithaca, New York (*R & N Wood Pellets*). Although we were initially cleared to use the processing machines available at AgroInnova, a lack of access to power for the machines prevented us from pelleting the mixture at AgroInnova’s facility in Caguas.

3.2.4 Farmer feedback on prototypes

We created a survey for obtaining feedback on the prototypes that we theorized (Table 5). The survey was designed to be distributed to farmers by AgroInnova and was to be accompanied by printed sheet with our feed prototypes on it (Table 7 and Table 8). Based on discussions with our liaisons, we determined the modes of delivery that would be utilized for receiving farmer feedback. The electronic delivery method would be via e-mail. The face-to-face delivery method would involve the survey being hand delivered to the farmer’s house or the farmer could visit AgroInnova to pick up the survey. The responses given by any farmer that completed the survey would then be collected for evaluation. These farmers included local rabbit and tilapia farmers.

Table 5: Animal feed prototype survey for interested farmers

Animal Feed Prototype Survey
Would you be willing to take part in a pilot study that involves feeding a small portion of your animals this alternative feed to evaluate its nutritional and economic benefits?
Are there any possible complications that you think could result from feeding this to your animals?
Do you have any suggestions for changes to the formula or alternatives that you think would improve the quality and/or effectiveness of the feed? Explain.
What other information would you want to have before considering a switch from your current animal feed to this alternative feed?
Considering the nutritional information sent to you, would you use this to replace the commercial feed you currently use? Why or why not?

Roberto Delgado, a rabbit farmer with whom we had significant communication, completed this survey orally (Appendix F). We utilized this feedback to further refine our prototypes to meet the needs of rabbit farmers on the island. By doing this, we could more effectively create feed formulations that were less expensive and met the nutritional requirements of the animals. Due to the fact that we were unable to deliver more surveys to farmers in the time and resources allotted to us, we discussed our plan with AgroInnova to assure that the needs of farmers would be considered as further work is done on developing alternative feeds.

3.2.5 Develop a plan for future experimental testing of the animal feed

We designed an experiment to compare the growth rate of the animal population, the growth rate of each individual animal, and the death rate of the population for each alternative option relative to the commercial feed. We developed experimental plans for testing the rabbit and tilapia feed prototypes. The designs include experimental and control groups, constructed to test the effect of alternative feed on the growth rate and reproduction of the farmed animals compared to the results seen from commercial feed.

The experiment involved the separation of the animals into experimental and control

groups. We determined that the selection of these animals was important to consider, as variance in factors such as sex and current stage of development would have a significant effect on the results. Both tilapia and rabbits develop at a high rate in the early stages of life, and the size difference between males and females is also significant for both. It was for these reasons that we determined that the two pre-determined groups would be provided the same type of environment and resources, with the only difference being the type of feed that was supplied to them. Each group would be isolated from the rest of the farm's total population, in order to simplify the process of tracking changes over time.

In our experiment, each organism will be tracked from birth until reaching market size. We determined that this would show the rate of development exhibited by the animals that consumed each type of feed. Each group would comprise of equal sex distribution to account for the potential difference in qualitative or quantitative changes exhibited both between the sexes and between the groups.

The full experimental process was outlined and provided to AgroInnova so they can replicate the experiment. We recommended that this information be communicated verbatim to the farmers, along with other materials that we developed to assist the farmers in the process of tracking changes over time exhibited by the control and experimental groups. Our experimental protocols and supplemental material can be found in section 4.2.5.

3.3 Objective 3: Develop an outreach program for AgroInnova to employ

For our final objective, we created several forms of outreach including a script for a radio advertisement, a Facebook video, and an informational pamphlet. The intention of these is to attract farmers to two financial strategy workshops that we created. These workshops focus on general financial planning and on the potential benefits of using alternative feeds. We developed one workshop for rabbit farmers and one for tilapia farmers. We made several pieces of material for the workshops, including handouts, surveys, PowerPoint documents, and a schedule. The workshop will teach farmers a variety of money-saving strategies for their farm, one of which being our alternative feed.

Through our research and contact with our sponsor, we decided on the forms of outreach that would best suit our workshops and animal feed. Using our sponsor's suggestions as a basis for possible outreach material, we then considered broader options. We thought that by creating

multiple forms of outreach material, we would increase the amount of people who would hear about the financial strategy workshops. Through communication with one of our liaisons, Ana Rodríguez, we learned that the municipality of Caguas has promoters. These are people who travel to the different neighborhoods in Caguas and speak directly with the community members about new programs and initiatives. We decided to create a pamphlet that could be used by AgroInnova, as well the municipality promoters, to communicate our research findings to the farmers and small enterprises of the Caguas community. We decided to create a pamphlet because AgroInnova currently uses pamphlets to communicate some of their information, and it would be easy for the municipality to use pamphlets as handouts for people that are interested.

We decided to place a small amount of our outreach effort on developing Internet resources, because only 5.95% of Puerto Rican farmers use the Internet for farm management purposes (National Agricultural Statistics Service, 2007). As a result, a Facebook video was the only form of Internet material we created. We made a video that highlights AgroInnova's objective and draws interest into the workshop. We recommended that the video be posted on AgroInnova's Facebook page because it is frequently visited by farmers and has almost 1,500 likes.

Another medium that we took advantage of for our outreach was the radio. Through research we concluded that radio was valuable because it has the ability to reach a wide and diverse audience (Chapman, 2003). This was important because we wanted our advertisement to reach as many people as possible and develop interest in our workshop from a diverse group of people. We conducted research on what makes a quality radio advertisement. A study in England tested the factors that cause a radio advertisement to be more easily remembered by its audience. This study concluded that involvement, entertainment, and enjoyment show positive correlations to the audiences' rating of the advertisement (Norris & Colman, 1996). Through this research we decided to include a jingle to entertain and cause enjoyment for the audience, and we added questions directed at the audience, to involve them in the advertisement. We also conducted research on how to get the advertisement on the air. This information we relayed to AgroInnova, so that they could record the advertisement and use it when they are ready.

AgroInnova also emphasizes the need for educating farmers and students. The workshop we developed was planned with the help of Joylin Guzmán because she holds several workshops for AgroInnova. We interviewed her to understand what workshops she has previously held,

what she considers to be a successful workshop, and which workshops she has had the most success with. We asked her specific questions on the workshops that AgroInnova conducts. We asked her what AgroInnova charges for their workshop, how long they typically run for, what days of the week they usually hold them on, and how often they have their workshops. We used that information to develop logistical guidelines for our workshops. By keeping the logistical information of our workshops consistent with normal practices of AgroInnova, we hoped that it would make our workshops easier for them to adopt. We also wanted to keep in consideration the demographics of our likely audience. We asked Joylin Guzmán the average age, gender, and education level of the farmers in Puerto Rico who would most likely be interested in the workshops. This information allowed us to develop our workshops with our audience in mind. Finally, we asked Joylin Guzmán how many farmers typically attend their workshops, in order to give a better idea of what activities could possibly be utilized at our workshops. We also obtained a PowerPoint presentation from a workshop that AgroInnova held on aquaponics. This presentation gave us insight on the approach and the content that AgroInnova opts to share at their workshops.

We created a schedule for our workshops. The schedule was made to provide AgroInnova with all of the information that they needed to operate the workshops. This included what topics to cover, what discussions to have, how long everything should run for, and who should speak at what times. This schedule would make sure that everything that needs to be covered in the workshops is, and that workshops are consistent every time that they are held.

We created two financial strategies workshops, one for tilapia farmers and one for rabbit farmers. A PowerPoint document was created as a guide for each workshop, and they were designed to inform workshop presenters about what information to provide on different money saving strategies that farmers could utilize. The PowerPoint documents supply information and images on the different strategies, and a large focus of the PowerPoint documents is on our alternative feed. The PowerPoint documents were formatted with AgroInnova's past workshop PowerPoint presentations in mind, this way they had similar amounts of information and visuals.

During the workshops, we decided that handouts would be necessary so farmers would have the information available to take home with them. We developed one handout for the tilapia workshop and another handout for the rabbit workshop. Although we think that the farmers should take notes throughout the workshops, these handouts make sure that they leave

with the most important information. We specifically made sure to add examples of our alternative feed formulas on the handouts, along with the detailed growing information of the different alternative plants.

Another piece of workshop material that we created was surveys. We decided that having a survey that asked the attendees what the farmers' prior financial knowledge was at the beginning of the workshop would be beneficial for both the farmers and AgroInnova. This survey would ask questions about what they already know, what they most want to learn from the workshop, and how they heard about the workshop. A similar survey would then be handed out at the end of the workshops. This survey would ask them what they learned and their overall evaluation of the workshop and its materials. Both of these surveys would be valuable to the structure of future workshops, as they would allow AgroInnova to determine what the attendees wanted to learn, needed to learn, and did learn.

The final piece of outreach material that we created was a mobile form of outreach, or a "workshop on wheels." We wanted to account for farmers who would be unwilling or unable to travel to AgroInnova for the workshop at their facility. To address this, we offered the idea of a workshop for which presenters travel to individual farms. This workshop would be held by AgroInnova and would allow all farmers to be involved and informed of different money saving strategies and our alternative feed formula. All of the material talked about in this section can be found in section 4.3.

After developing our outreach material, we asked Ana Rodríguez for feedback on it. She suggested a few areas in which we could improve the material. First, she stated that we need to include the Corporación Juvenil para el Desarrollo de Comunidades Sostenibles logo on our pamphlet because they are the company that AgroInnova belongs to. She also informed us that we could improve the surveys for our workshops by including some the same questions on both. The answers to these questions would be used to determine how much the farmers learned from the workshops. We listened to her suggestions and used them to improve our outreach material.

4.0 RESULTS AND DISCUSSION

Our major findings included the extensive knowledge gathered from farmers, the formulation of our feed prototypes, the recommended testing guidelines for the feeds, and the outreach materials. We received the knowledge from farmers throughout the duration of our project and implemented this information into our prototypes and outreach materials. An economic viability report was performed for each prototype to outline the benefits of replacing 100% commercial animal feed with our prototype. The tables detail the cost difference between our feed prototype and the commercial feed. The prototypes would need to be tested for their biochemical composition before animal testing can be performed to determine feed efficiency. This chapter includes the guidelines for testing the feed on animals. Lastly, several outreach materials were created.

4.1 Knowledge acquired from farmers and local experts

The two experts that we interviewed, Doctor Yamil Quijano and Joylin Guzmán, provided us with information on research that they conducted and gave us suggestions for our feed prototypes and economic viability report. The three farmers with whom we had significant contact (Roberto Delgado, Edgardo Ramírez, and Michael McGee) provided us with insight pertaining to farming and feeding strategies in Puerto Rico. Between the current approaches they are currently employing to save money and the ideas they shared with us about how to utilize alternative plants to feed rabbits and tilapia, we obtained information that proved invaluable to achieving our goal.

Visits to farms

Roberto Delgado shared with us during our interview with him that he feeds his rabbits as much as they regularly consume, no more and no less. He arrives at this point by feeding a cage of rabbits a particular amount of food that he estimates would be appropriate for all animals to receive proper sustenance. He fills the feeder at the beginning of the day, and notes how much food (if any) is left at the beginning of the following day. If there is no feed remaining, he increases the amount of food slightly, relative to what he gave on the previous day. He continues to adjust the quantity until he observes that there is a very small amount of food remaining in the feeder, but it is almost negligible because of how small the amount is.

Roberto Delgado informed us of the struggles he faces to sell his rabbit meat. He

described Puerto Rico's rabbit meat industry as inconsistent and lacking in production. Due to the fact that there are not enough rabbit farms and that the ones that do exist are typically small-scale, not enough rabbit meat can be produced to meet the demand. Grocery stores are unwilling to stock the meat because of the high possibility of having enough rabbit meat for one week but not enough the next week. At the same time, the demand for rabbit meat is substantial, as Roberto Delgado claimed that the rabbit meat industry is only producing about 750,000 pounds of the 1,750,000 pounds currently demanded by local consumers.

Edgardo Ramírez provided us with his strategies for feeding his farmed tilapia. He communicated to us aspects such as the delicate balance in the amount of feed given to the fish at any given time, the proper method of food dispersion within a pool or pond, and his ideas on how to create and effectively promote alternative tilapia feed. It is pivotal to assure that all fish in the population are being fed adequately. If the feed is not evenly dispersed, the larger and stronger fish can overpower the smaller ones and eat the food that was given with the intention of feeding all the fish. This imbalance creates an issue that can lead to animal death and ultimately population growth inhibition. Edgardo Ramírez showed us the proper way of feeding tilapia that are kept in a pond with a performance, captured in the photograph labeled Figure 9. The technique is referred to as feeding his fish *ad libitum*. This means that the fish are fed until full. The feed from the bucket was scooped up and thrown evenly into different areas of the pond. The portion of our interview with Edgardo Ramírez, that was recorded, can be found in Appendix G.



Figure 9: Edgardo Ramírez showing the proper feeding technique, *ad libitum*

Michael McGee explained to us how tilapia farms are run, the current state of the tilapia meat industry, and how beneficial an alternative feed could be for a tilapia farmer. He also took us on a tour of his farm, where he explained how tilapia farming worked, including aquaponics. Michael McGee spoke passionately of how impactful an alternative feed could be for a tilapia farmer. He told us that he currently does this on a very small scale by putting *Lemna minor* into some of his tilapia tanks. This acts as a supplement to the commercial feed that he used. His process for feeding his fish *Lemna minor* was very simplistic; he would just throw an unmeasured amount of it into the tank and allow them to eat it as they pleased. He stated that in other countries, specifically in Asia, poor farmers that cannot afford to buy feed for their fish use alternative plants and other supplements to feed them. He also said that these farmers run very self-sustainable farms. This led to his belief that the secret to running affordable tilapia farms involves a combination of alternative feeds and self-sustainable practices (like aquaponics).

Another key piece of information that was provided to us by Michael McGee was that for

about every two kilograms of tilapia feed, one kilogram of tilapia meat was produced. This feed-efficiency ratio was confirmed to be the same for rabbits through a report provided to us from Roberto Delgado that outlined how much he spends on feed relative to how many rabbits he raises (and how much rabbit meat he produces). Finally, Michael McGee broke down what goes into a tilapia feed, and explained to us how an alternative component could replace part of the commercial feed nutrition. We also asked him for a sample of *Lemna minor* and *Azolla caroliniana*. He stated that since they are both invasive, in terms of taking over a farm, he tries to eliminate *Azolla caroliniana* whenever it starts to grow and allows for only a small, contained amount of *Lemna minor* to grow. Because of this, he could not provide us with any *Azolla caroliniana*, but he managed to give us a small amount of *Lemna minor*. A transcript of our interview with Michael McGee can be found in Appendix H.

Edgardo Ramírez and Michael McGee told us of a very similar issue when it comes to the tilapia meat industry. The small amount of tilapia farms has resulted in low tilapia meat production, making grocery stores unwilling to stock their shelves with it. Unlike rabbit meat, the demand for tilapia is not too high. The main reason that Ramírez believes there is such a low demand is because of a common misconception that tilapia are unsanitary creatures. The reason for that belief is that since tilapia are bottom grazers, people began to believe that they only eat their own excrement, which made them unappetizing. Edgardo Ramírez filters his tanks to prevent his tilapia from feeding on their feces, yet the misconception hurts his business. As a result, he informed us that he sells many of his tilapia for ornamental use, in addition to consumption purposes.

[Expert Interviews](#)

Doctor Yamil Quijano provided us with information on the study that he conducted on the effect of *Pennisetum purpureum* (maralfalfa) as feed for cows. He provided us with an informational sheet on the study and talked about his findings, which can be found in section 2.4.2. Following that, we asked him questions on his knowledge of maralfalfa and the results of his study. He told us that maralfalfa grows best when it was grown twenty-four inches apart compared to thirty-six inches apart. The reasoning for this was that when grown twenty-four inches apart the plant does not grow as tall, but has thinner, more easily digestible stems that contain a higher concentration of protein. He also stated that his study found that maralfalfa had the highest protein amount when harvested between forty and fifty days from planting or

previous harvest. We used this information for what we suggested as the best growing conditions for maralfalfa and collected our nutritional data of maralfalfa from plants that were grown to meet these conditions. Lastly, Doctor Yamil Quijano was unsure of the effects that maralfalfa would have when fed to tilapia and rabbits, since he conducted his research on cows. Due to this, we used the information that he provided for the growing conditions of maralfalfa for our project and put less weight into his findings of the effect of maralfalfa as an animal feed.

Joylin Guzmán provided us with insight into AgroInnova's plan for growing the alternative plants and for producing the alternative feed. The transcript for this interview can be found in Appendix I. She told us that AgroInnova wanted the farmers to produce both the plants and the alternative feed using their own equipment on their farms. She also informed us that most farmers use between 60% and 70% of their farmland. This meant that they should have enough unused land to produce the alternative plants. She also agreed that our suggestion that AgroInnova should produce the alternative feed to give to farmers who are reluctant to start the process was sensible. She thought that it was a good idea because she agreed that some farmers would want to try the feed with their animals prior to committing the time, space, and expense to produce the plants and feed themselves. Lastly, she informed us of grants that could benefit any farmer interested in the feed. The government of Puerto Rico provides these grants. Joylin Guzmán said that interested farmers need to provide a proposal to the government, own land or have a contract to rent it for at least ten years, and work to make a profit for only themselves. If they met these requirements, farmers could receive money from the government to buy the equipment needed to harvest the plants and produce the alternative feed, with a maximum of \$8,000 per year. Joylin Guzmán provided us with helpful information, which we used in the creation of our economic viability report and our outreach program.

4.2 Feed formulations and strategies for experimental testing of feed

We utilized information we gained from farmers and local experts to decide on feed prototypes and feasible strategies to test our alternative feed formulations. The experiments were designed with the intention of determining whether or not the alternative feeds affected the growth rate of rabbits and tilapia. We designed these controlled experiments to eliminate other possible variables that could affect the results. We intended to provide support of the economic sensibility of alternative animal feeds.

4.2.1 Analysis of biochemical testing results and development of feed prototypes

As a model for our prototype, we used the nutritional content of 1.0 kg of one commercial rabbit feed that is currently being fed to farmed New Zealand white rabbits in Puerto Rico. Roberto Delgado told us that this option is the most available and least expensive for feeding rabbits on the island. As shown in Table 7, we created two rabbit feed prototypes. Each prototype was designed to mimic the nutritional composition of the *Federación* rabbit feed, the local brand used by Roberto Delgado. As previously stated in the chapter 3, we analyzed the biochemical breakdown of each alternative plant option to determine formulas that would effectively achieve similar nutritional content by using specific percentages of alternative plants and commercial feed.

The process of determining how to calculate the contribution of each nutritional component (in grams) provided by the plants and commercial feed was outlined in section 3.2.1. Both prototypes contain 80% alternative plant ingredients and 20% commercial feed. The biochemical composition of the alternative plants is shown below in Table 6. This is the same as Table 1, but has been copied here for convenient comparison of the biochemical composition between the plants and the prototypes.

Table 6: Basic information of the six potential alternative plants for animal feed

Species	Dry Matter (% fresh mass)	Crude Protein (%DM)	Crude Fat (%DM)	Crude Fiber (%DM)	Calcium (%DM)	Sodium (%DM)	Phosphorus (%DM)	Vitamin A (IU/kg DM)
<i>Pennisetum purpureum</i> (maralfalfa)[1,2]	18.67[1]	16.6[1]	13.0[1]	36.1[2]	0.36[2]	0.40[1]	0.29[2]	0[1]
<i>Morus alba</i> [3]	33.6	22.13	11.0	5.90	3.30	0	1.43	250
<i>Azolla caroliniana</i> [4,5]	5.3[4]	21.6[5]	4.5[4]	15.0[4]	0.6[5]	0[4]	1.3[5]	0[4]
<i>Lemna minor</i> [6]	7.0	20	5.0	22.5	0	0	0	0
<i>Moringa oleifera</i> [7]	42.7	20.9	2.3	18.5	2.64	0.50	0.26	75640
<i>Pueraria lobata</i> (kudzu)[8]	26.5	15.1	0.67	33.1	1.23	0	0.24	0

Sources: [1] Y. Quijano, personal communication; [2] FAO. (2010); [3] Deshmukh *et al.* (1993); [4] Huggins, (2007); [5] Hasan, (2009a); [6] Leng *et al.* (1995); [7] FAO, (2012b); [8] FAO, (2012a).

One problem that we faced while creating these prototypes was balancing the percentage of fiber and the percentage of calcium in the formula. We wanted to keep both components

below a certain value. We wanted to keep the fiber content low because too much fiber would cause the rabbits to suffer from diarrhea (J. Guzmán, personal communication). However, too little fiber can cause constipation (Smith *et al.*, 2009). We also wanted to keep the calcium level down because too much would cause the rabbits to suffer from calculi, urinary tract stones (King, 2002). This would be caused by the rabbit's calcium metabolism. Because rabbits do not use vitamin D to digest calcium, excess calcium is excreted in the urine. This may lead to kidney damage for the rabbit (Irlbeck, 2001). However, too little calcium would lead to bone density loss and tooth decay (Smith *et al.*, 2009) Other factors that we considered for adverse health effects were protein, and fat. Too much protein can cause high cholesterol while too little protein can cause decrease in growth and decreased immunity. Too much fat can cause heart disease and clogged arteries while too little fat can cause hair loss and brittle nails (Smith *et al.*, 2009).

