Local Feed Alternative in Barbados Blackbelly Sheep Production

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Abstract

Food insecurity is a complex phenomenon that has warranted great global concern in recent decades. Progress has been made in the Caribbean to reduce undernourishment and meet the global hunger targets put forth by the World Food Summit and the United Nations Millennium Development Goals. Despite Barbados's capacity to curb the percentage and prevalence of undernourishment, the incidence of diabetes and obesity remains high. Lamb production is one of four components in the livestock sub-sector to have expanded in past decades. The Barbados Blackbelly sheep is the country's primary sheep breed and is intended for meat consumption. The high costs of imported feeds on the island is making it increasingly difficult for Blackbelly sheep farmers to sustain production or for potential new farmers to enter into the industry. The aim of this project was to develop a by-product formulation that would produce equivalent or higher sheep weight gain in comparison to the commercial concentrate feed, all the while being both sustainable and economically viable. The ration was comprised of locally available by-products including wheat middlings, rice bran, soybean meal, ground corn, limestone powder and molasses. The feed formulation was supplemented by a mineral lick, with hay and water being replenished daily. Together, these provided energy, protein, fat and fiber in amounts equivalent to the concentrate feed. In this study, two feed trials were conducted. The Blackbelly rams involved in the trials were randomly assigned to one of three treatments (T1: Control - 100% Commercial Concentrate; T2: 50% Commercial Concentrate & 50% By-product Mixture; T3: 100% By-Product Feed) and fed their corresponding diets over a period of seven to nine weeks, with weight being monitored weekly. Additionally, surveys were administered to 20 farmers who rear Blackbelly sheep to collect data pertaining to the farmers' food security status along with some general information regarding their livestock production systems and the feeds they use to nourish their animals. Further, six of the surveyed farmers were selected to participate in a face-to-face discussion aimed to gather qualitative information concerning by-product ingredients and the willingness of these farmers to implement the developed by-product ration. Results from the feed trials indicate that the by-product ration proposed in this research can be used as an alternative to the commercial concentrate feed. Survey results show that the majority of interviewed farmers are food secure, landless or land-limited and currently use partial or complete by-product feeds to nourish their animals. Findings from the face-to-face discussions suggest that the social and cultural acceptability of by-product ingredients is high and that farmers are willing to try the by-product ration proposed in this study.

Résumé

L'insécurité alimentaire est un phénomène complexe qui a justifié de grandes préoccupations mondiales au cours des dernières décennies. Des progrès ont été réalisés dans la région des Caraïbes pour réduire la sous-alimentation et atteindre les objectifs fixés en matière de nutrition mis de l'avant par le Sommet mondial de l'alimentation et les Objectifs du Millénaire pour le développement des Nations Unies. Malgré les efforts de la Barbade pour diminuer le pourcentage et la prévalence de la sous-alimentation, le taux de diabète et le taux d'obésité restent élevés. La production d'agneau est l'une des quatre composantes du sous-secteur de l'élevage qui s'est développée au cours des dernières décennies. Le mouton de la Barbade Blackbelly est la race principale de moutons du pays et est destiné à la consommation de viande. Le cout élevé des matières premières importées pour l'alimentation des animaux contribue à exacerber les difficultés des éleveurs de moutons Blackbelly à maintenir leur production, en plus de décourager de nouveaux joueurs à entrer et se tailler une place dans l'industrie. Ce projet avait pour objectif de développer une ration de sous-produit permettant de produire un gain de poids équivalent ou supérieur aux aliments concentrés commerciaux tout en étant durable et rentable. La ration était composée de sous-produits disponibles localement, comme la farine de blé, le son de riz, la farine de soja, le maïs broyé, la poudre de calcaire et la mélasse. La ration a été enrichie par un apport en minéraux, du foin et de l'eau étant réapprovisionnés quotidiennement. Ensemble, ces sous-produits fournissaient de l'énergie, des protéines, des graisses et des fibres en quantités équivalentes aux aliments concentrés offerts sur le marché. Dans cette étude, deux essais alimentaires ont été réalisés. Les béliers Blackbelly impliqués dans les essais ont été répartis au hasard dans l'un des trois traitements (T1: Groupe contrôle - 100% concentrés commerciaux, T2: 50% d'aliments concentrés commerciaux et 50% de mélange de sous-produits, T3: 100% de sous-produit). Les béliers ont été alimentés selon leurs régimes respectifs sur une période de sept à neuf semaines, le poids étant surveillé à chaque semaine. De même, des sondages ont été réalisés auprès de 20 éleveurs de moutons de Blackbelly pour recueillir des données relatives au statut de sécurité alimentaire des agriculteurs ainsi que des informations générales concernant leurs systèmes de production animale et les aliments qu'ils utilisent pour nourrir leurs animaux. De plus, six des agriculteurs interrogés ont été choisis pour participer à une entrevue informelle visant à recueillir des informations qualitatives concernant les ingrédients dérivés et la volonté de ces agriculteurs de mettre en œuvre la ration proposée dans cette étude. Les résultats des essais alimentaires indiquent que la ration des sous-produits proposée dans ce projet peut être utilisée comme alternative aux aliments concentrés commerciaux. Les résultats du sondage montrent que la majorité des agriculteurs interrogés sont à l'abri de l'insécurité alimentaire, sont en opération sur des superficies de terre limitées, et utilisent actuellement des aliments partiels ou complets pour nourrir leurs animaux. Les résultats des entrevues suggèrent que l'acceptabilité sociale et culturelle quant à l'utilisation des ingrédients dérivés est élevée et que les agriculteurs sont prêts à essayer la ration des sous-produits proposée dans cette étude.

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List of Abbreviations

ADF	Acid Detergent Fiber
ADG	Average Daily Gain
ADL	Acid Detergent Lignin
ar(1)	Autoregressive
BIC	Bayesian Information Criterion
CARICOM	Caribbean Community
CARDI	Caribbean Agricultural Research and Development Institute
CP	Crude Protein
CS	Compound Symmetry
DM	Dry Matter
FAO	Food and Agriculture Organization of the United Nations
FIES	Food Insecurity Experience Scale
GAS	Government Analytical Services
IICA	Inter-American Institute for Cooperation in Agriculture
INRA	L'Institut national de la recherche agronomique
MDG	Millennium Development Goals
NAHFCA	National Agricultural Health and Food Control Agency
NDF	Neutral Detergent Fiber
SIDS	Small Island Developing States
SDG	Sustainable Development Goals
TDN	Total Digestible Nutrients
VFA	Volatile Fatty Acids
WFS	World Food Summit

1.0 GENERAL OVERVIEW

1.1 Introduction

Food insecurity is a complex phenomenon that has gained much traction in recent decades (Webb *et. al,* 2006). According to the Food and Agricultural Organization of the United Nations (FAO), food security exists when "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). Established in 1973, the Caribbean Community (CARICOM) is an organization consisting of twenty Caribbean countries whose primary goal is to coordinate foreign policy, support the economic integration and cooperation of its members and ensure that the benefits of integration are shared equitably (CARICOM, 2017). Progress has been made across the CARICOM in reducing undernourishment and meeting the global hunger targets put forth by the World Food Summit (WFS) of 1996 and the United Nations Millennium Development Goals (MDG) of 2000. The hunger targets by WFS and MDG aimed to halve the number and prevalence of undernourished people worldwide by 2015, respectively. Except for Haiti, per capita calorie consumption in the CARICOM exceeds the energy requirements suggested by the FAO. Moreover, food availability in these regions is increasingly derived from imports, as opposed to national food production. What's more, income inequality and unemployment has become largely prevalent in the region, with over 30 percent of the population living below the national poverty line in seven CARICOM countries (FAO, 2015). Additionally, there has been a broad regional dietary shift whereby domestically produced food items (root crops, tubers, fruits and vegetables) are disregarded in favour of imported processed canned goods and fried foods. Further, the regional risk for natural disasters is the predominant factor affecting the stability of food security in the CARICOM. Undeniably, the threat of climate change will likely only magnify the frequency of these occurrences (FAO, 2015).

Barbados is one of three CARICOM countries to have successfully achieved the global hunger targets by both WFS and MDG that have surfaced in past decades. However, despite the country's capacity to curb the number and prevalence of undernourished people, the incidence of diabetes and obesity in Barbados is at an all-time high. The diets that are characteristically favoured by the Barbadian public are those that are low-cost, calorie dense and rich in both fats and sweeteners. Although some families and individuals would prefer transitioning to a healthier dietary pattern, most are unable to afford the high prices of quality foods (FAO, 2015). In addition, per capita calorie consumption in Barbados exceeds 3,000 kcal. This calorie overconsumption combined with insufficient dietary choices suggests that malnutrition is indeed predominant in Barbados, leading to obesity and chronic non-communicable diseases such as diabetes. This theme has emerged mainly as a response to the country's high food import bill (FAO, 2015).

The role of livestock in the Caribbean is essential as it provides local populations with a basic source of food, thus improving the state of food insecurity in the region. Moreover, livestock production has been found to be the most suitable social, economic, and cultural strategy for safeguarding the welfare of local communities (FAO, 2017). Though the advantages related with livestock production are plentiful, the high costs of animal feeds, decreased forage availability and inefficient use of available food resources are preventing Caribbean livestock farmers from fully benefiting from their production systems (FAO, 2017). These constraints are also widely applicable to small ruminant production. In addition, most agricultural feeds used for small ruminant production in the region are imported (FAO, 2015). To be successful, initiatives to optimize these production systems should seek to address the needs and objectives of the farmers while promoting the rational use of local feed resources and native small ruminant breeds. Part of this process involves helping farmers to thrive on the feed resources that are available to them locally (Alexandre *et al.,* 2010).

Barbados is the east most country in the Caribbean and is completely surrounded by the Atlantic Ocean. Like most small island developing states (SIDS), Barbados is highly dependent on imports and has relatively high cost, uncompetitive agricultural production systems (Rawlins, 2003). The country's notable economic improvement in past decades can partly be attributed to the tourism industry, to which the country is largely reliant. In the last three years, the performance of the agricultural sector has been affected by unfavourable weather conditions, labour shortages, diminished acreage under cultivation, decreasing yields and increasing production costs (Thomas & Hunte, 2005). Economic development and diversification into the tourism industry, has resulted in the increased competition for land, labour and capital resources. There is also the problem of relatively high prices for basic agricultural inputs such as feed, chemicals, seeds, diesel, machinery and equipment (Thomas & Hunte, 2005).

The Barbados Blackbelly sheep is the country's primary sheep breed, with a population of roughly 25,000 heads (Thomas & Hunte, 2005). The Blackbelly is a tropical hair sheep that is native to the island of Barbados intended primarily for meat consumption. Lamb production is one of four components within the livestock sub-sector to have expanded in past decades. Blackbelly farmers generally use large quantities of imported commercial concentrate feeds and low levels of inexpensive, locally grown forages to feed their animals. The high costs of feeds on the island is making it increasingly difficult for Blackbelly sheep farmers to sustain production or for potential new farmers to enter the industry (Thomas & Hunte, 2005). For this reason, farmers have been turning to by-product feeds as a means of feeding their animals and cutting production costs (Asiedu, 2000).

1.2 Overall Study Aim & Rationale

The primary objective of this study is to develop a by-product ration for Blackbelly sheep that can be used as an alternative to the commercial concentrate feed. The secondary objective this project is to assess the food security status of Blackbelly sheep farmers as well as the social and cultural acceptability of by-product feeds.

1.3 Hypotheses

It is hypothesized that:

- The developed by-product formulation will produce sheep weight gain results that are comparable to those of the commercial concentrate feed.
- Most Blackbelly sheep farmers in Barbados are food secure.

2.0 LITERATURE REVIEW

2.1 Food Security

Food insecurity is a complex phenomenon that has warranted great global concern and discussion in recent decades. Its multifaceted nature makes it challenging to both define and measure. In fact, it has been stipulated that no single indicator can measure all of food insecurity's intricacies (Webb *et. al*., 2006). The most complete and well-rounded definition of food security was developed by the FAO and was first adopted during the 1996 WFS. It states that food security "exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

In the past 21 years, three internationally agreed targets for hunger reduction have been established in response to the staggering rise in the state of food insecurity. The first of these hunger targets was the WFS of 1996. Summit attendees vowed to achieve a determinate goal – "to eradicate hunger in all countries, with an immediate view to reducing the number of undernourished people to half their present level no later than 2015" (FAO, 2015). The second global hunger target was proposed four years later during the 2000 Millennium Summit, in which a set of eight MDG were declared. The first of these goals (MDG 1c) aimed to halve, between 1990 and 2015, the proportion of people suffering from hunger (FAO, 2015), a target that is substantially more conservative than that suggested during the WFS four years prior. The monitoring period for these global hunger targets was concluded in 2015 and the results are as follows. According to the FAO, more than half of the monitored developing countries have attained the MDG 1c hunger target. Overall, it was concluded that the hunger target outlined in the Millennium Declaration was achieved, having successfully decreased the prevalence of undernourished people by half, from 1990 to 2015. The WFS hunger target however, was missed by a large margin. Recent estimates predict that there are 780 million undernourished people in developing regions, 265 million more than the projected target of 515 million (FAO, IFAD and WFP, 2015).

In 2015, the United Nations released the Sustainable Development Goals (SDG), also entitled Transforming our world: the 2030 Agenda for Sustainable Development. As successor to the MDG, this new development agenda consists of 17 "Global Goals" and a total of 169 targets (United Nations, 2017). The second goal aims to end hunger (Target 2.1) and all forms of malnutrition (Target 2.2) by 2030. The Food Insecurity Experience Scale (FIES) is one of two indicators that are used for Target 2.1 and is discussed below (United Nations, 2017).

Today, roughly 24 percent of the global population suffers from food insecurity, with rural regions being disproportionately more affected (Rosen *et al.,* 2012). Additionally, more than 900 million people worldwide are undernourished, two billion are malnourished and upwards of two billion people suffer from one or more micronutrient deficiencies (FAO, 2010; WHO, 2007). It is important to note that malnutrition is not synonymous with undernourishment. Malnutrition is a complex issue and is generally brought on by an assortment of contributing factors. In its simplest form, malnutrition stems from a nutritionally insufficient diet and exists across income groups, impacting both developed and developing countries alike. For the world's poor, malnutrition is caused by diet that is lacking in energy, protein and micronutrients (FAO, 2011). This form of malnutrition is substantially more concerning and is more common in low income or developing countries (FAO, 2013). On the other hand, for those capable of affording the prescribed calories, malnutrition is triggered by overconsumption and poorly balanced diets (FAO, 2011). The prevalence of this issue has increased exponentially in recent decades. In fact, global estimates show that 1.4 billion adults are overweight, 500 million of which are considered obese (FAO, 2013).

According to the FAO, many countries do not have the capacity and national budgets for appropriate data collection and subsequent analyses of food insecurity. This makes it increasingly challenging to monitor the state of food insecurity in the country and develop suitable mitigation strategies (FAO, 2014). In 2013, the FAO collaborated with Gallup, Inc. to launch an initiative called Voices of the Hungry. The aim of this initiative was "to find a way to consistently measure food insecurity worldwide using an experience-based tool that can easily be applied in many different contexts" (FAO, 2014). Together, they developed the FIES, a food security measurement tool that relies on people's direct responses regarding their access to adequate food to measure the severity of food insecurity (FAO, 2014; FAO, 2017). This experienced-based metric has the added benefit of serving as a global standard of reference with which measurements from different countries, contexts and genders can be compared. The FIES-based measurement system differs from existing food security indicators as it estimates the severity of people's food insecurity directly, rather than using factors such as poverty, poor diets, nutritional status and social exclusions (FAO, 2014).

2.2 Food Insecurity in the Caribbean

Notwithstanding their upper-middle to high-income status (except for Haiti and Guyana), the food security and nutritional profile assessment of CARICOM countries is mixed (FAO, 2015). Progress has been made across the CARICOM in reducing undernourishment and meeting the global hunger targets put forth by the WFS and the MDG. Three CARICOM countries – Barbados, Guyana and St Vincent and the Grenadines – have successfully achieved both aforementioned hunger targets. Dominica, Bahamas, Belize, Jamaica and Trinidad and Tobago were able to curb undernourishment levels to less than 10 percent of their populations by 2015. All but one of the remaining CARICOM countries have undernourishment levels ranging from 10 to 20 percent. The prevalence of undernourishment in Haiti is considerable, consisting of 50 percent of the country's population. It should be noted that Haiti is a special case within the CARICOM. This country accounts for approximately 60 percent of the region's population and 90 percent of undernourished people (FAO, 2015). Further, 2014 prevalence rates of food insecurity in Belize, Haiti and Jamaica are 27.7%, 82.0% and 43.1% respectively (FAO, 2016).

With the exception of Haiti, daily calorie consumption in the CARICOM exceeds the targeted requirements. In Barbados and Dominica, per capita calorie consumption exceeds 3000 kcal. In all other CARICOM countries, except Haiti, the per capita calorie consumption is above 2400 kcal. As for Haiti, estimates suggest that the average is roughly 2000 kcal. This calorie overconsumption in most CARICOM countries can be attributed in part to processed foods. Dietary changes across the CARICOM have caused these islands to be ranked among the highest in the world with regards to the incidence of obesity. Moreover, the occurrence of being overweight or obese is more prevalent in the CARICOM region as compared to undernourishment. Among persons 15 years and above, male obesity rates in the region are substantially lower than those of females. For instance, obese females in Haiti outnumber obese males 16:1, and in Jamaica and St Lucia the ratios are 6:1 and 4:1, respectively (FAO, 2015).

What's more, food availability in these regions is increasingly derived from imports. This is highly problematic as it contributes to food import dependency, loss of foreign exchange and an increase in processed food consumption (FAO, 2015). In fact, CARICOM countries spend upwards of US$ 4 billion on imported foods annually; a rise of 50 percent since 2000. Most countries within the CARICOM import over 60 percent of the foods they consume. Half of these countries have a food bill consisting of more than 80 percent of imported foods. Belize, Guyana and Haiti are the only three countries that produce more than 50 percent of the foods they use for consumptive purposes. Moreover, grains (wheat and corn), livestock products (meat and dairy) and processed foods are among the top five food import categories, accounting for roughly 25 percent (US$ 1 billion) of annual CARICOM food imports. Also, the national per capita production of several essential food groups has declined, particularly in the fruits and vegetable category (FAO, 2015).

Furthermore, given the income classification status of most countries within the CARICOM, one could assume that access to healthy, nutritious food should not be a problem. However, income inequality and unemployment has become highly pervasive in the region, with upwards of 30 percent of the population living below the national poverty line in seven CARICOM countries. As for Haiti, it is estimated that 59 percent of the nation's population has fallen below the poverty line and as such, approximately 40 percent of the CARICOM population is considered poor. There is also significant disparity regarding consumption expenditure in the Caribbean. It has been established that the highest 10 percent of income earners have a consumption expenditure value that is 16.4 times greater than the lowest 10 percent of income earners (FAO, 2015).

Additionally, determinants such as capacity to purchase, food choices and food preparation is affecting food utilization. In recent decades, there has been a dietary shift whereby domestically produced food items such as root crops, tubers, fruits and vegetables are overlooked in favour of food that is nutrient deficient, energy-dense and high in fats, oils, sodium and sweeteners. What makes this even more alarming is that in most instances, the poor and unemployed cannot afford high priced quality foods (fresh fruits and vegetables) even if they wanted to and instead opt for inferior food items (imported processed canned goods and fried foods). This in turn has led to the increased observable rates of obesity and non-communicable diseases such as diabetes, which is only further exacerbated by the sedentary lifestyle choices that have become commonplace in the region (FAO, 2015).

In terms of stability, the food security of the CARICOM is precarious at best, given the regional risk for high occurrence tropical storms, floods, droughts and earthquakes. This is not the only factor that can influence the stability of food security in the region, but it is definitely the factor that can cause the greatest immediate damage. These natural disasters cause extensive property damage, loss of lives and frequently undermine national efforts to improve the state of food insecurity and to reduce poverty. The severity of the natural disaster can also interrupt the country's flow of goods and services, both from local and imported sources, thus increasing losses. The damage and losses associated with natural disasters have increased significantly over the past 15 years. Undoubtedly, the threat of climate change and its consequential impacts will surely influence the rate at which such disasters occur. As such, building resiliency at the regional and country level in the CARICOM has been widely articulated as a major development goal (FAO, 2015).

