Fish Processing Waste: A Valuable Co-Product of the Fishing Industry

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Western Pacific Regional Fishery Management Council
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ABSTRACT

This report outlines the results of a study on the utilization of raw fish processing waste generated on each of the five main islands (Molokai, Maui, Kauai, Big Island and Oahu) of Hawai‘i. This study is to determine the potential of obtaining better value and better use for Hawai‘i’s fish processing waste using developed technology that will bring additional benefits to the fisherman, fish processors, fish processing wastes recyclers and the agricultural and aquaculture communities that could use fish processing waste co-products that are locally developed from the fishing industry. This study will also provide a model for fish processing waste utilization for other Pacific Islands that face similar challenges in recycling and creatively utilizing their fish processing waste.

Keywords: fish waste, sustainable waste management, recycling, upcycling.

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1 EXECUTIVE SUMMARY

In Hawai‘i the commercial fishing industry harvests various types of fish, of which tuna comprises approximately 60 percent of the total fish landings. Once the fish are processed, a residue, or fish processing waste (FPW), is generated and has to be disposed of properly. Some of this FPW is converted and sold as an organic soil amendment by the local rendering plant on Oahu, and farmers are composting some FPW and feeding it to pigs. However, much of the FPW is treated as garbage and trucked off to the land fill for disposal, especially on the outer islands. This disposal requirement is a huge cost burden for the fish processors, but it also ignores the fact that this FPW is a valuable raw material that could be turned into an income stream and become an important factor in contributing to the sustainability of Hawai‘i's food production.

Each of the Hawaiian Islands has its own unique set of circumstances (e.g., volume of FPW produced, ability of processors to handle and store the raw product, cost of FPW disposal and demand from community to utilize a stabilized fish feed ingredient or fertilizer). All island communities share the remote location of the Pacific Islands, which creates specific challenges and opportunities: the high cost of shipping imported goods from the mainland states and foreign ports provides an opportunity for the same products to be developed on Island and to be competitively priced in the local market.

The current FPW generated in Hawai‘i, if maintained and processed properly, can meet or exceed the fishmeal market standards for the various fishmeals and fish oils that are sold commercially today. Potential products from a FPW are: a dry, high quality fishmeal; fish silage; fish oil; and ground, fresh frozen fish blocks. These potential products could be added to feed formulations for pet foods, livestock and aquaculture feeds that could be manufactured locally. Or with the high demands and shortages of fishmeal and fish oils on the commodity markets, could be exported and sold to markets overseas. FPW that does not meet the quality and specification for a high quality fishmeal, fish oil or fish silage could be converted into a liquid or dry fish fertilizer for use by farmers to raise local terrestrial and aquatic plant crops.

FPW products that are developed on the islands avoid the high cost of shipping imported goods from the mainland and other foreign ports, and could be competitively sold locally to farmers and livestock producers to support food security for the Islands. The effective recycling and utilization of FPW throughout the State would help create a more sustainable ecosystem-based management that the Western Pacific Regional Fishery Management Council (WPRFMC) envisions for the fisheries industry in the US Western Pacific Region.

This study is to determine the potential of obtaining better value and better use for Hawai‘i's FPW, using developed technology that will bring additional benefits to the fisherman, fish processors, FPW recyclers and the agricultural and aquaculture communities that could use the FPW co-products that are locally developed from the fishing Industry. This study will also provide a model for FPW utilization for other Pacific Islands that face similar challenges in recycling and creatively utilizing their FPW.

The volume of FPW being generated by major islands and by the State from selected high volume seafood wholesalers and retailers has been estimated. Laboratory analysis of FPW samples taken over several years has determined its quality, nutrient content and value. The data has been analyzed, reviewed and compared with similar imported products on the market. Several viable options have been put forward for technology to recycle and utilize FPW on Island into eco-friendly co-products of fish processing for use as a feed or fertilizer.

2 INTRODUCTION

The US commercial fisheries operating in US waters around the Pacific Islands are well regulated and monitored to ensure conservation and management of fish stocks, habitat and the ecosystem. In keeping with the WPRFMC principles of promoting an ecosystems approach to fisheries management, we have conducted a study to determine if we are able to effectively recycle and utilize the FPW that is being generated from our fisheries and minimize its impact on the environment in our Hawaiian Islands.