Table 7: Nutritional content of rabbit feed prototypes, in terms of grams (or IUs) of each nutritional component supplied by each prototype component per kilogram of prototype (prototype components expressed in percentage of 1.0 kg)

Nutritional Content of Rabbit Feed Options							
Alternative Rabbit Feed Prototype#1 Components	Protein (g)	Fiber (g)	Fats (g)	Calcium (g)	Phosphorous (g)	Sodium (g)	Vitamin A (g)
35% <i>Morus alba</i>	46.7	20.7	3.8	11.6	5.0	0.0	87.5
20% <i>Moringa oleifera</i>	54.2	38.4	4.6	4.0	0.4	0.1	15128.0
20% Commercial feed	34.0	27.0	4.0	2.3	0.8	1.3	2204.6
15% <i>Pueraria lobata</i> (Kudzu)	20.1	12.4	0.1	1.6	0.3	0.0	0.0
10% <i>Pennisetum purpureum</i> (Maralfalfa)	16.6	36.1	13.0	0.4	0.3	0.0	0.0
Total	171.7	134.6	25.4	19.9	6.8	1.5	17420
prototype	~17%	~13%	~2.5%	~2.0%	~0.7%	~0.15%	17420 IU
commercial (Federacion)	~17%	~11-16%	~2%	~1.1%	~0.6%	~0.30%	10000 IU
Alternative Rabbit Feed Prototype#1 Components	Protein (g)	Fiber (g)	Fats (g)	Calcium (g)	Phosphorous (g)	Sodium (g)	Vitamin A (g)
25% <i>Pennisetum purpureum</i> (Maralfalfa)	41.5	90.3	32.5	0.9	0.7	0.1	0.0
20% <i>Morus alba</i>	26.7	11.8	2.2	6.6	2.9	0.0	50.0
20% <i>Moringa oleifera</i>	54.2	38.4	4.6	4.0	0.4	0.1	15128.0
20% Commercial feed	34.0	27.0	4.0	2.3	0.8	1.3	2204.6
15% <i>Pueraria lobata</i> (Kudzu)	20.1	12.4	0.1	1.6	0.3	0.0	0.0
Total	176.5	179.9	43.3	15.4	5.1	1.5	17383
prototype	~18%	~18%	~4%	~1.5%	~0.5%	~0.15%	17383 IU
commercial (Federacion)	~17%	~11-16%	~2%	~1.1%	~0.6%	~0.30%	10000 IU

As a model for our feed prototypes, we used the nutritional content of 1.0 kg of two commercial tilapia feeds that are currently being fed to these farmed fish in Puerto Rico. Edgardo Ramírez disclosed that these two feed options are the most available and most effective for feeding tilapia. As shown in Table 8, we created three prototypes for testing. Two of the prototypes are modeled after the *Mid-South 36% Fingerling Fish Food* brand, while one prototype was created to contain comparable nutrients to the *Rise Floating Fish Diet* brand. The *Mid-South 36% Fingerling Fish Food* brand contained 36% crude protein because it is used for

the small fry. Tilapia require more protein in the early stages of development. The *Rise Floating Fish Diet* brand contains 24% crude protein because it is used for adult tilapia. As tilapia grow, they need less crude protein. The 24% crude protein meets the required intake for adult tilapia. As previously stated in chapter 3, we analyzed the biochemical breakdown of each alternative plant option to determine formulas that would effectively achieve similar nutritional content by using specific percentages of alternative plants and commercial feed.

The process of determining how to calculate the contribution of each nutritional component (in grams) provided by the plants and commercial feed was outlined in chapter 3. The prototypes that we created to be nutritionally comparable to the *Mid-South 36% Fingerling Fish Food* brand included a 70% commercial feed component. We determined that this was the correct course of action, despite the initial determination that we would devise formulas that only contained 20% commercial feed and 80% alternative plant material. The prototype that we created to replace the lower-protein commercial option (*Rise Floating Fish Diet*) included 20% commercial feed and 80% alternative plant material. We created all three prototypes using the *Mid-South 36% Fingerling Fish Food* brand as it has higher protein content.

The three prototypes that we created to be nutritionally adequate for farmed tilapia had similar nutritional breakdowns compared to the commercial options, as shown in Table 8. If all nutritional components are satisfied by the alternative feed prototypes, the tilapia should grow with equal effectiveness compared to when they are fed commercial feed. However, a biochemical testing of the alternative feed must be performed to know all of the nutritional content of the alternative feed. Even though the alternative feed theoretically meets the crude protein, crude fiber, fats, calcium, and phosphorus requirements in the diet of tilapia, we are unaware if there are nutrients in the alternative feed that could harm the tilapia. In respect to other adverse health effects caused by the minerals in the feed, it is currently not known what effects the intake of minerals has on tilapia. This is not known because little data is available on the mineral requirements of tilapia (El-Sayed, 2006).

We decided to create formulas that provided different levels of protein to satisfy the protein requirements of tilapia during different life stages, the protein requirements can be found Table 4 in section 2.4.1. To provide a higher protein level, a larger percentage of the commercial feed was needed. This phenomenon may cause the formula to be more expensive overall than an alternative that contains a smaller percentage of commercial feed and a larger percentage of

alternative plant ingredients. It was for this reason that we devised the lower-protein option that would likely be less expensive because it contains 80% alternative plants and 20% commercial feed.

Table 8: Nutritional content of tilapia feed options, in terms of grams of each nutritional component supplied by each prototype component per kilogram of prototype (prototype components expressed in percentage of 1.0 kg)

Nutritional Content of Tilapia Feed Options				
Alternative Tilapia Feed Prototype#1 Components	Crude Protein (g)	Crude Fat/Lipids (g)	Crude Fiber (g)	Phosphorous (g)
<i>70% Commercial</i>	252.00	42.00	38.50	6.30
<i>5% Morus alba</i>	6.68	0.54	2.95	0.72
<i>15% Azolla caroliniana</i>	43.20	9.00	30.00	2.60
<i>10% Lemna minor</i>	20.00	5.00	22.50	0.00
Total	321.88	56.54	93.95	9.62
<i>prototype</i>	32%	6%	9%	10%
<i>commercial (Mid-South 36% Fingerling Fish Food)</i>	36%	6%	6%	9%
Alternative Tilapia Feed Prototype#2 Components				
Alternative Tilapia Feed Prototype#2 Components	Crude Protein (g)	Crude Fat/Lipids (g)	Crude Fiber (g)	Phosphorous (g)
<i>70% Commercial</i>	252.00	42.00	38.50	6.30
<i>20% Azolla caroliniana</i>	57.60	12.00	40.00	3.47
<i>10% Lemna minor</i>	20.00	5.00	22.50	0.00
Total	329.60	59.00	101.00	9.77
<i>prototype</i>	33%	6%	10%	10%
<i>commercial (Mid-South 36% Fingerling Fish Food)</i>	36%	6%	6%	9%
Alternative Tilapia Feed Prototype#3 Components				
Alternative Tilapia Feed Prototype#3 Components	Crude Protein (g)	Crude Fat/Lipids (g)	Crude Fiber (g)	Phosphorous (g)
<i>45% Morus Alba</i>	60.08	4.86	26.55	6.44
<i>20% Commercial</i>	90.00	24.00	6.00	3.00
<i>20% Lemna minor</i>	40.00	10.00	45.00	0.00
<i>15% Azolla caroliniana</i>	43.20	9.00	30.00	2.60
Total	233.28	47.86	107.55	12.04
<i>prototype</i>	23%	5%	11%	12%
<i>commercial (Rise Floating Fish Diet)</i>	24%	4%	6%	8%

4.2.2 Template for economic viability

Alternative Plants

We developed a detailed breakdown of the expenses involved in creating feeds from alternative plants. As previously mentioned in chapter 3, the combination of knowledge obtained by farmers, extensive background research, and critical thinking contributed to the development of this analysis. The pertinent information is found below in Table 9.

Table 9: Economic viability report

		Economic Viability of Growing Alternative Plants and Creating Rabbit and Tilapia Alternative Feeds					Rabbit#1	Rabbit#2	Tilapia#1	Tilapia#2	Tilapia#3						
Category	Sub-category	Material	Fixed (units)	Variable (price/unit)	Total Price	Own/Rent	Notes										
Pre-Harvest	Planting	Kudzu clippings	-	-	-	own	Free anywhere	yes	yes	no	no	no					
		Azolla remnants	-	-	-	own	Free anywhere	no	no	yes	yes	yes					
		Lemna remnants	-	-	-	own	Free anywhere	no	no	yes	yes	yes					
		Maralfalfa seeds	100	\$	0.16	\$	15.69	own	Amazon pricing	yes	yes	no	no				
		Morus alba seeds	40	\$	0.32	\$	12.95	own	Amazon pricing	yes	yes	yes	no				
		Moringa seeds	100	\$	0.17	\$	16.94	own	Amazon pricing	yes	yes	no	no				
		Subtotal				\$	45.58		\$	45.58	\$	45.58	\$	12.95	\$	-	\$
Harvest	Machinery	Aerator and seeder	1	\$	199.00	\$	199.00	rent	Home Depot, 1-day	yes	yes	yes	no	yes			
		Pond Creation (equipment and labor included)	1	\$	10,000.00	\$	10,000.00	rent	Quote received by Michael McGee	no	no	yes	yes	yes			
		Water to fill pond (gallons)	~4 acre-feet	\$10/acre-foot		\$40.00	own	Quote by city water supply	no	no	yes	yes	yes				
		PVC Pipes	12	\$	8.99	\$	107.88	own	Michael McGee	no	no	yes	yes	yes			
		Subtotal				\$	10,346.88		\$	199.00	\$	199.00	\$	10,346.88	\$	10,346.88	\$
	Labor	8 hours	8	\$	7.50	\$	60.00	own	Local farming wage	yes	yes	yes	yes	yes			
		Subtotal				\$	60.00		\$	60.00	\$	60.00	\$	60.00	\$	60.00	\$
	Machinery	Tractor Loader Backhoe	6	\$	249.00	\$	1,494.00	rent	Home Depot, 1-day	yes	yes	yes	no	yes			
		Trailer	6	\$	109.00	\$	654.00	rent	Home Depot, 1-day (6x10, 4500 lb load)	yes	yes	yes	yes	yes			
		Gas (in liters)	5	\$	0.96	\$	4.80	own	Fuel efficiency of ~2 miles/L	yes	yes	yes	yes	yes			
Telescopic Pool Stick		1	\$	51.90	\$	51.90	own	Amazon pricing	no	no	yes	yes	yes				
Harvesting Net/Pool Rake		1	\$	14.99	\$	14.99	own	Amazon pricing	no	no	yes	yes	yes				
Subtotal					\$	2,219.69		\$	2,152.80	\$	2,152.80	\$	2,219.69	\$	725.69	\$	2,219.69
Labor	5 hours	30		\$7.50	\$225.00	own	Local farming wage	yes	yes	yes	yes	yes					
Subtotal					\$225.00		\$225.00	\$225.00	\$225.00	\$225.00	\$225.00	\$225.00					
Processing	Transportation	Gas (in liters)	6.65	\$	0.96	\$	19.17	own	Fuel efficiency of ~3 miles/L	yes	yes	yes	yes	yes			
		Tolls	2	\$	2.50	\$	15.00	own	Average farmer travel (20 mi., 1 toll)	yes	yes	yes	yes	yes			
		Subtotal				\$	34.17		\$	34.17	\$	34.17	\$	34.17	\$	34.17	
Machinery	Agrolnova 1-day rate	3		\$200.00	\$600.00	rent	Agrolnova pricing, processing 3 times/year	yes	yes	yes	yes	yes					
	Subtotal				\$600.00		\$600.00	\$600.00	\$600.00	\$600.00	\$600.00	\$600.00					
Packaging	Buckets (10 gallon)	10	\$	10.47	\$	104.70	own	Amazon pricing	yes	yes	yes	yes	yes				
	Subtotal				\$	104.70		\$	104.70	\$	104.70	\$	104.70	\$	104.70		
Labor	8 hours	24		\$7.50	\$180.00	own	Local farming wage	yes	yes	yes	yes	yes					
	Subtotal				\$180.00		\$180.00	\$180.00	\$180.00	\$180.00	\$180.00	\$180.00					
Commercial Feed	Rabbit or Tilapia Commercial Feed Component	*	*	*		own	Prices per kilogram included Rabbit: \$0.60/kg; Tilapia: \$1.10/kg, \$0.66/kg	yes	yes	yes	yes	yes					
								\$	668.52	\$	668.52	\$	17,463.60	\$	17,463.60	\$	1,496.88
Total Cost, Yearly Production of Rabbit and Tilapia Feed Prototypes								\$	4,269.77	\$	4,269.77	\$	31,246.99	\$	29,740.04	\$	15,280.27

We determined that there existed three major categories of expenses that we should consider: pre-harvest, harvest, and processing, these can be found in Table 9. We also evaluated this enterprise from the perspective of opportunity cost.

We also researched the potential annual yield (in kg of dried plant/hectare/year) based on the results that other farmers have reached with minimal treatment and similar environments to those present in Puerto Rico. This data can be found in Table 10 below. Once we retrieved the data, we projected the potential yield of the land in terms of kilograms of feed possible for each feed option for each plant (assuming that all other plants were available in excess). The plant component with the smallest maximum yield was noted as the limiting factor and was used to calculate the maximum yearly feed production. This data can be found in Table 11. The full process of determining the maximum annual feed production can be found chapter 3.

Table 10: Alternative plant annual yield projections

Annual Production of Alternative Plants, dried tons per 1/4 hectare		
Plant species	Dried tons/hectare/year	Dried tons/0.25 hectare/year
<i>Morus alba</i> [1]	8.6	2.15
<i>Moringa oleifera</i> [2]	10	2.5
<i>Pennisetum purpureum</i> [3]	36	9.0
<i>Pueraria lobata</i> [4]	10	2.5
<i>Azolla caroliniana</i> [5]	35	8.75
<i>Lemna minor</i> [6]	10	2.5

Sources: [1] Espinoza *et al.*, (1999); [2] Toensmeier, (2012); [3] FAO, (n.d.a); [4] FAO, (n.d.b); [5] Bijl, (n.d.); [6] Hasan, (2009b).

We converted from dried short tons (each equivalent to 907.19 kg) to dried kilograms, and determined (based on the percentage composition in terms of mass of each plant) the amount of feed producible given the productivity of that particular plant. As can be seen in Table 11 below (highlighted), we analyzed each result that was determined in this manner and reasoned that this was the amount of feed producible based on the parameters that each plant component was grown on ¼ hectare of land over the course of one year.

Table 11: Projections for producing alternative feed options

Annual Projection of Alternative Feed Production based on Plant Components						
Prototype	Plant species					
(%,kg)	<i>Morus alba</i>	<i>Moringa oleifera</i>	<i>Pennisetum purpureum</i>	<i>Pueraria lobata</i>	<i>Azolla caroliniana</i>	<i>Lemna minor</i>
<i>Rabbit#1, %</i>	35%	20%	10%	15%	-	-
<i>Rabbit#1, kg</i>	5571	11340	81650	15120	-	-
<i>Rabbit#2, %</i>	20%	20%	25%	15%	-	-
<i>Rabbit#2, kg</i>	9750	11340	32660	15120	-	-
<i>Tilapia#1, %</i>	5%	-	-	-	15%	10%
<i>Tilapia#1, kg</i>	39000	-	-	-	52920	22680
<i>Tilapia#2, %</i>	-	-	-	-	20%	10%
<i>Tilapia#2, kg</i>	-	-	-	-	39690	22680
<i>Tilapia#3, %</i>	45%	-	-	-	15%	20%
<i>Tilapia#3, kg</i>	4333	-	-	-	52920	11340

Table 12 summarizes the findings of the economic viability report presented in Table 9, as well as the research data in Table 10 and Table 11. Table 12 shows how the unit price of each alternative feed option was determined, factoring in the cost to produce each prototype and the maximum production of each prototype.

Table 12: Unit price of alternative feed options

Alternative Feed Prototypes, Determining Unit Prices					
Prototype	Rabbit#1	Rabbit#2	Tilapia#1	Tilapia#2	Tilapia#3
Cost to Produce (\$)	\$4,269.77	\$4,269.77	\$31,246.99	\$29,740.04	\$15,280.27
Amount Producible (kg)	5571	9750	22680	22680	11340
Unit Price (per kg)	\$0.77	\$0.44	\$1.38	\$1.31	\$1.35

We evaluated our alternative feed prototypes in two ways to determine the economic viability of each option. First, we determined the projected cost to produce each feed per kilogram (Table 12). We used the conclusions drawn from Table 12 to compare the prices of our prototypes to the feed prices provided to us by the local rabbit and tilapia farmers we interviewed. The unit costs of some of the alternative options were lower than those of the commercial feeds, providing support to our claim that alternative feeds may lower the expenses for rabbit and tilapia farmers. More specifically, “Rabbit Prototype #2” was less expensive to produce. The remaining four prototypes were projected to have a higher unit cost in the first year, taking into consideration all one-time costs (Table 13). However, all three of our tilapia feed prototypes were projected to be significantly less expensive after the payment of all one-

time costs (Table 14). We reasoned that these feeds might be economically feasible if farmers have the financial flexibility to account for the one-time costs, or they have access to the necessary resources to alleviate these costs. More specifically, one-time costs would not need to be paid if a farmer has access to the necessary equipment and ponds for growing the plants for the feed prototypes.

Table 13: Comparing alternative and commercial feed unit prices

Comparing Alternative and Commercial Feed Prices					
Prototype	Rabbit#1	Rabbit#2	Tilapia#1	Tilapia#2	Tilapia#3
Unit Price of Alternative (per kg)	\$0.77	\$0.44	\$1.38	\$1.31	\$1.35
Unit Price of Commercial (per kg)	\$0.60	\$0.60	\$1.10	\$1.10	\$0.66
Difference in Price (%)	28% more	27% less	25% more	19% more	105% more

Table 14: Comparing alternative and commercial feed unit prices after one year

Comparing Alternative and Commercial Feed Prices, Tilapia Feed After First Year			
Prototype	Tilapia#1	Tilapia#2	Tilapia#3
Total Cost to Produce	\$20,900.11	\$19,393.16	\$4,933.39
Kilograms Produced	22680	22680	11340
Unit Price of Alternative (per kg)	\$0.92	\$0.86	\$0.44
Unit Price of Commercial (per kg)	\$1.10	\$1.10	\$0.66
Difference in Price (%)	16% less	22% less	33% less

The second mode of evaluating economic viability was addressed by our development of strategies to test the alternative options. We spoke with rabbit and tilapia farmers that would be willing to conduct experimental trials. As we explain further in Section 4.2.5 of this chapter, we constructed these experiments to measure the kilograms of feed consumed per kilogram of animal meat produced. From this calculation, the feed-efficiency ratio can be determined for each feed option. If the alternative options have a more favorable feed-efficiency ratio (less feed is needed per kilogram of meat produced), this provides additional support to the economic benefits of utilizing alternative feeds instead of the 100% commercial options.

The following breakdown, Table 15, includes the information provided to our team by Roberto Delgado. We were able to determine from this information that the feed-efficiency ratio of his *Federación* feed is approximately 2:1. The amount of feed (in kilograms) per 100 kilograms of rabbit meat produced were projected to be 219.43, 201.15, and 201.15 for 100, 300, and 600 production does, respectively. When we interviewed Michael McGee, he independently

reported the same feed-efficiency ratio for tilapia as was found for rabbits.

Table 15: Rabbit farming feed expenses

Projections for Rabbit Farming Feed Expenses			
These values are approximations assuming a 15% mortality, modelling Sr. Delgado's farm in Caguas			
Number of Production Does	100	300	600
Average number of birthings per year	7.4	7.4	7.4
Average kitt survival number based on 15% mortality	5.5	5.5	5.5
Average total Kitts per year	4,097	12,291	24,582
Weight at sale (in lbs.)	2.75	3.00	3.00
Projected meat produced per year (in lbs)	11,267	36,872	73,745
Market price of meat per pound	\$ 3.75	\$ 3.75	\$ 3.75
Projected gross revenue from rabbit meat produced	\$ 42,249.68	\$ 138,271.68	\$ 276,543.37
Does Feed Consumption (lbs/day)	45.00	135.00	270.00
Bucks Feed Consumption (lbs/day)	1.88	5.63	11.25
Kitts Feed Consumption (lbs/day)	21.05	63.14	126.28
Total consumption (lbs/day)	67.92	203.76	407.53
Note: Price of 1 Quintal (100 lbs) of feed = \$27.30			
Total Quintals of feed consumed per day	0.68	2.04	4.08
Total Quintals of feed consumed per week	4.75	14.26	28.53
Weekly feed expense (\$)	129.80	389.39	778.78
Yearly feed expense (\$)	\$ 6,767.98	\$ 20,303.94	\$ 40,607.88
Feed expense (\$) per 100 lbs of rabbit meat produced	\$ 60.07	\$ 55.07	\$ 55.07
Amount of feed (in lbs) per 100 lbs of rabbit meat produced	219.43	201.15	201.15
Projected Total Expenses (feed is accountable for ~60%)	\$ 11,279.97	\$ 33,839.90	\$ 67,679.80
Projected Net Revenue (assuming conditions outlined for total expenses)	\$ 30,969.71	\$ 104,431.78	\$ 208,863.57

As outlined in Section 4.2.5, we developed experiments that can be followed by farmers to test our alternative feed prototypes. This will allow AgroInnova to determine the feed-efficiency ratio of the feeds. We determined that it was important to fully evaluate the cost-effectiveness of the feed. The alternative feeds may be less expensive for the pellet unit weight, but the ultimate goal was to create viable options that make the industries of meat production more viable. This concept is the reason why the cost of feed relative to the weight of saleable meat must be improved.

4.2.3 Creation of feed prototypes at AgroInnova facility in Caguas

To create a pelleted prototype for showing the farmers what alternative feeds will look like if they produced them, we weighed out all of the plant components and combined them in the proper ratios as stated in section 3.2.3. The plant ingredients were sent to *R & N Wood Pellets* facility for processing into pellets. The prototype was produced as outlined, and small samples of each alternative plant option were collected to serve as a visual aid on our final presentation. The prototype can be seen below in Figure 10. The pellets of our prototype are

shorter in length and smaller in diameter than most rabbit feeds. Roberto Delgado informed us that the smaller length was beneficial because, when rabbits eat longer pellets, the pellets typically break in half and half of the pellet falls through the cage. He also told us that the smaller diameter was not a major issue, but a larger diameter would be ideal because it is what the rabbits prefer. All of the products were retrieved on December 15th.



Figure 10: Rabbit feed prototype

4.2.4 Farmer feedback on feed prototypes

The three farmers that we interviewed (Roberto Delgado, Edgardo Ramírez, and Michael McGee) showed interest in our alternative animal feed prototypes when we first introduced it to them. Once we created the final formulas of the prototypes of our alternative animal feeds, we asked for the feedback of the three farmers. All of them stated that they were interested in testing the feeds, once they were created. Also, Roberto Delgado informed us that he knew three additional large-scale rabbit farmers who would be interested in testing our animal feed on their farms.