2.3 Food Insecurity in Barbados

Barbados is one of three countries in the Caribbean to have successfully achieved both of the global hunger targets that have surfaced in the past two decades. These include the hunger targets of the WFS, which was established in 1996, and that of the MDG in 2000 (FAO, 2015). However, regardless of the country's ability to curb the percentage and prevalence of undernourished people, which are extremely significant and important achievements, the incidence of diabetes and obesity in Barbados is at an all-time high.

The diets that are typically favoured by the Barbadian public are those that are low-cost, calorie dense (particularly refined carbohydrates) and rich in both fats and sweeteners. Although some families and individuals would prefer transitioning to a healthier dietary pattern, consisting mainly of lean meats, fish, vegetables, and fruits, many are unable to afford and /or sustain the purchasing of such foods on the long term. This is primarily because Barbados imports a large majority of its food inputs. In fact, it is among the top five food importers in the CARICOM, responsible for importing US$ 312 million worth of agricultural products in 2011. Barbados also happens to be among the top three countries within the CARICOM to have the highest variability in per capita food production; a factor that could explain the country's reliance on imported food. In addition, per capita calorie consumption in Barbados exceeds 3000 kcal, which is roughly 30 percent higher than the Recommended Population Food Goal (FAO, 2015). This evident calorie overconsumption coupled with insufficient dietary choices suggests that malnutrition is indeed a predominant theme amongst the Barbadian population. Malnutrition of this kind can lead to overweight and obesity as well as chronic non-communicable diseases such as diabetes. According to the FAO, Barbados has the highest observable rates of female obesity (67.7%) throughout the CARICOM region and the highest recorded lower extremity amputations related to diabetes in the world (FAO, 2015).

Barbados has been fortunate to be among the countries who have been the least impacted by natural disasters in past decades, experiencing lesser damage and losses (US$ 5.2 million) relative to other countries in the CARICOM (FAO, 2015). Rawlins (2003) stated that "although Barbados has not recently suffered from severe natural disasters, such as hurricanes, floods and other disasters, the possibility of such an event is a clear and ever-present threat to its agricultural sector". If such an event were to occur, it is almost guaranteed that the island's agricultural sector would suffer substantial damage. What's more, the absence of severe disasters in recent years means that the disaster recovery plan for the agricultural sector is limited and outdated (Rawlins, 2003), with the potential to largely affect the country's resiliency.

2.4 Livestock Production in the Caribbean

The role of livestock in the Caribbean is essential, providing local populations with a basic source of food and by extension improving the state of food insecurity in the region (FAO, 2017). Upwards of 1 billion people worldwide are dependent on the livestock sector, with roughly 616 million rural poor living on less than US$ 1.00 per day being partly dependent on livestock as a means of support (FAO, 2017). The FAO considers livestock production as the most suitable social, economic, and cultural strategy for upholding the welfare of local communities. In most instances, the rearing of livestock is the only activity that can concurrently provide security for daily subsistence, maintain ecosystems and promote wildlife conservation all the while satisfying cultural traditions and values. Also, family or backyard livestock production systems have the capacity to contribute to growth in the country's gross domestic product, boost livestock product exports and generate employment opportunities within the local community (FAO, 2017).

The great majority of Caribbean family farms are smallholdings. Despite them being significant producers of poultry, eggs, pork, goat meat and mutton, livestock family farming in CARICOM countries is not well recognized. Further, landless farming is common amongst Caribbean livestock producers. Farmers who fall into this category use produced goods for subsistence purposes, thus supporting the livelihoods of their families (FAO, 2015).

Though the advantages related with livestock production systems are plentiful, certain challenges exist that prevent Caribbean livestock farmers from fully benefiting from their production systems. Such hindrances include "the high costs of animal feed (60-70% of total production costs), the limited availability of quality forage and inefficient use of available food resources, which affect productivity; the increased risk of transboundary animal pests and diseases; threats associated with the degradation of natural resources and the negative impact of climate change on the livestock sector" (FAO, 2017).

2.5 Small Ruminant Production in the Caribbean

Small ruminants in the Caribbean represent a significant socio-economic asset that can be effectively used to diversify export-crop agriculture, alleviate poverty and improve regional rural development. Currently, the demand for livestock commodities is high throughout the CARICOM region, with locally produced goods generally receiving premium prices. However, imported mutton and goat meat has recently been taking up a great proportion of the domestic supply. For instance, from 1993 to 1996, the domestic supply of mutton and goat meat in Antigua and Barbuda consisted of 83 percent imports, 93 percent in Barbados, 63 percent in Jamaica and 73 percent in Trinidad and Tobago. These low domestic production levels can be ascribed to the structure of the prevailing livestock industry of the past decades (Asiedu, 2000).

For the most part, small ruminant production in the Caribbean is assumed predominantly by small and part-time farmers, and primarily on small tracts of agricultural land or on open lots and roadsides. Regardless of the selected rearing management type (extensive, semi-intensive or intensive), farmers in the region tend to use an all-in-one production approach whereby the same farmer will produce breeders, weaners and fatteners. As such, production systems that specialize in breeder stock, weaner stock and feedlot fattening are likely to be new and few. Thus, small ruminant production as the singular commercial enterprise or even as the major component in a mixture of commercial enterprises is considerably rare (Asiedu, 2000).

Marketing channels for the small ruminant industry in the Caribbean appears to be clearly demarcated. Most locally produced animals are sold on hoof at the farm gate. As for the meat market, domestically produced sheep and goat meat are typically distributed via supermarkets, meat shops and restaurants. Imported meat products, on the other hand, go through to the hotel industry to service tourism (Asiedu, 2000).

Significant improvements have been made in recent decades regarding the industry structure and production levels of local small ruminants. For example, between 1986 and 1998, local production of eight countries - Barbados, the British Virgin Islands, Cuba, Dominican Republic, Haiti, Jamaica, the Leeward Islands and Trinidad and Tobago – increased, on average, by 21 percent. In Jamaica, the total small ruminant population doubled from 206,000 to 450,000 heads between 1990 and 1999. This production increase can be attributed in part to natural progression and the apparent profitability of the small ruminant production industry, but mainly due to substantial technological advancements (Asiedu, 2000). Ministries of Agriculture and organizations such as the Caribbean Agricultural Research and Development Institute (CARDI) have been instrumental in the development and implementation of technologies aimed to improve the efficacy of the small ruminant production in the CARICOM. They have proposed breeding development programs, sustainable housing solutions and training in improved animal husbandry practices, with a specific emphasis on identification and record keeping. According to Asiedu (2000), the applied breeding programs have resulted in a broad "variety of quality pure and cross bred germplasm from Anglo-Nubians, Alpines, Saanens, Toggenburgs and Boers for goat production and the Barbados Blackbelly, Persian Blackhead, West African and Virgin Island White for sheep production". The Barbados Agricultural Society has identified export markets for the germplasm of the Barbados Blackbelly sheep and has established a committed feedlot production system. Moreover, these advancements have also shown farmers that by-product feeds, as complements to the commercial concentrate feeds, may have a positive influence on production systems (Asiedu, 2000).

2.6 Feed Replacements & Alternatives with Small Ruminants in the Caribbean

As mentioned previously, the largest source of food in most CARICOM countries stems from food imports, as opposed to national food production. By the same token, the great majority of agricultural feeds used for small ruminant production in the region are imported (FAO, 2015). Moreover, to be successful, initiatives to optimize the production systems of Caribbean small ruminant farmers "should directly address the needs and objectives of the keepers while promoting rational use of local feed resources and indigenous breeds" (Alexandre, G. *et al.,* 2010). Part of this process involves helping farmers to thrive on the feed resources that are available to them locally (Alexandre *et al.,* 2010). There is evidence from previous feeding trials with small ruminants that locally available feed alternatives can reduce the dependency on imported agricultural feeds, while maintaining animal productivity and health as well as reducing costs.

In a study by Archimède *et al.* conducted in 2008 on the Experimental Farm of L'Institut National de la Recherche Agronomique (INRA) Animal Production Research Unit in Guadeloupe, efforts were made to determine the effects of supplementing a concentrate feed with tropical forage on intake, growth and carcass traits of Ovin Martinik sheep. The study was comprised of forty male Ovin Martink hair sheep, with an initial body weight of 20 ± 3.7 kg. The rams began the trial at four months of age and were assigned to one of four treatments (L0: basal diet without concentrate;

L150: basal diet plus 150g of concentrate per lamb per day; L300: basal diet plus 300g of concentrate per lamb per day; L600: basal diet plus 600g of concentrate per lamb per day) according to their weight at weaning as well as their growth between 30 and 70 days during the suckling period. The experimental sheep were fed their respective diets for a total four months and weighed every 15 days in the mornings prior to eating. The basal diet was comprised of *Digitaria decumbens* and *Bracharia decumbens*, green tropical forages. The commercial concentrate consisted of 68% maize, 15% soybean cake, 11% wheat bran, 1% urea and 5% vitamin and mineral supplement. Results show that total feed intake augmented with increasing dietary levels of concentrate at 5% for L150, 15% for L300 and 24% for L600 in relation to the L0 group. What's more, the forage to concentrate substitution ratio (0.65) is comparatively high for tropical forage. Overall, the basal diet (*Digitaria decumbens* and *Bracharia decumbens*) proposed in this study presents a better nutritional profile compared to most frequently studied tropical forages. The average daily gain (ADG) of sheep per treatment are as follows: L0: 134g/d; L150: 166g/d; L300: 188g/d and L600: 203g/d. From these results, the authors concluded that the high cost of the pelleted concentrate feed, particularly at inclusion levels tested, makes its use commercially impractical. Also, the growth rates associated with the group of sheep fed no concentrate were deemed significantly better, thus signifying that, if effectively managed, *Digitaria decumbens* and *Bracharia decumbens* can be used a good basal diet for Martinik sheep. Including concentrate into the feed ration, at low inclusion levels, can lead to improved weight gain outcomes. This implies that locally grown tropical feed resources can successfully be used to partially or fully replace costly commercial concentrate feeds (Archimède *et al.*, 2008).

In a study conducted at the Unité de Recherches Zootechnique, INRA, Guadeloupe, French West Indies, Alexandre *et al*. (2008) determined feed intake, growth rate and carcass characteristics of Ovin Martinik hair sheep fed sugar cane supplemented with pea flour. Forty rams, with initial body weights of 20.2 ± 3.0 kg, were introduced to the feeding trial at 4 months of age and fed a diet of sugarcane and pea flour for a period of 117 days. Individual sheep weight gain was monitored weekly. The pea flour was freshly ground from dry *Pisum sativum* grains and made up 12-14% of the diet. The sugarcane was collected daily, chopped and provided to the animals *ad libitum* once they had finished consuming the prescribed quantities of pea flour. Once the trial complete, the sheep were then categorized per live weight and then brought to slaughter. The categorized slaughter weights were 28, 30, 33 and 36 kg. Overall, feed intake levels were evaluated as being satisfactory, which could have resulted from the supplementation of pea flour. It is an excellent source of both starch and protein, being known to positively influence small ruminant digestibility. Additionally, analyses show that there were statistically significant differences in ADG amongst the slaughtered weight groups, with group 1 (28 kg) exhibiting the lowest ADG at 105 ± 23 g/d, followed by group 2 (30 kg) with 118 ± 28 g/d, group 3 (33 kg) with 129 ± 27 g/d and finally group 4 (36 kg) with 146 ± 27 g/d. As such, a diet based on an energy-rich source, such as sugarcane, has the potential produce intensive weight gain outcomes for this breed. In fact, the performance observed in this trial is approximately 27 to 45% higher than values for tropical sheep fed grass alone. The authors concluded that a pea flour and sugarcane diet could contribute to increased growth rates, improved feed efficiency in addition to well-conformed carcass characteristics without negatively affecting the health of the animals. In short, a diet consisting of locally available feed resources, such as the one proposed in this study, could successfully be used as an effective feed ration alternative for hair sheep (Alexandre *et al.,* 2008).

A study conducted at the Unité de Recherches Zootechnique, INRA, Guadeloupe, French West Indies evaluated the capacity of local feed resources from tropical production settings to substitute imported feedstuffs as a feed for Martinik lambs (Archimède *et al*., 2010). The feeding trial consisted of forty male Martinik lambs, with an initial body weight of 29.4 ± 3.6 kg. The experimental rams were introduced to the feed trial at six months old and randomly assigned to one of four treatment groups, following a completely randomized design, and fed their respective diets for a total of 85 days. The treatments diets are as follows: T1) chopped green banana fruits and *Gliricidia sepium* at a low level of inclusion; T2) chopped green banana fruits and *Gliricidia sepium* at a high level of inclusion; T3) chopped green banana fruits and soybean cake; T4) Control: mixture of dry rolled commercial corn grain and soybean cake. All diets were supplemented with hay *ad libitum* and individual sheep weight gain was monitored weekly until the end of the trial. Results show that, except for lambs fed diet T1, sheep growth rates were considered within the normal range for Martinik sheep (140g/d) and was not negatively influenced by the inclusion of unconventional feeds such as green banana fruits and *Gliricidia sepium.* Moreover, lambs fed T1 diet exhibited the lowest ADG (71g/d), followed by T4 (141g/d), T3 diet (165g/d) and finally the T2 (173g/d). Thus, if provided in high enough quantities, locally available tropical feed resources (green banana fruits and *Gliricidia sepium*) can strategically replace imported commercial feeds without compromising the health and growth of the animals (Archimède *et al*., 2010).

2.7 Barbados and its Agricultural Sector

Barbados is the most easterly SIDS in the Caribbean and is surrounded by the Atlantic Ocean. Although English is the country's official language, locals frequently speak Bajan dialect. The island's total land area is 431 square kilometers and is divided into eleven parishes: St. Lucy, St. Peter, St. Andrew, St. James, St. Joseph, St. George, St. Thomas, St. John, St. Michael, St. Philip and Christ Church (Rawlins, 2003). Current United Nations estimates place the population of Barbados at 285,646 people (UNdata, 2017). Overall, Barbados has a maritime/ tropical climate and a sub-humid to humid rainfall regime, becoming increasingly semi-arid in drier parts of the island. Rainfall patterns are highly variable, with the dry season spanning January to May and the wet season June to December. Annual temperatures in Barbados are generally high, averaging between 24 and 27℃. Similarly, seasonal fluctuations in humidity are relatively low, where humidity levels average 71% during the dry season and 76% during the wet season (Thomas & Hunte, 2005). Further, Barbados suffers from many of the typical challenges experienced by SIDS, "including vulnerability to natural disasters such as hurricanes, droughts and floods, a high level of dependence on imports, […] and the existence of production systems which are relatively high cost and uncompetitive" (Rawlins, 2003).

The Barbados economy has seen a notable improvement since the lackluster performance of 2001 whereby output declined by 2.7%. This recovery can be attributed to tourism industry, to which the country is largely dependent, and sugar production. In 2003, wholesale and retail trade (19.5%), business and general services (16.8%), tourism (15.7%) and government service (13.9%) were the sectors that contributed most significantly to the real gross domestic product, with sugar production and non-sugar agriculture accounting for 5.8% and 3.5% respectively (Thomas & Hunte, 2005).

Extensive animal production systems are greatly restricted by environmental and economic factors. For this reason, future output growth should stem from production intensification on land resources that are already being utilized. Very little progress has been made so far in Barbados in achieving this goal, even as the country's food import bill continues to increase annually. Presently, the food import bill of Barbados is upwards of US$ 291 million, accounting for 89% of the total agricultural food trade and 14.8% of the total import bill. Livestock products are the most significant agricultural import category, tallying up to a total of roughly US$ 28.5 million. Imports of dairy products were a close second with US$ 24.7 million. The primary agricultural export commodity was raw sugar with earning totaling to US$ 71.7 million (Thomas & Hunte, 2005).

Most farmers in Barbados have received either a secondary or a tertiary education and 95% are part-time farmers. The country is virtually self-sufficient in whole chicken, eggs and pork. However, hatching eggs, poultry parts and approximately 80% of pork for the processing industry is imported (Thomas & Hunte, 2005). Given the island's close ties with tourism, the livestock sub-sector should attempt to form sustainable linkages to supply hotels and other tourist bound destinations with fresh meat products. This would likely decrease the food import bill, but livestock farmers must work to improve the quality, price and competitiveness of their products if they wish to supply such a market (Thomas & Hunte, 2005).

There are currently about 17,000 agricultural holdings on the island of Barbados, which adds up to just over 21,000 hectares of land dedicated to agriculture. Over 15,000 of these holdings are less than one hectare. Roughly, 100 holdings are greater than 50 hectares and only one is larger than 500 hectares. The wide majority of larger agricultural holdings serve commercial purposes and are likely engaged in the production of sugarcane. On the other hand, smaller holdings range from commercial agriculture to subsistence farming. Large holdings are typically managed through hired management while small holdings are mainly owner managed. The main farming systems in the country are extensive and semi-intensive for most livestock and intensive for poultry (Thomas & Hunte, 2005).

In the last three years, the performance of the agricultural sector has been affected by important changes in external trade and the prevailing domestic economic environment. Factors such as unfavourable weather conditions, labour shortages, diminished acreage under cultivation, decreasing yields and increasing production costs continue to threaten the success of the industry, despite its significant contribution to the gross domestic product (US$ 199 million). Employment in agriculture is consistently stigmatized by the perception of relatively great effort for relatively low wages. Nevertheless, the agricultural sector employs over 5,400 people, or 4.2% of total employment (Thomas & Hunte, 2005).

Economic development and diversification into the tourism industry has resulted in the increased competitiveness of land, labour and capital resources. These have serious repercussions on the agricultural sector, as it will become increasingly difficult to acquire the resources necessary for its continued growth and development. The economic and business climate in Barbados, in some regards, prevents against the competitiveness of agricultural production due mainly to the high services and input costs used by establishments operating in the sector. This, along with a primarily oligopolistic distribution system has led to relatively high prices for basic agricultural inputs such as feed, chemicals, seeds, diesel, machinery and equipment. In most instances, the production costs associated with agricultural commodities on the island is therefore higher than the cost of production (Thomas & Hunte, 2005).

2.7.1 Blackbelly Sheep Production in Barbados

The Blackbelly is a tropical hair sheep that is native to the island of Barbados and is intended primarily for meat consumption. Evidence points to Dutch wool breeds crossed with African hair sheep as the possible parent breeds of the Barbados Blackbelly sheep. The color of the Blackbelly varies from a light to dark reddish brown with very noticeable black under-parts. Black hair covers the animal’s lower jaw, chin, throat, breast, belly, inner legs and extends into a narrow line along the underside of the tail. The inner surface of the ear is also lined in black, with apparent black markings spreading from above each eye to the tip of the muzzle. The ears are considered medium in size and do not droop. Normally, the breed is hornless and rams will tend towards Roman noses. The weight of an adult ram can range from 60 to 90 kg while adult ewes can weigh between 40 and 60 kg. Blackbelly ewes have also been found to have well developed mammary systems. The Barbados Blackbelly sheep is highly prolific, being able to breed at any point during the year. It is common for ewes to have two lambings per year with a strong likelihood of multiple births (1.5-2.3 lambs/lambing). Recent estimates place the annual lambing rate of this breed at upwards of 150%. The Blackbelly is found throughout the CARICOM region and as far north as Oregon and Michigan in the United States. Many efforts have been made in recent years by the Ministry of Agriculture of Barbados and other international organizations such the FAO to increase the widespread utilization of this breed throughout the Caribbean due to its tolerance to tropical climates and high resistance to pests and diseases (Thomas & Hunte, 2005).

Lamb production is one of four components within the livestock sub-sector to have expanded in past decades, 90,100 kg of meat in 2003, nearly double the production levels of 1993. Regardless of this increase, Barbados still imports more than 1,500,000 kg of mutton annually and no Blackbelly meat is exported. The Barbados Blackbelly sheep is the country's primary sheep breed, with a population of roughly 25,000 heads. According to the FAO, most sheep (90%) on the island are reared by farmers who are considered landless or land-limited. Landless farmers, also known as backyard farmers, raise their flocks in pens just outside their houses and land-limited farmers' rear their sheep on agricultural farmland that is less than one hectare in size. These production systems are typically extensive and semi-intensive with relatively low production levels. In either of these production systems, farmers generally use large quantities of imported commercial concentrate feeds and low levels of inexpensive, locally grown forages, thus echoing the country's dependence on imported feedstuffs. The high costs of feeds on the island is making it increasingly difficult for Blackbelly sheep farmers to sustain production or for potential new farmers to enter the industry (Thomas & Hunte, 2005). For this reason, farmers have been turning to by-product feeds as a means of feeding their animals and cutting production costs (Asiedu, 2000).