A team comprising a WPRFMC program officer, a feed ingredient and animal feed processing specialist, an algal specialist and an analytical biochemist determined the amounts, general quality, nutrient content and value of FPW generated on the five main islands (Molokai, Kauai, Maui, Big Island and Oahu) in Hawai‘i. The team also determined what is currently happening to the FPW being generated, where it is going and how it is being utilized or disposed of by island as well as the costs incurred in its disposal. If this FPW were shown to be going to the land fill, this would not be compatible with WPRFMC principles that foster good stewardship practices that reduce and utilize the waste by-products created by the fisheries that they carefully manage. The WPRFMC is aware that this FPW is a valuable co-product that may not be recycled and utilized effectively in the Islands and that there may be a potential opportunity to improve and convert this FPW into higher value and eco-friendly product(s) through reviewing and researching alternative products from FPW that are already developed and being sold on the market.

The team of researchers collected data to quantify the amount of FPW being generated by the State and by Island, and determined its quality, nutrient content and value. The findings were analyzed and reviewed and some recommendations posed on potential viable options that would best utilize this co-product FPW on Island as an eco-friendly, sustainable feed ingredient or as a fertilizer.

This study addresses the WPRFMC’s objectives of creating education and outreach to foster good stewardship principles of reducing and utilizing the FPW created by the fisheries.

In keeping with the WPRFMC principles, a preliminary study was organized to determine the possibility of utilizing and reducing the FPW from our island fisheries and minimizing its impact on the environment in the Hawaiian Islands. A team of researchers collected and reviewed data on how the fisheries’ processing waste is currently being disposed of in the five main Hawaiian Islands (Oahu, Maui, Big Island, Kauai, and Molokai) and what alternative approaches might be adopted to recycle and leverage the most value from the fisheries’ processing waste without sending this valuable resource to the landfill.

The objectives of this study were to:

1. Estimate amounts of FPW being generated statewide and on each of the five main Hawaiian Islands of Molokai, Kauai, Maui, Big Island and Oahu;

a) Through statistics provided by the State of Hawaiʻi, Department of Land and Natural Resources (DLNR) fishery data on commercial marine fisheries landings.

b) Through onsite visits and interviews with the larger commercial FPW generators on each island.

2. Determine the average quality and nutrient content of FPW material that can be processed into various potential products;

a) Quality of FPW fishmeal, FPW fish oil.

b) Nutrient content of FPW fishmeal, FPW fish oil, FPW fertilizer.

3. Determine the grade of the FPW according to commodity market standards and values of the potential FPW products;

4. Identify technologies that can be applied to stabilize the raw FPW material for use as a feed ingredient or as a fertilizer;

a) Fishmeal plant – fishmeal, fish oil, fish solubles.

b) Fish silage plant – fish silage.

c) Fish liquid fertilizer plant – Organic liquid fish fertilizer, fish hydrolysates.

5. Identify potential commercial suppliers of the FPW as feed ingredients or fertilizer on each island;

6. Identify the potential users of the FPW as feed ingredients or fertilizer on each island;

7. Determine whether the FPW can be economically collected and converted to feed ingredients or a fertilizer on each island.

3 APPROACH

1. Determined the amounts of FPW generated statewide and on each of the five main islands.

a) Estimated amounts of FPW generated through State DLNR Commercial Marine Landings Data as a percentage of pelagic and nonpelagic commercial fisheries landings.

b) Compiled a list (Appendix 1) to identify the large commercial FPW generators on each island for an onsite visit in order to estimate the amounts of FPW generated through an interview and questionnaire (Appendix 2). The questionnaire also determined how the FPW was handled and processed at the facility prior to being disposed of, the cost of disposal and where it was taken for disposal. Discovery of how FPW was generated and stored prior to disposal showed the ability of the processor to maintain the quality of the FPW (Appendix 3).

c. Determined the composition of fish species that make up the FPW by categories of fish landings.

2. Developed general quality and nutrient profile trends of the local FPW being generated.

a. Retrieved and analyzed archival FPW data from the Aquatic Feeds and Nutrition Department at the Oceanic Institute on FPW for fishmeal and fish oil for quality and nutrient assessments by proximate/mineral, and amino acid analysis (Table 2a, b, c, 3a, b, c and 5). The nutrient profiling work done on FPW with commercial fish wholesalers during the years 2008, 2012 and 2013. Test methods used for the laboratory analysis are shown in Appendix 4, Lab procedures for sample analysis.

b. Visual observations (Appendix 3) during visit and personal interviews with seafood and fish wholesalers and retailers helped define how FPW was handled on the five main Islands, Molokai, Kauai, Maui, Big Island and Oahu.

3. Checked the commodity market for general quality standards (Table 4) and values of the potential FPW products (Table 6) for the State and each island.

