CONTRIBUTION 1.1

Driving the Circular Economy by Transforming Fish Offal ("fish waste") through Processing: a Barbadian Case Study for Resource Optimization in the Caribbean Region

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Abstract

Fish by-products constitute between 30–70 percent of fish after being processed into fillets and other edible products and were previously considered to be waste. In Barbados, approximately 5 tonnes of these fish parts are generated daily; the largest share of which is redirected to the landfill. The direct impacts include the environmental burden of the waste, since the decomposing offal produces abundant quantities of methane, a gas with an estimated 20 times more global warming potential than carbon dioxide, thus contributing to climate change. Another major consideration is the continued demand for landfill space in circumstances of land scarcity within the context of SIDS. This waste is a missed opportunity for transforming the previously untapped raw materials into valuable food and silage-derived products (feed and fertilizer). These lost opportunities are increasingly important in a world with rising food, feed and fertilizer costs impacting farmers and consumers alike.

The FAO and partners from national and regional institutions have been working to optimize the recovery process of the fish waste while establishing the safety, comparative growth performance and cost efficiency of fish silage-derived feed relative to imported feed, and their cost efficiency. Awareness of this prompted the establishment of a national fish silage platform, leading to the integration of the fish waste utilization concept in the 2022-2030 Fisheries Policy of Barbados, capacity building of women fish processors, inclusion of small-scale farmers and investment for scaling up.

The pipeline support to the establishment of a national fish silage reference training centre, and incubator unit for young farmers would further widen the potential for expansion of this innovative approach. It holds promise for other countries in the Caribbean region, given that livestock feed importation and fish processing are common to all CARICOM countries. Creating new revenue streams, coupled with the environmental and social benefits of fish waste recovery, as compared to dumping, can contribute to the realization of the commitment of CARICOM to reduce the region's large and unsustainable extra-regional food import bill by 25% by 2025 and is well aligned with the 2030 Agenda for Sustainable Development.

KEYWORDS: circular economy, fish waste, fish silage, feed, agribusiness

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1. INTRODUCTION

The findings of the feasibility study done by Drakes *et al*. (2020) on fish silage production and use in the Caribbean (Barbados and Saint Kitts and Nevis), which revealed that approximately 5 tons per day of fish parts are mostly discarded in the landfills, suggested that there is potential for transforming these raw materials into a valuable resource with potential to generate income through the production of fish silage. This work identified an entry point for locally-produced feed and fertilizer resources for livestock, agriculture and aquaculture production. According to that study, there was consensus among all livestock and aquaculture farmers surveyed that the cost of feed from local suppliers in Barbados is restrictive and presents a major barrier to profitability especially for smallholder farming.

Fish silage is a rich protein hydrolysate that contains high amounts of essential amino acids, is a less expensive alternative to fishmeal and fish oil, and it is increasingly used as a feed additive, for example, in aquaculture and the animal-food industry. By using a technology such as fish silage, fish and parts of the fish not used as human food could easily be preserved and transformed into a valuable feed input (Toppe *et al*., 2018). It is produced as a liquid product from the whole fish or parts of it (waste) to which acids, enzymes or bacteria are added, which over time changes the mass from solids to liquid by breaking down the components at a low pH. For the animal feeding trials in this study, fish silage composition included: fish waste, molasses and EM1 (Effective Micro-organism 1). Fish waste was ground, weighed and then mixed with molasses and a culture of micro-organisms (EM1) at 15% and 5% of the fish waste weight, respectively. The mix was then fermented for 72 hours in a vacuum tumbler. The resulting product is a brownish red liquid, which smells like anchovies or fish sauce. This fish silage was then mixed with water to produce fertiliser, or further combined with other components (moringa, wheat middling, river tamarind, etc.) and pelletised to produce livestock feed.

The opportunities involved in transforming the discarded raw material from fish processing into a valuable resource include supplementary agribusiness and income generation, contributions towards realizing CARICOM's goal of reducing the extra-regional food import bill by 25% by 2025 while simultaneously easing the local and regional feed import dependence and foreign exchange demand pressure, as well as other environmental, economic and land use impacts. In the context of Small Island Developing States (SIDS), land committed as landfills and waste sites impact its demand for other productive activities. The Barbados case also supports the government's zero-waste goals while incorporating two key stakeholder groups: Central Fish Processors Association (CFPA) and the Barbados Ruminant Farmers Society (BRFS).