With specific reference to the survey that we generated and delivered orally to Roberto Delgado, his responses can be found in Appendix F. He communicated to us that both

prototypes looked feasible in terms of the nutritional composition, but that prototype #2 (with a slightly elevated level of fiber) would be slightly favorable to prototype #1 (with a slightly elevated level of calcium). His feedback supported that our second alternative prototype was superior to the first.

4.2.5 Plan for future experimental testing of feed prototypes

The template for a cost-benefit analysis of rabbit feeding was designed by using one of our interview subjects, Roberto Delgado, as a “model farmer.” Roberto Delgado currently has approximately 200 rabbits on his farm in Yabucoa. He generates approximately 15-20 rabbits per week that are purchased for meat consumption. The average weight of a rabbit reared from his farm at day 100 of development is 6 pounds, and he sells his rabbits at a price ranging from \$3.00 to \$3.75 per pound. This results in a range from \$270-\$450 for weekly gross revenue. The price for Roberto Delgado’s product is largely based on the status of the economy of the island and the rabbit industry in particular. However, he also factors in his expenses when setting a price on his rabbit meat to make a profit from his farming business (R. Delgado, personal communication).

Our feed formula mixtures were confirmed to meet the nutritional requirements for tilapia and rabbits equivalent to 100% commercial feed options. Our experimental design began by establishing a control group, which would be fed according to the farmer’s normal practice.

The designed experiment also contained an experimental test group. All practices (including water treatment, vaccinations or medicine, sex of the organisms, and other common practices) were kept constant to those of the control group, with the exception of what was fed to the animals. The alternative formulation to be tested would be provided to these animals for consumption in the same manner as the commercial food is provided to the control group. The establishment of separate control and experimental groups serves as a way to infer the results of using commercial feed to our alternative formulations, as any differences in performance or growth rates between the two groups would be attributable to the single variable (feed).

The experimental design requires the farmer to record the number of animals within the control group, as well as the number of those within the experimental test group. Our experimental design instructs that the number of males and females, as well as the life stages of the organisms, should be kept constant. In addition to a record being kept of how many

organisms are within each group's population and keeping an account of the population growth and death rate over time, the design required for the farmer to weigh each animal in the two groups daily. This step allows for a successful comparison of animal growth rate and development while consuming each feed option. We have included below the list of steps used as a guide to test the nutritional viability of our alternative rabbit feed options.

Guidelines for Testing Alternative Rabbit Feed Option(s)

1. Designate three rabbit cages to be used for this experiment.
2. Select 10 young rabbits for this test. Prior to this time, treat all pups as you normally would, beginning this test directly after the weaning period is over.
3. Choose 5 of these rabbits to be placed in an experimental group and 5 to be in a control group. Ensure that all rabbits are seemingly in good health, and that the groups have the same distribution of the sexes.
 - Note: Record the number of males and the number of females in each group
 - Note: The determination of 5 rabbits for the experimental group was made to avoid farmers incurring a high risk to test the feed. This test was created with the intention that several rabbit farmers will be participating, and Roberto Delgado assured us that he and several other farmers he knew will be participating in this experiment.
4. Weigh each rabbit of the control group and record the values (in kilograms). Do the same for each rabbit in the experimental group.
 - Note: Record any significant qualitative observations. This includes, but is not limited to: coloration, body structure, and behavior.
5. Place all rabbits that are in the control group in one cage, and note the cage accordingly. Put those in the experimental group in the second cage. This assures separation of each group to record accurate data.
6. Designate one bucket for each type of feed, the commercial pellets and the alternative prototype.
7. Weigh each bucket without feed in it (separately).
8. Fill one bucket with 100% commercial feed that you currently use to feed your rabbit population, and the other bucket with the alternative feed prototype.
9. Weigh each bucket with the feed in it (separately). Record the measurements (in kilograms).
 - Note: The purpose of this step is to record the starting amount of each type of feed. This

- will allow for the accurate measurement of the amount of feed consumed over time.
10. Perform the same feeding practices for both groups in terms of the method of feeding. Follow the same feeding practices for these two groups as you do for the rest of your rabbit population.
- Note: Ensure that the quality of the cages and population density is not different for these two groups compared to the rest of the rabbit population. This will allow for proper measurement of the effect that one variable has on the growth of the rabbits.
11. Record the mass (in kilograms) of each rabbit once per week at the same time every week. This can be done by removing the rabbits one-by-one from the cages, weighing them individually, and placing them in the third cage to assure that you weigh every rabbit in each group (and do not repeat).
- Note: Follow the process described in step 7 with each rabbit in the control group, and place all rabbits back in the designated cage *before* beginning the process for the experimental group. This will assure that the populations will not be undesirably mixed during the process.
12. Document the values for all rabbits on the form provided (see Appendix J). This will allow for all data to be in one location.
13. In addition to the weekly measurements of the mass (in kilograms) of each rabbit, take a weekly measurement of the amount of feed remaining in each bucket on the same day of each week.
- Note: Subtract the current mass (in kilograms) of the bucket and feed from the value recorded from the previous week. This will allow for the proper calculation of the weekly feed consumption.
14. Record any qualitative changes you notice over the course of testing. Even if you think it might or might not be of significance, record your observations in the “notes” region of the form.
15. Repeat this weekly process for the development of all 10 rabbits from the post-weaning stage to market size. Once all rabbits reach market size, calculate the total amount of feed consumed by each group.
- Note: Sum the weekly consumption of each group to determine the total feed consumption.
16. Record the number of days required for each rabbit to reach market weight and the total mass

(in kilograms) of each group.

17. Record any qualitative observations that you believe represents benefits or drawbacks to each type of feed.

18. Report your findings to AgroInnova.

Guidelines for Testing Alternative Tilapia Feed Option(s)

1. Designate a tank, separated into two equal halves by a tank divider (Figure 11) that spans from the bottom of the tank to eight inches above water, to be used to perform this experiment.

2. Select 30 small-fry tilapia for this test. Prior to this time, feed all tilapia larvae as you would normally.

3. Choose 15 to be placed in an experimental group and 15 for a control group. Assure that all fish are seemingly in good health, and that each group has the same distribution of the sexes.

4. Weigh each fish of the control group, and record the values (in kilograms). Do the same for each fish in the experimental group.

- Note: Record any significant qualitative observations. This includes coloration, body structure, and behavior.

5. Place all fish that are in the control group on one side of the tank, and note the side. Put those in the control group on the other side of the tank. This assures separation of each group to record accurate data.

6. Designate one bucket for each type of feed.

7. Weigh each bucket without feed in it (separately).

8. Fill one bucket with 100% commercial feed that you currently use to feed your fish population, and the other bucket with the alternative feed prototype.

9. Weigh each bucket with the feed in it (separately). Record the measurements (in kilograms).

- Note: The purpose of this step is to record the starting amount of each type of feed. This will allow for the accurate measurement of the amount of feed consumed over time.

10. Perform the same feeding practices for both groups in terms of the method of feeding and the number of times per day that the groups are fed. Follow the same feeding practices for these two groups as you do for the rest of your fish population.

- Note: Ensure that the water quality, water temperature, and population density is not significantly changed for these two groups compared to the rest of the fish population. This will allow for proper measurement of the effect of one variable on the growth of the

fish.

11. Record the mass (in kilograms) of each fish once every week at the same time of day each time. This can be done by removing the fish one-by-one with a net, weighing them individually, and placing them in a bucket filled with water to assure that you weigh every fish.

- Note: Follow the process described in step 11 with each fish in the control group, then place all fish back in the designated section of the tank *before* beginning the process for the experimental group. This will assure that the populations will remain separated

12. Document the values for all fish on the form provided (see Appendix K). This will allow for all data to be in one location.

13. In addition to the weekly measurements of the mass (in kilograms) of each fish, take a weekly measurement of the amount of feed remaining in each bucket on the same day of each week.

- Note: Subtract the current mass (in kilograms) of the bucket and feed from the value recorded from the previous week. This will allow for the proper calculation of the weekly feed consumption.

14. Record any qualitative changes you notice over the course of testing. Even if you think it might or might not be of significance, record your observations in the “notes” region of the form.

15. Repeat this weekly process for the development of all 30 fish from the small-fry stage to market size. Once all fish reach market size, calculate the total amount of feed consumed by each group.

- Note: Sum the consumption of each group in every three-week period to determine the total feed consumption.

16. Record the number of days required for each fish to reach market weight, and the total mass (in kilograms) of each group.

17. Record any qualitative observations that you believe represents benefits or drawbacks to each type of feed.

18. Report your findings to AgroInnova.



Figure 11: Potential technique for separating fish into groups for testing, Edgardo Ramírez's farm

4.3 Development of outreach program for AgroInnova to utilize

Through our interview with Joylin Guzmán we obtained information that we needed in order to create our outreach program. We learned that our target population consisted of both male and female farmers that were, on average, between 30 and 50 years of age. Most of these farmers have not attended college (J. Guzmán, personal communication)

We created several pieces of outreach material to attract the attention of individuals interested in our financial strategies workshops and our alternative animal feeds. We made a pamphlet that could be handed out at different locations, we made a radio advertisement to reach a larger audience, we made a video for AgroInnova's Facebook page, and we created a "workshop on wheels" program. All of these materials would draw interest into the workshops that we created. For the workshops we made a PowerPoint, informational handouts, forms to collect data, and a schedule.

The pamphlet that we created for AgroInnova's outreach program can be found below in Figure 12 and Figure 13. The format of the pamphlet was created to have intriguing facts and numerous images in order to attract readers and to incite their interest in seeking more information.

Our Goal:

- Teach farmers money saving strategies
- Develop communication among the local farming community
- Further develop and test our alternative animal feed, as a possible money saving strategy
- Grow the Agricultural Industry of Puerto Rico (specifically the rabbit and tilapia industries)



“That is the path for the future”

Michael McGee (Tilapia Farmer, referring to these money saving strategies)

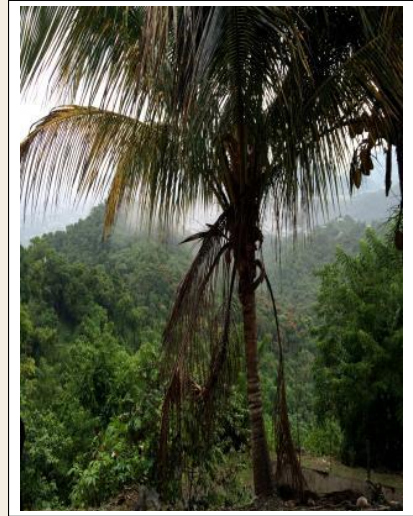


Let Us Introduce Ourselves!

AgroInnova helps entrepreneurs in the food industry develop their products using our facilities, licenses, permits, equipment and employees. We also provide consulting services and technical assistance in the areas of entrepreneurship, finance, marketing, and advertising.

Contact us at
(787) 961-2001 Ext 2132
Or through Facebook (search for keywords “AgroInnova Puerto Rico”)

Inova Caguas PR 34,
Valle Tolima West
Industrial Park,
Caguas, Puerto Rico



Financial Strategy Workshop For Farmers



Corporación Juvenil para el Desarrollo de Comunidades Sostenibles

agroinnova
Caguas, Puerto Rico

Figure 12: Front (right), back (center), and flap (left) of the outreach pamphlet. Note: The pamphlet should be translated into Spanish before distribution.



Figure 13: Middle sections of the outreach pamphlet.

This is a tri-fold pamphlet. In Figure 12, the left column is the first flap, the middle column is the back panel, and the right column is the front panel. In Figure 13, the layout is exactly the same as if you completely opened the pamphlet. The pamphlet contains information on what the financial strategy workshops are, what attendees get from them, logistical information on the workshops, and contact information for those who want more details.

We also created a video that can be used as an informational advertisement on AgroInnova's Facebook page. The link to where the video can be found is <https://www.dropbox.com/s/rp8131f2oegnm5b/AgroInnova%20facebook%20video.wmv>. The video contains images of what AgroInnova has been doing, music, and text that describes the work that AgroInnova does and the information that they can provide to farmers. The advertisement is intended to draw the interest of their Facebook page visitors and to get them to

contact AgroInnova for more information on their workshops and alternative animal feeds. The video accomplishes this by providing images and music to provide entertainment for the viewer. In addition, the text and images provide the viewer with some information of what AgroInnova is doing, but not enough so they will still want to know more. The video shows the various money saving strategies, including alternative animal feed, and also informs the viewer of how important it is for farmers to communicate and work together. The video contains Spanish text to be both consistent with the content on AgroInnova's Facebook page and comprehended by the audience that will be viewing the video. Figures 14, 15, and 16 are images from the video, showing some of the major points we wanted the video to highlight.



Figure 14: Image from Facebook video, expressing the positive impact that collaboration between farmers would have on the island's farming industries



Figure 15: Image from outreach Facebook video, giving an example of a farming byproduct that can be utilized to help farmers save money and employ more efficient farming strategies



Figure 16: Image from outreach Facebook video, showing fresh *Azolla caroliniana* and explaining the significant impact that would result from implementing alternative animal feed

We made a script for a radio advertisement for AgroInnova. The script can be found below in Figure 17.

Radio Advertisement Script

🎵 Aagrooo – Innnoovaaa (AgroInnova), Innovations for Agriculture, Innovations for You 🎵
(Sing the Tune)

Are you a tilapia or rabbit farmer, or are you interested in becoming one?

Are you struggling to make a profit?

If so, we can help you.

We are AgroInnova.

We are a non-profit organization, which works to aid the agricultural industry in Puerto Rico.

We hold workshops that allow us to teach you ways to increase the production of your tilapia or rabbit farm and increase your profit.

At these workshops we will help you learn different strategies to help save money, including an alternative animal feed that we developed.

This animal feed is made of alternative plants and could significantly reduce the cost that you spend on feed.

If you would like more information on our workshops and the alternative animal feed please contact us by our phone number, (787) 961-2001 Ext 2132, or through our Facebook page.

🎵 Aagrooo – Innnoovaaa (AgroInnova), Innovations for Agriculture, Innovations for You 🎵
(Sing the Tune)

Figure 17: Radio advertisement script for workshop outreach program. Note: The radio advertisement script should be translated into Spanish before use.

The radio advertisement starts and ends with a jingle to catch the attention of the listener and to help them remember the advertisement. The advertisement also provides some information on what AgroInnova is, the financial strategies workshops that they hold, and the alternative animal feeds. The information is enough to let the listener know what they need to know, but leaves them wanting to know more. This advertisement can be used in any radio station; however, we note that WKAQ 580 would be a proper station to play the advertisement. This radio station is a live news talk show that focuses on analyzing news and spreading information. This could be a great outlet for our advertisement, and AgroInnova could seek an

interview with the radio station to further inform the public of this new research and workshops. In the advertisement, we also provided the contact information for AgroInnova, so that interested listeners can inquire about more information. When AgroInnova is ready, they can record the radio advertisement in the language that they choose and play it on a radio station.

We created a schedule for our workshops. The schedule can be found below in Figure 18.

Financial Strategies Workshop Schedule

Time	Event	Speaker
11:00 - 11:05	Introductions/ Welcome (Provide Handout)	Instructor
11:05 – 11:15	Attendees' previous knowledge form and discussion (Handout Form)	Entire Group
11:15 – 11:30	PowerPoint (Present all information on money saving strategies, and allow for questions)	Instructor
11:30 – 11:40	Break the farmers into small groups and have them discuss what they do to save money on their own farm.	Small Groups
11:40 – 11:50	Bring the small groups together and have a large group discussion on what each individual farmer does to save money on their own farm.	Entire Group
11:50 – 12:05	Have a guest, expert speaker talk. This should be an established farmer who has used different money saving strategies on his farm.	Expert Speaker
12:05 – 12:15	Break the farmers into small groups and have them discuss what strategies they are most willing and excited to try	Small Groups
12:15 – 12:25	Bring the small groups together and have a large group discussion on what strategies they are most willing and excited to try	Entire Group
12:25 – 12:40	Provide information on all of the subsidies and grants that they could apply for to pay for their farming equipment. Show them how to apply for them.	Instructor
12: 40 – 12:50	As an entire group, use hypothetical data to show how money saving strategies could save a farm money.	Instructor

12:50 – 1:05	Have the instructors work individually with each farmer, using the expense breakdowns that they brought in to show how the money saving strategies that they learned could save them money	Instructor
1:05 – 1:20	Hand out samples of the plotted alternative plants and the animal feed pellets (for the attendees to take home). Ask for the opinions of the farmers and open up a discussion on what they think. Use this time to gauge interest in participating in testing the feed.	Instructor
1:20 – 1:25	Inform them of other places they can go for information. Also, encourage them to try out the strategies and then return to future workshops, with their new found insight.	Instructor
1:25 – 1:35	Workshop evaluation form (Handout Form)	Instructor
1:35 – 1:55	Give them a tour of the facilities. Demonstrate how some of the equipment works	Instructor
1:55 – 2:00	Ask them if they have any questions/ Thank You and Goodbyes	Instructor

Figure 18: Schedule for workshops. This schedule assumes a start of 11:00 AM, but this can be adjusted for any start time.

The schedule lays out the events that should happen during the three-hour workshop. The middle column of the schedule shows the event, the left column shows the time frame for the each event, and the right column shows who should be doing the majority of the speaking during each event. The workshop starts off with a welcoming, and then the handouts are distributed. Next, the form in Figures 24 and 25 will be handed out and discussed. Following that is the PowerPoint presentation, along with any questions that may arise from it. The next event is a group discussion on what each farmer does to save money on their own farm. This discussion is important because it allows for the farmers to work together, and it should allow for

new money saving strategies to be discovered. For this discussion, the farmers are first separated into small groups, and then are brought together for the large group discussion. The reason for this strategy is to allow the farmers to share their ideas with a small amount of people to help them gain confidence in what they are saying. This should result in greater participation during the large group discussion.

Following that discussion, a guest speaker will talk to the group. The expert should be a farmer from Puerto Rico who has experience with different money saving strategies. This guest speaker will provide additional knowledge and valuable insight into farming practices. For the rabbit workshop, an example of such an expert is Roberto Delgado, and for the tilapia workshop, Edgardo Ramírez could be a guest speaker. The reason that Roberto Delgado and Edgardo Ramírez would be good guest speakers is because during our interviews with them it was clear that they are both very knowledgeable of the current state of the meat industries and they both practiced different money saving strategies on their farms. Also, Roberto Delgado and Edgardo Ramírez have shown interest in this project and have been helpful towards the success of it, so it seems that they would be willing to help other farmers and to try and push the project even further. The next event is a group discussion on what strategies the farmers are most excited to try. The objective of this discussion is to get all of the farmers to think about the strategies that they will use on their own farms. This discussion will also start with small groups prior to moving to the large group. Following that, the instructors will provide information on different subsidies and grants that the farmers could apply for, and they will also show them how to apply for them. These subsidies and grants are available from the Puerto Rican Department of Agriculture and can provide the farmers with additional funds to pay for equipment.

The next activity is using hypothetical data to show how different money saving strategies can save farmers money. This leads to the instructors working individually with each farmer, using the expense breakdown that the farmers brought in to show them how they can save money. The farmers can bring in as much information as they want, ranging from an entire expense breakdown of their farm to how much they spend on just their feed. The farmers can learn how they can save money on the expenses that they choose. This exercise allows the farmers to clearly see how each money saving strategy could impact them. Next, the farmers will receive samples of the plotted alternative plants and samples of the alternative animal feed. This will lead into a discussion on the feed and will allow AgroInnova to gauge interest in the

feed. After that the farmers will be informed of other places they can go to learn additional information, for instance the University of Puerto Rico Mayaguez website and the Department of Agriculture website. The farmers will also be encouraged to try out the strategies and the return to future workshops. If they do return, their insight into the strategies and the impact that the strategies can have will be used to help teach the farmers who are attending for the first time. The next event is filling out the survey found in Figures 26 and 27. After that, the farmers will be given a tour of the AgroInnova facilities. This will show them all of the equipment that they could use to dehydrate their plants and pellet their alternative animal feed. The final event of the workshop is an open question-and-answer session. All of these events in the workshop were made with the intention to teach the farmers money saving strategies, to encourage them to work together, and to introduce them to the alternative animal feed.

Since we created one workshop for tilapia farmers and one workshop for rabbit farmers, we created a PowerPoint document for each. The PowerPoint document for the tilapia workshop can be found in Appendix L and the PowerPoint document for the rabbit workshop can be found in Appendix M. These current PowerPoint documents provide the presenter with the topics that he or she needs to cover, along with most of the information that he or she should provide. These PowerPoint documents should be used as a guide for the presenter, so that he or she would know what information to include. The presenter should create another PowerPoint document that is more visually appealing and contains less text, in order to present. Also, while creating the PowerPoint document for the presentation, they should consider their audience and decide whether they would like to translate it to Spanish. The PowerPoint documents contain information on different strategies that could save the farmers money. For the tilapia workshop, the document has slides on the current state of the tilapia industry, money saving strategies, recycled goods, donated equipment, self-sustainable farming practices, and alternative animal feeds. The PowerPoint document goes into detail on all of these topics, and also contains information on how hydroponics and aquaponics work and a large amount of information on the alternative animal feed that we created. The PowerPoint document also has numerous images that help the viewer to visualize many of the topics. The PowerPoint document for the rabbit workshop is similar in many ways. It has slides on the current state of the rabbit industry, money saving strategies, less expensive materials, recycled material, donated equipment, self-sustainable farming practices, and alternative animal feed. This PowerPoint document goes into

detail on how to make compost, and also goes into detail on our alternative animal feed. These PowerPoint documents supplies the presenter with the information that they need to show to farmers including ways to save money on their farm and to increase their profits. This PowerPoint document also allows the presenter to inform the farmers about detailed information on the alternative animal feed and all of its benefits.

We also made two informational handouts, one for the tilapia workshop and one for the rabbit workshop. The tilapia handout can be found in Figures 19 and 20 below, and the rabbit handout can be found in Figures 21 and 22 below.