4. Identified technologies that could be applied to stabilize the raw FPW material as a feed ingredient or as a fertilizer

a. Fishmeal plant description and products generated

b. Fish silage description and products generated

c. Fish fertilizer description and background (Appendix 5)

5. Identified potential commercial suppliers of the FPW as feed ingredients or fertilizer on each Island (Appendix 1)

6. Identified the potential users of the FPW as feed ingredients or fertilizer on each Island. (Department of Agriculture)

7. Determined whether FPW could be collected economically and converted to feed ingredients or a fertilizer on each island (Table 6).

4 RESULTS

4.1 Objective 1a. Estimate the amounts of FPW generated statewide and on each of the five main Islands (Molokai, Kauai, Maui, Big Island and Oahu) in Hawai‘i, through State DLNR fishery data on commercial fisheries landings

To determine the amounts of FPW being generated in Hawai‘i, the most recent State of Hawai‘i Commercial Marine Landings Summary Trend report by the Division of Aquatic Resources, DLNR (published 2011) was used. 2010 and 2009 are also shown in Table 1. From the Marine Landings report for the year 2011, 99.5 percent of the landings are from pelagic and nonpelagic fish, the other 0.5 percent nonfish category is made up of other organisms (crustaceans, squid, mollusks, and seaweeds) as shown in Table 1. It is estimated that about

40 percent of the total landed pelagic and nonpelagic fish catch will make up the FPW. The commercial pounds of pelagic and nonpelagic fish landed data does not include the FPW lost from the Billfishes & Swordfish category, where head, tail, gill and gut are removed and dumped at sea (Table 1, Appendix 3 and figures 4 and 5). In addition there is FPW lost from all fish that are caught that are greater than 20 pounds where the gills and guts are removed and dumped at sea (Table 1, and Appendix 3, figures 4 and 5),

Results – Objective 1a

According to the State of Hawai‘i commercial fish landings summary by the fishing industry (2011), the total commercial marine landings in Hawai‘i was 32,570,145 pounds (16,285 tons) per year or 99.5 percent of the total marine landings 32,407,294 pounds, (16,203 tons) per year, of which an estimated 40 percent would comprise FPW. This results in 12,962,917 pounds (6,481 tons)/year of FPW generated by the fishing industry. (http://dlnr.hawaii.gov/dar/fishing/commercialfishing/).

State of Hawai‘i marine landings or catch by the fishing industry by Island from (2011) DLNR data:

•Kauai County (Nihau) – 716,510 pounds (358.3 tons) per year

•Maui County (Molokai & Lanai) – 749,706 pounds (374.9 tons) per year

•Big Island – 2,885,270 pounds (1,442.6 tons) per year

•Oahu – 28,218,659 pounds (14,109 tons) per year

Total State of Hawai‘i fish landings for the 2011 calendar year was 32,570,145 pounds (16,285 tons).

Estimated FPW generated at 40 percent of the fish landings by Island and the total FPW for Hawai‘i from (2011) DLNR data:

•Kauai County (Nihau) – 716,510 pounds (99.5%) (40%) = 285,171 pounds (142.6 tons) per year

•Maui County (Molokai & Lanai) – 745,957 pounds (99.5%) (40%) = 298,382 pounds (149.2 tons) per year

•Big Island – 2,885,270 pounds (99.5%) (40%) = 1,148,337 pounds (574 tons) per year

•Oahu – 28,218,659 pounds (99.5%) (40%) = 11,231,026 pounds (5,615.5 tons) per year

Total estimated FPW generated for the 2011 calendar year was 12,962,917 pounds (6,481 tons) per year.

Objective 1b. Estimate the amounts of FPW generated statewide and on each of the five (5) main Islands (Molokai, Kauai, Maui, Big Island and Oahu) by an onsite visit to fish and seafood wholesalers and retailers on Molokai, Kauai, Maui, Big Island and Oahu.

Table 1 Department of Land and Natural Resources Commercial Marine Landing 2009, 2010 and 2011/Appendix A, Sea Landings by Species.

		2009 Pounds landed Invidual Sub Catageory	2009 Pounds landed Invidual Catageory	2010 Pounds landed Invidual Sub Catageory	2010 Pounds landed Invidual Catageory	2011 Pounds landed Invidual Sub Catageory	2011 Pounds landed Invidual Catageory
Pelagic Fish		(x1000)	(x1000)	(x1000)	(x1000)	(x1000)	(x1000)
Tuna							
Aku, Bigeye, Bluefin							
Kawakawa, Keokeo,							
Tombo, Yellowfin.,							
Tuna subtotal		15,229.3		17,242.5		19,990.6	
Bill & Swordfish							
Swordfish, Black Marlin							
Blue Marlin, Sailfish							
Striped Marlin							
Shortbill spearfish		-	-	-	-	-	-
Bill & Swordfish subtotal		5,967.9		4,814.1		5,602.3	
Misc. Pelagic Fish							
Mahi-mahi, Kaku,							
Ono, Walu, Mongchong							
Opah,		-					
Misc. Pelagic Fish subtotal		5,231.5		5,416.6		5,168.1	
Other Pelagic							
Sharks ; Hammerhead, Ma-ko							
Ocean White tip, Thresher							
unclass/misc.							
Other Pelagic subtotal		297.1		225.0		241.9	
Total Pelagic Fish	x(1000) lbs.		26,725.8		27,698		31,002.9