Beginning in 2019 as a collaborative effort of the FAO, the Barbados Ministry of Maritime Affairs and the Blue Economy, and the Argentina government, the project sought to assist local fish vendors in recognising the benefits of silage production, as well as determine best practices with respect to reducing fish wastage. Following up on this capacity building, the FAO engaged with the Caribbean Agriculture Research and Development Institute (CARDI) for animal feeding trials to determine the safety and comparative growth performance of fish silage-derived feed as compared to imported feed. A national fish silage (FLW) platform was established for sharing of information and experience. Since mid-2022, PLA Inc., a non-profit organization representing a collective of ruminant and livestock farmers and providing project management services, together with the BRFS have been providing support for on-farm operations with a business case, capacity development and strengthening the fishers (supplier) and farmers (user) of silage and feed connectivity for the optimization and promotion of livestock and other areas of national food security interest.

The CFPA, an all-women's fisherfolk association, was trained in fish silage production and feed formulation utilising raw materials of their post-harvest operations. Conclusive on-farm feeding of rabbits was completed in 2022, including introduction to school children as part of the Ministry of Youth, Sports and Community Empowerment's Pathway to Employability Initiative. Trials involving pigs and black belly sheep were completed in May 2023.

In the global food industry, there are several value-added options available for edible fish meat including minced fish meat, wieners, cutlets, balls, pickle, soup powder, wafers, ready-to-serve preparations in flexible pouches, and pet foods. However, the key stakeholders in Barbados identified with an initial interest in exploring the production of fish silage and its application for fish silage-based livestock feed and liquid bio-fertilizer.

The focus of FAO assistance was therefore on improving practices to add value to the fish harvests by utilizing fish waste for improved returns and new revenue streams for fishers, fish workers and agriculture (livestock and crops) smallholder farmers. Further, the incorporation of fish silage into local feed production with the direct involvement of farmers do-it-yourself labour showed an improved cost of production over the imported feed option. This allowed stakeholders to better leverage the environmental and social benefits of the recovery, without increasing the fishing pressure to create new value-added and derived products.

2. METHODOLOGY

The main approach included the identification of key stakeholders of the fish silage value addition effort in Barbados, pathways to associated business opportunities, requests for support from the FAO by smallholder farmers (including youth) to pursue the utilization of the raw materials from fish processing into livestock feed, and the conceptualization of a Cluster Development Model as presented in Figure 1 below. Put together, this was the catalyst for understanding the demand for feed alternatives, identifying clusters of stakeholders interested in production and use of fish silage-derived feeds and engaging with their need for farm-level support, capacity building and empowerment.

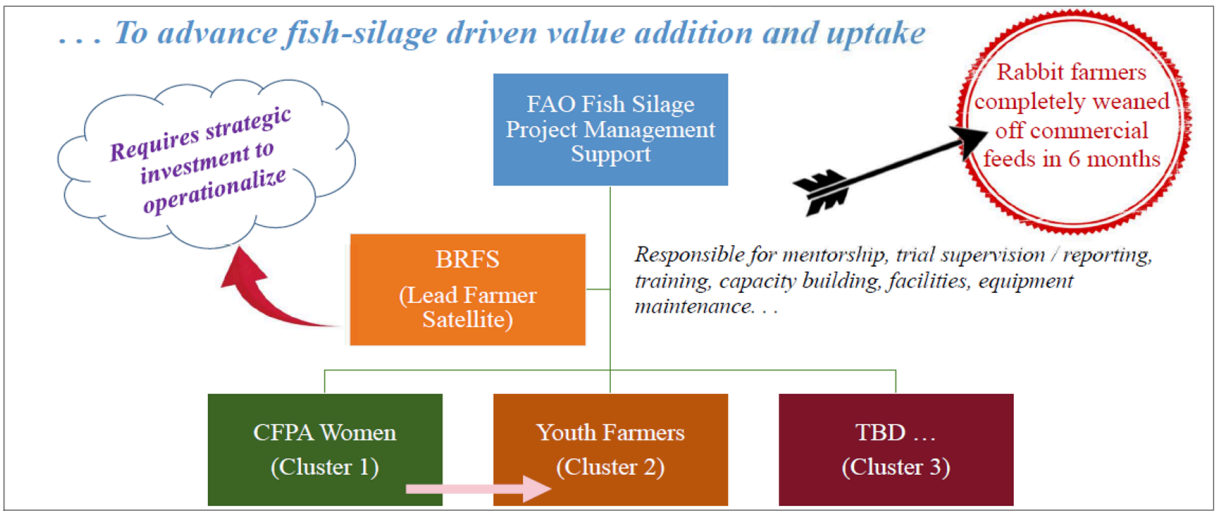

Figure 1. Cluster Development Model

The experience demonstrated that scaled-up business opportunities in fish silage value addition in Barbados require significant financial and technical resources. It is therefore more feasible and lends greater sustainability and inclusivity to approach fish silage production as a cluster operation rather than targeting individual farmers or their representative organizations in isolation. The CFPA was presented with different options as entry points and possibilities for

integration in the value chain based on the information available and interactions with other stakeholders as illustrated in Figure 2 below.