Agrofest is an annual agricultural exhibition, hosted by the Barbados Agricultural Society, situated in Queens Park close to country's capital, Bridgetown. This exhibition is a place where Barbadians gather to celebrate the island's agricultural achievements. Features of this event includes the best in agricultural products, renewable energy displays, educational exhibits, mini farm exhibit and much more. One of the highlights of this national agricultural exhibition is the livestock show, where livestock farmers across the island showcase their animals. Judges are elected to decide the winners of the various livestock show competitions, with prizes being distributed accordingly (Agrofest, 2017).

2.8 Feeds & Livestock Feeding in Barbados

2.8.1 By-Product Ingredients Used in This Study

The by-product ration proposed in this study is comprised of ground corn, ground limestone, molasses, rice bran, soybean meal and wheat middlings. Ground corn, rice bran and wheat middlings are high-energy feed sources, containing large amounts of readily digestible carbohydrates but also fiber, protein and certain nonstarch polysaccharides. These ingredients are essential to a feed ration as they produce absorbable energy-yielding compounds such as volatile fatty acids (VFA) and promote the flow of protein to lower parts of the gastrointestinal tract by increasing the rates of both rumen fermentation and microbial protein synthesis. They are also highly digestible and are an excellent source of metabolizable energy. Additionally, corn is a popular feed grain due to its high palatability. However, it is important to note that if fed in too high quantities, these high-energy sources can cause a reduction in the rate of plant cell wall constituent fermentation, which could be detrimental to the health of the animal. Rapid fermentation of the starch found in these grains can lead to acute and recurring rumen acidosis if not introduced into the diet gradually over time (NRC, 2007).

Soybean meal is considered a protein supplement as its protein content is greater than 20 percent of dry matter (DM) and exceeds the minimum protein levels required by small ruminants. This high-protein oil seed by-product meal is frequently used in mixed rations, used to boost the overall protein content of the recipe. Furthermore, soybean meal is highly digestible and palatable, factors that are largely desirable in small ruminant nutrition. This ingredient is a necessary addition to the recipe, but can become costly if added in too high quantities (NRC, 2007).

A calcium supplement is required, ground limestone, to compensate for the high phosphorous contents found in rice bran, soybean meal and wheat middlings to attain the desired calcium to phosphorus (Ca:P) ratio of 2:1. If the Ca:P ratio were to fall below 1:1, then this could cause urinary calculi, also known as water belly, thus preventing the animal from urinating (NRC, 2007).

The addition of molasses is crucial, as it will improve the overall texture of the by-product mixture by reducing the dustiness of the feed. It is commonly used by farmers to make feed rations more palatable to livestock. Molasses is also an excellent source of trace minerals and can assist in the fermentation of low quality forages (NRC, 2007).

Certain ingredients used in the formulation of the by-product ration are imported from nearby Caribbean countries. Wheat middlings and ground corn are imported from St Vincent while rice bran is imported from Guyana. Ground limestone and molasses are produced locally in Barbados and thus highly affordable. Soybean meal is the only by-product ingredient that was imported from outside of the Caribbean.

2.8.2 Feed Quality Standards in Barbados

Although the Ministry of Agriculture of Barbados has publicly acknowledged that it will be implementing the program put forth by National Agricultural Health and Food Control Agency (NAHFCA), there are currently no rigorous feed quality standards in place to which feed enterprises must be compliant (Ministry of Agriculture Barbados, 2012). The widespread implementation of the NAHFCA program is essential, as it will "ensure that its animal health, plant health and food safety systems comply with international standards thereby enabling Barbados to compete successfully on a global market scale" (Ministry of Agriculture Barbados, 2012). For this to be achieved, the country must first develop a national agricultural health and food control system designed to regulate both local and imported food as well as inputs for livestock and food production. Part of this process involves the updating of plant and animal health legislations, with emphasis on quality assurance and standards. Current systems consist of disjointed or outdated legislation, multiple jurisdictions in addition to weaknesses in enforcement, monitoring and surveillance (Ministry of Agriculture Barbados, 2012; Singh *et al.*, 2005).

3.0 OBJECTIVES

The global aim of this study is to develop a by-product feed ration that will have several key attributes including meeting the nutritional needs of the livestock, being sustainable, and economically viable. The challenge is to develop a formulation that provides equivalent nutritional components and health benefits as the commercial concentrate feed. This could then allow for economic, social, and environmental benefits for both local farmers and the Barbadian public.

The primary objective of this project is to develop a by-product formulation that will produce equivalent or higher sheep weight gain in comparison to the commercial concentrate alternative, while being both affordable, sustainable and reproducible.

The secondary objective of this research is to obtain information concerning the status of food insecurity amongst local Barbadian Blackbelly sheep farmers along with general information pertaining to size and diversity of these livestock production systems. Additionally, feedback will be acquired regarding the acceptability of by-product feeds/ingredients and overall willingness for daily implementation.

4.0 MATERIALS AND METHODS

4.1 Section 1 – Feed Trials

To develop an alternative feed formulation for Blackbelly sheep production in Barbados, we compared the performance of commercial concentrate with a formulation based on by-product feedstuffs. Given the variability in climatic conditions and quality of feed on the island, we conducted two independent feeding trials to assess the reproducibility of the results. This study was conducted under Animal Use Protocol approval from the Faculty Animal Care Committee McGill University Animal Care Committee (protocol No. 2016-7813).

4.1.1 Study Site

The project took place at the Ministry of Agriculture Greenland Livestock Research Station, located in St-Andrew, Barbados. This research station has two main farms, which are separated by a Highway. Site 1 is dedicated to rabbit, sheep and goat production, while the site 2 exclusively used for sheep production. The sites are less than one km apart.

The experimental pens were situated in a barn with cement floors, a galvanized metal roof and fence walls on Site 2. The barn design allows for optimal air circulation within the pens. Each pen was fitted with a feed trough, water bucket and hay feeder. Hay was also used as pen bedding, providing the sheep with a comfortable surface to rest or sleep.

The mixing and storage of the by-product feedstuffs was conducted in a shaded area on Site 1. The mixed and bagged by-product feed was transported to Site 2 twice weekly using the farm utility truck.

4.1.2 By-product Ingredients

The developed formulation was comprised of locally available by-product ingredients including wheat middlings, rice bran, soybean meal, ground corn, molasses and limestone powder. The nutrient composition of these feedstuffs was obtained from the Nutrient Requirements of Small Ruminants (NRC, 2007) and is summarized in **Table 1**.

Table 1. Nutrient composition of by-product feed ingredients (NRC, 2007)

Item	**DM** (%)	**TDN** (%)	**CP** (%)	**NDF** (%)	**Ca** (%)	**P** (%)
Ground corn	88.0	88.0	9.0	9.0	0.02	0.30
Ground limestone	100.0	0.0	0.0	0.0	34.00	0.02
Rice bran	91.0	72.0	14.0	24.0	0.07	1.70
Soybean meal	91.0	84.0	49.0	15.0	0.38	0.70
Wheat middlings	89.0	82.0	19.0	36.0	0.15	1.02
Molasses	76.0	75.0	6.0	0.0	0.97	0.10

Ground corn was incorporated into this by-product ration to act as a buffer against the common nutritional fluctuations of wheat middlings, specifically those concerning crude protein. Further, limestone powder was used as a calcium supplement to contribute to an optimal Ca:P ratio of 2:1. In this case, a calcium supplement was required to counteract the high phosphorus content found in both wheat middlings and rice bran. The experimental rams in this study were provided with a mineral lick, as a supplemental source of minerals and vitamins, and supplied with fresh hay and water daily. Together, these provided energy, protein, fat and fiber in amounts equivalent to the commercial concentrate feed.

4.1.3 Feed Trial # 1

The study consisted of three treatment groups: T1) Control - 100% commercial concentrate; T2) 50% commercial concentrate & 50% by-product feed, & T3) 100% by-product feed. Five or six sheep were randomly assigned to each of the trial's nine pens. Three pens were randomly allocated to each of the treatment groups, meaning 17 or 18 sheep per treatment group, for a total of 53 animals. The sheep were introduced into the feed trial at two weeks post weaning, with each animal being 9 or 10 weeks old, and were fed their respective diets for 7 weeks. The sheep were monitored closely and weighed weekly with a Salter scale to assess weight gain patterns throughout the trial. The scale was calibrated prior to the start of the trial (August 4th). This feed trial started on August 9th and ended on September 20th.

<u>*Creating the By-Product Formulation*</u>

As mentioned earlier, the purpose of this component of the project is to produce a ration comprised of locally available by-product ingredients that could serve as an alternative to the commercial concentrate feed. To do so, this new feed must be nutritionally comparable to the commercial concentrate.

The first step in the creation process was to identify the nutritional content of the concentrate feed and to use this as the standard to which the new ration will be compared. From the feed bag's label, the concentrate claimed to contain 16% CP, 3% crude fat, 12% crude fiber, 1% Ca and 0.6% P in a DM basis. Crude fat was disregarded as a nutritional component for comparison as many if not all of the selected by-product ingredients have negligible fat percentages. Further, NDF as opposed to crude fiber was selected as the more appropriate fiber measurement to be used in the creation of the by-product ration. The next step was then to identify the nutritional content of each by-product ingredient: Total Digestible Nutrients (TDN), Crude Protein (CP), Neutral Detergent Fiber (NDF), Ca and P. A summary of this information is provided in **Table 1**.

These values were then entered into an Excel document and used in the calculation of the by-product ration. The finalized formulation was validated by Dr. Arif Mustafa and can be seen in **Table 2**.

Table 2. By-product formulation for feed trial # 1

Ingredient	**Feed Content** (%)	**TDN** (%)	**CP** (%)	**NDF** (%)	**Ca** (%)	**P** (%)	**Cost** ($BDS/lbs)
Ground corn	14	12.32	1.26	1.40	0.003	0.042	0.128
Limestone	3.5	0	0	0	1.190	0.001	0.012
Rice bran	31.5	22.37	4.41	7.56	0.022	0.536	0.112
Soybean meal	11	9.24	5.39	1.65	0.040	0.077	0.083
Wheat middlings	30	22.50	5.10	11.40	0.042	0.306	0.112
Molasses	10	7.40	0.20	0	0.095	0.009	0.004
Total	*100*	*73.83*	*16.36*	*22.01*	*1.391*	*0.970*	*0.451*
Target – Commercial Concentrate		*70-75*	*16*	*CF = 12*	*1*	*0.06*	*0.545*

CF = Crude Fiber

Mixing of By-Product Feed

The by-product feed ingredients were mixed using a 485 liter (gross drum volume), battery powered, WINGET 200T concrete mixer. The mixer was rented from Innotech Equipment Ltd.

for 24 hours and delivered directly to Greenland on Monday mornings. The mixer was delivered weekly for the first two weeks of the feed trial and every second week for the remainder of the trial. Similarly, the by-product formula was mixed weekly for weeks 1 & 2 and every two weeks for weeks 3 & 4 and 5 & 6. In other words, mixer delivery and ration mixing occurred on the Monday of week 1, 2, 3 and 5. The mixer was thoroughly cleaned and dried prior to mixing. Due to the limited capacity of the concrete mixer, several batches of the ration were mixed to obtain the quantity of feed required to feed all of the sheep in T2 and T3 for a period of either one or two weeks. The number and size of the batches varied largely throughout the trial. For week 1, one batch of 122.5 lbs was mixed. For week 2, one batch of 245 lbs was mixed. For weeks 3 & 4, three batches of 245 lbs and one of 175 lbs were mixed. For weeks 5 & 6, four batches of 245 lbs and one of 203 lbs were mixed. The batch sizes were capped at 245 lbs to provide the space required for the homogeneous mixing of the by-product feed ingredients. Mixing began by starting the mixer and tilting it to an angle of roughly 45 degrees, rotating at a drum speed of 22 revolutions per minute. The ingredients were separately weighed, using a hand scale, and added one at a time to the mixer. The by-products ingredients were added in the following order: wheat middlings, rice bran, soybean meal, ground corn, limestone powder, and finally molasses. It should be noted that the ingredients were added to the mixer in 10 minute intervals to allow for a more thorough mixing of the ration.

Storage & Bagging of by-product feed

Once mixed, the by-product feed was stored in 100-gallon plastic drums, sealed with matching plastic lids and placed in the farm's feed room. The following day, the ration was weighed out and bagged such that each feed bag contained the amount of by-product feed required to feed all sheep in T2 (50% commercial concentrate & 50% by-product feed) and T3 (100% by-product ration) for one day. The bags were then labeled for clarity, with each bag outlining the treatment group to which it belonged (T2 or T3), the day of the week the bag was to be fed (Monday, Tuesday, Wednesday, etc.) and the quantity of feed the bag contained in pounds. Enough by-product feed was bagged at this time to last 7 days. The bagged feed was then transported to the feed trial barn on Site 2 and subsequently stored in a rectangular container to further prevent insect infestation and spoilage. On the Tuesday of weeks 4 & 6 the bagging process was repeated with the remaining feed being transferred from the plastic drums to their respective feed bags.

During the last four weeks of this trial (weeks 3-6), the full by-product ration was mixed in bulk to verify if it was indeed possible to store the ration successfully for a period of two weeks without spoilage. The rationale here was that if the ration did not begin to spoil by the end of the second week then it would allow farmers to save on mixer rental and delivery costs.

Feeding

The animals in T1 were fed the same commercial concentrate feed throughout the course of the feed trial. The sheep from T2 and T3 were introduced to the by-product ration gradually. The animals in T2 were fed a transition ration consisting of 25% by-product feed & 75% commercial concentrate during week 1 of the trial. They were introduced to their intended diet of 50% by-product feed & 50 % commercial concentrate on week 2 and maintained this diet until the end of the trial. The animals in T3 were fed the same transition ration (25% by-product feed & 75% commercial concentrate) as those animals in T2 during the first week of the trial. They were then fed a secondary transition ration of 50% by-product feed & 50% commercial concentrate over the course of week 2. They began consuming a diet of 100% by-product feed on week 3 and maintained this diet until the end of the feed trial. Along with the treatment feed, each pen was supplied daily with fresh hay and water.

All animals were fed 2 pounds of feed daily for the first two weeks of the trial, followed by 2.5 pounds daily over weeks three and four, 3 pounds daily during week five and 3.5 pounds of feed daily during week six. For further clarification, see **Table 3**.

Table 3. Feeding schedule per treatment of feed trial # 1 (lbs/sheep/day)

	Week 1	**Week 2**	**Week 3**	**Week4**	**Week5**	**Week 6**
T1 (Control - 100% CC)	2 100% CC	2 100% CC	2.5 100% CC	2.5 100% CC	3 100% CC	3.5 100% CC
T2 (50% BP & 50% CC)	2 25% BP 75% CC	2 50% BP 50% CC	2.5 50% BP 50% CC	2.5 50% BP 50% CC	3 50% BP 50% CC	3.5 50% BP 50% CC
T3 (100% BP)	2 25% BP 75% CC	2 50% BP 50% CC	2.5 100% BP	2.5 100% BP	3 100% BP	3.5 100% BP

BP = By-Product Feed; CC = Commercial Concentrate

4.1.4 Feed Laboratory Analyses

Samples of the by-product ingredients along with two additional samples of the commercial concentrate feed were collected and analysed for CP, NDF, ADF, ADL, DM and Ash to ensure that the by-product and concentrate feeds were nutritionally comparable.

A sample of soybean meal, wheat middlings and commercial concentrate were collected on May 13th, prior to the start of the first feed trial. A sample of ground corn was not collected at this time, as this ingredient was not expected to be incorporated into the by-product ration. Moreover, a sample of rice bran was not collected, as an open bag of this ingredient could not be located amongst the local farming community. The samples were taken to Dr. Arif Mustafa's feed analysis laboratory, located on the Macdonald Campus of McGill University. The following analyses were performed: NDF, ADF, ADL, DM and Ash. Unfortunately, the instrument used to analyze CP was broken and thus no CP values for the by-product and commercial concentrate samples were determined. The results of these analyses were obtained on July 21st, 2016 and can be seen in **Section 5.1.3**.

A sample of ground corn, rice bran, soybean meal, wheat middlings and commercial concentrate were collected on August 9th (day 1 of the first feed trial) and brought to Government Analytical Services (GAS), located in St. Michael, Barbados. This is the only laboratory on the island of Barbados that is equipped to analyze CP. It was essential to determine the CP of the samples to complete the nutritional profile of both the individual by-product ingredients and the commercial concentrate. The results of the CP analysis performed on the provided samples were obtained on September 30th, 2016.

Based on the results of the above analyses taken in conjunction with lab analyses performed on individual by-product ingredients and commercial concentrate samples collected in summers 2013 & 2014, modifications to the by-product ration were made and implemented into the second feed trail. See by-product formulation **Section 4.1.6** for the new ration and **Section 5.1.3** for the results of the lab analyses.

Additional sampling of the individual by-product ingredients and commercial concentrate feeds were conducted on two separate occasions during feed trial # 2. All samples were brought to GAS for a CP analysis. Duplicates of these samples were brought to the feed analysis laboratory of Dr. Arif Mustafa and their content analyzed for CP, NDF, ADF, DM and Ash. At this point, the instrument used to determine CP was functional. The CP values generated through this process served as a baseline and were compared to those obtained from GAS, thus verifying their validity. See **Section 5.1.3** for the results of these analyses.

4.1.5 Feed Trial # 2

This feed trial consisted of the same three treatment groups as in feed trial # 1 namely T1) Control - 100% commercial concentrate; T2) 50% commercial concentrate & 50% by-product feed, & T3) 100% by-product feed. Four or five sheep were randomly assigned to each of the trial's nine pens. Three pens were randomly allocated to each of the treatment groups, meaning 14 or 15 sheep per treatment group, for a total of 43 animals. The sheep began the trial at one or two weeks post weaning and fed their respective diets for 9 weeks, the length of the trial. Further, as in feed trial # 1, the sheep were weighed weekly using a Salter scale.

By-Product Formulation

As mentioned, the original by-product formulation used in the first feed trial was adjusted in order to take into account the results of the various laboratory analyses that were performed on the collected samples and to provide a much more realistic nutritional profile of the chosen by-product ingredients and commercial concentrate feed. The first step in the adjustment process was to replace the feed composition table CP values of the by-product ingredients with an average of the CP values obtained from GAS and previously analyzed by-product CP values from 2013 & 2014. Next, the analyzed NDF values obtained for soybean meal and wheat middlings were used to replace the feed composition table NDF values. The remaining ingredients kept their respective feed composition table NDF values. All TDN, Ca and P values remained the same. The following changes have been bolded and are summarized in **Table 4** below.

Table 4. Nutrient composition of by-product ingredients with update CP & NDF values

Item	**DM** (%)	**TDN** (%)	**CP** (%)	**NDF** (%)	**Ca** (%)	**P** (%)
Ground corn	88.0	88.0	6.0	9.0	0.02	0.30
Ground limestone	100.0	0.0	0.0	0.0	34.00	0.02
Rice bran	91.0	72.0	9.3	24.0	0.07	1.70
Soybean meal	91.0	84.0	38.0	11.8	0.38	0.70
Wheat middlings	89.0	82.0	15.9	38.1	0.15	1.02
Molasses	76.0	75.0	1.6	0.0	0.97	0.10

These modifications were used in the adjustment of the new by-product ration to be utilized in feed trial # 2. Also, the CF value of the commercial concentrate feed was replaced with the NDF value determined through Dr. Arif Mustafa's NDF analysis. See below for the new by-product formulation.