Table 1 Department of Land and Natural Resources Commercial Marine Landing 2009, 2010 and 2011/Appendix A, Sea Landings by Species.

		2009 Pounds landed Invidual Sub Catageory	2009 Pounds landed Invidual Catageory	2010 Pounds landed Invidual Sub Catageory	2010 Pounds landed Invidual Catageory	2011 Pounds landed Invidual Sub Catageory	2011 Pounds landed Invidual Catageory
Non Pelagic Fish							
Deep Bottom Fishes							
Deep 7 ...etc.							
Deep Bottom Fishes subtotal		512.3		447.0		358.4	
Akule /Opelu							
akule, halalalu,opelu, opelu mama							
Akule /Opelu subtotal		617.3		855.3		600.5	
Jacks							
White,Papa, Omilu, Kamanu, Dobe,							
Butaguchi, Menpachi....etc.							
Jacks subtotal		44.6		47.0		44.4	
Inshore Fishes							
Parrotfishes, Goatfishes, Damselfishes							
Surgeonfishes , Squir-relfishes, Wrasses							
Misc. Inshore Fishes							
Inshore Fishes subtotal		325.7		470.8		421.1	
Total Non Pelagic	x(1000)		1,499.9		1,820.1		1,424.4

Table 1 Department of Land and Natural Resources Commercial Marine Landing 2009, 2010 and 2011/Appendix A, Sea Landings by Species.

		2009 Pounds landed Invidual Sub Catageory	2009 Pounds landed Invidual Catageory	2010 Pounds landed Invidual Sub Catageory	2010 Pounds landed Invidual Catageory	2011 Pounds landed Invidual Sub Catageory	2011 Pounds landed Invidual Catageory
Non Fish							
lobsters		29.6		12.4		10.8	
crab		48.4		46.1		34.8	
shrimp		0.0		0.0		6.1	
other animals		57.0		67.5		48.7	
seaweed		10.4		12.6		13.4	
unclass/ misc.		5.1		7.4		29.0	
Total Non Fish	x(1000) lbs.		151		146.0		142.8
Total all Islands Sea Landing	x(1000) lbs.	28,376.2	28,376.2	29,664.3	29,664.3	32,570.1	32,570.1

STATE WIDE TOTAL: PELAGIC + NON PELAGIC FISH CATCH AS A PERCENTAGE OF TOTAL COMMERCIAL LANDINGS								99.50%
Total all Islands Sea Landing	x(1000) lbs.	28,376.2		29,664.3		32,570.1		% average
Total Pelagic Fish	x(1000) lbs.	26,725.8	0.942	27,698.2	0.934	31,002.9	0.952	94.2%
Total Non Pelagic Fish	x(1000) lbs.	1,499.9	0.053	1,820.1	0.061	1,424.4	0.044	5.3%
Total Non Fish	x(1000) lbs.	150.5	0.005	146.0	0.005	142.8	0.004	0.5%
Total all Islands Fish Landing	x(1000) lbs.	28,376.2	1.000	29,664.3	1.000	32,570.1	1.000	100%

Table 1 Department of Land and Natural Resources Commercial Marine Landing 2009, 2010 and 2011/Appendix A, Sea Landings by Species

FPW Composition						
Approximately a 60:40 ratio	2009	2010	2011	Average		%
Tuna	15,229.3	17,242.5	19,990.6	17,487.5	Tuna	0.58
Non-Tuna*	12,996.4	12,275.8	12,436.7	12,569.6	Non Tuna	0.42
Total all Islands Sea Landing	28,225.7	29,518.3	32,427.3	30,057.1		

*NON TUNA = pelagic fish (sword & bill) + misc pelagic (mahi, ono...etc) + other pelagic (shark) + non pelagic fish (bottom fish, akule/opelo....etc).