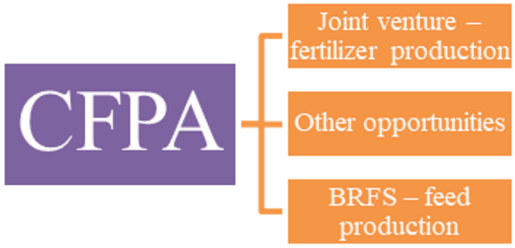

Figure 2. CFPA Entry Points for Integration in the Fish Silage-derived Value Chain

A private sector fish processing company involved in the consultations acknowledged and demonstrated the capacity to pursue the development of a liquid fertilizer product. The CFPA expressed an interest in independently pursuing an enterprise based on their fish processing industry experience and, more so, the skills acquired through the FAO in fish silage and fish silage-derived livestock feed production. This further guided the focus of this study into livestock feed production.

A strategic and valuable opportunity therefore arose in the form of supporting the fish workers and smallholder livestock farmers with the capacity to produce livestock feeds, integrate their operations, and tentatively impact the cost of production, profitability and consistency in quality and volume of feed available to their farm business. The approach may hold in the short to medium-term to allow for critical mass and fresh investment flows which can cause a re-orientation of the value chain in the longer term as the fish raw material processing industry is established in Barbados.

Summarily, it became necessary to analyse the business opportunities in fish silage-based feed production with respect to cost of production (COP), profitability, market sensitivity and competitiveness. The methodology for analysis encompassed:

1. Development of a COP methodology and analysis for fish silage and fish silage-derived feed rations considering the participation of both the farmer clusters and the CFPA in this business pathway. This considered key cost centres and established assumptions based on various identified scenarios such as: proposed user fees for processing facility, utilities, production space, in-kind contributions of labour and fish processing raw materials, and ration formulation for analysis;
2. Incorporation of COP analysis into a wider business profile, compared to market pricing of imported feeds in order to observe the profitability and scale of the fish silage-derived business in Barbados.

3. RESULTS

3.1 Cost of Production for Fish Silage and Fish Silage-derived Feeds

For both scenarios, CFPA or farmer clusters participating in feed production activities, the cost of production per unit can be improved if the volume of production per cycle is increased. This is achievable with an upgraded equipment capacity, operating space and consideration of drying and storage. The demand for feed and therefore expanded production output will happen through public education and awareness targeted to existing smallholder farmers who previously and otherwise would not have access and knowledge of this type of feed. The formulations are also very important to note. To produce 100lbs of fish silage, 83.3% or 83.3lbs of raw material from fish processing is required. However, much less of this fish silage is utilized in the current production schedules. Rabbit ration requires 6% or 6lbs of fish silage while the sheep ration utilizes 13% or 13lbs of fish silage; both with the aim of producing 100lbs of animal ration each. This suggests that several runs of feed production can be done successfully from the initial fish silage production or, alternatively, proposing the option of developing a marketable product of fish silage for possible sale to fertilizer production in

Barbados or eventual export to other eastern Caribbean countries with perhaps less organized fish processing activities or access to clean, quality raw materials.

3.2 Disaggregated CFPA Cost of Production

Table 1 presents the cost summary for one fish silage production cycle for the CFPA. For this cluster, there are several variations which will impact their operations. Firstly, all bone meal, a commercial by-product or the "sawdust" from the serrated band-saw blade is currently purchased from the commercial fish processors for use in fish silage production. This raw material from fish processing is not currently obtained from CFPA own activities or at the public markets. Lack of equipment capacity to grind the materials was identified. However, if

The production requirements are also different for the CFPA. The COP acknowledges that this cluster is not currently in possession of a production location and therefore will have to identify a suitable site. According to the Barbados Investment and Development Corporation (BIDC), although no factory space is currently available, the current value added tax (VAT) exclusive cost per square foot is BBD[1] 15 per annum. A rental fee for a 2,000 sq. ft. space as well as utility costs are therefore estimated.

A proxy user fee (machine time) of BBD 8.50 was determined in line with the cost of labour per hour. This was considered and discussed early with stakeholders to assist in maintenance and upkeep as well as lending a dimension of sustainability to the project. Increased operating time will increase this revenue stream for the facility. Logistics is the cost associated with supporting production activities such as collecting Bone Meal, River Tamarind, and Other Dry Material Inputs. This is a standard BBD 50 consideration across both clusters under comparison.