Financial Strategies for Tilapia Farmers

Money Saving Strategies

1. Alternative Animal Feed
2. Recycled Goods
3. Donated Equipment
4. Cheaper Materials
5. Self-Sustainable Farming Practices

Recycled Goods

- Almost all equipment on a tilapia farm can be made from recycled goods, this includes:
 - Tanks
 - Bio balls
 - PVC pipes

Donated Equipment

- If requested many large scale companies will donate their old liquid storage containers, that can be used to store water or even as tanks for your tilapia

Self-Sustainable Farming Practices

- Practices like aquaponics can be self-sufficient, and have numerous benefits, including the use of waste as fertilizer, the growing of plants, and the filtration of water.

Alternative Feed Formula

The alternative animal feed is made of a percentage of commercial feed in addition to alternative plants. This formula is currently being tested. If you are willing to try the feed for yourself and record the affect it has on your tilapia, please inform AgroInnova.

70% <i>Commercial</i>
20% <i>Azolla caroliniana</i>
10% <i>Lemna Minor</i>

Benefits of Using Alternative Feed

Farmers who use this alternative feed can grow a large amount of the required components on their farm. This greatly reduces the cost of feed. With the lowered costs, tilapia farming is more profitable and production can be expanded.

The animal feed has been compared to many of the most popular commercial feeds in Puerto Rico. As a result, the quality of the feed is not reduced, while the cost of the feed is. The animal feed is currently being tested to confirm all of these claims.

How to Create the Feed

- AgroInnova: \$200 for one day; production of X pounds of feed by using the machines available at the Caguas facility
- Transport fresh plant ingredients to the facility
- Processing of material with machines
- Dried and crushed plant material combined in correct percentages
- Pelleted, packaged, and returned/stored

Figure 19: The front of the handout for tilapia workshop. Note: The handout should be translated into Spanish before use.

How to Grow the Plants

Species	Light	Water	Harvest	Processing	Temperature
<i>Pennisetum purpureum</i> (maralfalfa)[1]	Full	Prefers areas with high level of rainfall, but maintains growth with minimal irrigation during dry season	Every 40-60 days; cut 4 inches away from the base to maximize product and allow for regrowth	Grinding of the dried radial plant (not roots) allows for use in livestock feed	Higher growth rate in hot, tropical environments
<i>Morus alba</i> [2]	Full	Drought tolerant, fruit does not ripen fully; prefers moist areas	Every 90-120 days (tropical); cut away from trunk base (time needed to heal)	Grinding of the dried plant forage allows for use in livestock feed	>= 10C average temperature required; optimal growth in hot, tropical weather
<i>Azolla caroliniana</i> [3]	25-50% is ideal (out of this range results in lower growth rate)	Absorbs nutrients available in aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Can grow in temperatures ranging from freezing to arid; Optimal growth at 20-30C
<i>Lemna minor</i> [4]	Full results in optimal growth, able to grow with moderate sunlight	Absorbs nutrients available in the aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Tolerant in range of temperatures; normal growth observed at as low as 7C, but hot temperatures are ideal
<i>Moringa oleifera</i> [5]	Full results in optimal growth, able to grow with moderate sunlight	Dependent on irrigation during severely dry seasons or extended droughts	Entire plant can be harvested from every two weeks to every 50-60 days; cut at the stem, leaving >0.5m out of the ground.	Grinding of entire radial plant allows for use in livestock feed	Can survive lower temperature, prefers semi-arid or tropical environments with high temperatures
<i>Pueraria lobata</i> (kudzu) [6]	Does not need full sunlight, but will grow towards the sun if more light is needed	Highly durable/tolerant to drought; grows at a higher rate with available moisture	Can be harvested at any time, grows freely in various areas. Entire vine achieved by various methods	Grinding of entire plant material allows for use in livestock feed; can be fed directly from harvest	Is found in a variety of environments, but grows rapidly in hot, humid environments

Figure 20: The back of the handout for tilapia workshop



Financial Strategies for Rabbit Farmers

Money Saving Strategies

1. Alternative Animal Feed
2. Recycled Goods
3. Donated Equipment
4. Cheaper Materials
5. Self-Sustainable Farming Practices

Less Expensive Materials/ Do it Yourself

- Often it is much cheaper to make the equipment needed for your farm, especially when you use less expensive material. One example of this is making your rabbit cages out of wire meshing.
- Recycled material is another less expensive option, this material can be used for numerous reasons including PVC pipes to both deliver water to your rabbits, and/or to transport urine to septic tanks.

Self-Sustainable Farming Practices

- One example of these farming practices is using the waste of your rabbits as fertilizer. This fertilizer can then be used to help grow the plants that you use to feed your rabbits.

Alternative Feed Formula

The alternative animal feed is made up of a percentage of commercial feed in addition to alternative plants. This formula is currently being tested. If you are willing to try the feed for yourself, and record the affect it has on your rabbits, please inform AgroInnova.

25% <i>Pennisetum purpureum</i> (maralfalfa)
20% <i>Morus alba</i>
20% <i>Moringa oleifera</i>
20% Commercial feed
15% <i>Pueraria lobata</i> (kudzu)

Benefits of Using Alternative Feed

Farmers who use this alternative feed can grow a large amount of the required components on their farm. This greatly reduces the cost of feed. With the lowered costs, rabbit farming is more profitable and production can be expanded.

The animal feed has been compared to many of the most popular commercial rabbit feeds in Puerto Rico. As a result, the quality of the feed is not reduced, while the cost of the feed is. The animal feed is currently being tested to confirm all of these claims.

How to Create the Feed

- AgroInnova: \$200 for one day; production of X pounds of feed by using the machines available at the Caguas facility
- Transport fresh plant ingredients to the facility
- Processing of material with machines
- Dried and crushed plant material combined in correct percentages
- Pelleted, packaged, and returned/stored

Figure 21: The front of the handout for rabbit workshop. Note: The handout should be translated into Spanish before use.

How to Grow the Plants

Species	Light	Water	Harvest	Processing	Temperature
<i>Pennisetum purpureum</i> (maralfalfa)[1]	Full	Prefers areas with high level of rainfall, but maintains growth with minimal irrigation during dry season	Every 40-60 days; cut 4 inches away from the base to maximize product and allow for regrowth	Grinding of the dried radial plant (not roots) allows for use in livestock feed	Higher growth rate in hot, tropical environments
<i>Morus alba</i> [2]	Full	Drought tolerant, fruit does not ripen fully; prefers moist areas	Every 90-120 days (tropical); cut away from trunk base (time needed to heal)	Grinding of the dried plant forage allows for use in livestock feed	>= 10C average temperature required; optimal growth in hot, tropical weather
<i>Azolla caroliniana</i> [3]	25-50% is ideal (out of this range results in lower growth rate)	Absorbs nutrients available in aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Can grow in temperatures ranging from freezing to arid; Optimal growth at 20-30C
<i>Lemna minor</i> [4]	Full results in optimal growth, able to grow with moderate sunlight	Absorbs nutrients available in the aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Tolerant in range of temperatures; normal growth observed at as low as 7C, but hot temperatures are ideal
<i>Moringa oleifera</i> [5]	Full results in optimal growth, able to grow with moderate sunlight	Dependent on irrigation during severely dry seasons or extended droughts	Entire plant can be harvested from every two weeks to every 50-60 days; cut at the stem, leaving >0.5m out of the ground.	Grinding of entire radial plant allows for use in livestock feed	Can survive lower temperature, prefers semi-arid or tropical environments with high temperatures
<i>Pueraria lobata</i> (kudzu) [6]	Does not need full sunlight, but will grow towards the sun if more light is needed	Highly durable/tolerant to drought; grows at a higher rate with available moisture	Can be harvested at any time, grows freely in various areas. Entire vine achieved by various methods	Grinding of entire plant material allows for use in livestock feed; can be fed directly from harvest	Is found in a variety of environments, but grows rapidly in hot, humid environments

Figure 22: The back of the handout for rabbit workshop

The handouts provide the workshop attendees with much of the information that can be found on the PowerPoint documents. It allows the farmers to take home the most important information. On both handouts is the formula for the animal feeds and a chart showing the growing demands of the different alternative plants.

For the workshops we also developed two surveys, one for the start of each workshop and another for the end. The survey for the start can be found in Figures 23 and 24, and the survey for the end can be found below in Figures 25 and 26.

Prior Financial Strategy Knowledge

Please answer the following questions to give us a better idea of your prior knowledge, and to help both this workshop and future workshops.

Thank you in advance for your cooperation!

Date of Workshop _____

ANSWER TO THE BEST OF YOUR ABILITY

1. Have you attended a financial strategy workshop with us in the past? Yes/No
2. Have you had any formal education on financing and/or money saving strategies? Yes/No
 - a. If yes, where? _____
3. Did you bring the financial material that we suggested? Yes/No (If No, Why Not?)

4. What are the forms of advertisements that attracted you to this workshop? (pamphlet, radio, Facebook, word of mouth)

5. What are you most anticipating to learn from this workshop?

6. List money saving strategies that you could use on your farm, star any that you have actually used on your own farm.

7. Do you feel confident that you could apply for a subsidy or grant from the Department of Agriculture on your own? Yes/No
8. Do you keep track of the finances on your farm? Yes/No

Figure 23: The front of the prior knowledge workshop survey. Note: The survey should be translated into Spanish before use.

9. Are you confident in your ability to keep track of the finances of your farm? Yes/No

PLEASE RATE (circle one) (5 being most, 1 being least)

1. How confident are you in your financial/ money saving strategies knowledge. 5 4 3 2 1

2. How willing are you to discuss different topics with your fellow farmers..... 5 4 3 2 1

3. Your willingness to try our alternative animal feed on your farm..... 5 4 3 2 1

Figure 24: The back of the prior knowledge workshop survey

Workshop Evaluation

Please evaluate the workshop for its quality and usefulness. Your suggestions and comments will help us in planning future workshops.

Thank you in advance for your cooperation!

Date of Workshop _____

Rating Scale

- 5 Excellent = Outstanding; superior; exemplary
- 4 Very Good = Well above average; very competent
- 3 Good = Above average
- 2 Adequate = About average; could use improvement
- 1 Deficient = Definite weakness; inadequate

PLEASE RATE (circle one)

1. The workshop overall..... 5 4 3 2 1
2. The value of handouts and audio-visual presentations..... 5 4 3 2 1
3. The value of the group discussions..... 5 4 3 2 1
4. The value of the samples that were provided..... 5 4 3 2 1
5. How confident are you in your financial/ money saving strategies knowledge. 5 4 3 2 1
6. The likeness that you will use some of the money saving strategies you learned during this workshop..... 5 4 3 2 1
7. The likeliness that you will return to future workshops..... 5 4 3 2 1
8. Your willingness to try our alternative animal feed on your farm.....5 4 3 2 1
9. If we give you the feed for free, would you be willing to test the feed on your farm?
Yes/No
10. List money saving strategies that you could use on your farm.

Figure 25: The front of the workshop evaluation sheet. Note: The evaluation sheet should be translated into Spanish before use.

11. Do you feel confident that you could apply for a subsidy or grant from the Department of Agriculture on your own? Yes/No

12. In the future will you keep track of the finances on your farm? Yes/No

13. Are you confident in your ability to keep track of the finances of your farm? Yes/No

ANY COMMENTS OR SUGGESTIONS?

Figure 26: The back of the workshop evaluation sheet

The survey that will be handed out at the start of the workshops is used to gauge the prior knowledge of the farmers who attend. It asks them if they have attended a financial strategies workshop in the past, how willing they are to discuss their finances with a group, if they have any money saving strategies that they currently use, and how confident they are in their money saving knowledge. These questions allow AgroInnova to assess what the farmers know prior to arriving at the workshops, and allow them to alter the workshop and future workshops to accommodate this. The way that they can alter future workshops is by understanding what the farmers who attend the workshops already know when they arrive. AgroInnova can change the information that they cover in the workshop to make sure that they are teaching the farmers new material. The advantage of having a survey at the start of the workshop is that they learn about the farmers' prior knowledge.

Additionally, by asking some of the same questions on a post survey, they can learn if the workshop was successful at providing information to the farmers. If the farmers leave question number 10 on the preliminary survey blank, but they state some strategies in the evaluation survey, it can be deduced that the farmer learned this information through the workshop. The last three questions on the preliminary and evaluation surveys focus on the farmer's comfort level in sharing their information amongst farmers and different strategies for increasing the production of their farms. These questions will allow AgroInnova to assess the farmer culture. This is very important because collaboration is vital for the success of the workshop. With this information, AgroInnova can assess if the workshops are leading the farmers towards collaboration or if other strategies must be explored. Another question on the survey asks them what kinds of advertisements drew their interest to the workshop. This question allows AgroInnova to understand what forms of outreach are working and what forms are not. The final question on the survey asks them if they are interested in trying the alternative feed. This question will allow AgroInnova to know if there are any new farmers who would like to contribute to the study on the alternative animal feed.

The survey that will be handed out at the end of the workshops is used to evaluate the quality of the workshop. This survey asks the farmers to rate the workshop overall, the handouts and presentations, the discussions, the free samples, and asks them to leave comments or suggestions. All of this information collected through this survey will allow AgroInnova to improve their future workshops and to make sure that farmers are satisfied. They will be able to

improve using this survey in a couple of ways. The first half of the workshop evaluation form will help AgroInnova get information on the farmer satisfaction towards the workshop. The second half of the evaluation form will give feedback on confidence and knowledge gained by the farmers on the topics covered in the workshop. These latter questions are identical to those in the prior financial strategy worksheet. If the farmers' confidence level and/or answers to questions do not improve between surveys, then AgroInnova knows that they must fix the way that they are presenting the material.

The overall goal of the workshops is to benefit the farmers. These forms allow AgroInnova to determine if the workshops are achieving this goal. All of this outreach material has been created with the assumption that the testing of the alternative feed has not been completed. These materials can be used as a way to inform farmers on the tests and recruit farmers to test the feed on their farms. On the evaluation survey, the last question was added to find participants for the testing.

The final aspect of outreach that we created was the "workshop on wheels" program. For this program we determined how it should be operated and what materials AgroInnova would need. The intention of this program is to bring the workshop to farmers who either were unwilling or unable to travel to AgroInnova. Although the workshop on wheels will not be as detailed or as long as the workshop at AgroInnova, it will provide helpful information and could convince farmers who were unwilling to travel to change their mind. The "workshop on wheels" would consist of an AgroInnova employee traveling to individual farms. He would have the handouts that would be used at the normal workshops, along with a sample of the alternative animal feed. The employee would talk to the farmer about the different money saving strategies, and would take a tour of the farm to point out specific areas that could be altered to save the farmer money. Since AgroInnova is a nonprofit, they would only charge however much it costs them to provide the service. This includes transportation, labor, and any materials that they provide to the farmers.

5.0 RECOMMENDATIONS AND CONCLUSION

Based on the results from Chapter 4 and the research presented in the background chapter, our team developed a set of recommendations on the economic viability of rabbit and tilapia farming and the feasibility of an alternative animal feed in Puerto Rico. We have created these recommendations for AgroInnova, the local rabbit and tilapia farmers, and other parties that may find this information valuable. These recommendations include outreach strategies for AgroInnova. Because we focused on small-scale farms and six specific alternative plants, we consider our results applicable to any person interested in rabbit and tilapia husbandry or alternative plants as animal feed. In this chapter, we also discuss the limitations of our project so future studies can properly evaluate and potentially expand on it.

5.1 Recommendations for rabbit and tilapia farmers

We recommend that farmers attend financial strategy workshops to increase their knowledge on cost-effective and more efficient farming strategies.

Employing good financial strategies can increase the efficiency and profitability of a farm. As we worked with the different farmers, we realized that feed is not the only production cost that can be improved in the local farms. Attending a workshop on financial strategies can inform farmers on different ways to cut down on costs.

Some of these strategies include using wire mesh to construct cages instead of buying new cages for the rabbits and using the rabbit feces to create compost with the purpose of adding organic matter to the soil. Similar strategies for tilapia farming include using recycled tanks and culturing *Lemna minor* in water-filtering tanks to change ammonia into nitrate. These and other strategies would be discussed in the financial strategy workshops. If farmers supply their financial documents for the workshop, specific improvements can be recommended in these workshops using the expertise of the workshop coordinators. Also at these workshops, all farmers will be able to share their knowledge with the group. This allows everyone to benefit from each other's ideas and discoveries.

We recommend that farmers apply for subsidies and grants from the Department of Agriculture.

Subsidies and grants from Puerto Rico's Department of Agriculture can help farmers pay for equipment that is needed to grow alternative plants and produce alternative feed. We have developed a plan for AgroInnova to assist farmers in learning how to apply for these grants at their workshops. If farmers apply for grants and subsidies, they can cut down the cost of the already less expensive option of producing our alternative feed.

We strongly recommend that farmers pursue other business ventures involving tilapia and rabbit, to help improve the demand and to create additional selling options.

There are many different options of how to market both the meat and the animals that these two industries produce. One strategy is to build a connection with restaurants and produce different food dishes using the rabbit or tilapia meat. One example of this is producing empanadas filled with rabbit meat. Roberto Delgado informed us that he is working with several partners in creating empanadas using rabbit meat. This use of rabbit meat is much more efficient because the meat is combined with other ingredients like potatoes and vegetables. The use of these other ingredients means that empanadas contain less meat. Because the Puerto Rican culture enjoys empanadas as a comfort food, this business venture could lead to a much higher demand of rabbit meat through its use in the empanadas. Also, the increase of demand on the rabbit meat causes the economic viability of the industry to increase. This kind of business venture creates more options in different selling markets for the rabbit farmers.

Another example of an additional business venture would be ornamental fish. The two tilapia farms that we visited had ornamental fish for sale. Edgardo Ramírez informed us that he sells tilapia and other fish for ornamental purposes more than consumption, due to the lack of demand. Tilapia can be raised for both meat production and ornamental sale, and other fish like koi are also useful for ornamental sale. The red color of the tilapia makes it an aesthetically pleasing fish to possible buyers (E. Ramírez, personal communication). This business option gives farmers more flexibility for selling their fish, even when the demand for the meat is not high. Although ornamental fish does create more demand for tilapia, it is not enough to increase the profitability of the tilapia industry. The use of different business ventures can increase the profitability of both the rabbit and tilapia industries.

We recommend that farmers pursue small-scale business options in addition to rabbit or tilapia farming that involves minimal maintenance and can be sustained from the byproducts of animal husbandry.

On both tilapia and rabbit farms, there are multiple options for gaining income. Other strategies that use byproducts from their current farming methods are an option. On all three farms that we visited, we witnessed several of these strategies. One recommendation that we have is to use the waste of the tilapia or rabbits as compost to grow plants. These plants can be grown for both the production of their alternative feed components, or they could be grown for sale. Michael McGee grows cilantro on his farm, and fertilizes it using the waste from his fish. He then sells the cilantro to grocery stores each week; this option adds additional revenue to his farm. Another example of one of these business strategies is raising crustaceans, like shrimp, on tilapia farms. Shrimp can be raised, even in the same tank as the tilapia, and require limited maintenance (M. McGee, personal communication). Both of these business options are examples of processes that use byproducts that normally go unused on farms, to create an additional income.

We recommend that AgroInnova create a meeting where farmers can actively communicate with one another.

From our visit to the experimental station in Gurabo, we witnessed that many of the farmers had different money-saving and animal rearing strategies. During our visit, other farmers were present during Doctor Yamil Quijano's informal presentation. This presentation was left open for discussion so that it allowed all of the farmers to share their strategies and information with one another. Each farmer was able to ask questions to one another, and everyone joined the conversation. When there was a question someone did not know the answer to, there was usually someone else who could provide an answer or some assistance. A community meeting from AgroInnova would create an opportunity for farmers to communicate with each other. This community meeting could encourage community farmers to exchange ideas and strategies in the same way that Doctor Yamil Quijano's presentation encouraged farmers to ask questions and speak freely.

We think that AgroInnova could use a space in their facility or in the Hormigas farm for this meeting. An email invitation could be sent out to any farmer interested, and collaboration

with the Puerto Rico Department of Agriculture could help advertise the meeting. The meeting would have one lead speaker and the rest of the farmers would speak up whenever they have something to say. If the number of farmers and the space allows, chairs would be set up in a circle so that each farmer can see whoever may be speaking at a given time. If the number of farmers is too large to make this feasible, then the chairs would be set up in rows. The meeting would conclude after an hour or two, whichever the leader considers most appropriate.

If having this meeting once a month is not feasible for AgroInnova, a Facebook page could be created to encourage farmers to more actively and frequently communicate new strategies they either think of or attempt. If most farmers do not use or have a Facebook account, a cooperative could be created. This cooperative would be in charge of communicating information on logistics of meetings. These logistics could include meeting topics, location, time, and special guests.

5.2 Recommendations for Outreach Program

We recommend that AgroInnova seek funding from the Puerto Rico Department of Agriculture to continue our project by using and improving the workshop and advertising material we created. This would help advertise farming in the island of Puerto Rico.

Roberto Delgado communicated to us that the Puerto Rico Department of Agriculture, as an organization, is very successful in the promotion of projects. In his personal experience, he noted a drastic increase in the level of interest from individuals and organizations in his project after submitting his materials to the Department of Agriculture in Caguas. The department can be contacted at (787) 743-8570. Further contact would need to be made to network with the representative of the aquaculture industry of Puerto Rico. In addition, the department has been strongly encouraging further research in alternative agriculture. For these reasons, we believe that AgroInnova should pursue submitting our report and ideas for advertisement and workshops. Although the individuals in AgroInnova's farming network will benefit from the material we developed without doing this, we feel that connecting with the Puerto Rico Department of Agriculture on this project will be critical in maximizing change and increasing alternative and sustainable farming strategies across the island. There are business plan worksheets and forms on the site of the United States Department of Agriculture. Collaboration from AgroInnova with the Puerto Rico Department of Agriculture can help get these useful resources to the farmers that

need them. The following link can be used to find these forms and more,
<http://ric.nal.usda.gov/small-farm-funding>.