Table 5. By-product formulation of feed trial # 2

Ingredient	**Feed Content** (%)	**TDN** (%)	**CP** (%)	**NDF** (%)	**Ca** (%)	**P** (%)	**Cost** ($BDS/lbs)
Ground corn	4	3.52	0.24	0.40	0.0008	0.012	0.037
Limestone	3.5	0	0	0	1.190	0.001	0.012
Rice bran	31.5	22.37	2.92	7.56	0.022	0.536	0.116
Soybean meal	21	17.64	7.98	2.47	0.076	0.147	0.151
Wheat middlings	30	22.50	4.78	11.44	0.042	0.306	0.114
Molasses	10	7.40	0.16	0	0.095	0.009	0.004
Total	*100*	*73.43*	*16.08*	*21.87*	*1.425*	*1.010*	*0.434*
Target – Commercial Concentrate		*70-75*	*16*	*25.02*	*1*	*0.06*	*0.545*

Mixing

The by-product ingredients were mixed using the same concrete mixer as in feed trial # 1. The mixer was rented weekly, as opposed to once every two weeks, to ensure that the freshness of the feed was not compromised. Similarly, the by-product ration was produced weekly, being mixed in a manner equivalent to one used in the first feed trial.

Storage & Bagging

In feed trial # 2, the by-product feed was poured directly into 30 kg recycled feed bags, as opposed to large plastic drums, and transported to the experiment site. This feed storage modification was implemented purely on a practicality basis. Once inside the barn, the bags were stored in the same rectangular container as in feed trial # 1. All tasks related to the mixing and storage of the by-product feed were completed each Monday for the duration of the 9 week feed trial.

Feeding

The animals in T2 (50% by-product feed & 50% commercial concentrate) and T3 (100% by-product feed) were introduced to their intended diets gradually, following the same feed transition schedule as in feed trial # 1. Once again, the treatment pens were supplied daily with fresh feed, hay and water.

All animals were fed 2 pounds of feed daily for the first two weeks of the trial, followed by 2.5 pounds daily over weeks three and four, 3 pounds daily during weeks five and six and fed 3.5 pounds daily during the final two weeks of the trial. **Table 6** illustrates the feeding schedule used in feed trial # 2.

Table 6. Feeding schedule per treatment of feed trial # 2 (lbs/sheep/day)

	Week 1	Week 2	Week 3	Week4	Week5	Week 6	Week 7	Week 8
T1 (Control - 100% CC)	2 100% CC	2 100% CC	2.5 100% CC	2.5 100% CC	3 100% CC	3 100% CC	3.5 100% CC	3.5 100% CC
T2 (50% BP & 50% CC)	2 25% BP 75% CC	2 50% BP 50% CC	2.5 50% BP 50% CC	2.5 50% BP 50% CC	3 50% BP 50% CC	3 50% BP 50% CC	3.5 50% BP 50% CC	3.5 50% BP 50% CC
T3 (100% BP)	2 25% BP 75% CC	2 50% BP 50% CC	2.5 100% BP	2.5 100% BP	3 100% BP	3 100% BP	3.5 100% BP	3.5 100% BP

BP = By-Product Feed; CC = Commercial Concentrate

4.1.6 Experimental Design and Statistical Analyses

Statistical analyses were carried out using a nested model design, with pens nested within treatment and sheep nested within pens. In addition, there is a repeated measures component to consider as each individual sheep was weighed several times throughout the course of each feed trial; 7 weight measurements per sheep in feed trial # 1 and 9 measurements in feed trial # 2. Two feed trials were conducted to determine if the weight gain outcomes could be easily replicated. The full model considered as a starting point for alternative reduced models was:

$$Wt_{ijkl} = \mu + trt_i + pen_{ij} + sheep_{ijk} + week_l + trt_{i*}\ week_l + e_{ijkl}$$

where Wt_{ijkl} was the recorded body weight of the k^{th} sheep from the j^{th} pen within the i^{th} treatment; μ was the overall average body weight of the sheep, irrespective of treatment or pen; trt_i, $i = 1…3$, was the fixed effect of the i^{th} treatment; pen_j, $pen_j \sim N(0, \sigma^2_{pen})$, was the random effect of the j^{th} pen within the i^{th} treatment; $sheep_{ijk}$, $sheep_{ijk} \sim N(0, \sigma^2_{sheep})$, was the random effect of the k^{th} sheep in the j^{th} pen within the i^{th} treatment; $week_l$, $l = 1\ldots7$ (for feed trial # 1) and $l = 1\ldots9$ (for feed trial # 2), was the fixed effect of the l^{th} week on the weight of a sheep; $trt_{i} * week_l$, was the fixed effect interaction between the i^{th} treatment and the l^{th} week; e_{ijkl}, $e_{ijkl} \sim N(0, R)$, with R representing the covariance structure which accounts for the correlation between repeated measures, as the random residual associated with the k^{th} sheep in the j^{th} pen within the i^{th} treatment.

As mentioned previously, two sets of analyses were carried out using SAS statistical software (SAS Institute Inc., 2012). In the first, a standard PROC MIXED procedure was used and the compound symmetry (CS) and autoregressive 1 (ar(1)) structures compared. In both feed trial # 1 and 2, the covariance structure that produced the lowest overall Bayesian Information Criterion (BIC) value was ar(1), and thus was chosen as the better fitting model. A separate analysis was then performed to establish whether there was a statistically significant difference among pens and sheep.

There was, however, substantial variation amongst sheep in their initial weights, notwithstanding that they were randomly allocated to both the pens and treatments. Hence a second set of analyses was performed, using initial weight as a covariate. Although not ideal, using this variable as a covariate was the only way whereby one could try to account for the variation in the initial sheep weights. Once again, a PROC MIXED procedure was applied, now using initial weight as a covariate, and the CS and ar(1) structures compared. As with the previous PROC MIXED procedure, the structure that generated the lowest BIC value, in both feed trials, was ar(1), and thus was selected as the better fitting model. A separate analysis was conducted to determine if there was a statistically significant difference among pens and sheep. This was achieved by removing each of the random effects from the model, one at a time. If there was a difference in the BIC values of more than three units then the random effect was considered to be statistically significant.

Least squares means and standard errors were generated, along with a corresponding set of pairwise differences. Since there are three treatments (T1, T2, T3), then there will be $3 \times (3-1) / 2 = 3$ possible comparisons amongst the three treatment means. This therefore implies that there is a multiple comparison issue. Given that the comparisons were pre-planned, it is then valid to utilize

Bonferroni's test to retain the Family Wide Error Rate at 5% probability. As such, a nominal probability (p) of $0.05/3 = 0.016667$ was used in generating the tabulated t-values. This value was then compared to its respective set of t-calculated values to determine if there was a statistically significant difference amongst the treatments.

4.2 Section 2 – Social & Cultural Acceptability

4.2.1 Research Design

The social and cultural aspect of this study was assessed using both a quantitative and qualitative approach. The quantitative social and cultural acceptability component of this project uses a cross-sectional survey design. This implies that data was collected at one point in time with the outcomes of the survey being used to describe relevant characteristics concerning the population of interest (Hall, 2008), namely the local Barbadian Blackbelly sheep farming community.

The qualitative aspect of the assessment involved conducting informal face-to-face guided discussions with individual Blackbelly sheep farmers across the island to obtain feedback on the acceptability and utilization of by-product feeds amongst Barbadian farmers along with conditions required for their implementation.

Ethics approval was obtained from the Faculty of Agricultural and Environmental Sciences Research Ethics Board of McGill University (Permit no. 87-0716). All study participants gave written informed consent.

4.2.2 Sample Selection

There are thousands of Blackbelly sheep farmers on the island of Barbados, which vary both in size and in purpose. Some are small-scale farmers, producing sufficient quantities to supply the needs of their families. Such farmers may be described as sustenance or self-sufficiency farmers. In fact, 90 % of the sheep on the island of Barbados are reared under extensive and semi-intensive conditions and owned by farmers who are considered landless or land-limited (< 1 ha) (Thomas & Hunte, 2005). Others are larger scale farmers, producing in excess of their own needs to then sell their meat products both in local grocery stores and markets (Thomas & Hunte, 2005).

The proposed inclusion criteria required that participating farmers be aged 18-65 years of age and rear Blackbelly sheep in some capacity.

Limitations

Originally, it was estimated that randomly selecting 110 Blackbelly sheep farmers, 10 farmers for each of the island's eleven parishes, to participate in the surveying process would provide a sufficient and representative sample size. Further, it was established that selecting farmers from all parishes would provide a more realistic perspective on the current Blackbelly sheep production industry in Barbados. However, due to limited time and resources only 20 Blackbelly sheep farmers from six parishes (St. Lucy, St. Peter, St. Andrew, St. James, St. Joseph and St. John) were selected at random and interviewed.

The first and arguably the most significant limitation associated with this section of this project was the limited time available through which to conduct the minimum required number of surveys. Ethics approval for this section of this project was obtained on November 7th and with the research component of this project set to end on December 13th, this left roughly just over one month to both schedule and administer the surveys and guided face-to-face discussions. Moreover, as most farmers on the island are part-time farmers with full-time jobs it was increasingly difficult to schedule appointments with the selected candidates.

The second limitation was that of limited resources and manpower. This component of the project would have largely benefited from having additional trained survey assistance and local drivers, all preferably from the Ministry of Agriculture Greenland Livestock Research Station, as this would have permitted for a larger number of farmers to be interviewed. However, given the limited timeline and lack of available farm staff members, only one trained surveyor and Ministry of Agriculture Greenland Livestock Research Station staff member (Greg Welch) could be involved in the surveying process.

Farmer Selection Process & Survey Protocol

The selection process began by obtaining the full list of registered Blackbelly sheep farmers from the Ministry of Agriculture Livestock Research Station database. This included both small and large-scale Blackbelly sheep farmers. This list was provided by the manager of the research station, John Vaughan. Farmers from this list were selected at random. The surveys were administered at the homes of the participants, by the M.Sc. candidate, and accompanied by Greg Welch from the Ministry of Agriculture Greenland Livestock Research Station. Greg Welch was responsible for scheduling appointments with participating farmers as well as general introductions.

4.2.3 Survey

Surveys were used as a quantitative platform through which baseline information could be collected concerning three important areas of interest to this research project. These are (1) the level of food insecurity amongst local Blackbelly sheep farmers, (2) the animal species and livestock production systems utilized by these same farmers and (3) the feed(s) they used to sustain their livestock production systems.

<u>Survey Questionnaire</u>

As mentioned, the first component of this survey aimed to shed light on the level of food insecurity experienced by rural Barbadian Blackbelly sheep farmers. The FIES, an eight-question survey module developed by the FAO in collaboration with Voices of the Hungry, was used to assess food insecurity. The FIES is an experience-based scale that relies on people's direct responses to measure the severity of food insecurity (FAO, 2017). It should be noted that only one yes answer to any of the eight FIES survey questions can classify a farmer as being food insecure. The goal of component two of the survey was to determine the size and diversity of the production systems of Blackbelly sheep farmers on the island, along with an idea of how they go about using their sheep (ie. consumption, sale, research, reproduction, etc.). Questions in this section were also intended to establish the quantity of animal by-products generated in a given production system and what proportion of these were consumed by the farmer. The third and final component of the survey aimed to determine the types of feed(s) farmers used to feed their animals, the cost(s) of these feeds, how frequently they are purchased, how they are stored and, most importantly, the reason why they are used.

The survey was performed by myself, in private, ensuring that all personal information revealed throughout the survey remained confidential. The surveys were conducted between November 26th and December 12th, 2016. Each farmer was attributed a five-digit code to ensure confidentiality. This code was stored in a password-protected file in a password-protected computer to ensure confidentiality. The survey was audiotaped, with the collected audiotape files being stored following the same procedure as the five-digit farmer code.

The consent form was read aloud to the farmer and the appropriate documentation signature obtained prior to the start of the survey. The survey lasted approximately 10-20 minutes.

Data Analysis

Once the surveying process complete, the data were entered into STATA 14.0 © 2017 statistical software. Analyses were then carried out to produce results that could be used to answer important questions concerning the three main areas of interest outlined earlier on in this section; (1) the food insecurity status of local Blackbelly sheep farmers, (2) the size and diversity of the livestock production systems of these same farmers and (3) the feed(s) they use to sustain their production systems.

4.2.4 Face-to-Face Discussion

The informal face-to-face discussion was used as a qualitative tool that served to compliment the data obtained from the quantitative surveying process. This qualitative process involved a set of pre-determined open questions designed to prompt responses on the topic of by-product feeds in general along with possibilities of their utilization and implementation in livestock production. The information collected during the discussion was used to develop recommendations concerning the project methodology and by-product ration. Such recommendations are outlined at length in **Section 6.2**.

Farmer Selection Process & Face-to-face Discussion Protocol

One third of the surveyed Blackbelly sheep farmers, which totalled to an amount of 6 farmers, were randomly selected to participate in a guided face-to-face discussion. This discussion session took place immediately after the survey. It was conducted by the M.Sc. candidate, in private, ensuring that all personal information revealed throughout the discussion remained confidential. The discussion was audiotaped and the generated audio files were stored in a password-protected file in a password-protected computer to further ensure confidentiality. The informal face-to-face discussion lasted approximately 10-15 minutes.

5.0 RESULTS & DISCUSSION

5.1 Section 1 – Feed Trial

5.1.1 Feed Trial # 1

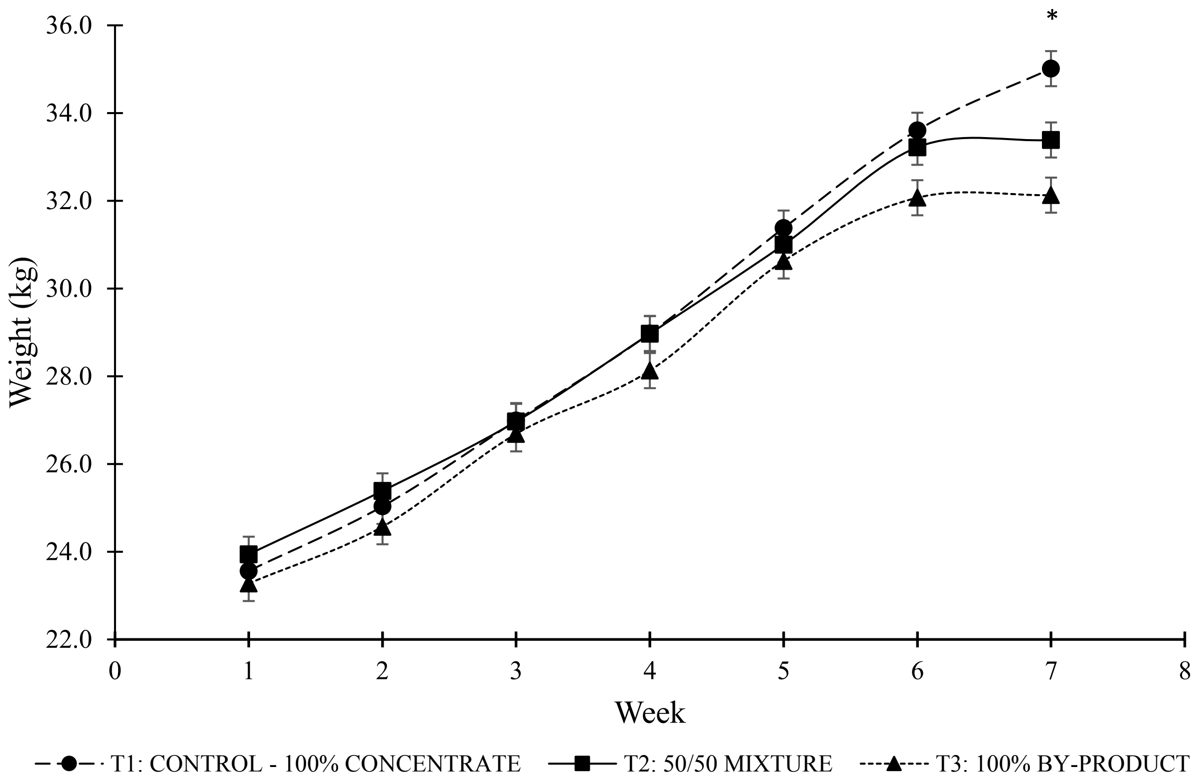
Results from the first feed trial show that, up until week 6, there was no statistically significant difference amongst all of the treatments (T1-T2: p = 0.5; T1-T3: p = 0.02; T2-T3: p = 0.07). By end of the feed trial, week 7, the weight gain of sheep in T2 (50% Concentrate & 50% By-Product Mixture) and T3 (100% By-Product) begin to plateau. Overall, there was no statistically significant difference between the sheep weight gain of T1 (Control - 100% Commercial Concentrate) and T2 (50% Concentrate & 50% By-Product Mixture) (p = 0.02). Similarly, there was no statistically significant difference amongst the sheep weight gain of T2 (50% Concentrate & 50% By-Product Mixture) and T3 (100% By-Product) (p = 0.05). There was however, a statistically significantly difference between T1 (Control - 100% Commercial Concentrate) and T3 (100% By-Product) (T1-T3: 2.88 ± 0.58; p = *0.0006)*, whereby the sheep in T1 produced higher sheep weight gain than those in T3. **Table 7** and **Figure 1** were generated using the SAS outputs generated through the second set of PROC MIXED statistical analyses; ie the procedure that used initial weight as a covariate. See **Appendix Section 1** for the pairwise differences that correspond with the results for feed trial # 1.

Table 7. Least squares mean & standard errors of sheep weight per treatment for feed trial # 1

Week	T 1		T2		T3	
	LSM	SE	LSM	SE	LSM	SE
1	23.56	0.40	23.94	0.39	23.28	0.40
2	25.03	0.40	25.39	0.39	24.57	0.40
3	26.99	0.41	26.97	0.39	26.69	0.40
4	28.98	0.41	28.97	0.39	28.13	0.40
5	31.38	0.41	31.00	0.39	30.63	0.40
6	33.61	0.41	33.22	0.39	32.07	0.40
7	35.01	0.41	33.39	0.39	32.13	0.40

LSM = Least Squares Mean; SE = Standard Error

Figure 1. Weekly least squares mean of sheep weight per treatment for feed trial # 1



This graph illustrates the weight gain patterns of Blackbelly sheep in three treatment groups. Sheep in treatment 1 (T1) were fed a commercial concentrate diet (●), those in treatment 2 (T2) were fed a 50/50 mixture of the by-product ration and commercial concentrate feed (■) and sheep in treatment 3 (T3) were fed a diet consisting of the by-product ration (▲). All diets were supplemented with fresh hay and water daily. Up until week 6, all diets produced equivalent weight gain results (T1-T2: $p = 0.5$; T1-T3: $p = 0.02$; T2-T3: $p = 0.07$). By week 7, treatment 1 had outperformed treatment 3 (*) (T1- T3: 2.88 ± 0.58; $p = 0.0006$).

In the first set of PROC MIXED analyses, ar(1) was selected as the better fitting model as it produced a BIC value that was lower than that of the CS structure. Removing the random effect of pen from the model changed the BIC by more than eight, suggesting that there is a very strong statistically significant difference amongst the pens. Upon eliminating the random effect of sheep from the model, the BIC changed by more than three, thus there is a statistically significant difference amongst the sheep. In summary, there is statistically significant variability amongst the pens and amongst the sheep.

In the second set of PROC MIXED analyses, using initial weight as a covariate, the ar(1) structure was chosen as the better fitting model as it generated the lowest overall BIC value. Eliminating the random effect of pen from the model changed the BIC value by more than three, indicating that there is in fact a statistically significant difference amongst the pens. Removing the random effect of sheep from the model modified the BIC by a factor less than three and hence there is no statistically significant difference amongst the sheep once adjusted for the effects of initial weight. In short, there is statistically significant variability amongst the pens but not amongst sheep once corrected for initial weight.

Table 8 shows that there is little to no variation amongst the pens in feed trial # 1. Further, an ar(1) estimate of 0.72 indicates that there is a moderate correlation between consecutive weekly sheep weight measurements.

Table 8. Covariance parameter estimates using initial weight as a covariate for feed trial # 1

Covariance Parameter	**Estimate**
Pen(Treatment) or σ^2_{pen}	0.13
ID(Pen*Treatment) or σ^2_{sheep}	0.43
ar(1)	0.72
Residual or σ^2_e	1.56

As can be seen in **Figure 1**, the by-product ration can be considered a competitive feed option as compared to the commercial concentrate for the first six weeks of this trial, with T1 (Control – 100% Concentrate), T2 (50% Concentrate & 50% By-Product Mixture) and T3 (100% By-Product) producing statistically equivalent sheep weight gain.