Table 1. CFPA: Cost Summary for One Fish Silage Production Cycle

FIXED COSTS

Item	QTY	Unit Cost (BBD)	Total Cost
Machine Time (Proxy User Fee)	3	8.50	25.50
Electricity (per month)	31	900.00	29.03
Water (per month)	31	400.00	12.90
Packaging, Marketing & Distribution	0	NIL	0.00
Rent (2,000 SQ.FT., $15/sq.ft. (annum), VAT 17.5%)	31	2,937.50	94.76
Subtotal Fixed Cost			162.19

VARIABLE COSTS PER PRODUCTION CYCLE

Item	QTY	Cost (BBD)	Unit Cost (BBD)	Formulation (%)	Total Cost per 100lbs (BBD)
Bone Meal (lbs)	100	IN-KIND	0.00	83.30	0.00
Bone Meal (lbs)	100	35.00	0.35	83.30	29.16
Molasses (lbs)	12	2.50	0.21	13.30	2.77
EM1 (lbs)	83.4	125.00	1.50	3.40	5.10
Labour (Workers)	3		68.00		204.00
Logistics	1		50.00		50.00
Subtotal Variable Cost Per Cycle (IN-KIND Raw Material)					$261.87
Subtotal Variable Cost Per Cycle (Purchased Raw Material)					$291.02
TOTAL COSTS per production cycle (IN-KIND Raw Material)					$424.06
TOTAL COSTS per production cycle (Purchased Raw Material)					$453.22
Fish Silage Unit Cost (BBD/lb)					**$4.24**
Fish Silage Unit Cost (BBD/lb)					**$4.53**

[1] It should be noted that the Barbados dollar is tied to the US currency at a rate of BBD 2.02 to USD 1.

Based on a 100lb production cycle, the COP per pound of fish silage is BBD 4.53; however, if the raw materials from fish processing are brought to the business activity as in-kind contribution from the CFPA, the COP can potentially reduce to BBD 4.24 per pound.

Within the 3-hour production cycle, the fish silage is then utilized in the production of fish silage-derived feeds namely a rabbit ration and a sheep ration. There are other business opportunities related to poultry, aquaculture, other livestock and possibly penetrating the pet food market; however, these were not the focus of the feeding trials given time and resource constraints.

Having accounted for the fixed costs of an operating day, Table 2 presents the variable costs associated with the production of 100lbs of rabbit ration. River Tamarind could possibly be considered as an endemic forage available in Barbados. Although it grows wild and abundant, there must be a cost associated with its collection and transport. This cost is already included in logistics and therefore, although itemized for the formulation, it is considered as a task. All other formulation inputs are imported. Perhaps with technical support, locally available substitutes can be identified.

Table 2. CFPA: Cost Summary for Rabbit Ration Production Cycle

VARIABLE COSTS PER PRODUCTION CYCLE					
Item	QTY	Cost (BBD)	Unit Cost (BBD)	Formulation (%)	Total Cost per 100lbs (BBD)
FISH SILAGE (lbs)			4.24	6.00	25.44
FISH SILAGE (lbs)			4.53	6.00	27.19
Soyabean Meal (lbs)	50	55.00	1.10	5.00	5.50
Fresh River Tamarind (lbs)	3	TASK	0.00	35.00	0.00
Wheat Middling (lbs)	80	40.00	0.50	35.00	17.50
Rice Bran (lbs)	80	40.00	0.50	16.00	8.00
Mineral Mix (lbs)	55	100.00	1.82	3.00	5.45
Subtotal Variable Cost Per Cycle (IN-KIND Raw Material)					$61.90
Subtotal Variable Cost Per Cycle (Purchased Raw Material)					$63.65
TOTAL COSTS per production cycle (IN-KIND Raw Material)					$61.90
TOTAL COSTS per production cycle (Purchased Raw Material)					$63.65
Rabbit Ration Unit Cost (BDS$/lb)					**$0.62**
Rabbit Ration Unit Cost (BDS$/lb)					**$0.64**

The COP schedule for 100lbs of rabbit ration shows that the COP per pound is BBD 0.64; however, if the raw materials from fish processing are brought to the business activity as in-kind contribution from the CFPA, the COP can potentially reduce to BBD 0.62 per pound.

A sheep ration can be produced under similar assumptions of in-kind contribution by the CFPA. As presented in Table 3, the COP schedule for 100lbs of sheep ration shows that the COP per pound is BBD 0.97; however, if the raw materials from fish processing are brought to the business activity as in-kind contribution from the CFPA, the COP can potentially reduce to BBD 0.93 per pound.