We recommend that AgroInnova brings in financial experts and established tilapia and rabbit farmers from Puerto Rico to their workshops, to help explain and validate the information.

During the financial strategies workshop, any guest with expertise who could speak to the farmers would help to better explain the information and help to make the farmers trust the information. While the staff of AgroInnova have expertise that will be valuable to farmers, it would be beneficial to include additional guest speakers who could explain the financial benefits that various strategies, like our alternative animal feed, would offer. Also, it would be helpful to have established farmers, like Roberto Delgado, Edgardo Ramírez, and Michael McGee, speak at the workshops. Farmers who have developed a productive farm and know numerous money saving strategies would be able to teach the farmers valuable information. In addition, as farmers who already have faced numerous challenges and have already went through the startup phase, they would have a better understanding of what is important to communicate to their fellow farmers.

We recommend that AgroInnova develops an outreach program to help increase the demand of the tilapia industry.

If the production of the tilapia and rabbit meat industries improves, the demand for the meat should be high. In the rabbit industry there is a high level of demand for the meat that is unmet. The same is not true for the tilapia industry, as the demand for the meat is low. According to the farmers that we visited, there are two main reasons behind the low demand. First, people in Puerto Rico believe that since tilapia are bottom feeders they eat their own waste, making them unappetizing (E. Ramírez, personal communication). Secondly, the people in Puerto Rico who do eat tilapia are fine with eating tilapia meat that is imported from Asia (M. McGee, personal communication). We recommend that an outreach program is created for the public that focuses on addressing these two issues. If the program can provide information to the public such as that tilapia tanks contain filters that remove waste, they can start to change the negative opinion associated with tilapia meat. The program should also use the strong pride in

culture that many Puerto Ricans have to attempt to get more of them to eat tilapia that is raised in Puerto Rico over imported tilapia. Many of the citizens in the other Caribbean islands prefer tilapia grown in their own country over imported tilapia (M. McGee, personal communication). If an outreach program could encourage residents of Puerto Rico eat homegrown food over imported food, it would help increase the demand for tilapia on the island. With demand high for both tilapia and rabbit meat, the increased productivity of the farms would be even more beneficial.

5.3 Recommendations for further research

We recommend that our animal feed prototypes be tested for feed efficiency and possible complications.

With the research we collected in the background chapter, we were able to formulate several feed prototypes; however, we were unable to reach the stage of testing our prototypes because of our time constraints. Our prototypes would need to be tested to understand if the prototypes can be successfully used in place of the commercial feed. During our time working on this project, Edgardo Ramírez volunteered to test the tilapia feed on some of his tilapia, and Roberto Delgado indicated that he and three fellow farmers would be interested in volunteering to test the rabbit feed on some of their rabbits.

The experiments would be carried out using our guidelines, found in section 4.2.5. This testing would focus on the weight gain and general health of the animals. The test should include recording of the animal's weight and any health complications. If any adverse health effects occur more frequently in the experimental group than in the control group, the testing should be terminated until the cause of those effects is determined. The testing should conclude with a discussion chapter to analyze the information recorded. This could then be used for validation of our feed prototypes or further testing of the feed.

We recommend that the alternative plants undergo testing for their biochemical composition. The plants must be tested after being grown in all possible conditions.

While we were able to estimate the nutritional composition of our six alternative plant options, the most accurate values of our plant ingredients would come from a biochemical analysis of the formulations themselves. This would be more accurate because each growing and

processing decision may affect the nutritional composition of the plants. As shown in the maralfalfa case study by Doctor Yamil Quijano (section 2.4.2), a difference in the time of harvest can dramatically affect the nutrition of the plant; even the spacing in between the plants created a difference in the growth and nutritional composition of the plant. For this reason, further research should be done on the best growing conditions of the six alternative plants. The current limited research is not enough to outline the best growing conditions. Tests, such as those performed by Doctor Yamil Quijano, could lead to higher nutrition efficiency for the plants. By changing the distance between the plants, the stem of the plants grew either thicker or longer. The thicker stem had a higher percentage of ash and indigestible fiber. These are factors that could be investigated for all the plants.

Another consideration for this test will be the difference between the aquatic and terrestrial plants. While distance between plants can be measured for terrestrial plants, aquatic plants float on the surface. The test for aquatic plants could focus on the available surface area of the pond. These tests can be expanded to focus on the effects the following factors have on the nutritional content of the plants: sunlight, fertilizer, harvest time, and watering. A test can consist of a farmer varying these factors. One test could focus on having the plants exposed to full sunlight, half sunlight, and no direct sunlight. Another test could focus on the effect of using fertilizer on the plants. Although some research has been done on these effects, it has not been done on all the plants. A third test can focus on the nutritional contents of plants harvested at different time intervals. The plants can be harvested 20 days after being cultivated, and then every 10 days after. This would be continued until day 90. Lastly, a test can be performed focusing on the effect of watering the plants. These tests should give quantifiable results on what are the best growing conditions for each plant.

From our research, we were able to find the crude protein, crude fiber, calcium, and phosphorus levels in each of the six plants we used in our feed prototype. This information can be found in section 2.3.2. Yet, there remains uncertainty over the essential amino acids that each plant contains. For this reason, a biochemical analysis would acquire information on what amino acids are in the plants. With the biochemical analysis and tests of growth in different conditions, the formulas may be recalculated to meet the nutritional demands of the rabbit and tilapia diets.

We recommend that, if tests determine that the alternative feed results in worse production than the commercial feed, AgroInnova continues to research alternative plants and to develop additional animal feeds.

This project can still have a significant impact on Puerto Rico, even if the alternative feed that we produced fails to be as productive as the commercial feed. All of the research that we have done on this topic would still be beneficial towards future efforts. Also, the outreach program that we created would still be a productive way to communicate money saving strategies to farmers and introduce them to alternative animal feed. Through our research we have discovered that alternative animal feeds are an effective strategy to save farmers money. If the alternative formulas fail, we recommend two main ways to proceed from there. The first option is to use the same plants that we used in our formulas, but to adjust the percentage of all of the components. We feel strongly that the alternative plants that we identified for use in our formulas are all strong options for a feed. If the feed fails, a slight adjustment of the amount of each plant could result in a better outcome.

The second option we recommend would be to research additional alternative plants, and to create completely new formulas implementing those plants. There are many different plants that could possibly be used in a feed, so the options are not limited. If the research is done correctly, a new successful formula could be created. Either of these options would need to be tested in a manner much like ours will be tested. No matter the results of the tests on our formulas, the research and outreach that we have done shows the benefits that a successful alternative feed can have.

5.4 CONCLUSION

Our project focused on creating alternative rabbit and tilapia feed prototypes, investigating cost-effective farming strategies, and developing an outreach program to raise awareness of our findings and those of AgroInnova. We created several alternative feed options for rabbits and tilapia, supported the economic viability of each through a detailed report, and supplied AgroInnova with several modes of outreach in an effort to strengthen the industries and increase local food production.

We learned a great deal while working on our project, and one thing that we will always remember is how proud Puerto Ricans are of their culture. However, the island is significantly

dependent on other regions for food. If this project is continued, it can help return Puerto Rico to a strong economy and a state of self-sustainability. We accomplished our goal to help AgroInnova promote local food production through rabbit and tilapia farming, and we hope that the farmers we met and the individuals at AgroInnova with whom we worked continue to make strides towards transforming the vision of Puerto Rico as a self-sustainable island into a reality.

REFERENCES

- Abaye, A., Scaglia, G., & Teutsch, C. (2009). *The Nutritive Value of Common Pasture Weeds and Their Relation to Livestock Nutrient Requirements*. Virginia Cooperative Extension, (418-150), 1-8.
- AgroInnova. (2013). "Centro de Desarrollo de Productos Agroecológicos [Facebook Page]." Retrieved November 8, 2014, from <https://www.facebook.com/pages/Agroinnova/145947435610405?sk=info>
- America's Library. (n.d.). "U.S. Raised the Flag in Puerto Rico." Retrieved October 16, 2014, from http://www.americaslibrary.gov/jb/progress/jb_progress_puerto_3.html
- Ameur, C. (1995). *Vulgarisation agricole un pas de plus*. Washington, D.C: Banque mondiale.
- Ayala, C. (1996). *The Decline of the Plantation Economy and the Puerto Rican Migration of the 1950s*. *Latino Studies Journal*, 7(1), 61-90.
- Bamikole, M. A., Ikhatua, M. I., Ikhatua, U. J., & Ezenwa, I. V. (2005). *Nutritive Value of Mulberry (Moms Spp.) Leaves in the Growing Rabbits in Nigeria*. *Pakistan Journal of nutrition*, 4(4), 231-236.
- Bijl, P. K. (n.d.). "World record biomass producer." *Azolla*. Retrieved December 5, 2014, from <http://lpp-foundation.nl/azolla/>
- Birkhaeuser, D. (1991). *The Economic Impact of Agricultural Extension: A Review*. In *Economic Development and Cultural Change* (3rd ed., Vol. 39, pp. 607-608). The University Press of Chicago.
- Bureau of Labor Statistics (BLS). (2004). "Databases, Tables & Calculators by Subject." Retrieved October 5, 2014, from http://data.bls.gov/timeseries/LASST720000000000003?data_tool=XGtable

- Branch, A. (2013, July 10). "WORLD | Homelessness in Puerto Rico and other poverty news. Andrew Branch | July 10, 2013." Retrieved September 15, 2014, from http://www.worldmag.com/2013/07/homelessness_in_puerto_rico_and_other_poverty_news
- Bridgman, B., Maio, M., Schmitz, J.A., Teixeira, A. (2012). *What Ever Happened to the Puerto Rican Sugar Manufacturing Industry?* Federal Reserve Bank of Minneapolis Research, Department Staff Report 477.
- Briney, A. (2007). "All You Wanted to Know about the Green Revolution." Retrieved October 1, 2014, from <http://geography.about.com/od/globalproblemsandissues/a/greenrevolution.htm>
- Caraballo, J. (2014). "History: Agrarian Reform of 1941." Retrieved October 12, 2014, from <http://www.encyclopediapr.org/ing/article.cfm?ref=06102002>
- Central Intelligence Agency (CIA). (2014). "Field Listing : Land use." Retrieved October 7, 2014, from <https://www.cia.gov/library/publications/the-world-factbook/fields/2097.html>
- Chapman, R. (2003). "Rural Radio in Agriculture Extension: The Example of Vernacular Radio Programmes on Soil and Water Conservation in N. Ghana." *Agricultural Research and Extension Network*, (127). Retrieved from ftp://193.43.36.92/SD/SDR/SDRE/ruralradio/publications/agrenpaper_127.pdf
- Conrad, A., Rubal-Lopez, A., & De Gruyter, W. (2004). *Post-imperial English status change in former British and American colonies, 1940-1990*. Berlin: Mouton de Gruyter.

- Cook, B.G., Pengelly, B.C., Brown, S.D., Donnelly, J.L., Eagles, D.A., Franco, M.A., Hanson, J., Mullen, B.F., Partridge, I. J., Peters, M. and Schultze-Kraft, R. (2005). *Tropical Forages: an interactive selection tool*. CSIRO, DPI&F(Qld), CIAT and ILRI: Brisbane, Australia.
- Del Mar Lopez, T. (2000). "Urban Expansion and the Loss of Prime Agricultural Lands in Puerto Rico." *AMBIO: A Journal of the Human Environment*. Retrieved September 26, 2014, from <http://dx.doi.org/10.1579/0044-7447-30.1.49>
- Dercon, S. (2009). *The Impact Of Agricultural Extension And Roads On Poverty And Consumption Growth In Fifteen Ethiopian Villages*. *American Journal of Agricultural Economics*, 1007-1021.
- Deshmukh, S., Pathak, N., Takalikar, D., & Digraskar, S. (1993). *Nutritional Effect of Mulberry (Morus alba) leaves as sole ration of adult rabbits*. In *World Rabbit Science* (Vol. 2, pp. 67-69).
- Diver, S. (2010). "Aquaponics - Integration of Hydroponics and Aquaculture." National Sustainable Agriculture Information Service. Retrieved December 11, 2014, from http://www.extension.org/mediawiki/files/2/28/Hydroponics_with_Aquaculture.pdf
- El-Sayed, A-F. M. (2006). "Tilapia Culture." Oxfordshire, CABI Publishing. 277 pp.
- Erdmann, R. & Jones , M., (1989) "The Amino Revolution." First Fireside Edition, p2.
- Espinoza, E., Benavides J.E., y Ferreire, P. (1999). "Evaluación de tres variedades de morera (Morus alba) en tres sitios ecológicos de Costa Rica y bajo tres niveles de fertilización." Benavides, J.E., 1999.
- Febles, A. N. (1992). *The Agroecology Movement in Puerto Rico*. Agro-Organics, Incorporated. Cahovanas, Puerto Rico.

- Fitzsimmons, K. (2013). "Introduction to Tilapia Nutrition." Retrieved September 21, 2014, from <http://americastilapiaalliance.org/2013/11/12/introduction-to-tilapia-nutrition/>
- Food and Agriculture Organization of the United Nations (FAO). (1980). "Chapter 1: Nutrients in livestock wastes. Feed from animal wastes: state of knowledge." Retrieved September 29, 2014, from <http://www.fao.org/docrep/004/x6518e/x6518e01.htm>
- Food and Agriculture Organization of the United Nations (FAO). (2012a). "Kudzu, aerial part, fresh". Retrieved December 4, 2014, from <http://www.feedipedia.org/node/11546>
- Food and Agriculture Organization of the United Nations (FAO). (2012b). "Moringa (*Moringa oleifera*), leaves, fresh". Retrieved November 19, 2014, from <http://www.feedipedia.org/node/12344>
- Food and Agriculture Organization of the United Nations (FAO). (2010). "Napier grass (*Pennisetum purpureum*), aerial part, fresh." Retrieved September 15, 2014, from <http://www.feedipedia.org/node/12365>
- Food and Agriculture Organization of the United Nations (FAO). (2014a). "Nile tilapia - Nutritional requirements." Retrieved November 2, 2014, from <http://www.fao.org/fishery/affris/species-profiles/nile-tilapia/nutritional-requirements/en/>
- Food and Agriculture Organization of the United Nations (FAO). (n.d.a). "Pennisetum purpureum Schumach." Retrieve December 18, 2014, from <http://www.fao.org/ag/AGP/AGPC/doc/Gbase/data/pf000301.htm>.
- Food and Agriculture Organization of the United Nations (FAO). (n.d.b). "Pueraria phaseoloides (Roxb.) Benth." Retrieved December 12, 2014, from <http://www.fao.org/ag/AGP/agpc/doc/GBASE/data/pf000058.htm>

- Food and Agriculture Organization of the United Nations (FAO). (2014b). “Top production – Ghana – 2001.” Retrieved October 30, 2014 from <http://faostat.fao.org/site/339/default.aspx>
- Gould, W. (2007, January 1). “Land Use, Population Dynamics, and Land-Cover Change in Eastern Puerto Rico.” Retrieved October 4, 2014, from <http://pubs.usgs.gov/pp/1789/pdfs/ChapterB.pdf>
- Govardhan, S. (2007). “Food Security in Puerto Rico.” Retrieved October 10, 2014, from http://organicfarm.net/Article_food_security_in_puerto_rico.htm
- Halls, A. (2010). “Nutritional Requirements for Rabbits.” Retrieved September 21, 2014, from <http://www.nutrecocanada.com/docs/shur-gain---specialty/nutritional-requirements-of-rabbits.pdf>
- Hasan, M., & Chakrabarti, R. (2009a). Floating aquatic macrophytes – Azolla. In *Use of algae and aquatic macrophytes as feed in small-scale aquaculture* (pp. 17-27). Rome: FAO.
- Hasan, M., & Chakrabarti, R. (2009b). Floating aquatic macrophytes – Duckweeds. In *Use of algae and aquatic macrophytes as feed in small-scale aquaculture* (pp. 29-51). Rome: FAO.
- Horn, M. (n.d.). “Tropical soils and weathering – why are the soils so infertile?” Retrieved October 12, 2014, from [http://www.mikehorn.com/media/files/Text and workbook Amazon\[4\].pdf](http://www.mikehorn.com/media/files/Text%20and%20workbook%20Amazon[4].pdf)
- Huggins, D. (2007). “Evaluation of Azolla plant as an alternative stockfeed source”. Prepared For: Goulburn Broken Catchment Authority. Retrieved November 14, 2014, from http://www.gbcma.vic.gov.au/downloads/EnvironmentalFlows/2007-12-13_Evaluation_of_Azolla_Plant_as_an_Alternative_Stockfeed_Source.pdf

- IRIN. (2012, February 21). "Analysis: Worrying signs for food security in Syria." Retrieved September 22, 2014, from <http://www.irinnews.org/report/94914/analysis-worrying-signs-for-food-security-in-syria>.
- Irlbeck, N. A. (2001). *How to feed the rabbit (Oryctolagus cuniculus) gastrointestinal tract*. Journal of Animal Science, 79(E-Suppl), E343-E346.
- King, C. (2002). "Calcium Problems in Rabbits." Retrieved December 5, 2014, from <http://www.rabbitwelfare.co.uk/resources/content/info-sheets/calcium.htm>
- Latin American Herald Tribune. (2014). "Puerto Rico Imports 85 Percent of its Food." Retrieved October 6, 2014, from <http://www.laht.com/article.asp?CategoryId=14092&ArticleId=342325>
- Leng, R., Stambolie, J., & Bell, R. (1995). "Duckweed - a potential high-protein feed resource for domestic animals and fish." Retrieved October 30, 2014, from <http://www.lrrd.cipav.org.co/lrrd7/1/3.htm>.
- Lobb, R. (2003). "Green Revolution." Retrieved October 13, 2014, from http://www.encyclopedia.com/topic/Green_Revolution.aspx
- Luto, J. (2014). "Plant Finder Home - Azolla caroliniana." Retrieved November 14, 2014, from <http://www.aquaticplantcentral.com/forumapc/plantfinder/details.php?id=145>.
- McDowell, G. (2001). *Land-Grant Universities and Extension into the 21st Century*. Ames: Iowa State University Press.
- Medina, E., & García, L. (2005). *Utilización de morera (Morus alba) en la alimentación de tilapia (Oreochromis niloticus)*. Guácimo: Licenciatura. Retrieved November 5, 2014, from: <http://usi.earth.ac.cr/glas/sp/ColeccionVirtual/pdf/200547.pdf>

- Mintz, S. (1953). *The Culture History of a Puerto Rican Sugar Cane Plantation: 1876-1949*. In *The Hispanic American Historical Review* (2nd ed., Vol. 33, pp. 224-251). Duke University Press.
- Moncada, K. (n.d.). "Chapter 14 - Alternative Crops." Retrieved October 11, 2014, from <http://www.organicriskmanagement.umn.edu/alternative14.html>
- Mora-Valverde, D. (2010). *Usos de la morera (Morus alba) en la alimentación del conejo*. *En Agronomía Mesoamericana*, 21(2), 357-366.
- National Agricultural Statistics Service (NASS) (2007). "2007 Census of Agriculture" Retrieved December 5, 2014, from http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Desktop_Application/AG2007help.pdf
- Norris, C. E., & Colman, A. M. (1996). *Context effects of radio programming on cognitive processing of embedded advertisements*. In *Applied Cognitive Psychology*, 10(6), 473-486.
- Northwestern University. (2014). "What is a herbivore?" Retrieved September 21, 2014, from <http://www.qrg.northwestern.edu/projects/marssim/simhtml/info/whats-a-herbivore.html>
- Nuhu, F. (2010). *Effect of Moringa Leaf Meal (MOLM) on Nutrient Digestibility, Growth, Carcass, and Blood Indices of Weaner Rabbits*. Cape Coast: Kwame Nkrumah University of Science and Technology. Retrieved October 28, 2014, from: <http://miracletrees.org/moringa-doc/study-moringa-diet-for-rabbits.pdf>
- Paarlberg, D., & Paarlberg, P. (2000). *Chemical Advances In The agricultural revolution of the 20th century*. Ames: Iowa State University Press. pp 23-33

- Rivera, M. (2014). "Economy." Retrieved September 15, 2014, from <http://www.topuertorico.org/economy.shtml>
- Rook, E. (2006). "Lesser Duckweed, Lemna minor." Retrieved November 14, 2014, from <http://www.rook.org/earl/bwca/nature/aquatics/Lemna.html>
- Santana, R. R., Chin, E. V., & Macchiavelli, R. (2011). "Valor nutritivo y ganancia en peso del *Morus alba* (Morera) en la alimentación de cabras de reemplazo en Puerto Rico." [PowerPoint slides]. Retrieved October 28, 2014.
- Santiago, J. (2012, September 13). "Agriculture, the essential missing link." Retrieved October 12, 2014, from http://caribbeanbusinesspr.com/prnt_ed/agriculture-the-essential-missing-link-7542.html
- Small Business Encyclopedia (n.d.). "Business Incubator Definition." Retrieved October 9, 2014, from <http://www.entrepreneur.com/encyclopedia/business-incubator>
- Smith, M.H., Meehan, C.L., Ma, J.M., Hisakawa, N., Dasher, H.S., Camarillo, J.D., & Techanun, J. (2009). *Rabbit Nutrition: What You Need to Know*. In Rabbits: From the Animal's Point of View. Publication 8376. Retrieved December 12, 2014, from <http://anrcatalog.ucdavis.edu/pdf/8376.pdf>
- Tamsin. (2014). "Comparison of Rabbit Dry Foods" . Retrieved October 11, 2014, from <http://www.therabbithouse.com/equipment/index.asp>
- The New York Times. (1981). "Puerto Rico's Agricultural Woes Reflect Dangers of Rapid Growth." Retrieved October 15, 2014, from <http://www.nytimes.com/1981/02/17/us/puerto-rico-s-agricultural-woes-reflect-dangers-of-rapid-growth.html>.

The World Bank. (2014). "Agriculture, value added (% of GDP)." Retrieved October 15, 2014, from <http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS/countries/PR?display=graph>.

Thomlinson, J. (1996). *Land-Use Dynamics in a Post-Agricultural Puerto Rican Landscape (1936-1988)*. In *Biotropic* (4th ed., Vol. 28). The Association for Tropical Biology and Conservation.