There are many potential reasons that could explain the leveling off of sheep weights in treatments 2 and 3 from week 6 to 7. One such possibility could be a decrease in the freshness of the by-product ration. As mentioned in **Section 4.1.4**, the by-product feed was mixed once every two weeks for the last 4 weeks of the trial. However, it was observed that by the second week the stored feed started to smell mildly acidic, suggesting that it was beginning to ferment. This is most likely due to the country's high heat and humidity, which was only amplified in the farm's non-ventilated feed room. As such, the fermentation process could have caused a slight decrease in the nutritional content of the by-product feed, which could then explain the slowing weight gain of the sheep in treatments 2 and 3.

Another factor potentially influencing the weight discrepancy gap amongst the treatments from week 6 to 7 is the intermittent provisioning of damp hay to the experimental rams throughout the feed trial. The first 2016 feed trial began in early August, which happens to line up perfectly with the country's wet season. These frequent and heavy rainfall events are extremely disruptive to farmers' hay bailing processes, as the hay must be provided with sufficient time to dry prior to bailing. If the moisture content of the grass does not fall below 15-18% moisture at bailing, then the risk of molding or bacteria accumulation becomes much more likely (Porter, 2009; Suttie, 2000). If damp hay is fed recurrently over a period of several weeks then the mold or bacteria within the hay can have a cumulative and negative effect of the animal's digestion, which in some circumstances could lead to weight loss (Gallo *et al*, 2015).

5.1.2 Feed Trial #2

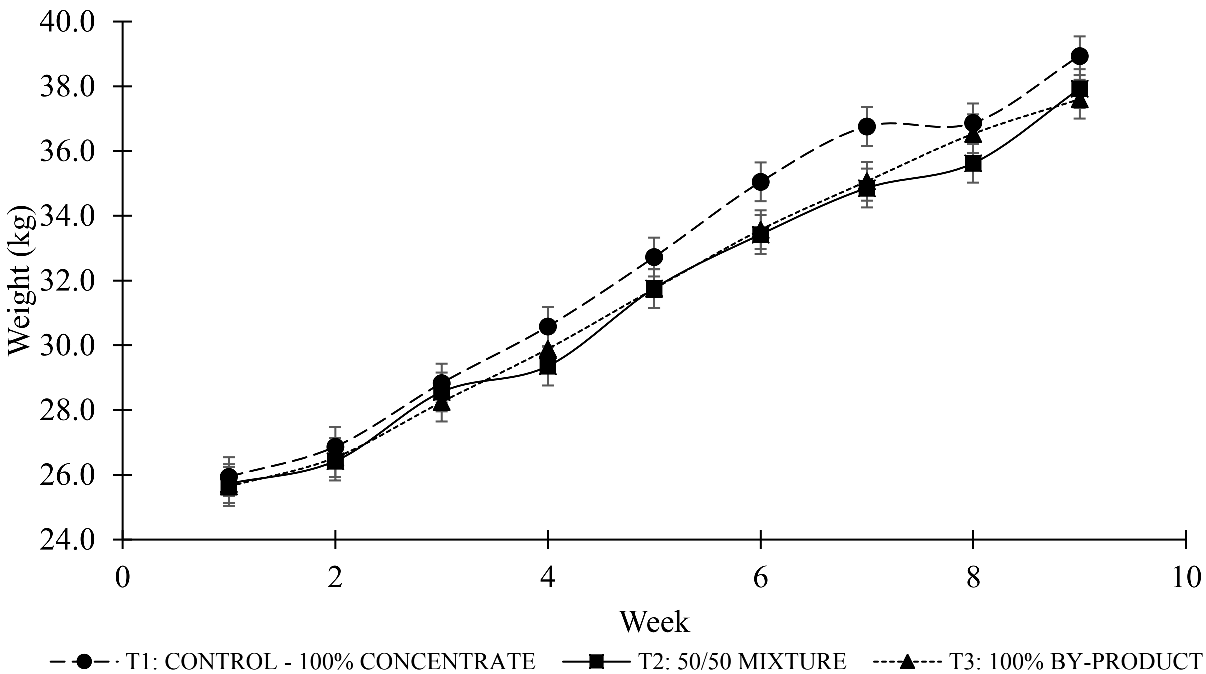
Results from the second feed trial show that, by week 9, there is no statistically significant difference amongst all of the treatments, with T1, T2 and T3 producing statistically equivalent sheep weight gain (T1-T2: $p = 0.2$; T1-T3: $p = 0.1$; T2-T3: $p = 0.7$). This therefore implies that the by-product feed is successful in providing the sheep with the nutrients required for sustained health and a growth comparable to that of the commercial concentrate. **Table 9** and **Figure 2** demonstrates the outputs that were produced by using initial weight as a covariate. See **Appendix Section 1** for the pairwise differences that correspond with the results for feed trial # 2.

Table 9. Least squares mean & standard errors per treatment for feed trial # 2

Week	**T1**		**T2**		**T3**	
	LSM	SE	LSM	SE	LSM	SE
1	25.94	0.57	25.73	0.55	25.64	0.57
2	26.87	0.57	26.43	0.55	26.53	0.57
3	28.83	0.57	28.56	0.55	28.25	0.57
4	30.58	0.57	29.36	0.55	29.89	0.57
5	32.73	0.57	31.76	0.55	31.75	0.57
6	35.05	0.57	33.43	0.55	33.57	0.57
7	36.76	0.57	34.86	0.55	35.07	0.57
8	36.87	0.57	35.63	0.55	36.53	0.57
9	38.94	0.57	37.93	0.55	37.60	0.57

LSM = Least Squares Mean; SE = Standard Error

Figure 2. Weekly least squares mean of sheep weight per treatment for feed trial # 2



This graph illustrates the weight gain patterns of Blackbelly sheep in three treatment groups. Sheep in treatment 1 (T1) were fed a commercial concentrate diet (●), those in treatment 2 (T1) were fed a 50/50 mixture of the by-product ration and commercial concentrate feed (■) and sheep in treatment 3 (T3) were fed a diet consisting of the by-product ration (▲). All diets were supplemented with fresh hay and water daily. By week 9, all diets produced equivalent weight gain results (T1-T2: $p = 0.2$; T1-T3: $p = 0.1$; T2-T3: $p = 0.7$). As such, the by-product ration can be used as an alternative to the commercial concentrate feed.

In the first PROC MIXED procedure, ar(1)was selected as the better fitting model as it generated a BIC value that was lower than that of the CS structure. Removing the random effect of pen from the model changed the BIC by more than three and hence there is a statistically significant difference amongst the pens. Upon removing the random effect of sheep from the model, the BIC stayed constant, indicating that there is no variation amongst sheep.

Similar outcomes were determined in the second PROC MIXED procedure, which used initial weight as a covariate.

Table 10 shows that there is no variation amongst the pens in feed trial # 2. Further, an ar(1) estimate of 0.91 indicates that there is a high correlation between consecutive weekly sheep weight measurements.

Table 10. Covariance parameter estimates using initial sheep weight as a covariate for feed trial # 2

Covariance Parameter	Estimate
Pen(Treatment) or σ^2_{pen}	0
ID(Pen*Treatment) or σ^2_{sheep}	0
ar(1)	0.91
Residual or σ^2_e	4.53

Figure 2 illustrates that there is in fact no statistically significant difference amongst the treatments by week 9, the end of the feed trial. This therefore implies that T3, the full by-product ration, can successfully be used as an alternative to the commercial concentrate feed. Further, the fact that similar results were observed in both feed trials indicates that the by-product feed is not only successful in producing comparable sheep weight gain, but also that it is a reliable, cost-effective feed option for local Blackbelly sheep farmers.

The improvement in the weight gain results obtained in this second feed trial over those of the first suggests that mixing weekly, as opposed to once for a period of two weeks, ensures continued feed freshness while minimizing the possibility of fermentation and thus the potential for detrimental health impacts on the animals.

The ration proposed in this project could also be used by farmers, specifically those who are habitual commercial concentrates users, as a backup plan in the occasion that the commercial concentrate is either unavailable or deemed unreliable.

An additional remark that applies to both of the performed feed trials is that it would have been preferable had the initial weights of the sheep been more uniform at the start of the trial. Doing so, would have facilitated the statistical analysis process of the collected weight data and made the overall results of the trials more accurate. See appendix section 1 for the recorded weights of the animals in feed trial # 1 and 2.

5.1.3 Feed Lab Analyses Results

Three separate sets of samples of the individual by-product ingredients and commercial concentrate were collected and analysed for CP, NDF, ADF, ADL, DM and Ash. These samples were analysed so that a more representative nutritional profile of these feeds could be established and to ensure that the by-product and concentrate feeds were nutritionally comparable.

The crude protein analyses were conducted at GAS laboratory, which is located in St. Michael parish, Barbados. These CP samples were collected on May 13th, August 9th and December 6th.

Complementary feed analyses were performed at the laboratory of Dr. Arif Mustafa, at the Macdonald Campus of McGill University. The samples were collected on May 13th, September 15th and December 6th. The first round of samples (May 13th) could not be analyzed for CP, as the required instrumentation was non-functional, thus explaining why the samples were brought to GAS. By the time the second (September 15th) and third (December 6th) rounds of samples were brought to Dr. Mustafa's lab, the CP instrument was operational and could therefore be used to determine the protein content of the second and third samples. The results of these various feed analyses are shown in the tables below.

Table 11A. Feed analysis results of the by-product ingredients and commercial concentrate

Sampled on: May 13th, 2016						
	GAS	**Dr. Arif Mustafa's Lab**				
Feeds/Feed Ingredients	*CP (%)*	*DM (%)*	*Ash (%)*	*NDF (%)*	*ADF (%)*	*ADL (%)*
By-Product Ration	N/A	N/A	N/A	N/A	N/A	N/A
Ground Corn	N/A	N/A	N/A	N/A	N/A	N/A
Rice Bran	N/A	N/A	N/A	N/A	N/A	N/A
Soybean Meal	41.20	88.50	6.87	11.78	7.00	N/A
Wheat Middling	16.60	89.12	5.32	38.12	11.00	3.30
Commercial Concentrate	13.50	90.12	6.33	25.02	14.50	1.13

Table 11B. Feed analysis results of the by-product ingredients and commercial concentrate

Sampled on:						
	August 9th, 2016	September 15th, 2016				
	GAS	**Dr. Arif Mustafa's Lab**				
Feeds/Feed Ingredients	*CP (%)*	*DM (%)*	*Ash (%)*	*NDF (%)*	*ADF (%)*	*CP (%)*
By-Product Ration	N/A	N/A	N/A	N/A	N/A	N/A
Ground Corn	6.00	87.10	1.51	12.96	5.02	9.36
Rice Bran	8.30	91.79	5.75	16.52	8.37	13.39
Soybean Meal	33.30	91.51	6.46	12.82	10.23	46.33
Wheat Middling	13.80	93.54	5.91	41.94	12.08	19.57
Commercial Concentrate	11.70	89.66	6.57	30.40	17.75	18.70

Table 11C. Feed analysis results of the by-product ingredients and commercial concentrate

Sampled on: December 6th, 2016						
	GAS	**Dr. Arif Mustafa's Lab**				
Feeds/Feed Ingredients	*CP (%)*	*DM (%)*	*Ash (%)*	*NDF (%)*	*ADF (%)*	*CP (%)*
By-Product Ration	16.8	92.29	9.52	21.69	8.68	20.85
Ground Corn	6.9	88.75	1.53	13.15	4.13	8.50
Rice Bran	11.8	91.13	5.16	16.39	7.74	13.87
Soybean Meal	26.1	92.17	6.41	13.22	11.19	45.70
Wheat Middling	16.6	90.29	5.86	40.10	12.90	20.28
Commercial Concentrate	15.8	N/A	N/A	N/A	N/A	N/A

Of the samples analyzed by GAS, it can be seen that there is a high variation in the CP content of the commercial concentrate and soybean meal feeds; ones that were both purchased from the same feed supply company. Two of the three samples collected for the commercial concentrate feed contained protein levels that were far below the guaranteed value of 16% CP. Moreover, the CP values of the collected soybean meal samples were not only substantially variable amongst themselves but especially with the aforementioned textbook value of 49% CP, which was used upon creating the by-product formulation of feed trial # 1.

Variation amongst the CP levels of the remaining individual by-product ingredients (ground corn, rice bran and wheat middlings) analyzed by GAS, were lower than anticipated. There was very little variation in the two collected ground corn samples in terms of their CP content. CP values for the rice bran presented more variability than expected. As for wheat middlings, two of the three collected samples contained equivalent CP concentrations, with the third sample having a lower CP content. Overall, this ingredient presented CP variation that was much less than originally anticipated.

Upon closer observation, there is also a significant variation amongst the CP values of the samples generated by GAS and those produced by the feed analysis laboratory of Dr. Arif Mustafa. The protein content of the samples analyzed by Dr. Mustafa are not only much less variable amongst themselves but also happen to closely resemble their textbook CP values. This suggests that the instrumentation and or the techniques used by GAS to analyze the crude protein content of livestock feed samples are insufficient and potentially misleading. In other words, the current CP lab analysis system offered by GAS does not correctly represent to the true CP value of the by-product ingredients or feeds, making it very difficult for farmers to distinguish the nutritional profiles of the rations they are developing for their animals. Further, with no alternative legitimate feed analysis service on the island, the consequences of this is particularly worrisome, especially for those farmers who seek to develop by-product feed formulations for their animals as a means of decreasing production costs.

5.2 Section 2 - Social & Cultural Acceptability

5.2.1 Survey

Table 12 summarizes the findings pertaining to the food security status of the farmers involved in the surveying process. Complementary visual aids and descriptions will follow.

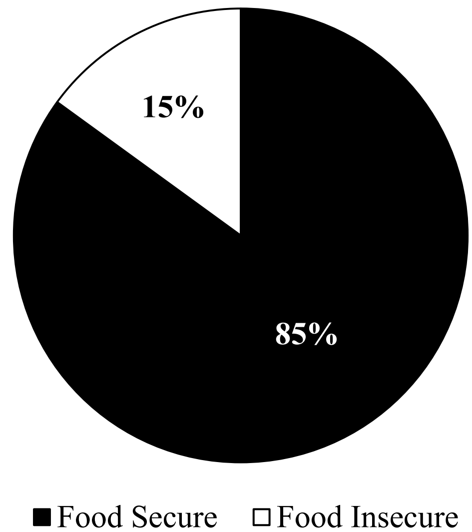
Table 12. Food security status of farmers by general livestock production characteristics

	Food Secure	Food Insecure
Food Security Status of Participating Farmers (#)	17	3
Food Security Status of Participating Farmers (%)	85	15
Agricultural Land Size Category of Farmers (#)		
Land-Limited (x < 1 ha)	14	3
Not Land-Limited (x ≥ 1 ha)	3	0
Agricultural Land Size Category of Farmers (%)		
Land Limited (x < 1 ha)	82	18
Not Land Limited (x ≥ 1 ha)	100	0
Diversity of Livestock Production System (# of Animal Species)	2.41	1.67
Common Blackbelly Sheep Uses Amongst Farmers (%)		
Consumption	100	100
Sale (Meat)	94	100
Field Research	24	0
Reproduction	100	100
Breeding For Sale (Live Animal)	53	33
Show	18	33
Food Security Status of Farmers Using: (%)		
By-Product Feed(s) or Ingredients Only	100	0
By-Product Feed(s)/Ingredients & Commercial Concentrate Combination	77	23
Commercial Concentrate Only	100	0

Food Security Status of Participating Blackbelly Sheep Farmers

Results from the FIES module of the survey show that 85% of the Blackbelly sheep farmers that participated in the interviewing process are food secure and the remaining 15% are food insecure. The pie chart below illustrates this finding.

Figure 3. Food security status of interviewed farmers

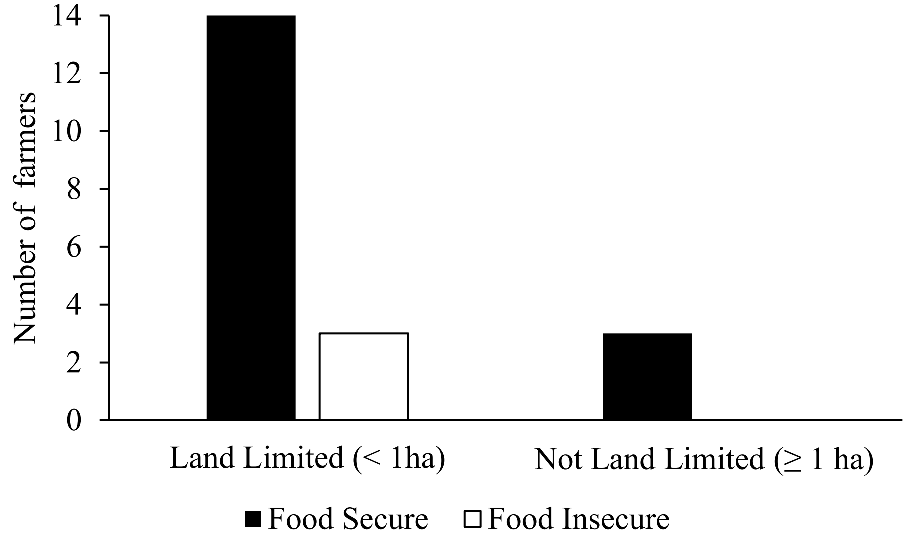


This implies that, for the most part, these farmers have both physical and economic access to food in quantities sufficient to satisfy their hunger. Although the FIES module of the survey did in fact permit for the determination of the food security status of the farmers, it did not provide information pertaining to the kinds of foods these same farmers were consuming. This makes it impossible to conclude if these Blackbelly sheep farmers consume the typical low-cost, calorie dense Bajan diet (high in carbohydrates, fats and sweeteners) or if they opted for a healthier dietary lifestyle (lean meats, fish, vegetables and fruits).

Food Security Status by Agricultural Land Size Category

The size of the farmers' agricultural land was divided into two land size categories: land-limited and not land-limited. The land-limited category can be defined as livestock farmland that is less than 1 hectare. This category also includes landless or backyard farmers. The not land-limited land size encompasses the farmland that is greater than or equal to 1 hectare. Results indicate that 85% of farmers who participated in the survey fall under the land-limited category, with the remaining 15% being not land-limited. Further, of the 17 farmers in the land-limited category, 14 are food secure and 3 are food insecure. Moreover, of the 3 farmers that correspond with the not land-limited category, all are food secure. Overall, the only category found to contain food insecure farmers is the land-limited category.

Figure 4. Food security status by agricultural land size category



As mentioned, 85% of the interviewed farmers rear their animals on farmland that is less than 1 hectare in size. This corresponds with a finding determined by the FAO which stipulates that 90% of sheep on the island of Barbados are owned by farmers who are considered landless or land-limited (1 < ha) (Thomas & Hunte, 2005). Additionally, there is a trend which indicates that farmers in the land-limited category are more likely to be food insecure than in the not land-limited category. Farmers in the land-limited category could be at a greater risk of becoming food insecure as they may have less access to land space and resources, which could in turn hinder the effectiveness of their livestock production systems and subsequently its profitability. Farmers that fall into this category could also be prioritizing the purchasing of food for their animals over that of their own. These same farmers could also be further prioritizing the sale of their Blackbelly sheep meat for profit rather than holding some back for their own consumption. Either of these scenarios would be largely detrimental to their food security status.