Table 3. CFPA: Cost Summary for Sheep Ration Production Cycle

VARIABLE COSTS PER PRODUCTION CYCLE					
Item	QTY	Cost (BBD)	Unit Cost (BBD)	Formulation (%)	Total Cost per 100lbs (BBD)
FISH SILAGE (lbs)			4.24	13.00	55.13
FISH SILAGE (lbs)			4.53	13.00	58.92
Soybean Meal (lbs)	50	55.00	1.10	9.00	9.90
Fresh River Tamarind (lbs)	3	TASK	0.00	35.00	0.00
Wheat Middling (lbs)	80	40.00	0.50	20.00	10.00
Rice Bran (lbs)	80	40.00	0.50	8.80	4.40
Corn (lbs)	50	47.00	0.94	8.80	8.27
Mineral Mix (lbs)	55	100.00	1.82	3.00	5.45
Subtotal Variable Cost Per Cycle (IN-KIND Raw Material)					$93.15
Subtotal Variable Cost Per Cycle (Purchased Raw Material)					$96.94
TOTAL COSTS per production cycle (IN-KIND Raw Material)					$93.15
TOTAL COSTS per production cycle (Purchased Raw Material)					$96.94
Sheep Ration Unit Cost (BBD/lb)					**$0.93**
Sheep Ration Unit Cost (BBD/lb)					**$0.97**

At the moment, all farmer training and activities related to fish silage and fish silage-derived feed production are conducted at Graeme Hall, premises of the Ministry of Agriculture, Food and Nutritional Security. The building and utilities are provided for by the government of Barbados for use by the BRFS. This partnership and support to farmers improves the cost of production of feed for this cluster and hence the proposal of empowering livestock farmers, through their mentorship, to become engaged in their own feed production with a view to marketing same in the medium-term. Therefore, in estimating the COP for the farmer cluster, the cost of labour is also considered to be an in-kind contribution. The immediate goal is to wean beneficiary farmers off of imported feeds and thereby reduce feed imports, demand for foreign exchange for this purpose and, as demonstrated, their cost of production.

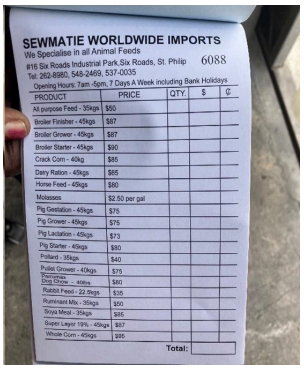

Figure 3. Snapshot of Imported Feed Prices (February 2023)

A comparison of the cost of production and savings by cluster is presented in Table 4 below. An additional product of top-dressing pig ration is identified. In this trial, the fish silage was added as a top-dressing to the imported pig ration; readily accepted by the animal and therefore carries the same cost of production. The farmer cluster COP for all products (Fish Silage, Top-Dressing Pig Ration, Rabbit Ration, and Sheep Ration) is notably less primarily due to the support received through government's involvement with the BRFS and the in-kind contribution of labour. Importantly, the savings to the farmer becoming involved in feed production for own operations as compared to a dependence on imported feeds is relatively higher. For every

100lbs of feed, the farmer is now able to save BBD 26.79 (rabbit ration) and BBD 12.35 (sheep ration). There is a level of savings to the farmer if the CFPA were to become involved in the production of rabbit ration. However, this is for discussion purposes mainly as a selling price from CFPA to farmers was not determined. This can be linked to the fish silage (a high-cost input) in its formulation.

The profitability and competitiveness of the 100lb feed cycle could be scaled against the individual farmer's feed needs. Two important points, mentioned by the youth farmers, were:

Farmers can sell surplus feed from their own production to recoup on their expenditure or as a separate business activity to other smallholders in their districts who may not have the time and flexibility to participate in the production activities, and access to relatively higher quality and cheaper feeds is an incentive to expand the number of heads of livestock in production. The only limitation being access to farmland.

Table 4. Financial Profile: Comparison of Cost of Production and Savings by Cluster

	Farmer Cluster	CFPA (Purchased Fish Raw Material)	CFPA (In-Kind Fish Raw Material)	Price of Imported Equivalent
Cycle Output (lbs of fish silage, derived feeds)	100	100	100	
Cycle Output (Kgs of fish silage, derived feeds)	45.36	45.36	45.36	
Labour (Worker Per Day)	IN-KIND	$68.00	$68.00	
Machine Time (Proxy Service Fee) (BBD/hour)	$8.50	$8.50	$8.50	
Fixed Costs (Per Operating Day)	$25.50	$162.19	$162.19	
Fish Silage Unit Cost (BBD/lb)	$1.13	$4.53	$4.24	$0.00
Top-Dressing Pig Ration (BBD/lb)	$1.13	$4.53	$4.24	$0.00
Rabbit Ration Unit Cost (BBD/lb)	$0.43	$0.64	$0.62	$0.70
Sheep Ration Unit Cost (BBD/lb)	$0.53	$0.97	$0.93	$0.65
Cost to the Farmer (BBD/100lbs):				
Fish Silage	$112.52	$453.22	$424.06	$0.00
Top-Dressing Pig Ration	$112.52	$453.22	$424.06	$0.00
Rabbit Ration	$43.21	$63.65	$61.90	$70.00
Sheep Ration	$52.65	$96.94	$93.15	$65.00
Savings to the Farmer (BBD/100lbs):				
Rabbit Ration	$26.79	$6.35	$8.10	
Sheep Ration	$12.35	-$31.94	-$28.15	