Toensmeier, E. (2012, July 29). "Cuba Mass-Planting Moringa and Mulberry." Retrieved December 18, 2014, from <http://www.perennialsolutions.org/cuba-mass-planting-moringa-and-mulberry>.

Umrani, R., & Jain, C. (2010). *Agricultural Extension Worldwide Innovations*. Jaipur, IND: Oxford Book Co.

University of Minnesota. (2014). "Feed is feed... or is it?" (2014). Retrieved September 21, 2014, from <http://www.extension.umn.edu/youth/mn4-H/projects/docs/rabbit-feed.pdf>

White, J. (2008, January 1). *Straight talk about high fructose corn syrup: what it is and what it ain't 1'2'3'4*. In *The American Journal of Clinical Nutrition*. Retrieved October 12, 2014, from <http://ajcn.nutrition.org/content/88/6/1716S.full>

APPENDIX A: Roberto Delgado Interview Guide

We used these questions as a guide during our interview and site visit with Roberto Delgado, but because of the active nature of the visit, we did not adhere to a formal interview script. We did not record the interview and relied on handwritten notes. Therefore, we do not have an interview transcript for this visit.

Questions for Roberto Delgado (Rabbit Farm)
1) Do you give us permission to use your name in connection with your answers? (yes/no)
2) In detail, please explain what is most important to you when it comes to animal feed.
3) Please describe what animal feed you use, how you choose it, where you get it, and the unit cost of it. Also, how productive has this form of animal production been for you, using your current animal feed? What costs/types of expenses go into rearing rabbits (materials for fences)?
4) How much are the most relevant agricultural expenses for animal production and plant cultivation? (Including cost of labor, transportation, fertilizer, equipment, etc.)
5) Would you be willing to test our animal feed prototype once it is ready?

APPENDIX B: Edgardo Ramírez Interview Questions

Questions for Edgardo Ramírez
1. Can we record you?
2. Can we associate your name in connection with your answers?
3. Can we contact you via phone or email if we have further questions?
a. Which method of communication would you prefer?
4. Can we have a sample of <i>Azolla caroliniana</i> , <i>Lemna minor</i> , and <i>Leucaena</i> ?
5. Can we have your business card?
6. Can we have all of the biochemical information that you have researched for each plant?
7. Are there any additional plants that you have researched that you thinks could benefit us?
8. Do you have any formulas for tilapia animal feed?
9. The following are specific questions on <i>Azolla caroliniana</i> , <i>Leucaena</i> , and <i>Lemna</i> ?
a. How long will it take to grow a certain amount of the plant?
b. What is a method for harvesting?
c. What is a method for processing?
d. How much (weight) do you harvest per month or per certain time?
e. Expenses involved in harvesting of plant?
f. How does growth rate vary depending on rain?

g. How does the growth rate vary depending on the time of year (season)?
h. Are the plants invasive?
i. What complications have you had harvesting and/or cultivating these plants?
j. What are your cultivating and planting strategies?
10. Please describe what animal feed you use, how you choose it, where you get it, and the unit cost of it. Also, how productive has this form of animal production been for you, using your current animal feed? What costs/types of expenses go into rearing tilapia? Do you have data showing growth rate and feed used for your tilapia? Can we have any breakdown of your monthly expenses for the tilapia farm?
11. How much are the most relevant agricultural expenses for animal production and plant cultivation? (Including cost of labor, transportation, fertilizer, equipment, etc.)
12. Would you be willing to test our animal feed prototype once it is ready?

APPENDIX C: Michael McGee Interview Questions

Questions for Michael McGee	
1.	Can we record you?
2.	Can we associate your name in connection with your answers?
3.	Can we contact you via phone or email if we have further questions?
a.	Which would you prefer?
4.	Can we have a sample of <i>Azolla caroliniana</i> and <i>Lemna minor</i> ?
5.	Can we have your business card?
6.	The following are specific questions on <i>Azolla caroliniana</i> and <i>Lemna minor</i> :
a.	How long will it take to grow a certain amount of the plant?
b.	What is a method for harvesting?
c.	What is a method for processing?
d.	How much (weight) do you harvest per month or per certain time?
e.	How is each plant treated with regard to the water, soil, sun, and fertilizer requirements?
f.	What are the expenses involved in harvesting of plant?
g.	How does growth rate vary depending on rain?
h.	How does the growth rate vary depending on the time of year (season)?
i.	Are the plants invasive?
j.	What are your cultivating and planting strategies?
k.	What complications have you had harvesting and/or cultivating these plants?
7.	Please describe what animal feed you use, how you choose it, where you get it, and the unit cost of it. Also, how productive has this form of animal production been for you, using your current animal feed? What costs/types of expenses go into rearing tilapia? Do you have data showing growth rate and feed used for your tilapia? Can we have any breakdown of your monthly expenses for the tilapia farm?
8.	How much are the most relevant agricultural expenses for animal production and plant

cultivation? (Including cost of labor, transportation, fertilizer, equipment, etc.)
9. Would you be willing to test our animal feed prototype once it is ready?
10. Can you tell us what your opportunity costs (explain opportunity cost, if needed) are for growing the alternative plants on your farm?
a. This includes what you would be using the land for instead and what your time and labor would be put towards instead.
11. Can you give us a summary of how you started in the tilapia farming business and how you managed to become a large scale producer?
12. Do you have any recommendations for small scale farmers on how to grow their production and increase their profits? This includes any money saving strategies that you utilize or utilized in the past.

APPENDIX D: Doctor Yamil Quijano Interview Guide

We used these questions as a guide during our interview and site visit with Doctor Yamil Quijano, but because of the active nature of the visit, we did not adhere to a formal interview script. We did not record the interview and relied on handwritten notes. Therefore, we do not have an interview transcript for this visit.

Questions for Doctor Yamil Quijano
1. Can we associate your name in connection with your answers?
2. Can we have your business card?
3. Can we contact you via phone or email if we have further questions?
a. Which method of communication would you prefer?
4. When you dehydrate your plants, we found that you use 18-20% humidity, would you recommend this same value for our animal feed?
5. Can we have all of the biochemical information that you have researched for maralfalfa?
6. Are there any additional plants that you have researched that you thinks could benefit us?
7. Do you have any formulas for rabbit and tilapia animal feed?
8. The following are specific questions about maralfalfa:
a. How long will it take to grow a certain amount of the plant?
b. What is a method for harvesting?
c. What is a method for processing?
d. How much (in weight) do you harvest per month or per certain time?

e. What are the specific requirements of water, soil, and sun for maralfalfa?
f. What are the expenses involved in harvesting maralfalfa?
g. How does growth rate vary depending on rain?
h. How does the growth rate vary depending on the time of year (season)?
i. Is maralfalfa invasive to other plant species?
j. What are your cultivating and planting strategies?
i. How much distance do you plant the maralfalfa apart?
ii. What equipment do you use to cultivate, plant, and harvest maralfalfa?

Appendix E: Joylin Guzmán Interview Questions

December 4, 2014

Plans of AgroInnova

Questions for Joylin Guzmán
1. What is AgroInnova's plan for growing the different alternative plants?
2. Have you considered growing the alternative plants and/or producing the feed and then selling that to the farmers?
3. What is your concern with the fact that many farmers do not have the land capability to grow any of these alternative plants at the needed quantities?
4. Has AgroInnova considered leasing their land to farmers?
a. How much do you think that you would charge per year for an acre of land? What would this cost include? (meaning would they also have to pay for equipment on the farm and water?)

APPENDIX F: Roberto Delgado, Survey Responses

December 9, 2014

Craig: Would it be OK if we record you?

Roberto: Yes.

Craig: Alright. Um, so for our survey questions we'd like to ask you:

Would you be willing to take part in a pilot study that involves feeding a small portion of your animals this alternative feed to evaluate its nutritional and economic benefits?

Roberto: Yeah, yes.

Craig: Ok. Are there any possible complications that you think could result from feeding this to your animals based on what you viewed in the charts?

Roberto: No. No, I don't think.

Craig: Ok. Um, do you have any suggestions for changes to the formula or alternatives that you think would improve the quality and/or effectiveness of the feed?

Roberto: Well, the uh the only thing is that it uh must be the two formulas:, you know, for maintenance and for uh growth. Um that should be as uh as economic as possible. Craig: Mhm.

Roberto: Because this uh especially in Puerto Rico, the cost of feed, it has to be imported, all of it. Uh It is driving ranchers uh I mean breeders to quit.

Craig: Right.

Roberto: And uh to be able to..to raise the amount of people that uh farm rabbits, you know, the feed has to be uh less expensive but at the same time of good quality.

Craig: And what other information would you want to have before considering a switch from your current feed to this alternative feed, in terms of either the nutritional content or the potential economic benefits? What would you like to see in terms of additional information?

Roberto: Nutritional content.

Craig: Ok.

Roberto: You know, that's uh if it's comparable in price uh but the nutritional content is better uh and it is better quality, ok?, then uh there'll be no problem to use it.

Craig: Ok. Considering the nutritional information sent to you, would you use this, again? Why or why not? And we specifically noticed that one of our feed prototype, the first one, had, uh, slightly elevated level of calcium.

Roberto: Mhm.

Craig: And we did some research and that could potentially uh present some problems in the urine, but we also didn't know because it was slightly unclear what the information was saying exactly how much more calcium over the um required daily consumption would present that sort of problem. And also the second prototype, which is considered to be the most cost-effective based on our projections, um that one has slightly higher level of fiber. So that one could present a slightly less um effective absorption from the rabbits in terms of nutrition and thinks like that.

Roberto: And that uh on the fiber, if it is um absorbed by the rabbit uh as it is feed, it's ok. But if not, they have that process, you know where they reuse the uh fiber through uh, the fecal...

Craig: Yep.

Roberto: ...fecal process. You know when they reuse it and then process the fiber so it is digestible by them.

Craig: Absolutely.

Roberto: And the fiber is ok; the calcium is a problem.

Appendix G: Edgardo Ramírez Interview Transcript (Barrio Beatriz Farm)

November 18, 2014

(Patrick Reyes is a tilapia-farming expert who was also at Edgardo Ramírez's farm)

Edgardo Ramírez: "Eso es recolección de cosecha."

Patrick Reyes: "They are harvesting there."

Edgardo Ramírez: "Eso es un terreno de ellos."

Patrick Reyes: "Eso es en Honduras. Con camarones?"

Edgardo Ramírez: "No. Todo es tilapia."

Patrick Reyes: "A como es la libra allá. Es barata la libra allá, la libra."

Edgardo Ramírez: "Entiendo que si. Pero es parte de su de su alimentación diaria. Tu sabe, no es como aquí que cuando pueda cuando quiera cuando le de la gana."

Patrick Reyes: "A pero espérate, esta es la etapa de producción."

Edgardo Ramírez: "Sí, de producción y después lo tiran allá."

Patrick Reyes: "This is the nursery."

Edgardo Ramírez: "Eso es Nuevo. Prácticamente es nuevo."

Patrick Reyes: "Y son revertidos sexualmente?"

Edgardo Ramírez: "Yo les hice esa pregunta y ellos me dijeron que no. pero lo dudo mucho. Tienen que ser revertido."

Patrick Reyes: "Okay. Es que esas tilapias, is uhh common that people feed for the first month you know during the growing period. Feed at sixty ehhhh milligrams per kilogram of feed of male testosterone."

Craig Teed: "Okay."

Patrick Reyes: "It ehh changed the sex of the fish to males. Because males have a better conversion rate than the females because females start to reproduce very small and part of the energy that is going to be used to grow is going to be used to to to make eggs to reproduce, and if they can reproduce, they are going to hold those eggs and fry for two weeks. So there are two weeks more that they are not going to it."

Craig Teed: "Got it. So in terms of when you said 60 milligrams of testosterone per kilogram..."

Patrick Reyes: “It can be three forms of synthetic testosterone.”

Craig Teed: “Will it be per kilogram of feed or per kilogram of weight?”

Patrick Reyes: “It would be per kilogram of feed.”

Edgardo Ramírez: “I hope that the first company that work with this product with the food, fish food, is in the US. This person have the agreement with FDA to produce that.”

Patrick Reyes: “El alimento.”

Joylin Guzmán: “Yea, but it is not allowed to use it in San Juan.”

Edgardo Ramírez: “Es la única que produce.”

Patrick Reyes: “In the state.”

Joylin Guzmán: “The name is tilapia.”

Patrick Reyes: “No, tiene otro nombre.”

Edgardo Ramírez: “Fresco frasco, algo así.”

Joylin Guzmán: “Yea but it’s uh uh es vendido como tilapia. Es como se dice, marketing, mercadeo. I showed them the umm.”

Patrick Reyes: “Yo creo que ya estamos si?”

Edgardo Ramírez: “Si. Ehh que mas tienes por ahí que valga la pena para los muchachos y yo creo que ya cuadramos ahí.”

Craig Teed: “So was that the same thing as the what you showed us that had the artificial insemination, was that something or you talked about that but but when you showed us all the changing of the sex, was that still giving the testosterone in the feed in the first thirty days. Ok, okay.”

Edgardo Ramírez: “Pole es un reproductor de supermacho lo que se dedica es hacer supermacho.”

Joylin Guzmán: “He sexed he sexed the tilapia and he sells the males.”

Edgardo Ramírez: “But by generation. No lo hacen utilizando testorenes por generaciones. Por genética.”

Patrick Reyes: “Yes because in tilapia they are not like us, we are como era, es tee, X Y y females are XX. In the case of tilapia, they are YY males so if you want all males you need all YY males to produce, in the case of females, all the Y are going to be true males when they breed.”

Craig Teed: “So how do you know on a genetic level, what you would do?”

Joylin Guzmán: “That’s all genetics. It is a chromosomatic mixture that they do a chromosomatic test on males and they chose the males that chromosomes are full Y.”

Craig Teed: “Okay. Okay. That’s what I was thinking.”

Joylin Guzmán: “It’s chromosomatic. They chose those males that are full Y and they chose those females that the chromosomes, that they tend to have the extra chromosome.”

Patrick Reyes: “In the case of trout and salmon you do not want male. You want females because they grow faster. So what you do is you inject female trouts and change them into males. But they are functionally males but genetically females. They do not have the system to deliver the sperm. So what you do is you kill the fish and if you cannot get milk from the fish you know if it is a female that has turned into the male. You take out the testicles. You slice them . put them in ice and then you string px from the trout and then use the milk from the sperm source from teste and fertilize those eggs. In that case all the fish that are produced are females. So in the case of tilapia. Males are good, females are bad. And in trout, females are good, males are bad.”

Edgardo Ramírez: “Todo lo que produce Gonzales es e tee macho. Más o menos lo que muestra esta presentación.”

Edgardo Ramírez: “Eso prácticamente son la facilidades de ellos. Y ellos lo que se dedicaban era a criar cerdos.”

Patrick Reyes: “Y cambiaron.”

Joylin Guzmán: “Las charcas de oxigenación las cambiaron entonces?”

Patrick Reyes: “Es un montón de gente.”

Edgardo Ramírez: “Sí, recuerde que viven de eso. Eso son piscinas pero hecho de geomembranas. Eso es lo que se estaba moviendo en ese momento en ese país. Versus una piscina de playa.”

Patrick Reyes: “Y esta diseñado para eso. Tu sabe.”

Edgardo Ramírez: “Se utilizan mucho allá en estados. Mhm las geomembranas.”

Patrick Reyes: “Dejó 15 años de garantía alguna de ellas.”

Edgardo Ramírez: “Después que tengan agua no tiene problemas. Se tuestan mucho.”

Patrick Reyes: “You see over here, this is the standby.”

Edgardo Ramírez: “Eso son tanques de reproducción. The hatcheries. Eso es de la ocasión de crear súper machos. Pero si u lo quieres hacer en una forma artesanal, tu lo pones en un tanque y

los tienes y después los mueves a un lugar más grande. Eso es la ventaja de la tilapia, tu no tienes que comprar semillas. Eso es lo que yo tengo allá abajo. La negrita.”

Juan Torres: “That’s the one he has down there, the black one.”

Edgardo Ramírez: “Pero es la mezcla de rojo.”

Patrick Reyes: “He is drying the pond.”

Juan Torres: “How do you lower the... Como baja el agua aquí, cuando va a sacar los peces?”

Edgardo Ramírez: “Yo hago el mismo proceso que viste ahorita. Yo no, al menos que cosechar todo lo que esta en la charca, yo no la vaciaría. Uno porque el costo del agua es muy alto y si la baseo tengo que empezar con el proceso de alkalao y hacerle un montón de cosas. Ya una vez lo hice y fue bastante costoso.”

Juan Torres: “Algo que le quería preguntar algo que yo se que ya lo había hablado con Craig es, usted cómo escogió qué terreno usar para ser esa...”

Edgardo Ramírez: “Eso es una historia larga. Yo abajo era una planisia y en esa planisia yo tenía cabros. E la intención es, que es lo que yo le estaba contando aquí al socio es que cuando estén evaluando también, no solo nos concentremos en el alimento. Si no, busquemos también alternativas de especie. Que especie me podría ser más productiva y más costo-efectiva. Mas rentable. Y en el caso del pangasio podría ser una solución. En plástico, no crece, el crecimiento es bien lento. Y lo otro es el frío. La charca se construyó para el pangasio, fue la única razón de eso. E tee, preguntas, dudas. Yo se que he hablado mucho.”

Juan Torres: “Usted aquí tiene la Azolla. Usted a usado estas plantas antes o no?”

Edgardo Ramírez: “Bueno, la Azolla. En un momento dado cuando yo traje unos guppys, vino con esto. Pero fue un tiempo poco. No podría decirte cuanto fue. Si te mencione que si buscas el video de bowfish vas a ver ellos alimentan con Lemna, y eso es en Méjico. Ahí les estoy mostrando una presentación de pangasio versus tilapia. Otra cosa que tiene como defecto es que yo puedo vender la tilapia, la gisero entera y se puede comer sin problema. El basa lo tienes que filetearla. Y es muy raro que alguien venda basa enrojada.”

Juan Torres: “Otra pregunta que tenia es, yo se que usted nos mandó la información que tiene para el alimento que usa para la tilapia y para sus peces pero usted cómo escogió ese alimento, de donde lo escogió?”

Edgardo Ramírez: “Mira, tiene una historia. Aquí en Puerto Rico, actualmente hay dos suplidores de alimento, que yo conozca. Uno de ellos es el de rice que yo te mencione que es el

de 20 por ciento de proteína y el otro era otra persona y era un producto de 32 por ciento de proteína. En tilapia hablando mas o menos, son 30 por ciento a 35. Fuera de eso estas perdiendo el alimento. Rice es una compañía americana, ADN, y eso ellos mercadean ese producto en particular. Con la gente del otro, que es un suplidor, yo tuve la opción de decirle, mira ese producto no me gusta porque tiene bha. Sabes que es un bha? Bha es un preservativo. Y buscando opciones yo fui a la persona y le dije, mira no quiero este producto, tiene esto. Podemos conseguir otro. Y cogimos ese que no tiene bha. Pero casi todo lo de gargil tiene bha y bht creo que es. Son dos carcinogénicos, son dos preservativos. Y ahí es que ella ese producto y ese prácticamente es el que se mercadea en Puerto Rico, por que es un solo suplidor. Había otro suplidor, pero ya no lo trae. Ese mercado mío puede estar 25-26 dólares el saco. Si lo compras afuera, al mayorista, el comerciante, esta cerca de los 40 dólares. Si Señor y es de 50 libras. Y eso si se hace bien te da un semana. Y si lo que estas buscando es crecimiento y si tienes venta, si no tienes venta tienes que cogerlo sin los gramos. Prácticamente eso es lo que hay. Porque el cigler no lo trae más y era más costoso.”

Juan Torres: “Y si nosotros creamos este nuevo alimento, específicamente para la tilapia, para después hacer el examen para ver como le esta yendo y si les esta gustando. Usted que sugiere seria como en examen para ver si de verdad esta funcionando como debe de funcionar?”

Edgardo Ramírez: “Lo que tiene que hacer es decirme si lo tienen listo y escogemos una área lo probamos. Yo escojo una área y los probamos. De hecho podemos trabajar un tanque y lo dividimos por etapa. Lo que es crecimiento y engorde y mantenimiento para ver como se comporta. Porque en esas etapas los peces se comportan diferente. La tilapia después de que tenga hambre usualmente come.”

Craig Teed: “So would there be a way to weigh them in each step of the way?”

Edgardo Ramírez: “Sí pero hay diferentes factores que no son solo la comida. Explico, la temperatura, en clima frio el pez no come. Ese es el problema de navidades. El pez para de comer porque esta muy fria el agua. Si tu le mantienes calentadores entonces siguen comiendo todo el tiempo. Pero también es cuánta comida le estas dando a los peces. Porque no le puedes estar dando comida todo el día. Yo saco de eso [el alimento] una semana.”

Patrick Reyes: “Also very important is the storage capacity. Because your feed can spoil.”

Edgardo Ramírez: “Algunos productos sobrepasan el límite de procesacion para que dure más en el shelf life. Yo compre un producto en esta cooperativa y era de gargil, y la bolsa parecía

grasosa.”

Patrick Reyes: “And this feed said it would last up to 3 months.”

Joylin Guzmán: “There is a test available that is called shelf life that lets you know what is the expiration date for processed food.”

Edgardo Ramírez: “En la forma que tu puedas crear un alimento que sea atractivo. Que puedas convencer al público que el alimento es bueno, ellos en teoría entienden que el pez es bueno. Entonces es más fácil tratar de mercaderarlo. Volvemos a lo mismo, yo estoy seguro que en Colombia no van a preguntar que le dan al pescado que produce Henry o Gonzalo. Todo es parte de su cultura. Aquí no es así.”

Patrick Reyes: “In the United States people are really concerned because there have been several news saying that tilapia are very bad nutritionally.”

Edgardo Ramírez: “Si pero tienes que tener bastante alimento que sea paliativo y digestivo para el animal. Tienes que tener un producto que sea bueno y que puedas vender como producto bueno y saludable para que tu producto final sea bueno. Porque al contrario puedes hacer el mejor producto del mundo pero nadie va a querer comer ese pescado. Y lo otro es que sea accesible. Esta era la pregunta que yo le iba hacer a ustedes es, si ustedes están buscando eso, ustedes entienden que aquí hay un mercado para eso?”