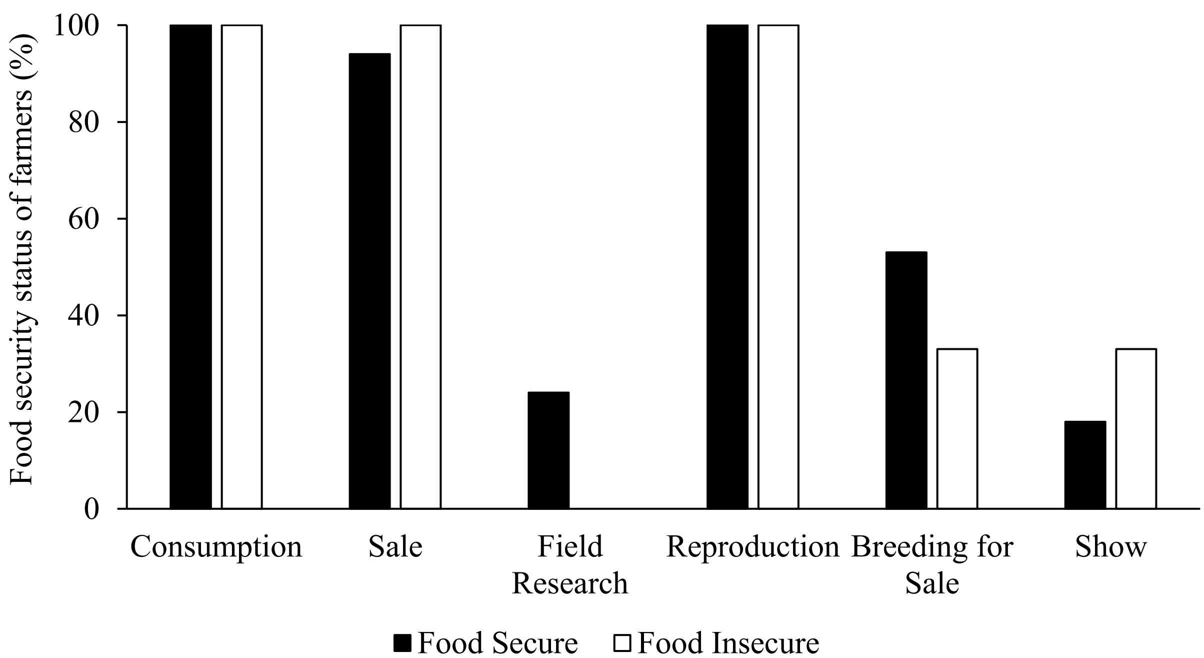
Food Security by Livestock Production Diversity

As demonstrated in **Table 12**, Blackbelly sheep farmers that have been identified as being food secure tend to have 2.41 animal species, on average. On the other hand, food insecure farmers have been found to have an average of 1.67 animal species. This shows that food secure farmers have a larger animal livestock species diversity than those who are food insecure. Once again, this could be due to a lack of space and availability of resources on the part of the farmer.

Common Blackbelly Sheep Uses of Barbadian Farmers

From **Figure 5**, of the farmers that were surveyed, both food secure and insecure farmers alike use their sheep for their own consumption, thus providing their own families and relatives with a source of fresh lean meat protein, which in turn contributes to their food security status. Similarly, all interviewed farmers, regardless of their food security status, use their sheep for reproductive purposes and have implemented a breeding program of sorts that allows their flock to grow in size, thus sustaining their meat production systems. Further, 94% of food secure and 100% of food insecure farmers sell their sheep meat to neighbours or markets for profit. Moreover, 24% of food secure farmers conduct their own field research, where they will come up with their own sheep feeds and monitor its success. On other hand, of the surveyed farmers, none of the food insecure farmers perform their own feeding trials. A greater number of food secure farmers (53%) breed their Blackbelly sheep for sale, as live weight, than food insecure farmers (33%). Finally, 33% of food insecure farmers rear Blackbelly sheep for show as compared to 18% of food secure farmers.

Figure 5. Food security status of interviewed farmers by common Blackbelly sheep uses



As observed in **Figure 5**, the majority if not all of the interviewed farmers, regardless of their food security status, use their Blackbelly sheep as 1) a quick lean meat protein essential to any healthy diet, 2) a source of income (via the selling of sheep meat, breeding for sale and showing at

Agrofest) and 3) a means of reproduction, sustaining the health and vitality of their production systems. Such trends show that consumption, sale and reproduction are factors that are central to the success of their livestock businesses.

As demonstrated in this project, field research in the form of feeding trials are highly time, energy, and resource intensive. Results from this survey suggest that only some of the food secure farmers met the criteria required to be able to both develop and monitor an alternative feed option for their animals. An additional factor to consider is that although some farmers can dedicate some of their time into creating a new feed ration, this does not necessarily imply that these farmers have the knowledge and the training required to produce a nutritionally balanced feed. In fact, most farmers who do create their own formulations tend to blindly mix together ingredients and hope the final product generate optimal weight gain results, a completely unscientific approach. For the most part, the success of these feeds are intermittent at best with strong tendencies towards unreliability. In these instances, the health of the animals could be compromised, thus affecting their growth and development and in turn the farmer's opportunity for profit. Such outcomes were also mentioned by those farmers participating in the face-to-face discussion.

A larger proportion of food secure farmers over food insecure farmers were involved in breeding their Blackbelly sheep for sale as live weight. Often the goal of selling and purchasing sheep in this manner is to revitalize the genetic diversity of their flocks. Selecting the appropriate candidates to both sell and purchase can be time consuming and expensive, especially if the incoming sheep is known to be a prolific breeder expressing the desired traits. In circumstances such as these, farmers who lack a surplus in disposable income and other important resources could be at a disadvantage. This could affect their ability to acquire good quality stock and maintain the generic diversity within the flock. Such issues could trigger a decrease in overall productivity, having ramifications on both the farmers' profit and food security status.

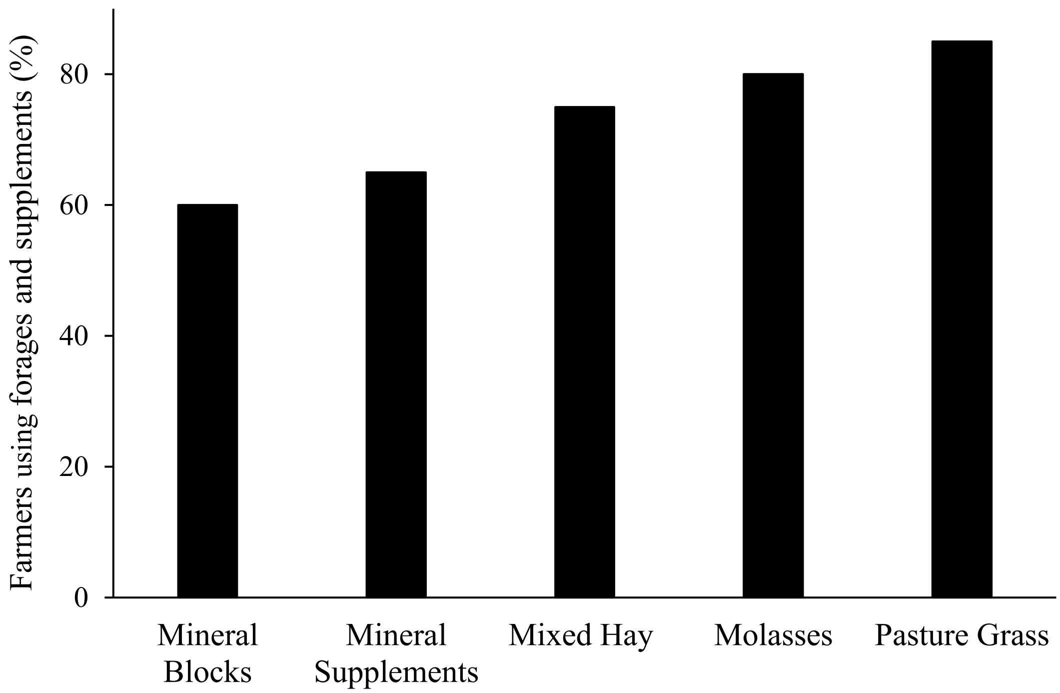
Figure 5 shows that a greater proportion of food insecure farmers are choosing to rear their Blackbelly sheep for showing purposes as compared to food secure farmers. As mentioned in **Section 2.7.1**, every February the Barbados Agricultural Society hosts its annual national agricultural exhibition (Agrofest). Winners of this exhibition receive a range of prizes. These will vary largely depending on the quality and purity of the Blackbelly sheep(s) the farmer chooses to show. This annual event is known to attract sheep farmers from across the island. Agrofest could be considerably appealing to those farmers seeking a quick, generous source of income, which they could partly or fully reinvest into their own production systems. This could then lead to an increase in system productivity, profit and improve the farmer's food security status.

Before presenting the results pertaining to the food security status of farmers according to their selected sheep feed type, (1) by-product rations only, (2) a combination of by-product and commercial concentrate and (3) commercial concentrate feeds only, general findings concerning the feed types used in general by farmers along with the rational supporting the usage of the commercial concentrate feeds with be introduced.

Forages and Mineral Supplements

Forages (mixed hay and pasture grasses), dietary supplements (mineral block and powdered supplements) and molasses are feedstuffs that are used by many Barbadian farmers regardless of what feed types they use to feed their animals. As such, pasture grass and mixed hay are forages that are used by many of the surveyed farmers, 85% and 75% respectively. Furthermore, mineral blocks (60%) and powdered mineral supplements (65%) are frequently utilized by farmers to enhance the mineral and vitamin content of the animals' diets. Molasses, a popular feed binding agent used to increase the palatability of feeds, was used by 80% of the farmers.

Figure 6. Percentage of farmers using forages and dietary supplements



Overall, pasture grass was found to be the more popular forage choice over mixed hay bails as it is the cheaper and more convenient alternative. The use of hay bails will also greatly vary depending on the season, with a larger number of bails being purchased by farmers in the dry season. During these drier periods of the year, pasture grasses tend to both decline in volume and in quality, thus validating the need for an alternate forage source.

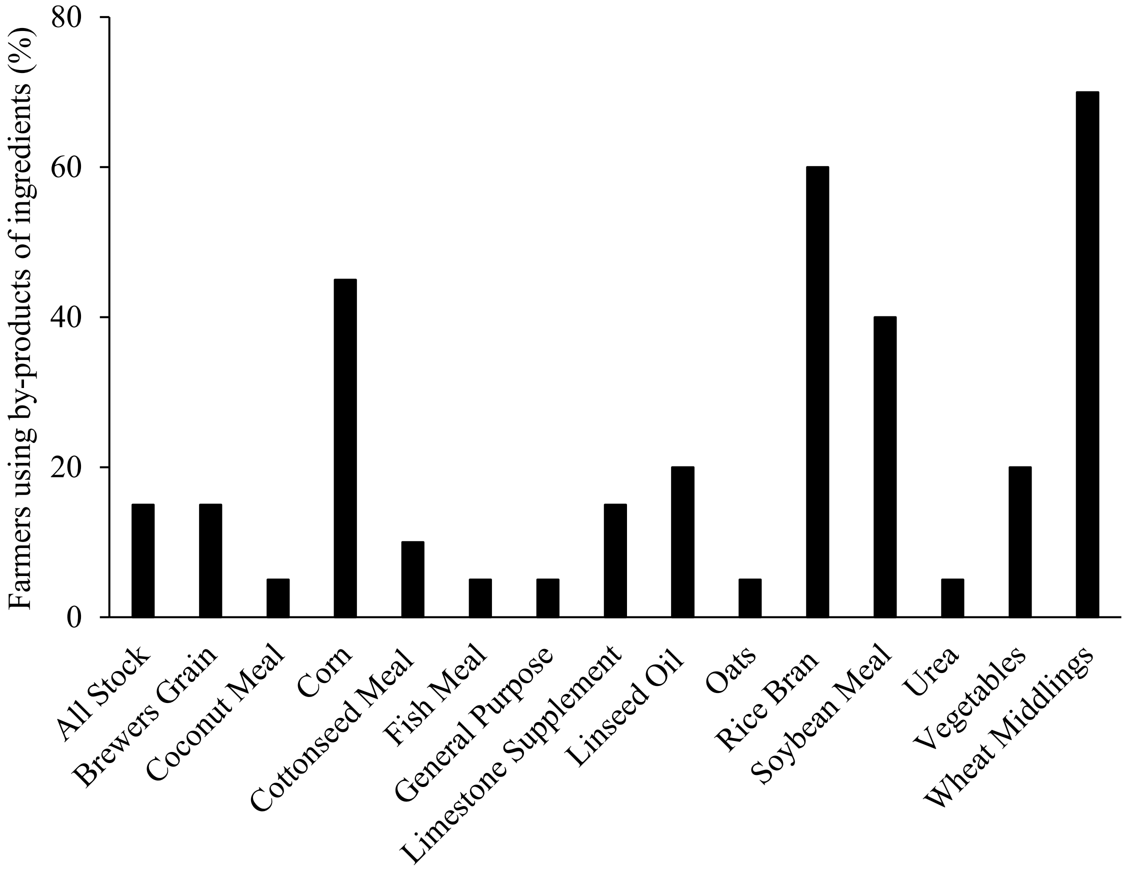
Further, mineral supplements are also frequently used by the majority of farmers, with powdered mineral supplements being used marginally more so than mineral blocks. As seen in **Section 5.1.3**, the nutritional profile of by-product ingredients can tend to vary largely throughout the year. Generally speaking, the addition of powdered mineral supplements can do a great deal in complementing the nutritional content of a by-product formulation (NRC, 2007). However, with the common nutritional fluctuations found in these by-product ingredients it can be difficult to determine the ideal quantity of powdered supplement to be added to a ration. For example, if a set amount of powdered supplement is added to a batch of by-product feed with lower nutritional values than originally anticipated, then the sheep will be eating a feed that does not meet the standards required for optimal growth and development. On the long term, the intermittent or consistent provisioning of a feed with a nutritional profile that falls below the desired standards will slow the growth rate of the animals and directly impact the success of the farmer's production system. On the other hand, the addition of powdered supplements in quantities greater than what is required does not necessarily guarantee a faster sheep growth rate. This would, over the long term, become increasingly costly for the farmer and thus diminish the efficiency of his livestock production system. Further, it should be noted that as part of the ruminant family, Blackbelly sheep have the ability to determine both the frequency and quantity of additional minerals and vitamins that they require (NRC, 2007). Keeping this in mind, Barbadian farmers should rely on mineral blocks rather than powdered mineral supplements as a means of balancing the nutritional content of their feed formulations. This would produce more consistent growth rate results amongst their animals while eliminating much of the tedious guesswork associated with powdered supplements.

Molasses is an extremely cost effective by-product ingredient that is produced entirely in Barbados and is used by the great majority of the farmers that were selected to participate in the survey. Overall, this binding agent improves the texture of loose feeds, increases its palatability and contributes to the rations mineral and vitamin content.

By-Product Feeds & Ingredients

Most of the farmers involved in the surveying process use a complete or partial by-product feed ration to nourish their Blackbelly sheep. Coconut meal, fish meal, general purpose feed (a complete feed ration), oats and urea are the feeds or feed ingredients that are the least used amongst the interviewed farmers, with each ingredient being used by only 5% of the farmers. All stock (a livestock maintenance feed) (15%), brewers grain (the by-product left over from the brewing of Banks beer) (15%), cottonseed meal (10%) and limestone supplement (15%) are used by farmers only slightly more than the previous set of by-product feeds/ingredients. Linseed oil and vegetables (some farmers use the vegetables that they grow or have on hand to supplement they sheep diets) are each used by 20% of the farmers. Corn, rice bran, soybean meal and wheat middlings are the top four by-product ingredients used by the surveyed farmers, 45%, 60%, 40% and 70% respectively. These trends can be observed in the figure below.

Figure 7. Percentage of farmers using by-product feeds or ingredients



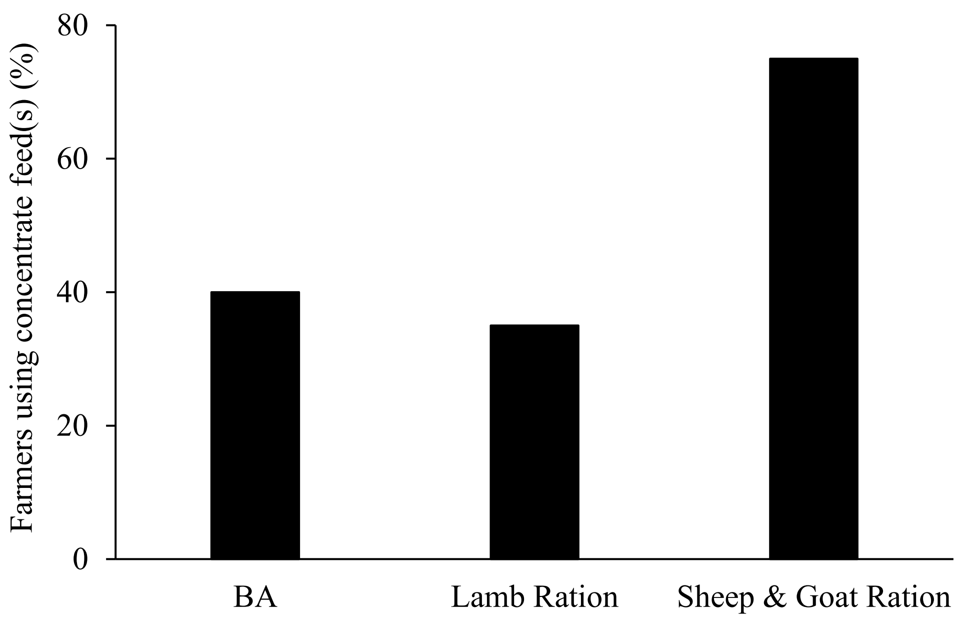
As seen in **Figure 7**, a wide diversity of by-product ingredients and feeds are used by Blackbelly sheep farmers in feeding their animals. The top four most used by-product ingredients are corn, rice bran, soybean meal and wheat middlings. This finding is particularly interesting as these are the four main ingredients that make up the by-product ration proposed in this project. If the majority of farmers are already purchasing and using these feeds in some capacity, then this would facilitate the transitioning process and make implementing this new feed much less daunting.

As previously mentioned, most of the by-product ingredients in Barbados are imported. There already exists many irregularities regarding the consistency of shipment deliveries of certain by-product feeds or ingredients, notwithstanding the delays encountered once the feeds have reached the island's busy and overcrowded port. As such, one foreseeable issue that should be considered is that if a larger number of farmers were to begin using these by-product ingredients regularly as part of their feeding routines, then their supply and availability could significantly decrease, preventing farmers from being able to fully benefit from this proposed ration.

<u>*Commercial Concentrate Feeds*</u>

Some farmers, use commercial concentrate feeds as a complete feed ration or as a way of supplementing their by-product mixtures. BA, Lamb Ration feed and Sheep & Goat Ration are commercial concentrate feeds that are all produced by the same concentrate feed company, which is incidentally the only concentrate feed company on the island of Barbados. BA is general maintenance livestock feed that is used 40% of the interviewed farmers. The Lamb Ration, the feed used as in the control treatment of this study, is used by 35% of the farmers. Lastly, the Sheep & Goat Ration (75%) is the most used commercial concentrate feed amongst the surveyed Blackbelly sheep farmers.

Figure 8. Percentage of Blackbelly sheep farmers using commercial concentrate feed(s)



Of the 20 farmers chosen to participate in the surveying process, the most commonly used commercial concentrate feed is the Sheep and Goat Ration, followed by BA and finally the Lamb Ration. The Sheep & Goat Ration and BA concentrate feeds are probably more popular amongst the local Blackbelly sheep farmers as they are multi-purpose feeds that could also be used to nourish some of the other animals in their production systems. An additional factor to consider is the price of the feeds themselves. The Lamb Ration and Sheep & Goat Ration both cost $37 BDS, with the BA feed coming in cheaper at $30 BDS. Put together, multi-purpose rations that are either cheaper or priced equivalently to the Lamb Ration, seem to be more appealing feeding options to local farmers.