The analysis suggests that while it may be less expensive to use an imported concentrate feed, the ability of the farmer to now substitute input costs provides an incentive for a farmer to seek to leverage the benefits of the proposed cluster approach to feed production. This is only possible through in-kind contribution, FAO support and wider eco-system support through the government of Barbados as well as their overall knowledge of animal nutrition and health in this process.

3.3 Fish Silage and Fish Silage-derived Livestock Feed Production: Potential National Impact

At a national level in Barbados, there is a concern about the approximately 5 tons per day of raw materials from fish processing activities that are mostly discarded in the landfills. Barbados' imports of preparations of a kind used in animal feeding was worth approximately USD 8.2 million in 2022 as presented in Table 5 below. Poultry, pig and other complete animal feeds excluding dog or cat food for retail trade form were the largest demand by volume but are currently not manufactured using fish silage in Barbados. Approximately 2 tons of complete sheep feeds were imported annually until 2019. More recent data on this particular trade was not available. Within the medium term, increasing the processing of up to 1 metric ton or 1,000kgs per day of fish raw materials per day has the potential to eliminate almost 20% of the daily burden on landfills while creating the previously discussed benefits for the circular agricultural economy.

Table 5. Barbados Imports of Preparations of a Kind Used in Animal Feeding (2022)

Product label	Value (USD)	Volume (kgs)
Prepared complete poultry feed	2,636,000	3,505,996
Other food used in animal feeding	2,449,000	769,799
Other prepared complete animal feeds	1,533,000	2,859,411
Prepared complete pig feed	1,004,000	1,748,568
Mixed bird seeds	253,000	160,267
Prepared complete cattle feed	162,000	302,362
Other foods for pets	141,000	32,176
Source: ITC Data		

As presented in Table 6 below, it was estimated that 90% of the raw material is useful for value addition processing or 1.08 million kgs per annum. As presented previously in the COP, the formulation for fish silage requires 83% of fish raw materials. At the moment, per daily cycle (100lbs = 45kgs), only 0.84% of national production can be utilized. Scaling the activity would increase the uptake of raw materials and, by extension, fish silage and fish silage-derived feed production. Increasing capacity (farmer skill training and equipment) and throughput of the production facility carries the potential to make a tangible difference in alleviating the waste problem while strengthening the circular flow of the agricultural economy.

Table 6. Estimated Uptake of Raw Materials from Fish Processing in Barbados

	kgs/ day	Working Days/ Yr	kgs/ Yr	Availability	National (kgs)/ Yr	Utilization of National Raw Material Availability
Estimated Volume of National Raw Material Production	5,000	240	1,200,000	90%	1,080,000	
2023 Current CFPA / BRRMS Demand for Fish Raw Material	45	240	10,886	83%	9,036	0.84%
2024 Target Cluster Demand for Fish Raw Material	500	240	120,000	83%	99,600	9.22%
2025 Target Cluster Demand for Fish Raw Material	750	240	180,000	83%	149,400	13.83%
2026 Target Cluster Demand for Fish Raw Material	1,000	240	240,000	83%	199,200	18.44%

The redirection of this raw material from waste to a valuable resource would now positively impact the domestic production of fish silage and fish silage-derived animal feed. Based on the estimates presented in Table 6, the utilization of the national raw material availability can be considered for fish silage, top-dressing pig ration, rabbit ration and sheep ration based on the formulation requirements. Increasing the uptake of raw materials to 1,000kgs per day with

prompt 18.44% utilization overall. It is worth reminding at this point that these estimates relate to one production facility operating with the support, FAO facilitation and beneficiary stakeholders directly involved. The model is intended to act as a catalyst to expand private sector interest and further uptake of available raw materials.