Juan Torres: “El plan sería hacer un alimento que se podría hacer aquí. Un granjero o alguien como usted [Edgardo Ramírez] pueda crecer la misma planta y el producto y pueda crear el producto usted mismo. Entonces qué causa eso, usted puede hacer lo que usted hace aquí que todo corre. Señor Ramírez, algo así rapidito, esta bien que usemos su nombre en conexión a sus respuestas.”

Edgardo Ramírez: “Si. Qué preguntas tienen?”

Juan Torres: “Al lado de los gastos que nos mandó, usted tiene gastos de luz y agua que no pueda mandar.”

Edgardo Ramírez: “No me lo pediste, pero lo que si quiero que veas es que yo soy artesano. Todo aquí es artesanal. No me puedes comparar con un grande. Si quieres partir de la idea que cada persona o un agricultor pueda tener esto, si se puede.”

Appendix H: Transcript for Michael McGee Interview (Lajas)

December 4, 2014

Juan: “So one of the first questions is if we can record you?”

Mike McGee: “Yes”

Juan: “Then next one would be, can we associate your name in connection with your answers?”

Mike McGee: “Sure, no problem”

Juan: “Thank you very much. And then for future contact, would you rather have us email you or give you a call?”

Mike McGee: “Email”

Juan: “Email?”

Mike McGee: “I mean if there is a real urgency you can call me, but normally it is easier for me to do it by email.”

Juan: “Sounds good, do you have a business card or an email address?”

Mike McGee: “Yes, I can get it for you later.”

Juan: “Okay, perfect. The next question would be on, I would say, what do you currently use on your farm to feed your tilapia?”

Mike McGee: “Okay, here we grow a lot of different fish. We are mostly an ornamental fish farm, that means aquarium fish. We grow about 30 different varieties, but we also do grow the tilapia and we grow the basa catfish and we grow fresh water prawns. Mostly we’ll use a commercial feed, that’s we get it made here locally by the feed mill. Uh, but it’s based on corn, soy bean, and fish meal. Kind of the big three main ingredients in most commercial feeds. And the fish meal component is added because they are aqueduct organisms, and they need some of the amino acids are are that they can’t manufacture or get from other sources comes from the fish meal. So we use in the um, for the starter we feed we use about a 40% protein um for the baby fish, and again this is almost across the board for most fish. And then for the grow out phase, which is the majority of the time, that would be um I think it’s a 24% protein feed, which as a very much smaller component of the fish meal, and um it’s really more similar to something like a chicken feed. But again it’s based on corn, soybean, other grains, with a little bit of fish meal in it. We, I really like the idea of alternative feed, um and we try and do some of that indirectly by supplementing um, well not really with feed per say, but adding organic matter to the pond

and stimulating the naturally productivity, so the fish can get the natural food supply and the pond is enhanced. So that would apply to the tilapia and also to the ornamental fish and to the basa catfish and even to the prawns really.”

Juan: “Okay, thank you very much. So um to add this organic matter, what exactly do you do?”

Mike McGee: “Well in the process of fertilizing the pond, I mean you can use inorganic fertilizers like nitrogen and phosphorus, just a bag of fertilizer, or you can use things like chicken manure or rabbit manure. Um and then sometimes we use um molasses, which is a carbon source, like sugar. What that does, especially the molasses, stimulates the growth of bacteria, which can serve as food for plankton, which serve as food for fish, so you are kind of creating a food chain. And the basis of this food chain is the addition of the organic matter and the nitrogen and phosphorus. Ah if you’re using chicken manure for example, that has all three components that has organic matter that has carbon, I mean it has nitrogen and phosphorus. Um sometimes we do not have enough, so we go out and buy a couple of bags of fertilizer, and then we add the molasses, and we create this soup, kind of, which is basically triggers this natural food chain. And that’s one of the ways that when you look at developing countries, or when you look at people who don’t have access to feed, or can’t afford it, that’s one of the ways that you can really accomplish it. I mean if you’re a farmer, or you are living in a community that doesn’t have the resources to get feed, how can you stimulate you’re your fish production? And it would be similar, I tell people that for most of these fish like tilapia, it’s just like feeding chickens or pigs, in the sense that you can go to the store and you can buy the exactly right diet for chickens and grow them, but you also know, common sense is that the chicken is running around, and you got left over scraps from your kitchen, and you throw it out there the chicken eats that, and the chicken goes and eats some bugs it finds in the garden. And you know the chicken scavenges around, and the fish will do the same thing. So when you augment the natural productivity in an environment, you augment the food supply.”

Craig: “So it terms of adding, um whether it be a type of fertilizer or a rabbit feces or what not, how do you know, given a pond of a given size, how much is enough, how much is too much, how much is not enough? Would it just be like a you know, like prior knowledge, or how would you gain that certain information into knowing. Is there like signs that you can see to know it’s enough?”

Mike McGee: “Yeah, there’s guidelines, and some of that comes from experience of course.

Um but, you know the the fertility of the pond can normally be gauged by the color, which when the pond has a phytoplankton would get green, and when it has a lot of zoo-plankton it would maybe get brown. But you can get a sample of the water, and you can look at it, and you can kind of see what's going on, so within the range of commonsense, you might say, you might go about it, again the way you might go about feeding a chicken. I mean if I gave all you guys a project to raise ten chickens you don't really have to ask me how much feed should I feed these chickens, because you are going to kind of experiment with it, and you are going to see that that chicken ate that, and I can give it some more, or it has food left over it's not interested. So it's kind of a commonsense thing, but um there are some ranges, and if you are looking through literature on the internet, you can find what's recommended as organic fertilizer rates. But a lot of it is done kind of by eye

Craig: “Okay, and I think, because what we are trying to do when we try to construct this sort of economic viability report, and the expenses involved, we are trying to kind of think in our minds of a model. So you have an acre of land and right there in it we want to just create this hypothetical situation, where we have this ten foot by ten foot pond that we want to create. So we have to get the equipment for creating the pond, then we want to be able to fertilize the pond, we want to be able to put the tilapia in, so we want to make sure that we definitely hit on all of those key points, so that we are not missing any expenses. Because we want to really get a thorough report of everything that would be involved in that.”

Mike McGee: “Yeah, well that idea is very, I think, good cus the biggest expense in fish farming is feed, that's always the bottom line and the highest cost. Um, and yet you've got people in south-east Asia and Vietnam and China and Thailand that traditionally, for hundreds and hundreds and hundreds of years, they've been raising their fish and they probably don't have ten dollars in their pocket. You know? So when you look at how they are doing it, they're a lot of them are not just fish farming, they're animal farming, they're vegetable farming, and they're fruit crops, they have all of these different things growing, they're growing some rice. And they're recycling their animal manures into their gardens, and then their garden scraps into their chickens, and then their chickens manure into their fish pond, and so on. And that's really when you talk about sustainability, it's really what is the ultimate, you know model, because what it is is almost like an eco-system, a natural system, that's been designed or managed by humans. I have some information on that I can give you because I, like I said, I really like the concept. We

have been trying to a little bit of that here, and I don't want to get too far off the subject. For example when we raise our fish, and we process our fish, we have some fish waste left over, right, and you guys go on with your questions, and we will get to that, because you guys are interested in the economics and stuff.”

Juan: “So going off of a little bit of what we were talking about before, more specifically what feed do you use for your fish?”

Mike McGee: “The commercial fish feed that's prepared here in the feed mill. I can show you the ticket for that feed and I can even give you some samples if you want to look at it. But it's based on grains, mostly corn, soybean meal, ah and oat bran, and and some fish meal.”

Juan: “Um and do you have any records of how much feed you need to buy, say per month or whenever you need to buy it? Um and maybe how much fish is sold during that time period?”

Craig: “Or I guess you sell for a combination for meat or ornamental or what have you, we were also interested in if it wasn't sold for meat, the amount of saleable meat. So like the poundage of fish, if there is even an approximation. We are trying to get a ration.”

Mike McGee: “Yeah, yeah, well there is a ratio; I mean that's a ratio that's used a lot in general aquaculture literature, what they call a food conversion ratio. Food conversion ratio, a food conversion ratio means how many pounds of feed does it take to produce a pound of fish. Normally, with commercial feeds, normally you're in a range of 1.6 to 2. That means 1.6 pounds of feed, 1.6 pounds to 2 pounds of feed, will produce you 1 pound of fish, of whole fish. Um and that's considered to be pretty efficient, you know, it's more efficient than chickens, or pigs, or so on. And partly because fish are cold blooded animals and they don't have to spend a lot of energy, they don't have burn a lot of calories just trying to stay warm, um or trying to stay cool. I mean they basically, they live at natural temperature. Um so that number you can use, if you want to pick out a number like 1.8 or 2, now that's a number that you apply to standard food conversion ratio for fish. Now what happens when you start using lower quality feeds, or feeds that, you know, don't have as much protein or or less balanced in their nutritional make up, your food conversion will tend to go up. So then it becomes a question of cost versus benefits. If I can get 1., let's say that I can get 2:1 conversion with a feed that costs me \$40 for a hundred pounds, or \$4 a pound, or no excuse me 40 cents a pound. And I have another feed that gives me a 4:1 conversion, but it only costs me \$5 a pound. I'm actually better off using the worst feed conversion, that means that I trading off feed conversion, I'm getting worse feed conversion, but

I'm getting a cheaper price. So that's the kind of thing that you guys are going to run into, that almost no homemade feed will be able to produce as efficiently as a balanced diet from a feed mill, but on a cost basis it might compete very well. So I think that goes back to these guys in Asia, you know, and they're growing all these fish and they don't have money, and they can't afford the feed, but what they do have is organic matter, material that they gather up and they process and they make their feed with it. Okay.

Juan: "Um and then a little bit of the whole story, how did you start?"

Mike McGee: "This?"

Juan: "Yes"

Mike McGee: "Haha that's a good story, but well really, I've been involved in aquaculture for many years. When I got out of college my first job happened to be at a fish farm in my home town. And I liked it, and I got interested in it, so I went back to school, and I didn't really think about being a fish farmer at that time, but I knew that I wanted to study aquatic sciences and so on so I studied that. Then I went back to the fish farm and got a little more involved in it, because right about at that time the whole concept of aquaculture was starting to grow in peoples' minds. And then um I went and got my PhD at Auburn University for aquaculture, and I still didn't think about being a fish farmer, but I ended up being a professor of aquaculture for a couple of years. Ah until I realized that one of the main reasons that I got into fish farming , was that I could get to work in an environment like this, instead of in an office with four walls and a haha window. So I said well I'm going to have to make some career decisions here, and I ended up visiting some friends here in Puerto Rico that took me to visit a shrimp farm, which was having some trouble with their farm and I got involved with them, and they offered me a job, and here I am. So I basically took the big jump when I left the university and came here and worked for the shrimp farm for a while, and then ultimately bought this place and I've been here for twenty-five years. Um and this is something, and when you guys talk about your project and stuff, nobody is talking about getting rich, this is not a get rich quick business, this is a farming business, where you you don't necessarily make a lot of money, but what you do have is if you enjoy this life style you have the quality of life that is way different than in a city or in an office or corporate type of environment. So that's the kind of things that motivate people to do these kinds of projects, where financially it's not going to leave you a lot of money, but it's something that you really have to enjoy."

Craig: “Absolutely, and in terms of meat production in Puerto Rico, and in terms of meat importation, the amount of importation that there is just for food supply as a whole for the population, that’s another reason why we were sort of centered around this promoting of these sort of moves in agriculture. Just because if there’s a heightened amount of rabbit meat and tilapia meat and things like that, and it’s able to be done in an economically viable way, it really does help in multiple areas. It’s kind of a snowball effect, in a good way, because it really does help in the lean meat necessity, in the diet. And it’s more local, and less is imported, therefore there is an improvement in sort of the agricultural sector, which then has an impact on the overall economy. So we are really looking at that from a big picture, we really felt like it would be beneficial on a number of levels.”

Mike McGee: “I think so too, and again I’ve been a proponent of that, but ask me about tilapia and food fish here, and I have to say we really do it on a small scale. We do sell fingerlings to other people who grow them, but it’s a lot of people who are doing for their own consumption, that is to say that there is a lot of small-scale projects, like aquaponics. And people have them even in their backyards, or even in their balcony in their on their apartment. Um so we supply that. One of the things that happens, happened to me, in the food fish market is that we have the capacity to produce a lot of fish here, I mean we could do that. But when you get to the marketplace somebody has to process those fish, and in order to process those fish you have to have a processing plant, and the processing plant has to have an inspection and a license. We ran into the problem, we can grow the fish, but because this is the United States, Puerto Rico, United States, federal law, local law, sanitary law require you to have a processing facility. And that’s a long list that you have to, and they treat the little guy just like they treat the giant guy. And that becomes an issue, because since there is a cost on running a processing plant, unless you have a large volume of product it’s hard to compete. So sometimes what happens is, I still sell fish, I still raise fish, but I do it on such a small-scale, that I don’t attract much attention to the, from the government let’s just say. But I’ll sell to my friends, I’ll sell to my costumers that I have that know me. And without a license, but what I can’t do is take my fish to a grocery store and say will you sell this fish for me, because I don’t have the license. So when people do it on small-scale, or whatever, they are going to have to deal with that issue. And I think the way that I’m going it, I think there are ways around it, but it’s kind of a gray zone right now in the way the law is structured. Now a lot of these countries, like Dominican Republic, or Jamaica, or I mean

these other small Caribbean islands or Caribbean islands, where they are producing fish and they are selling them, I mean they don't have that regulatory environment. I mean I can harvest my fish, put them on a cooler with some ice, set up my stand on the side of the road, and people come by and buy fish all day long. And that's the way it should be from my point of view. But that's one of the issues, that's kind of impacting, impacting the development of the fish business right now. So go ahead, more questions?"

Juan: "Um, yeah I know you talked a little bit about using the azolla or Lemna."

Mike McGee: "Yeah"

Juan: "So do you have a supply of azolla and Lemna on your farm?"

Mike McGee: "We do, actually both of those plants are aquatic, could be considered aquatic weeds, weeds because they're invasive. I mean if you let them get loose in your environment they can take over. We had a big big problem with the azolla, because I mean it just multiplies so quickly that you can't hardly keep up with it. So we in a general sense we don't encourage them to grow haha, but you could. What happens, and what I tell people, in a way the Lemna, and I think the azolla would probably be the same, it's kind of like the fish can eat it, the fish can utilize it, the fish can get benefit from it, but it's kind of like a salad. I mean it's like a salad versus a steak, you know, and you have to eat a lot of salad to get the same nutrients, or protein that you would from eating a steak. So, um I think that it would be could to consider those components supplementary diet, because what you guys are talking about with this low cost feed and stuff, I am working with a group in Haiti, where they are trying to do the exact same thing, they are trying to get some low cost feeds that they can give these poor Haitian farmers have nothing. And that they can grow fish, and if they can grow fish, I mean for them that's a quality protein, um and and what I'm telling them is that it might be hard to become a 100% based on local low cost feeds, but if you can cut down even say 50% of what your high quality feed that you use, if you can cut it that you use in half by supplementing these other feeds I mean you're doing way better. Because feed costs using a commercial diet like we do, feed cost are normally 70-80% of your total operating budget, that is to say that is what you could calculate normally on a fish farm 70-80% of your operating cost is going to be feed, so if you can cut down 80% to 40% you just changed your profitability a lot. So that's why feed is so important."

Craig: "I there anyway, we actually have some prototypes, theoretical, on paper, given certain nutritional analysis that we have gotten through literature on some of the plants. Would you

mind if we sent you that via email, and you could let us know what you think about it? Because we actually broke it down in terms of the percentages of each plant that we were thinking about and then the percentage of the commercial feed, with the brand nutritional characteristics, and the percentage of protein, the percentage of fiber, the percentage of different things, And yeah we would love your feedback if you wouldn't mind."

Mike McGee: "Oh wow, I would like to see it. You guys may be ahead of me in figuring all of that out. Well yes I would be very interested in seeing that."

Juan: "Something that we were wondering, if the Lemna and azolla are so invasive how are you controlling them, at least the amount that you are using?"

Mike McGee: "Were not using it, we have them in some of the ponds, and again we kind of discourage it. So what we're doing, if we see it we get rid of it. But if you wanted to grow it for example, you could allocate a pond for that, because the azolla and the Lemna actually will grow together, they actually grow well together. You can grow all you want, but then you have to have a way to dry it and process it and that sort of stuff. And and you know for the most part what we do here a lot is work with baby fish, reproducing fish, and fingerlings, so they are just like babies of anything else, they need a higher protein diet, they need specialty foods. So for our purposes it's not that useful, but for somebody with tilapia, that wanted to grow tilapia, yes you could grow it."

Craig: "In terms of opportunity cost, if you wanted to allocate a pond for just growing those plants and the way I was kind of thinking about it, if we have specific components in terms of percentages of each, so azolla and Lemna in the diet we probably want to keep them separate, maybe keep them together, we just want a way to maybe differentiate so you get the correct percentages. But what I guess I am trying to say is in terms of the profitability of that space as a pond space, is there any ideas about how you could still put that pond onto another use while you were growing those plants? So that you could have another source of revenue, so that it's not just a pond for those two plants I suppose."

Mike McGee: "I think you could. I mean there are fish that you could put in there. Freshwater shrimp, you know, I don't know if you saw the shrimp in the tanks over there, that's a species that you could polyculture easily with fish. It doesn't really eat the plants directly, so you could have them in there, they live on the bottom, so you could have them in there and you could have the plants in there too. Yeah that's easily done, um again I don't, when you talk about the

economics exactly, I'm not sure how that's going to work out. What I said earlier is that normally this kind of business on a small-scale is not a big money maker, but it can produce. Just like I have that little bit of recow over there, the cilantro. And we sell that to grocery stores every week, and I don't make a ton of money, but every week I get a hundred dollars in my pocket. You know, and it's just out there, I don't need to do much to it, I just go out there and harvest a hundred dollars. So that's pretty nice, and somebody if they had a diversified farm or if you had another job, another source of income, you can easily do these sorts of things on a small-scale as a supplemental income, and make money on it. I think you are on the right track with this. And some of the issues in Puerto Rico, and Joy may know more about this than I do, but in some ways there's a cultural resistance, even to agriculture itself. People say oh know that was the old days, we don't do that anymore. Um and if you go to the Dominican Republic or Jamaica and you see a whole, they are Caribbean islands, you know one, two, three. And they are basically the same geographic environment, what's different is the culture. Their people are very very keen on this idea of raising their own food, or eating local food, or going to the market to buy fresh fish, you know. They are not so turned on by Costco or Sam's or the big chain stores that sell, they would look at a fish that's imported from China, like, what is that haha. Why should I buy that? They would much prefer to go down the road and buy from Joe the fish guy. So we've got to work, I mean in some ways, on the cultural perceptions of what that means."

Craig: "And we have really been trying to hit that in our research and as part of our project. Because agriculture, even eighty ninety years ago was a big part of the economics, was really a big part of the strength of the economy in Puerto Rico and how that came to a decline. And we saw a number of factors, but there is still sort of that sense that of identity it terms of a culture in Puerto Rico. And since that moved away from Agriculture, but there is still that feeling of being Puerto Rican. We think it would be interesting to show the exact numbers for importation, because if you want to be self-sufficient as an island, I mean there's a lot of things that come from that. It's a very difficult area, because there is really no pointed area, it just kind of phased out because of sociopolitical things and restrictions, and there was just a lot involved. But that is what we are really looking for, is how to hit form that social aspect too and to have that perception not be changed, but be seen in a way that could benefit."

Mike McGee: "Well of course there are people here that would agree with you and I think that I

agree with you, I think that is the path for the future. Um but again here on this island you have an economy that has been basically sold to the big interests, you know? And the difficulty of recapturing that small, local agricultural market is even for vegetable, but even for fish and chickens, is used to grow a lot of chickens on the island here for a while, but now it's all collapsed. But you know that the competition or the imports are so cheap, because they are coming from these giant industrial farms and even they are subsidized by some extent by the federal government, or in the case of Vietnam they are subsidized by the Vietnamese government, so that they can export these products, and what they do create a lot of cash flow, they create a lot of foreign exchange and they Vietnam get U.S. dollars in return for sending their fish out. And that's something that they want, even if they are only making a 2% profit, they are stilling getting all this U.S. dollars. Um and so that really hurts the local guy or the small guy that has to try and compete in that market, but when you start to incorporate that consciousness that social awareness, in the sense that I make a conscious decision that I want to eat food from Puerto Rico or I want to eat organic food from Puerto Rico or I want to eat fish from Puerto Rico. That changes everything, but it changes it, because you decided to change it. So that's we're we need to convince people. I mean it's kind of easy to think like that, but not everybody.

Craig: “We want to hit on that social aspect of this, because we do want this to not be something that's like it was a good idea and not go anywhere, we wanted to create something that could really help. We can really put our thoughts and our efforts into what we are trying to bring up here.”

Mike McGee: “Okay I am going to give you guys my business card, you should go into my website, if you haven't already, and there are publications in there and you can read some of those that talk about some of the stuff we are talking about today. I think that right now they are estimating that fish imports are about 95% of the haha, and the rest of it is wild caught around the coast by the fishermen, because the aquaculture production around here is zero, it just never really blossomed. I tell people that this is the island that aquaculture forgot haha. It's funny though, because I do travel around, and for me when I go to Jamaica and when I go to the Dominican Republic, you can be on the island and you can be looking around and be like this looks just like Puerto Rico, and yet the way aquaculture works over there is completely different. I mean it is big, it's big, and you don't have to look far to find the guy selling fish, you see it all along the road. So maybe we will get back to that, but we are not really there right now. So do

you have any more questions for me?”

Juan: “Nope. The last thing is do you have any suggestions that you might have and if we can take little bit of the azolla and Lemna?”

Mike McGee: “Oh yeah yeah, azolla we will have to look around for to find out where it is hiding because like I say we don’t like it to get loose on us, and when it did get loose, like I say it’s so invasive, but we will get you some.”