Reasons for Commercial Concentrate Usage

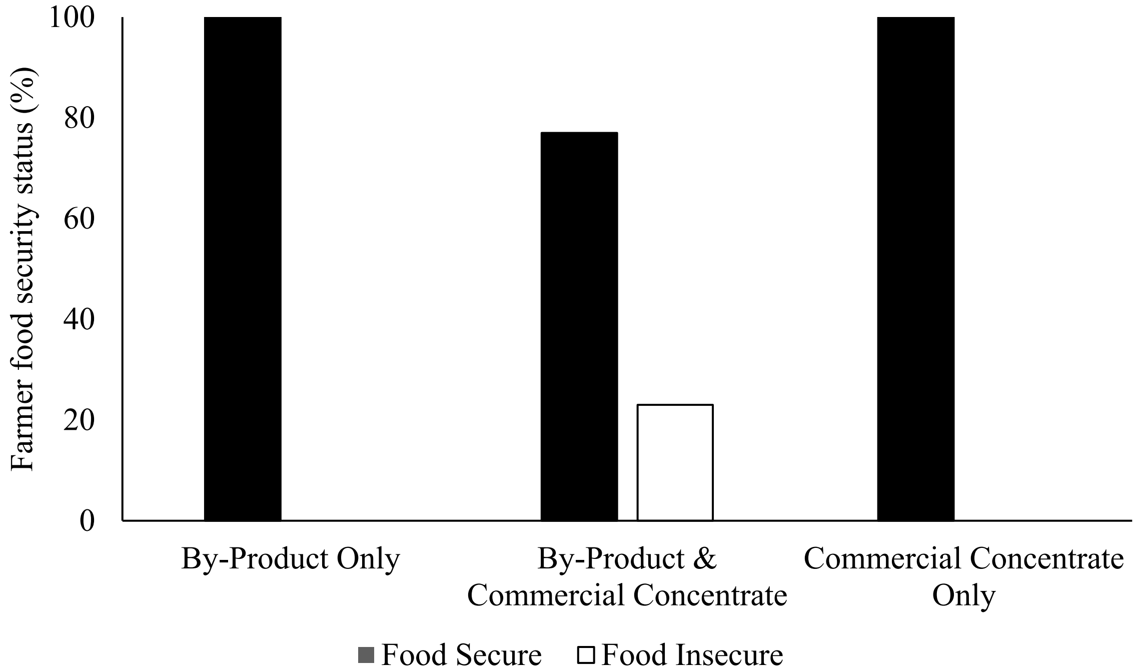
Once this section of the survey was complete, participating farmers that used one or more of the commercial concentrate feeds were asked to provide a rationale as to why these were selected as a feed type for their animals. Statistical analyses show that 14% of farmers use commercial concentrate feed(s) because it is reliable, 24% say it is practical, but 62% of the interviewed farmers only use these feeds because there is no other true alternative feed source.

A large proportion of the surveyed farmers chose to use commercial concentrate feeds, in some capacity, only because there is no other trusted feed alternative. This is a significantly valuable finding as it justifies the serious need for a different feed source that provides similar nutritional benefits and weight gain results as compared to the commercial concentrates feeds, the aim of this study. This further illustrates that the work done in this research is warranted and has the great potential to guide farmers down the path to success.

Farmer Food Security Status by Feed Type

Figure 9 shows that all farmers using a feed type of by-product feeds only, accompanied by some or all of the forages and dietary supplements mentioned previously, are food secure. Likewise, farmers that utilize a commercial concentrate feed only, once again with all or some of the forages and dietary supplements, are all food secure. On the hand, of the farmers that use a mixture of by-product feeds or ingredients and commercial concentrates, including the use of forages and dietary supplements, 77% of the farmers are food secure and the remaining 23% are food insecure.

Figure 9. Farmer food security status by selected feed type



This figure shows that of the farmers that were interviewed, those who chose to use by-products or commercial concentrates only tend to be food secure while those who use a combination of by-product ingredients and commercial concentrates have a 23% chance of being food insecure.

Farmers who fall into the by-product only group tend to have more land and available resources. Further, they may also have more time that can be dedicated to designing and testing the success of their by-product feeds. These two factors combined could contribute to a more stable and fruitful livestock production system and potentially improve their food security status.

Farmers who follow a by-product/commercial concentrate approach could have a higher likelihood of being food insecure, as they tend to have less land and available resources as well as less time to invest into creating a nutritionally sound by-product ration. As such, they could be producing a feed that falls below the required nutritional standard for sheep, which could influence the success of their production system and in turn their food security status.

Users of commercial concentrate feeds only tend to have less time and more available resources, both financial and land based, to dedicate to their production systems. These farmers also happen to be among those who believe that the commercial concentrate feeds are somewhat practical and reliable, acknowledging however that there are no other true feed alternatives.

5.2.2 Face-to-Face Discussion

As mentioned, six Blackbelly sheep farmers were randomly selected, from the list of surveyed farmers, to participate in an informal face-to-face discussion. During this discussion, the farmers were asked a set of pre-determined open questions designed to prompt responses on the topic of by-product feeds in general along with possibilities of their utilization and implementation in their own livestock production routines. Below, is a summary of the responses obtained from this qualitative process.

For the most part, the farmers have either used or are currently using a by-product mixture of some kind to feed their animals. There are some farmers, however, who have never used a by-product feed or are reluctant to implement a by-product mixture as there is an intermittent problem concerning the supply and availability of the individual ingredients that they require to mix their feed.

The majority of farmers that were interviewed for the face-to-face discussion find that by-product mixtures are a cost effective alternative to the commercial concentrate feed, not excessively labour intensive and produce equivalent or higher sheep weight gain than with the concentrate feed. It should be noted, that most farmers do acknowledge that there is an issue surrounding the supply of their by-product ingredients.

All of the interviewed farmers expressed that they would be willing to try implementing a new by-product ration into their daily farming routines if it were cost effective and equivalently nutritious to the commercial concentrate feed. Farmers would be further encouraged to implement this feed, or by-product feeds in general, if a feed mixing COOP were available at the Ministry of Agriculture Greenland Livestock Research Station, a central location on the island. If this service were in fact available, most farmers would be willing to stop by the farm 1-3 times per week in order to mix their feed. Additionally, instructional workshops and training sessions concerning the mixing and storing of mixed feeds seem to be a factor that would make by-product feeds considerably more appealing.

Finally, farmers described their ideal by-product feed as being affordable, dependable, nutritionally sound and easy to control. They would also require that the by-product ingredients be available in constant supply. Further, it was mentioned that farmers would greatly benefit from having access to informative brochures and a wider array of useful agricultural tools and materials.

Results from the guided face-to-face discussion revealed that most farmers were indeed reluctant to use the commercial concentrate to feed their sheep as it is both expensive and unreliable. Likewise, farmers expressed concern regarding inconsistent weight gain results amongst their animals, a problem that stems form variations in CP content, and more importantly the transitory mycotoxin problems. Such general remarks were mirrored by those obtained in the survey and feed trial sections of this project, meaning that there is both quantitative and qualitative validation that these are in fact real issues that livestock farmers are forced to confront on a daily basis.

These issues, coupled with a desire to save money, have pushed farmers to begin using by-product ingredients as a means of feeding their sheep. For the most part, farmers use by-product mixtures to either partially substitute or fully replace the commercial concentrate feed. The overwhelming drawback to using by-products as feeds is that most farmers have little to no knowledge concerning the suitable feeding and mixing standards required to both promote and sustain weight gain. In other words, they will mix together by-product ingredients of their choosing at random and hope that the final mixture will contain enough of the required nutrients to encourage the optimal growth and development of their sheep. This feeding style, although a proactive strategy on the part of the farmer, cannot consistently guarantee the preferred weight gain outcomes. This problem is even further exacerbated by the fact that there is a supply and availability issue associated with certain by-product ingredients. Additionally, there is a severe lack of informative workshops and training opportunities on the island for farmers, making it increasingly difficult for them to profit from their own production systems. In some instances, this has caused certain farmers to prioritize the purchasing of feeds for their animals over and above the purchasing of healthy, nutritious foods meant for their own consumption. In cases like these, farmers have a much higher tendency to become food insecure.

Despite these shortcomings, the guided face-to-face discussion further revealed that the acceptability of by-product feeds and ingredients amongst local Barbadian Blackbelly sheep farmers remains high. What's more, they seemed eager to try to implement the by-product ration proposed in this project.

6.0 RECOMMENDATIONS

6.1 Section 1- Feed Trial

A solution that could be implemented to prevent fermentation of the by-product feed would be to mix weekly for those farmers that are either renting or borrowing mixers or to mix the dry ingredients in bulk in amounts equivalent to approximately 3 to 4 weeks, store appropriately (cool, dry, shaded and preferably elevated areas) and to mix in the molasses daily for those farmers owning a mixer.

Furthermore, it is strongly recommended that farmers ensure that the moisture content of their grass is kept below the ideal threshold of 15-18% and that hay bails are kept in a dry, well-ventilated barns or storage rooms. Doing so will help keep mold development and bacteria accumulation at bay, thus minimizing the possibility of negative health impacts for the animal.

Laboratory feed testing is essential when developing by-product feed formulations. Otherwise, there would be no really way to ensure that what is being fed to the animals meets their specific nutrient requirements. For this reason, it is recommended that the Government of Barbados reinstate its feed analysis laboratory, so that farmers may have their feed samples tested for CP, NDF, ADF, ADL, DM and Ash. Doing so would mean investing in the island's agricultural industry and provide much needed support to those farmers attempting to produce their own by-product feed formulations. Moreover, this would allow farmers to better track what their animals are ingesting, thus optimizing the efficiency of their livestock production systems. Overall, the implications could be financially beneficial to the farmers themselves and on long-term the Barbados economy.

Finally, it is suggested that the Ministry of Agriculture invest in a feed or cement mixer and implement a CO-OP mixing service, which would be situated at the Ministry of Agriculture Greenland Livestock Research Station, a central location of the island. This would allow local farmers to mix their own by-product ration (dry or wet) for free and in bulk, thus alleviating the burden of having to purchase or rent their own mixers and make the concept of mixing their own feed much less daunting.

6.2 Section 2- Social & Cultural Acceptability

Overall, a definite need has been identified; that being an affordable and nutritionally sound feed that can be used an alternative to the commercial concentrate feed. There is an opportunity here for the Ministry of Agriculture and various other agricultural organizations on the island, including CARDI, FAO and IICA, to step in and provide the support, guidance and necessary training required for local Barbadian livestock farmers to thrive. They could also assist in the development of cooperatives aimed to provide farmers with a platform through which they could share knowledge, materials and tools all related to livestock production. These same organizations could dedicate part of their efforts to the mass growing and processing of locally produced feed ingredients that could be used in the creation of by-product formulations meant for livestock feeding. Doing so would not only be advantageous from an economic standpoint, by creating less of a dependency on imported feedstuffs, but will also promote local agriculture across the island of Barbados.

7.0 CONCLUSION

Providing farmers with the knowledge on how to design and create their own alternative feeding options, using feed resources that are available to them locally, has the ability to lower their dependency on costly commercial concentrate rations and improve the efficiency of their livestock production systems. However, research is lacking regarding feed replacements or alternatives for sheep in the Caribbean. Additionally, attaining a broader understanding of the factors that contribute to food insecurity has been a global concern for decades, yet there is limited research with respect to the food insecurity of rural smallholder livestock farmers. This study’s contribution to knowledge is two fold. Firstly, it attempts to provide a methodology that Barbados Blackbelly sheep farmers could follow in developing their own by-product formulations as well as a ration that could be used as an alternative to commercial concentrate feeds. Secondly, efforts will be made to uncover the factors that contribute to the food insecurity of the Blackbelly sheep farmers, specifically in rural Barbados.

The overarching goal of this project was to develop a nutritionally comparable, cost effective by-product feed formualtion, which could generate equivalent weight gain patterns as the currently available commercial concentrate feed. Two feed trials were conducted. The experimental rams involved in the trials were randomly assigned to one of three treatment groups (T1: Control – 100% Concentrate; T2: 50% Concentrate & 50% By-Product Mixture; T3: 100% By-Product) and fed their respective diets over a period of seven to nine weeks, with weight being monitored weekly. Overall, results showed that there was no statistically significant difference amongst all of the treatments. This means that the by-product formulation developed in this study could in fact be used as a sustainable, cost-effective alternative to the commercial concentrate feed.

The secondary objective of this research was to determine the factors contributing to the food insecurity of Blackbelly sheep farmers along with general information pertaining to the size and diversity of their livestock production systems. Surveys were administered to 20 farmers to collect data on the island's livestock industry, with a specific focus on Blackbelly sheep production, and the food security status of participating farmers. Further, informal guided face-to-face discussions were conducted with six of the surveyed farmers to access the social and cultural acceptability of the developed feed ration and by-product feeds in general. Results from the survey show that 85% of participating farmers are food secure and 15% are food insecure. Further, 85% of Blackbelly sheep farmers rear their animals on farmland that is less than 1 hectare; this includes farmers that are landless and land-limited. Farmers in the land-limited category (< 1 ha) are 18% more likely to be food insecure that those farmers who are not land-limited (> = 1 ha). Moreover, food insecure farmers tend to have a lower animal livestock diversity (1.67) than those who are food secure (2.41). Additionally, farmers who use a combination of by-product feeds/ingredients and commercial concentrates to feed their animals are more likely to be food insecure than those who use by-products or commercial concentrate feeds only. Lastly, the survey revealed that 14% of farmers use a commercial concentrate feed(s) because it is reliable, 24% say it is practical, but 62% of the interviewed farmers only use these feeds because there is no other true alternative feed source. Results from the guided face-to-face discussion show that Blackbelly sheep farmers have either used or are currently using by-product feeds or ingredients to feed their animals. The majority of farmers find by-product feeds to be cost-effective, not excessively labour intensive and have the potential to produce weight gain results equivalent to those resulting from concentrate feeds. All farmers who participated in the discussion expressed interested in the by-product ration proposed in this research and would be willing to try using the formulation in their daily farming routines. Farmers also stipulated being further encouraged in using a by-product feed if they had access to a COOP mixing service, workshops and training opportunities as well as informative brochures.

Future research should aim to continue performing feed trials with the island's local sheep breed and supplement some or all of the ingredients used in this by-product ration with ingredients that are grown locally. It would also be interesting to attempt a scale up project with Barbadian Blackbelly sheep producers using the by-product ration proposed in this research to verify if the methodology and expected results established in this trial translate well into the daily production systems of local farmers. Additional research should be done to assess the food security status of farmers who rear livestock other than Blackbelly sheep, thus providing a more well-rounded and comprehensive understanding of the prevalence of food insecurity amongst Barbadian livestock farmers. Supplementary research could also be done to assess the nutritional soundness of diets and foods consumed by Barbadian livestock farmers. This could perhaps provide complementary information that could be used to address some of the issues regarding the increased incidence of diabetes and obesity on the island.

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APPENDIX

Section 1 – Feed Trials

Feed Trial # 1

<u>Recorded Weekly Sheep Weight</u>

Obs	Pen	Treatment	ID	Week_0	Week_1	Week_2	Week_3	Week_4	Week_5	Week_6	Week_7
1	1a	3	3586	32	34.5	34	37	37	40	42	42
2	1a	3	3628	24	24.5	25.5	28.5	29	32	32	33
3	1a	3	3576	22.5	23	23	25	26	27	28.5	27
4	1a	3	3578	35	34.5	35.5	37	37.5	40.5	42	40
5	1a	3	3602	26	26.5	27.5	29	30.5	32	34	34.5
6	1a	3	3621	31	30	31.5	35	35	39	40.5	41
7	1b	1	3633	23	23.5	24.5	26	29.5	31	35	35
8	1b	1	3623	27.5	28	30	31.5	32	36.5	38	39.5
9	1b	1	3587	21	21.5	21.5	24	26	29	31	33.5
10	1b	1	3622	28	28	29.5	31	34.5	36.5	39	41.5
11	1b	1	3641	29	28.5	29.5	30.5	33	36	40	41.5
12	1b	1	3313	24	25	25	28.5	29.5	30.5	34	35.5
13	1c	2	3630	19.5	21	21	21.5	24	26	28.5	28.5
14	1c	2	3603	27	28.5	29	30.5	33	34	37	35.5
15	1c	2	3605	28.5	29.5	29.5	31	34	36	37.5	37.5
16	1c	2	3649	24	25.5	26.5	28	29.5	31	33.5	34
17	1c	2	3651	24	25.5	27.5	30	33	35	37.5	36.5
18	1c	2	3581	25	26.5	27	29	30	32	34.5	34
19	2a	2	3693	14	14.5	16	17.5	19	20.5	22	23
20	2a	2	3687	23	22.5	26	27.5	29.5	31	34	34.5
21	2a	2	3676	13	14	15	16.5	18	20	21.5	21.5
22	2a	2	3648	30.5	30.5	33.5	36.5	36.5	38	41.5	42
23	2a	2	3709	12.5	14	15	16.5	18.5	20.5	22	24
24	2a	2	3613	26.5	26	28.5	30.5	32.5	34	37	39
25	2b	3	3666	20	21	22.5	22.5	25.5	28.5	29.5	30.5
26	2b	3	3674	21.5	21.5	23.5	26.5	28	30.5	31.5	33
27	2b	3	3612	19.5	20	22	25	26	29	30.5	30
28	2b	3	3717	10	10.5	11	12.5	14	15.5	17.5	18.5
29	2b	3	3696	21.5	21.5	22.5	24	26	27.5	29.5	29.5
30	2b	3	3647	25.5	25	27	30	30.5	33	34	34
31	2c	1	3716	12	13.5	15	16	17.5	20	21	23
32	2c	1	3624	17	19	20.5	22	23	26.5	28	29.5
33	2c	1	3652	22	22.5	25	27	29	31	32	34.5

34	2c	1	3684	17	19	20.5	21	24	26.5	29	30
35	2c	1	3664	21	21.5	24.5	26	28	31	33	32.5
36	2c	1	3704	15	16	17	19.5	20.5	22	24.5	25.5
37	5a	2	3636	25	26.5	27.5	29.5	31	34	36.5	34.5
38	5a	2	3713	17	18	19.5	20.5	22	25	25.5	27
39	5a	2	3663	25	28.5	30	30.5	34.5	37	39	39
40	5a	2	3656	24.5	25.5	27.5	28.5	31	34	37	36.5
41	5a	2	3575	22.5	24	25.5	27.5	29.5	32	34	35
42	5a	2	3703	25	25	27	28.5	30.5	32.5	34	33.5
43	5b	1	3572	26.5	27	30	32.5	33.5	35.5	37.5	38.5
44	5b	1	3585	35.5	37	40	43	44	45.5	47	48
45	5b	1	3617	18	19	21.5	23.5	26.5	28.5	30	31.5
46	5b	1	3631	23	21	17.5	.	.	.	.	.
47	5b	1	3314	25.5	26.5	30	31.5	33.5	35.5	37.5	39
48	5c	3	3315	23.5	25	27	28	30	32.5	34.5	34.5
49	5c	3	3611	22.5	22.5	23.5	27.5	29.5	32	34	33
50	5c	3	3710	19	20.5	21.5	22.5	26	29	30	30
51	5c	3	3660	23	22	24.5	27	28.5	31	32	32
52	5c	3	3711	22	22.5	25	26	28.5	31	32.5	33

SAS Code: Using Initial Weight as a Covariate; ar(1)

```
proc sort data = ds3;
by treatment pen id week;
run;

data ds4;
retain IWt;
set ds3;
by treatment pen id week;
if (first.id) then do;
IWt = wt;
end;
run;

data ds5;
set ds4;
if (week ge 1);
run;

proc mixed data = ds5 lognote;
class treatment pen id week;
model wt = IWt week treatment treatment*week/ ddfm=kr htype=1;
random pen(treatment);
random id(treatment pen);
repeated week/type = ar(1) subject = id(treatment pen);
lsmeans treatment*week / pdiff adjust = scheffe slice = week;
run;
```

Type 3 Tests of Fixed Effects

Effect	Numerator Degrees of Freedom	Denominator Degrees of Freedom	F-Value	Pr > F
IWt	1	32.4	965.90	<0.0001
Treatment	2	4.99	2.41	0.1854
Week	6	184	300.61	<0.0001
Treatment*Week	12	211	3.38	0.0002

Pairwise Differences (SAS Results Output)