Table 7. Potential for Fish Silage and Fish Silage-derived Feed Production

Fish Silage-derived Feed Production		**Fish Raw Material (kgs)**	**Fish Silage (kgs)**	
Raw Material to Fish Silage Conversion		38	45	
	2024 Target	99,600	120,000	
	2025 Target	149,400	180,000	
	2026 Target	199,200	240,000	
Fish Silage to Feed Conversion		**Rabbit Ration kgs (6%)**	**Sheep Ration kgs (13%)**	**Surplus for Top-Dressing Pig Ration / Fertilizer / Export Potential kgs (81%)**
	2024 Target	7,200	15,600	97,200
	2025 Target	10,800	23,400	145,800
	2026 Target	14,400	31,200	194,400

The potential for fish silage and fish silage-derived feed production is estimated in Table 7 above. With the formulation for fish silage requiring 83% of fish raw materials, it suggests that 83kgs of fish raw materials go into the production of 100kgs of fish silage. Therefore, based on the proposed targets, of the 99,600kgs of fish raw materials for 2024; 120,000kgs of fish silage can be made available for further value addition. By 2026, a proposed facility processing 1 ton of fish raw materials per day (199,200kgs per year) would be producing 240,000kgs of fish silage. Of this, 194,400kgs is still on-hand to be utilized. At the current rate, it would take 5 years of rabbit and sheep ration production to use this silage volume. Therefore, feed production planning, public education and awareness to increase farmer acceptance at a national level, price setting and other market development and marketing activities are required beforehand.

4. DISCUSSION

Success in the animal feeding trials was measured by farmer satisfaction and education on fish silage-derived feeds, animal acceptance and the growth performance observed during the period. While all three trials were favourable, the results showed that the fish silage-derived ration is at least as effective as the current commercial rations, and that for younger rabbits for example, it promotes weight gain and leads to a heavier fabricated carcass. These strengthen the business outlook and potential for the small farmers involved since they are now able to lower cost of production with a more cost-effective feed option and carry a wholesome product to market.

Generally, rabbit meat is known to have the highest percentage of protein, the lowest percentage of fat and the fewest calories per pound as compared to beef, pork, lamb, turkey, veal and chicken. The Ministry of Agriculture and Food Security has, more so since 2018, been

promoting rabbit meat for local consumption. "I note that the rabbit compares favourably with most other meats, especially with pork, beef and lamb, which are considered poor [health] choices as far as meats are concerned, and it holds its own against chicken as well," was part of the reported feedback in local media. Further public education and awareness can increase future prospects in terms of linking fish silage-derived feed production and the promotion of particular feeding regimes and meat consumption to food and nutrition security implications.

Further, there is now heightened concern by key stakeholders, particularly smallholder farmers of crops and livestock in Barbados and likewise in the Caribbean region, about the rate of price increase and general availability of traditional imported fertilizers and commercial livestock feeds. The CFPA, their project interest and the FAO's continued support towards smallholder farmers, their livelihoods and the utilization of the raw material from fish processing are, therefore, all at a critical juncture.

Building on prior support, a business model as well as the CFPA orientation to the fish silage value addition business (feed production, handling and packaging, market development, marketing and distribution) remains to be addressed holistically in order to steer the CFPA towards operating such an enterprise independently over time. Having identified the opportunities associated and carving the pathway to assist the CFPA towards earning sustainable livelihoods from the raw material processing, effort was put into understanding the CFPA's readiness to operate a business enterprise as well as mapping the eco-system of resources and stakeholders needed to actively develop a fish silage enterprise and value chain in Barbados. This enterprise and industry development require business strategy and networking, technical, financial and other resources to move forward. A stakeholder mapping of value chain actors assisted in determining different pathways to the business prospects identified with fish silage, livestock feed and fertilizer.

The CFPA membership's personal goals and desires, business acumen, governance, technical and financial capacity to undertake an investment as a collective as well as expectations of fish silage-derived value addition activities must therefore be aligned. The alignment can be seen through a proposed Cluster Development Model which groups stakeholders according to their interests and competencies as well as the wider inclusive goal of sustainable livelihoods and utilization of the raw material from fish processing in an effort to impact the cost of production for smallholder farmers and other policy, social, economic and environmental goals. This approach also allows FAO a more strategic identification of entry points for technical and resource mobilization support to maximize impact as well as associating stakeholders more clearly with the levels of support and capacity development needed.

The eco-system of support describes a multi-stakeholder approach which lends competitiveness to the farmer cluster pathway. Facilitated by FAO with participation and support of the government of Barbados through its agents (Ministry of Agriculture, Food and Nutritional Security, Ministry of Environment, National Beautification, and the Green and Blue Economy, Ministry of Youth, Sports and Community Empowerment), CARDI, and other NGO's, farmers, and fish workers working together for the common purpose of increasing food and nutrition security as well as strengthening sustainable livelihoods on the island as illustrated in Figure 4 below. In Barbados context, this would be extended to include marketing agencies and other private sector interest.