Appendix I: Transcript for Joylin Guzmán Interview

December 4, 2014

Juan: “Can we record you?”

Joylin Guzmán: “Yes”

Juan: “Can we associate your name with your answers”

Joylin Guzmán: “Yes”

Juan: “What is AgroInnova’s plan when it comes to the alternative plants?”

Joylin Guzmán: “The point of it would be so that the farmers would use this information in their own farms. That’s the main goal.”

Craig: “Señora Guzmán, is it possible that when we start to get together the plants for this preliminary prototype for AgroInnova to like take the like forefront in producing on a small scale some of them, at least so that the prototype itself could be available before the farmers that like are interested in trying it, actually have the um resources to do that. You know what I mean? Because especially with the azolla and the Lemna, it’s like not as like grown as widely, especially the azolla.

Joylin Guzmán: “Uh huh”

Craig: “So in terms of the like once that’s found do you think um AgroInnova could like...”

Joylin Guzmán: “Propagate it?”

Craig: “Propagate it”

Joylin Guzmán: “Yes”

Craig: “Each one a little bit so at least once it is on the small scale for the prototype we could kind of have that hitch of, oh if you want to try it here’s a small sample. You know what I mean? Do you think that could be possible?”

Joylin Guzmán: “Yes that’s possible, because um at the sustainable farm you saw that we are starting to develop the facilities of agriculture. So over there it is possible to do that, because if we want to ferment the agricultures to to well develop their own plants we have to gave them the tools how to develop the things that we have to let them know that we are available with those plants for you to start to grow.”

Craig: “Right, and that first place that we went and saw, um that you showed us around for that was under construction, and you said that some of it was going to be for um production for an

extant, but for more like show to show them how it is done. There as well, where there is a lot of land, do you think there will be sections where it's like this is potential alternative plants, and this is how it could be grown. You know what I mean? Because um especially with the kudzu um if that's a possibility um because we actually did some more research on it and we think that it may be good in a small percentage, especially for rabbit feed. Um do you have any ideas of how we might go about doing that? Because it is a creep plant, like it creeps and it's a vine and things like that, maybe like a post or something. We are just trying to think of like strategies that could possibly be tried how to grow it like a crop. You know what I mean, some organized way."

Joylin Guzmán: "Well to be honest, um to grow it on a slope is better way to do that. It grows easier on a slope, so most agriculturists do not use slopes at all, so I think that is one of the areas that can be impacted with the kudzu. Or it is a vine that actually crawls up, maybe you can have some like posts with wire so that it can..."

Craig: "Yeah that's what I was thinking, maybe, because then that would promote the growing upward, because it would be towards the sun, but then it would also be um growing vertically which could increase the production of it, the volume of production of it per square you know area of land. Um yeah that's what we were thinking. But we were just trying to really solidify some things that we could try and recommend and try to expand on."

Joylin Guzmán: "Yes, because if a farmer does not have a slope or somewhere where he can grow it, where is he going to grow it?"

Juan: "So would you say that most of the farmers have more of a flat land?"

Joylin Guzmán: "Um over here, yeah. They tend to have flat lands."

Juan: "And from your experience, do most farmers have the capacity to designate certain areas to grow these plants, or are most of them using all their land right now?"

Joylin Guzmán: "Most of them are using like 60% of their land."

Juan: "So they have a lot of available space you would say?"

Joylin Guzmán: "Yeah. Most of the ugh agriculturists her use 60-70% of their land, that's all, doesn't use 100%. As you saw at Michael McGee, he uses a small percent of land. It has a lot of land to expand"

Craig: "Right, do you that for theses alternative plants, given that they do not require a lot of nutrients, they grow on soil that's pretty hardy. You know what I mean? Do you think that crop

turn over would still need to be a thing that we might need to consider? Like growing it on the land for a certain period of time, then we would need to clear that land and turn it over, then not grow it for a little while, then grow it again. Do you think that would still need to be a thing that we would have to do?”

Joylin Guzmán: “All the important stuff of these plants are that most of them, they are rich in nutrients and um in nitrogen. So these plants are even used to raise up the nitrogen levels of the soil. Okay? So when you harvest, most of these plants, there is material that’s left, enough to start it over with the nitrogen cycle.”

Craig: “Right, so ultimately that it could be growing this plant as a prerequisite to another crop could be possible to. Like if you wanted to produce this on a small scale, then you produce a certain amount of feed for the next three months. Given that it is only forty to fifty days that you need for something like maralfalfa, you could have one growing period of a plant that grows pretty fast and still be okay if you chopped it, kind of prepare the soil, then grow another crop.”

Joylin Guzmán: “That’s one of the NCRS practices for soil protection and everything.”

Craig: “So if they are really rich in nitrogen and nutrients, probably not even fertilization would be needed, for growing those plants in particular.”

Joylin Guzmán: “Nope, it would not be needed at all. Maralfalfa is one of those plants that, they told you to introduce nutrients and fertilizer, but I have harvested without any fertilizer.”

Craig: “Yeah if you don’t need to spend it, why would you spend it.”

Joylin Guzmán: “And it grows the same.”

Juan: “Another question that we have is if a farmer is interested in growing these plants, but growing it like as their own business, kind of like how AgroInnova is a business incubator. Would they be able to come in and almost lease per say, a farm or a certain area of farming so that they could grow plants, or is that not something that is done?”

Joylin Guzmán: “Well at least we do not have land for rent, cus we have the incubator, but not land for rent. Farmers should have enough land, because if you are farming already, you should have enough land to.”

Craig: “If before they want to take on the, kind of going off of that small scale creating the prototype on AgroInnova’s land, um could it be possible also that um while the farmers are still trying to test out this feed, to see if they do want to take it on, that additional expense of growing it on their own. Could that be extended past just the prototypes, for example have it for a for-

sale basis on a small-scale. Do you think that that could be possible? AgroInnova could sell the feed on a small-scale, while it is still developing.”

Joylin Guzmán: “Um yeah. Just enough to cover the expenses of making the animal feed, it can be done that way. Because we are a non-profit, our mission is not to profit from anything. It’s just to try to help farmers and to help persons who want to grow as entrepreneurs.”

Craig: “Do you think um maybe not in this question and answer session, but maybe in a separate time we could talk to you, because we are trying to really develop um whether it be for AgroInnova, or for a farmer that is trying to take this on, all of the cost that would be involved in the actual, from planting the alternative plants to harvesting them. So like how do they get the initial ingredients? Whether it be the little remnants of Lemna and azolla, what costs would be involved in that? Preparing the soil or preparing the water, everything, every little bit. So if AgroInnova was to take that on, to do that, if we could quantify all of the prices in that and all of the costs involved, from in the beginning from when the feed is created, that would be great.”

Joylin Guzmán: “Yes”

Craig: “And break it down as detailed as we possibly can.”

Joylin Guzmán: “That’s great for farmers, because they want to know how much money will be involved in making all of those changes.”

Craig: “Absolutely, and we are still looking into you know...”

Joylin Guzmán: “From the beginning before making any adjustments or something, you will definitely know how much it will cost. And if it is considerable, economic way for them to alternate the feeds.”

Craig: “Absolutely, because that is what we want to try and get to by the end. Because we want to have some sort of projection, because we are still trying to figure out all of the even equipment that is being used for preparing the soil, all of the equipment that is being used for harvesting the plants, you know what I mean. Because we do have an idea if farmers want to use AgroInnova’s facilities, the flat daily rate. Um we were also hoping to get, at some point, if farmers were able to produce unlimited amounts of these plants what would be the maximum, in terms of pounds or kilos, that they could process of this dry ah plant in one day. For that \$200, what is the max feasibly that they could do?”

Joylin Guzmán: “The idea is not for them to go to AgroInnova to process that, it’s for them to process that at their own...”

Craig: “So so being the actually machine itself, that creates the pellet.”

Joylin Guzmán: “Yeah, yeah. So the agricultural department in Puerto Rico, you as a farmer, you can go over there, and ask for them to give you the money for them to buy the machines.”

Craig: “Okay, and would there be any sort of inter-farmer rental thing that they could do, instead of having to purchase it?”

Joylin Guzmán: “The main goal for the farmer, is to not go to the facility to produce their feed. It’s to like have their machine and they can produce what they want and as many as they have. Because that machine it could pellet in an hour, I think it was like a thousand pounds. It depends on the cost of the machine, and how much you want to produce, because those pellet meals come from a thousand pounds, a hundred pounds, and you know a hundred thousand pounds.”

Craig: “Yeah so if it is a thousand pounds an hour, if they did it for twelve hours it would be twelve-thousand pounds.”

Joylin Guzmán: “Yeah and I know you ain’t gonna have one thousand pounds of dry matter. It’s too much, so it depends on how much you are going to have then, for the machine that you are going to buy. And the less you will harvest the less it will cost for the machine, and it depends from \$800 to \$2000, \$3000.”

Craig: “So that’s the range of the pellet mill, \$800 to \$2000-3000.”

Joylin Guzmán: “Ugh huh”

Craig: “Okay”

Joylin Guzmán: “So it cost that much. So you want to write a proposal, go to the agriculture department here in Puerto Rico, and let them know that you need this machine, the cost of the machine, give them two different quotations, two different quotes. And they give you the money to buy it, so that’s one of the government kind of help trying to help the agriculture.”

Juan: “So is that more of a grant or is that more of a loan?”

Joylin Guzmán: “No no no, it’s kind of like a grant. You have a proposal and they give you the money to buy it. You don’t have to repay them money.”

Craig: “So what would be the circumstances in which you could receive that money from the um, so I guess I’m missing something here. So if it’s \$800 to \$2000-3000, are you saying that if you reach out to them that they can help you help fund you to get that machine. So it could potentially, you wouldn’t, that could potentially not be an expense to buy it. Is that what you are saying? Like they would pay for it for you?”

Joylin Guzmán: “They pay for you.”

Craig: “So under what circumstances. Because like you said you have to supply them information.”

Joylin Guzmán: “You have to write them a proposal, you have to be what is called a bona fide agriculture, um you have to have a land already working, if that land doesn’t belong to you, you have to have a like a rent that says that that land is rented for you for at least ten years. If you owns it you just have to to give them the papers of ownership of the land. If the land belongs to government, anyway you will have a contract for ten years, because contracts for land for agriculture uses are for ten years. Because of that, because they ask of you for giving money, giving the machines, even the buildings that you saw when we were going, even for that, you need that contract.”

Juan: “Awesome. Thank you very much.”

Joylin Guzmán: “Okay”

APPENDIX J: RABBIT TESTING, RECORDING TEMPLATE

Testing the Feed Efficiency of Alternative and Commercial Rabbit Feed																	
Rabbit	Weight each week and notes																
<i>Control</i>	<i>Week 1</i>	<i>Week 2</i>	<i>Week 3</i>	<i>Week 4</i>	<i>Notes</i>	<i>Week 5</i>	<i>Week 6</i>	<i>Week 7</i>	<i>Week 8</i>	<i>Notes</i>	<i>Week 9</i>	<i>Week 10</i>	<i>Week 11</i>	<i>Week 12</i>	<i>Notes</i>	<i>Week 13</i>	<i>Week 14</i>
1																	
2																	
3																	
4																	
5																	
<i>Experimental</i>	<i>Week 1</i>	<i>Week 2</i>	<i>Week 3</i>	<i>Week 4</i>	<i>Notes</i>	<i>Week 5</i>	<i>Week 6</i>	<i>Week 7</i>	<i>Week 8</i>	<i>Notes</i>	<i>Week 9</i>	<i>Week 10</i>	<i>Week 11</i>	<i>Week 12</i>	<i>Notes</i>	<i>Week 13</i>	<i>Week 14</i>
1																	
2																	
3																	
4																	
5																	

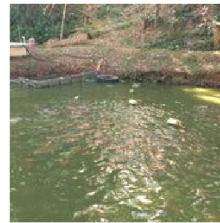
APPENDIX K: TILAPIA TESTING, RECORDING TEMPLATE

Testing the Feed Efficiency of Alternative and Commercial Tilapia Feed																	
Tilapia	Weight each week and notes																
Control	Week 1	Week 4	Week 7	Week 10	Notes	Week 13	Week 16	Week 19	Week 22	Notes	Week 25	Week 28	Week 31	Week 34	Notes	Week 37	Week 40
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
Experimental	Week 1	Week 4	Week 7	Week 10	Notes	Week 13	Week 16	Week 19	Week 22	Notes	Week 25	Week 28	Week 31	Week 34	Notes	Week 37	Week 40
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	

Financial Strategies for Tilapia Farms



AgrolInnova



Current State of the Tilapia Industry

- FDA/USDA regulations
 - What is and is not regulated, and what that means for you
- Supply vs. demand of meat production
 - Tilapia meat: insufficient demand; other methods for selling tilapia (decoration or “looks”) is being employed
- Private market; no supermarket involvement
- Large percentage of farming cost is animal feed (50-80%)

Money Saving Strategies

- Recycled Goods
- Donated Equipment
- Cheaper Materials
- Self-Sustainable Farming Practices
- Alternative Animal Feed

Recycled Goods

- Recycled goods cost you nothing, and with a little hard work and creativity they can cut your expenses for equipment
- Almost all equipment on a tilapia farm can be made from recycled goods, this includes:
 - Tanks
 - Bio balls
 - PVC pipes



Donated Equipment

- If requested many large scale companies will donate their old liquid storage containers.
- These containers can be used to store water or even as tanks for your tilapia (typically small-fry)



Self-Sustainable Farming Practices

- Practices like aquaponics and hydroponics can practically run themselves, and have numerous benefits, including the use of waste as fertilizer, the growing of plants, and the filtration of water.
- These methods allow all of your products to feed into each other, eliminating wasted material, and increasing the efficiency of your farm

How Hydroponics/Aquaponics Work



AgroInnova offers additional workshops on these methods. For more information, just ask.

Alternative Animal Feeds

- An alternative animal feed is used as a supplement to an already used commercial feed
- The alternative feed replaces a portion of the expensive commercial feed, thus reducing the cost to feed the animals
- The alternative feed should not have a reduction in quality compared to the commercial feed, but should be less expensive

Our Alternative Feed Formula

70% <i>Commercial</i>
5% <i>Morus Alba</i>
15% <i>Azolla caroliniana</i>
10% <i>Lemna Minor</i>

- This alternative animal feed is made up of a percentage of commercial feed in addition to alternative plants. This formula is currently being tested. If you are willing to try the feed for yourself, and record the affect it has on your tilapia, please inform Agrolnova

Benefits of Using Alternative Feed

- Farmers who use this alternative feed can grow a large amount of the required components on their farm. This greatly reduces the cost of feed. With the lowered costs, tilapia farming is more profitable and production can be expanded.
- The animal feed has been compared to many of the most popular commercial feeds in Puerto Rico. As a result, the quality of the feed is not reduced, while the cost of the feed is. The animal feed is currently being tested to confirm all of these claims.

How to Grow the Plants

Species	Light	Water	Harvest	Processing	Temperature
<i>Maral/fai/fa</i> [1]	Full	Prefers areas with high level of rainfall, but maintains growth with minimal irrigation during dry season	Every 40-60 days; cut 4 inches away from the base to maximize product and allow for regrowth	Grinding of the dried radial plant (not roots) allows for use in livestock feed	Higher growth rate in hot, tropical environments
<i>Morus alba</i> [2]	Full	Drought tolerant, fruit does not ripen fully; prefers moist areas	Every 90-120 days (tropical); cut away from trunk base (time needed to heal)	Grinding of the dried plant forage allows for use in livestock feed	>= 10C average temperature required; optimal growth in hot, tropical weather
<i>Azolla caroliniana</i> [3]	25-50% is ideal (out of this range results in lower growth rate)	Absorbs nutrients available in aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Can grow in temperatures ranging from freezing to arid; Optimal growth at 20-30C
<i>Lemna minor</i> [4]	Full results in optimal growth, able to grow with moderate sunlight	Absorbs nutrients available in the aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Tolerant in range of temperatures, normal growth observed at as low as 7C, but hot temperatures are ideal
<i>Moringa oleifera</i> [5]	Full results in optimal growth, able to grow with moderate sunlight	Dependent on irrigation during severely dry seasons or extended droughts	Entire plant can be harvested from every two weeks to every 50-60 days; cut at the stem, leaving >0.5m out of the ground	Grinding of entire radial plant allows for use in livestock feed	Can survive lower temperature, prefers semi-arid or tropical environments with high temperatures
<i>Kudzu Pueraria lobata</i> [6]	Does not need full sunlight, but will grow towards the sun if more light is needed	Highly durable/tolerant to drought; grows at a higher rate with available moisture	Can be harvested at any time, grows freely in various areas. Entire vine achieved by various methods	Grinding of entire plant material allows for use in livestock feed; can be fed from harvest without processing	Is found in a variety of environments, but grows rapidly in hot, humid environments including tropical places

How to Create the Feed

- AgrolInnova: \$200 for one day; production of X pounds of feed by using the machines available at the Caguas facility
- Transport fresh plant ingredients to the facility
- Processing of material with machines
- Dried and crushed plant material combined in correct percentages
- Pelleted, packaged, and returned/stored

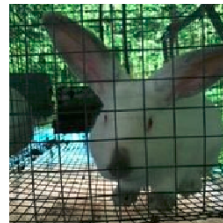
Thank You

Any Questions?

Financial Strategies for Rabbit Farms



AgrolInnova



Current State of the Rabbit Industry

- FDA/USDA regulations
 - What is and is not regulated, and what that means for you
- Supply vs. demand of meat production
 - Rabbit meat: 750,000 lbs. is currently produced; 1,000,000 additional lbs. in demand
- Private market; no supermarket involvement
- Large percentage of farming cost is animal feed (50-80%)

Money Saving Strategies

- Recycled Goods
- Donated Equipment
- Less Expensive Materials
- Self-Sustainable Farming Practices
- Alternative Animal Feed

Less Expensive Materials/ Do it Yourself

- Often it is much cheaper to make the equipment needed for your farm, especially when you use less expensive material. One example of this is making your rabbit cages out of wire meshing.



Recycled Material

- Recycled material is another cheap option, this material can be used for numerous reasons including PVC pipes to both deliver water to your rabbits, and/or to transport urine to septic tanks.



Donated Equipment

- If requested many large scale companies will donate their old liquid storage containers.
- These containers can be used for a variety of reasons including to store water



Self-Sustainable Farming Practices

- One example of these farming practices is turning the waste of your rabbits into compost. This fertilizer can then be used to help grow the plants that you use to feed your rabbits.
- These methods allow all of your products to feed into each other, eliminating wasted material, and increasing the efficiency of your farm

How to Make Compost



Alternative Animal Feeds

- An alternative animal feed is used as a supplement to an already used commercial feed
- The alternative feed replaces a portion of the expensive commercial feed, thus reducing the cost to feed the animals
- The alternative feed should not have a reduction in quality compared to the commercial feed, but should be less expensive

Our Alternative Feed Formula

35% Morus alba
20% Moringa oleifera
20% Commercial feed
15% Pueraria lobata (Kudzu)
10% Pennisetum purpureum (Maralfalfa)

- This alternative animal feed is made up of a percentage of commercial feed in addition to alternative plants. This formula is currently being tested. If you are willing to try the feed for yourself, and record the affect it has on your rabbits, please inform AgrolInnova.

Benefits of Using Alternative Feed

- Farmers who use this alternative feed can grow a large amount of the required components on their farm. This greatly reduces the cost of feed. With the lowered costs, rabbit farming is more profitable and production can be expanded.
- The animal feed has been compared to many of the most popular commercial rabbit feeds in Puerto Rico. As a result, the quality of the feed is not reduced, while the cost of the feed is. The animal feed is currently being tested to confirm all of these claims.

How to Grow the Plants

Species	Light	Water	Harvest	Processing	Temperature
<i>Marai/fai/fa</i> [1]	Full	Prefers areas with high level of rainfall, but maintains growth with minimal irrigation during dry season	Every 40-60 days; cut 4 inches away from the base to maximize product and allow for regrowth	Grinding of the dried radial plant (not roots) allows for use in livestock feed	Higher growth rate in hot, tropical environments
<i>Morus alba</i> [2]	Full	Drought tolerant, fruit does not ripen fully; prefers moist areas	Every 90-120 days (tropical); cut away from trunk base (time needed to heal)	Grinding of the dried plant forage allows for use in livestock feed	>= 10C average temperature required; optimal growth in hot, tropical weather
<i>Azolla caroliniana</i> [3]	25-50% is ideal (out of this range results in lower growth rate)	Absorbs nutrients available in aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Can grow in temperatures ranging from freezing to arid; Optimal growth at 20-30C
<i>Lemna minor</i> [4]	Full results in optimal growth, able to grow with moderate sunlight	Absorbs nutrients available in the aquatic environment it is growing in	Drag any solid object across the water, allowing for collection of surface contents, and remove	Can be fed fresh or grinding of this plant material after dry can allow for use in livestock feed	Tolerant in range of temperatures, normal growth observed at as low as 7C, but hot temperatures are ideal
<i>Moringa oleifera</i> [5]	Full results in optimal growth, able to grow with moderate sunlight	Dependent on irrigation during severely dry seasons or extended droughts	Entire plant can be harvested from every two weeks to every 50-60 days; cut at the stem, leaving >0.5m out of the ground.	Grinding of entire radial plant allows for use in livestock feed	Can survive lower temperature, prefers semi-arid or tropical environments with high temperatures
<i>Kudzu Pueraria lobata</i> [6]	Does not need full sunlight, but will grow towards the sun if more light is needed	Highly durable/tolerant to drought; grows at a higher rate with available moisture	Can be harvested at any time, grows freely in various areas. Entire vine achieved by various methods.	Grinding of entire plant material allows for use in livestock feed, can be fed from harvest without processing	Is found in a variety of environments, but grows rapidly in hot, humid environments including tropical places

How to Create the Feed

- AgrolInnova: \$200 for one day; production of X pounds of feed by using the machines available at the Caguas facility
- Transport fresh plant ingredients to the facility
- Processing of material with machines
- Dried and crushed plant material combined in correct percentages
- Pelleted, packaged, and returned/stored

Thank You

Any Questions?