Obs	Effect	Treatment	week	_Treatment	_week	Estimate	StdErr	DF	tValue	Probt
1	Treatment*week	1	1	2	1	-0.3789	0.5632	8.98	-0.67	0.5180
2	Treatment*week	1	1	3	1	0.2876	0.5697	9.39	0.50	0.6253
3	Treatment*week	2	1	3	1	0.6665	0.5637	9.01	1.18	0.2673
4	Treatment*week	1	2	2	2	-0.3528	0.5632	8.98	-0.63	0.5466
5	Treatment*week	1	2	3	2	0.4640	0.5697	9.39	0.81	0.4355
6	Treatment*week	2	2	3	2	0.8168	0.5637	9.01	1.45	0.1812
7	Treatment*week	1	3	2	3	0.01950	0.5663	9.14	0.03	0.9733
8	Treatment*week	1	3	3	3	0.3020	0.5727	9.54	0.53	0.6100
9	Treatment*week	2	3	3	3	0.2825	0.5637	9.01	0.50	0.6283
10	Treatment*week	1	4	2	4	0.006355	0.5682	9.22	0.01	0.9913
11	Treatment*week	1	4	3	4	0.8477	0.5745	9.64	1.48	0.1720
12	Treatment*week	2	4	3	4	0.8413	0.5637	9.01	1.49	0.1697
13	Treatment*week	1	5	2	5	0.3804	0.5692	9.28	0.67	0.5203
14	Treatment*week	1	5	3	5	0.7495	0.5756	9.69	1.30	0.2229
15	Treatment*week	2	5	3	5	0.3691	0.5637	9.01	0.65	0.5290
16	Treatment*week	1	6	2	6	0.3875	0.5699	9.31	0.68	0.5131
17	Treatment*week	1	6	3	6	1.5377	0.5762	9.72	2.67	0.0241
18	Treatment*week	2	6	3	6	1.1502	0.5637	9.01	2.04	0.0717
19	Treatment*week	1	7	2	7	1.6260	0.5704	9.32	2.85	0.0184
20	Treatment*week	1	7	3	7	2.8840	0.5767	9.74	5.00	0.0006
21	Treatment*week	2	7	3	7	1.2580	0.5637	9.01	2.23	0.0525

Feed Trial # 2

Recorded Weekly Sheep Weight

Obs	Pen	Treatment	ID	Week_0	Week_1	Week_2	Week_3	Week_4	Week_5	Week_6	Week_7	Week_8	Week_9
1	1a	3	3795	16.5	18.5	17.5	20	21.5	23	25.5	28	30.5	32
2	1a	3	3797	29.5	31	33	34.5	38	39	41.5	43.5	45	46.5
3	1a	3	3826	19.5	21	21.5	24	26	29	31	34	34.5	36.5
4	1a	3	3824	11.5	13.5	15	16	17.5	19	21.5	23.5	25	26.5
5	1a	3	3784	37	38.5	39.5	41	42	42.5	44	45.5	45.5	45.5
6	1b	1	3753	26.5	28	29	31	33	36	39.5	39.5	39.5	42
7	1b	1	3744	15	16.5	16.5	18.5	20	23	25.5	26	27	30
8	1b	1	no tag	33.5	35.5	37	41	42	43.5	45	47	47.5	49.5
9	1b	1	3748	26	28.5	30	31	33	36.5	40	41	41.5	44
10	1b	1	3769	20	21	21.5	22.5	25.5	27	29	31	31.5	33
11	1c	2	no tag	28.5	31	31.5	33	34.5	37	38	39.5	41	42.5
12	1c	2	3779	32.5	35	35.5	37.5	39	40.5	42	42	42	45
13	1c	2	3733	20.5	22	22.5	24	25.5	28	29	30.5	32	34.5
14	1c	2	3758	24	26.5	28.5	29.5	30	33	35	35	37	39
15	1c	2	3741	20.5	22.5	23	26	28.5	30	33	35.5	36	38.5
16	2a	2	3780	30	31.5	31.5	34.5	34.5	36	37	38.5	39	41.5
17	2a	2	3821	26.5	30.5	31	34.5	34.5	37	38.5	41.5	41	45
18	2a	2	no tag	31	33	34	36.5	37.5	40.5	41	42.5	42.5	44.5
19	2a	2	3808	20.5	21	21	22.5	22.5	26	27	29.5	29	31
20	2a	2	3787	29	30	31	33.5	33.5	37	37	37	38.5	40.5
21	2b	3	3774	29	31	31.5	32.5	35	36	35.5	36.5	37.5	39
22	2b	3	3800	30.5	31	33.5	34.5	35	37.5	40	40	40.5	42.5
23	2b	3	3801	28	30	31	32.5	33.5	34.5	35.5	38	39.5	40.5
24	2b	3	3825	12.5	13.5	13	14	15	17.5	19	20	21	22.5
25	2b	3	3764	25	28	29	30.5	31.5	33.5	35.5	36.5	37.5	39
26	2c	1	no tag	28	30.5	32.5	33.5	37.5	38.5	42	42.5	42	44.5
27	2c	1	3791	32	36	37	39.5	42	43.5	45	46	44	44
28	2c	1	3831	22	23.5	23.5	26	29	32	35	38.5	36.5	42
29	2c	1	3811	12.5	13.5	13.5	14	14	15.5	16	17	18	19.5
30	2c	1	3832	12.5	14.5	15.5	17.5	19	22	24	26.5	26.5	29.5
31	5a	2	3734	21.5	22	23	25.5	25.5	28.5	31	31	31	33
32	5a	2	3761	22	23.5	24	26	26	27	27	30	30	32
33	5a	2	3759	15	16	16.5	17	18	20	22.5	23	25.5	27.5
34	5a	2	3740	25	27.5	28	30.5	32	35	38.5	41	41.5	45
35	5a	2	3731	26	27	28.5	31	32	34	38	39.5	41.5	42.5
36	5b	1	3736	24	26	27	29.5	31	32	34	37	37.5	38.5
37	5b	1	3720	28.5	30.5	32	33	35	36	38	41	42	43
38	5b	1	3742	20	20.5	21.5	23.5	24	27	30	32	32	34
39	5b	1	3762	26	29	30	33.5	33.5	36	38	40	41	42
40	5c	3	3738	26.5	28	28.5	31	33	34.5	36.5	37.5	39.5	39.5
41	5c	3	3726	18	19	20	21.5	23.5	26.5	29.5	30	32	33.5
42	5c	3	no tag	27	29.5	30	32.5	34.5	37.5	39	40.5	43.5	42.5
43	5c	3	3767	22	23	25	27.5	29	31	32.5	34	36.5	37

SAS Code: Using Initial Weight as a Covariate; ar(1)

```
proc sort data = ds3;
by treatment pen id week;
run;

data ds4;
retain IWt;
set ds3;
by treatment pen id week;
if (first.id) then do;
IWt = wt;
end;
run;

data ds5;
set ds4;
if (week ge 1);
run;

proc mixed data = ds5 lognote;
class treatment pen id week;
model wt = IWt week treatment treatment*week/ ddfm=kr htype=1;
random pen(treatment);
random id(treatment pen);
repeated week/type = ar(1) subject = id(treatment pen);
lsmeans treatment*week / pdiff adjust = scheffe slice = week;
run;
```

Type 3 Tests of Fixed Effects

Effect	Numerator Degrees of Freedom	Denominator Degrees of Freedom	F-Value	Pr > F
IWt	1	40.5	537.68	<0.0001
Treatment	2	42.6	1.20	0.3126
Week	8	316	174.35	<0.0001
Treatment*Week	16	317	2.84	0.0002

Pairwise Differences (SAS Results Output)

Obs	Effect	Treatment	week	_Treatment	_week	Estimate	StdErr	DF	tValue	Probt
1	Treatment*week	1	1	2	1	0.2153	0.7936	67.1	0.27	0.7870
2	Treatment*week	1	1	3	1	0.3009	0.8045	67.3	0.37	0.7096
3	Treatment*week	2	1	3	1	0.08553	0.7922	67.2	0.11	0.9143
4	Treatment*week	1	2	2	2	0.4439	0.7936	67.1	0.56	0.5778
5	Treatment*week	1	2	3	2	0.3366	0.8045	67.3	0.42	0.6770
6	Treatment*week	2	2	3	2	-0.1073	0.7922	67.2	-0.14	0.8926
7	Treatment*week	1	3	2	3	0.2748	0.7936	67.1	0.35	0.7302
8	Treatment*week	1	3	3	3	0.5866	0.8045	67.3	0.73	0.4685
9	Treatment*week	2	3	3	3	0.3117	0.7922	67.2	0.39	0.6952
10	Treatment*week	1	4	2	4	1.2248	0.7936	67.1	1.54	0.1275
11	Treatment*week	1	4	3	4	0.6937	0.8045	67.3	0.86	0.3916
12	Treatment*week	2	4	3	4	-0.5311	0.7922	67.2	-0.67	0.5049
13	Treatment*week	1	5	2	5	0.9677	0.7936	67.1	1.22	0.2270
14	Treatment*week	1	5	3	5	0.9794	0.8045	67.3	1.22	0.2277
15	Treatment*week	2	5	3	5	0.01172	0.7922	67.2	0.01	0.9882
16	Treatment*week	1	6	2	6	1.6225	0.7936	67.1	2.04	0.0448
17	Treatment*week	1	6	3	6	1.4794	0.8045	67.3	1.84	0.0703
18	Treatment*week	2	6	3	6	-0.1430	0.7922	67.2	-0.18	0.8573
19	Treatment*week	1	7	2	7	1.9034	0.7936	67.1	2.40	0.0193
20	Treatment*week	1	7	3	7	1.6937	0.8045	67.3	2.11	0.0390
21	Treatment*week	2	7	3	7	-0.2097	0.7922	67.2	-0.26	0.7921
22	Treatment*week	1	8	2	8	1.2439	0.7936	67.1	1.57	0.1217
23	Treatment*week	1	8	3	8	0.3366	0.8045	67.3	0.42	0.6770
24	Treatment*week	2	8	3	8	-0.9073	0.7922	67.2	-1.15	0.2562
25	Treatment*week	1	9	2	9	1.0153	0.7936	67.1	1.28	0.2052
26	Treatment*week	1	9	3	9	1.3366	0.8045	67.3	1.66	0.1013
27	Treatment*week	2	9	3	9	0.3212	0.7922	67.2	0.41	0.6864

Section 2 – Social & Cultural Acceptability

CONSENT FORM – SURVEY (READ BEFORE QUESTIONNAIRE)

McGill University

Title of Research: Local Feed Alternative in Barbados Blackbelly Sheep Production
Researcher: Stephanie Trempe, MSc candidate, Dept. Animal Science
Contact Information : Email : stephanie.trempe@mail.mcgill.ca
Student Supervisors:

1) Hugo Melgar-Quiñonez; Tel: 514-398-7671 ; Email: hugo.melgar-quinonez@mcgill.ca
2) Sergio Burgos : Tel : 514-398-7802 ; Email : sergio.burgos@mcgill.ca

Hello, my name is Stephanie Trempe and I am a graduate student from McGill University. I am currently working in collaboration with IICA, the Ministry of Agriculture Greenland Livestock Research Station, McGill University and Bellairs Research Institute on a research project involving Blackbelly sheep.

The objective of this project would be to develop a by-product formulation that would produce equivalent or higher sheep weight gain in comparison to the commercial concentrate alternative. This project is comprised of two main components. The first consists of a feed trial, where 60 experimental rams will be fed one of three diets (Control - 100% Commercial Concentrate, 50% Commercial Concentrate & 50% By-product Feed, 100% By-product Feed) and their weights monitored closely over a period of 9 weeks. The second component involves the social and cultural acceptability of the project.

I will be asking you a series of questions relating to food security and your own personal livestock production system. The time and length of the survey will be at your own convenience and should not take longer than 20 minutes.

The results of this project will be disseminated via thesis, scientific journal article(s), brochures, presentations, conferences and poster sessions in scientific meetings. I do not foresee there being any risks to farmers participating in this survey.

Your participation in this survey is completely voluntary and you may choose to refuse to answer any question(s) and/or withdraw from the surveying process at any time. Anything you say throughout this process will only be connected to you with your permission, otherwise the information will be reported such that direct association with yourself will be impossible. This will be accomplished by attributing your name to a five-digit farmer identification code. Also, with your permission, I would like to record (audio-tape) the interview. This will be only to ensure to that the information written on the hard-copy of the questionnaire is accurate and to be used as a reference in the occasion that the hard-copy is lost. This audio file along with the farmer identification file will be stored in a password-protected file on a password-protected computer and will only be accessible to myself and my supervisors. The hard-copies of the survey will be kept in a locked location only accessible to myself and my supervisors. Further, as this project is a pilot study, there will be no compensation available for participating farmers.

Please contact me at the coordinates listed above if you have any questions about this study.

Do you understand the above, and if so, do you agree to participate in this study and be interviewed?

Your signature below serves to signify that you agree to participate in this study.

Consent: I agree to be audiotaped ____YES ____NO

I understand the above information and I agree to participate in this study

Signature: __________________
Printed Name: ______________________
Date: _______________________

If you have any questions or concerns about your rights or welfare as a participant in this research study, please contact the Manager, Research Ethics at 514-398-6831 or Lynda.mcneil@mcgill.ca.

SURVEY

Farmer Name: ______________________________ Farmer ID #: _ _ / _ _ _

Date: _ _ / _ _ / 2016

Component 1. MEASURING FOOD INSECURITY THROUGH PEOPLE'S EXPERIENCES - VOICES OF THE HUNGRY (FAO)

During the last 12 months, was there a time when, because of a lack of money or other resources:

The FIES Questionnaire	**Yes = 1** **No = 0**
1. You were worried you would not have enough food to eat?	
2. You were unable to eat healthy and nutritious food?	
3. You ate only a few kinds of foods?	
4. You had to skip a meal?	
5. You ate less than you thought you should?	
6. Your household ran out of food?	
7. You were hungry but did not eat?	
8. You went without eating for a whole day?	

Component 2. LIVESTOCK PRODUCTION

Section 1: Animals & Livestock Production

	Unit of Measure
1. How much agricultural land have you had access to in the last 12 months?	
2. How much of the agricultural land have you dedicated to livestock production in the last 12 months?	

	3. Over the last 12 months, have you actively participated in livestock breeding or production?	**Yes = 1 No = 0**	4. How many [*animal(s)*] do you currently have on your farm? *INDICATE THE TOTAL **QUANTITY***	5. How do you use your [*animal(s)*]? *For your own consumption……………1* *Sale………………………………………2* *Field work………………………………3* *Reproduction……………………………4* *Breeding for sale (auction)…………5* *Other (specify) – <u>prepare other choices as the surveying process progresses.</u>* *Ex: gift,*
A	Cows			
B	Goats			
C	Sheep			
D	Chicken			
E	Turkey			
F	Rabbits			
G	Pigs			
G	Other (Specify)			
G1				
G2				
G3				

Section 2: Animal By-products & Egg Production

	6. Over the last 12 months, have you produced [*product]* ?	**Yes = 1 No = 0**	7. How much [*product*] have you produced in the last 12 months? *INDICATE THE* ***WEIGHT****, THE* ***VOLUME*** *OR THE* ***QUANTITY*** *FOLLOWED BY THE* ***UNIT OF MEASURE (UM)***	**UM**	8. How much of the [*product*] have you consumed in the last 12 months? *INDICATE THE* ***WEIGHT****, THE* ***VOLUME*** *OR THE* ***QUANTITY*** *FOLLOWED BY THE* ***UNIT OF MEASURE (UM)***	9. How do you store your [product]? *Fridge…………1* *Storage bins…..2* *Other (specify)*
A	Cow milk					
B	Goat milk					
C	Cow cheese					
D	Cow yogurt					
E	Butter					
F	Beef					
G	Lamb					
H	Rabbit meat					
I	Chicken meat					
J	Fried chicken					
K	Eggs					
L	Pork meat					
M	Other (Specify)					

Component 3: Feed for Livestock Production

					Unit of Measure or Yes = 1 No = 0
	1. Over the last 12 months, have you used [*feed*] to feed your animals?	Yes = 1 No = 0	2. On average, how much money do you spend on [*feed*] in a month? *INDICATE THE TOTAL ANNUAL* ***COST***	**If answered no** to any of the Pinnacle feeds in questions 1 then skip to question 4. **If answered yes** to any of the Pinnacle feeds in questions 1 then ask the following question: 3. What is the main reason why you use Pinnacle concentrate feeds? *Practicality……………………………1* *Reliability………………………………2* *No other alternative………………….3* *Other (specify) – prepare other choices as the surveying process progresses.* *Ex: gift,*	
A	Mixed hay				
B	Grasses				
C	Pinnacle sheep ration				
D	Pinnacle sheep and goat ration				
E	Molasses				
F	Brewers grain				
G	Wheat middlings				
H	Rice bran				
I	Limestone supplements				
J	Mineral blocks				
K	Mineral supplements				
L	Other (specify)				
	4. How frequently do you purchase your feed(s)?			5. How do you store your feed(s)? *Fridge……………………………………1* *Storage bins.......................................2* *Other (specify)*	

	6. Did you ever grow your own feed ingredients?	**Yes = 1 No = 0**	7. If so, when did you stop? *Indicate month & year*	8. What is the main reason why you stopped growing your own feed ingredients? *Subsidies……………….....................1* *Labor intensive……………………….2* *Did not have adequate equipment......3* *Not enough arable land……………...4* *Other (specify)*
	Mixed hay			
	Grasses			
	Wheat middlings			
	Rice bran			
	Molasses			
	Brewers grain			
	Other (specify)			

Comments and feedback:
Thoughts about by-product recipes?

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CONSENT FORM – GUIDED FACE-TO-FACE DISCUSSION (READ BEFORE DISCUSSION)

McGill University

Title of Research: Local Feed Alternative in Barbados Blackbelly Sheep Production
Researcher: Stephanie Trempe, MSc candidate, Dept. Animal Science
Contact Information : Email : stephanie.trempe@mail.mcgill.ca
Student Supervisors:

1) Hugo Melgar-Quiñonez; Tel: 514-398-7671 ; Email: hugo.melgar-quinonez@mcgill.ca
2) Sergio Burgos : Tel : 514-398-7802 ; Email : sergio.burgos@mcgill.ca

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The objective of this project would be to develop a by-product formulation that would produce equivalent or higher sheep weight gain in comparison to the commercial concentrate alternative. This project is comprised of two main components. The first consists of a feed trial, where 60 experimental rams will be fed one of three diets (Control - 100% Commercial Concentrate, 50% Commercial Concentrate & 50% By-product Feed, 100% By-product Feed) and their weights monitored closely over a period of 9 weeks. The second component involves the social and cultural acceptability of the project.

This guided face-to-face discussion involves a set of pre-determined open questions designed to prompt responses on the topic of by-product feeds in general along with all possibilities of their utilization and implementation in livestock production. The qualitative information collected throughout this process will be used to improve the project methodology and by-product recipe. This informal discussion should last no more than 10-15 minutes.

The results of this project will be disseminated via thesis, scientific journal article(s), brochures, presentations, conferences and poster sessions in scientific meetings. I do not foresee there being any risks to farmers participating in this discussion.

Your participation in this guided face-to-face discussion is completely voluntary and you may choose to refuse to answer any question(s) and/or withdraw at any time. Also, with your permission, I would like to record (audio-tape) the interview. This will be only to ensure to that all shared information and farmer feedback on the project has been correctly interpreted. This audio file will be stored in a password protected file on a password protected computer and will only be accessible to myself and my supervisors. Further, as this project is a pilot study, there will be no compensation available for participating farmers.

Please contact me at the coordinates listed above if you have any questions about this study.

Do you understand the above, and if so, do you agree to participate in this study?

Your signature below serves to signify that you agree to participate in this study.
Consent: I agree to be audiotaped ____YES ____NO

I have read the above information and I agree to participate in this study

Signature: __________________

Printed Name: ______________________

Date: _______________________

If you have any questions or concerns about your rights or welfare as a participant in this research study, please contact the Manager, Research Ethics at 514-398-6831 or Lynda.mcneil@mcgill.ca.

INFORMAL FACE-TO-FACE DISCUSSION

Date: _ _ / _ _ / 2016

Social & Cultural Implementation of a By-Product Feed (Qualitative)

1. Have you ever used a by-product mixture to feed your animals?
2. Did you stop because it was costly?
3. Did you stop because it was labour intensive?
4. Did you stop because it did not produce optimal weight gain?
5. Would you be willing to try implementing an equivalently nutritious, cost effective and sustainable by-product feed alternative?
6. Would access to a mixer encourage you to implement the by-product mixture?
7. Would instructional workshops providing information on how to mix and store the dry feed ingredient make you more willing to implement the by-product recipe?
8. What would you need in a by-product mixture for you to actually want to implement it into your daily farming routine?
9. How frequently would you be willing to come by Greenland to mix your by-product feed?

Comments and feedback on the by-product mixture:

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