Figure 4. Eco-system of Key Stakeholders

The abundance of evidence through requests for support by smallholder farmers and fish workers in Barbados to FAO and government creates the impetus that interventions that strengthen inclusive and sustainable livelihoods are needed. The willingness and availability of beneficiaries to participate in their own development process as well as, in this case, the availability of fish raw materials which has the established value in conversion from waste to resource cannot be overlooked.

Given the results, an appropriate business model should therefore be framed as a reflection of the current eco-system of support with institutional and resource strengthening. Increasing capacity (farmer skill training and equipment) and throughput of the Graeme Hall production facility carries the potential to make a tangible difference in alleviating the fish waste problem, cut feed imports by widening the variety of animal rations in alignment with the types currently imported: pig, broiler, horse, pullet, dairy, layers, and aquaculture while strengthening the circular flow of the agricultural economy in Barbados. The business model should be structured upon finalization of the processing and storage capacity of the facility as well as market price determination, marketing costs and development of the wider range of fish silage-derived livestock feeds.

Although producing independently is not a cost-effective option for the CFPA, the proposed cluster pathway to feed development in Barbados still holds the opportunity for the group to be a supplier of raw material from fish processing to support each cluster's feed production cycles. The multi-stakeholder approach also spreads the potential returns from this project as the environmental burden of discarded fish raw materials is lessened, fish loss and waste are reduced, and feed and fertilizer production capacity and affordability in Barbados is strengthened alongside the inclusion of women and youth throughout the value chain. Figure 5 summarizes the potential benefits.

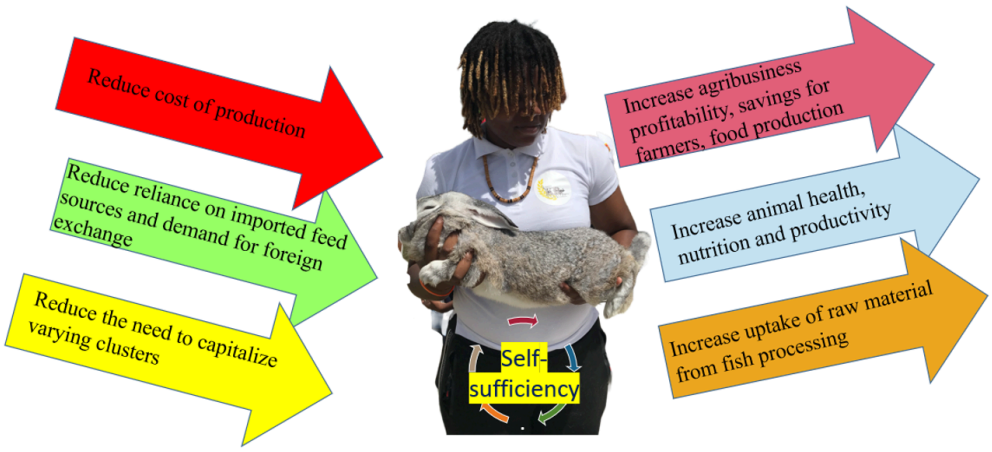

Figure 5. Potential Benefits of Expanded Fish silage-based Feed Production

The fish silage to feed conversion formulation ratios must be considered. Of the 120,000kgs of fish silage anticipated to be produced in 2024; rabbit ration production (6%), sheep ration (13%) and top-dressing pig ration / fertilizer / export potential (81%). The volume of fish silage will increase significantly in Barbados with an upgraded processing facility which justifies the need for continued and expanded animal feeding trials to develop a wider variety of animal rations in alignment with the types currently imported: pig, broiler, horse, pullet, dairy, layers, and aquaculture. This also has the potential to provide support and engagement to a wider portfolio of farmers and greater national impact.

In summary, FAO in partnership with national and regional institutions and stakeholders optimized the recovery process of the raw materials from fish processing, established the safety, comparative growth performance of fish silage-derived feed with imported feed, and their cost efficiency. The awareness raised prompted the establishment of a national fish silage platform, the integration of the fish waste utilization concept in the 2022-2030 Fisheries Policy of Barbados, capacity building of women fish processors, inclusion of small-scale farmers and investment for scaling up. The pipeline support to the establishment of a national fish silage reference training centre, and incubator unit for young farmers would further widen the potential of this innovative approach for expansion. It holds promise for other countries in the Caribbean region, given that livestock feed importation is common to all CARICOM countries and therefore helps to reduce the region's large and unsustainable extra-regional food import bill by 25% by 2025 and is well aligned with the 2030 Agenda for Sustainable Development. This experience, FAO approach and stakeholder engagement in Barbados can serve as a model for development in CRFM countries with similar fish waste management dynamics as well as feed and food production cost challenges.

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