Tuna (58%) : Non Tuna (42%)

A list was made of selected larger wholesalers and retailers. The list of the top volume processors of fish and seafood both wholesale and retailers was created from:

1. WPRFMC years 2005 – 2006 list of the main Deep 7 bottom fish dealers that purchased over a 1,000 pounds per year.

2. Web search of seafood/fish wholesalers and retailers on each of the five Islands.

3. Personal communication with individuals working in the fish processing industry on each island to identify the larger commercial FPW generators currently operating on each Island.

From the above information a contact list was made that contained: company's name, address, phone numbers and usually a name of a contact person, such as a manager or owner (Appendix 1). From this contact list the fish and seafood dealers and processors of both wholesalers and retailers were asked nine simple questions from a brief questionnaire survey (Appendix 2) on the amount of FPW their operation generated per day or week, their cost to dispose the FPW, how the FPW was stored prior to disposal, was the FPW mixed with other garbage, where did their FPW go when disposed of and did they have the capability of making ice.

Results – Objective 1b. FPW generated

Estimated FPW generated by the fish processors by Island were compiled and summarized. These were from estimates made at onsite visits from the list of selected wholesalers and retailers (Appendix A).

Total FPW per year generated by Island by the fish processors that were visited, interviewed and filled out a questionnaire:

•Kauai County (Nihau) – 159 tons per year

•Maui County (Molokai & Lanai) – 220 tons per year

•Big Island – 689 tons per year

•Oahu – 3,328 tons per year

Total estimated State FPW from WPRFMC (2014) Questionnaire = 8,792,000 pounds (4,396 tons per year.

Comparison of DLNR (2011) calculated FPW and the FPW per year by Island questionnaire survey (Appendix 2 and 6).

	2011/DLNR	2014/WPRFMC	Difference
• Kauai County (Nihau)	142.6	159	+ 15.7
• Maui County (Molokai & Lanai)	149.2	220	+ 70.1
• Big Island	574	689	+ 132.0
• Oahu	5,615.5	3,328	-2,315.6
Total estimated State FPW per year	**6,461.3 tons**	**4,396 tons**	**-2,065.3 tons**

Compared with the 2011 DLNR estimated figures, the completed 2014 questionnaire showed an actual increased production of FPW generated in Kauai, Maui County and Big Island by 15.7, 70.1 and 132 tons per year respectively. For Oahu, the 2011 DLNR estimated figures for FPW generated was reversed by an overestimation of the FPW by 2,065.3 tons when compared to the 2014 questionnaire. On Oahu, the two major collectors of FPW, have a combined average of about 56 tons of FPW that they dispose of per week or 2,912 tons per year. This was 416 tons per year less than the 3,328 tons per year total FPW for Oahu as estimated by the questionnaire and 2,065.3 tons less than the FPW for Oahu as estimated by DLNR.

Summary

The current FPW generated in Hawai‘i is estimated by DLNR figures (Table 1) as 40 percent of pelagic and nonpelagic fish landings (99.5 percent) and results in 6,461.3 tons per year of FPW. Estimations of FPW from information gathered through the questionnaire from the top volume processors of fish and seafood, both wholesale and retailers, on each island was 4,396 tons/ year (Table 6). FPW disposal companies, accounted for 2,912 tons /year of the FPW collected.

Objective 1c. Determine the composition of fish types that make up the FPW

Table 1 – DLNR Commercial Marine Landings 2009, 2010 & 2011 (in DLNR's Summary, Appendix A – Sea Landings by Species), gives a breakdown of the categories of species of fish landings that would make up the major portion of the FPW being generated. In the State of Hawai‘i, *Commerical Marine Landings Summary Trend Report Calendar Year 2011*, in Appendix A – Marine Fish landings by species were condensed into three categories 1) pelagic fish, 2) nonpelagic fish and 3) nonfish species. In the first category, pelagic fish as shown in Table 1, include: tuna, bill and swordfish, miscellaneous pelagic (mahi, ono…etc.), and other pelagic (sharks) to round out that group. In the second category, nonpelagic fish included deep bottomfish, akule/opelu, jacks and inshore fish. The third and nonfish category included lobsters, crabs, shrimp, other animals, seaweed and unclassed/miscellaneous items. Summarizing the data into these three categories, the pelagic fish landings for the years 2009, 2010, and 2011 averages out to be 94.3 percent of the total fish landings. Nonpelagic fish averages out to be 5.2 percent of the total marine landing and the average landing for the nonfish category was 0.5 percent. Therefore, we can conclude that the FPW is mainly being generated by this pelagic and nonpelagic fish category (99.5 percent). In this 99.5 percent fish category we can also segregate it into two fish groups; tuna and non-tuna fish, which is comprised of approximately 60 percent tuna and 40 percent non-tuna fish, so we have assumed that the FPW being generated on average

consists of a 60:40 ratio of tuna to non-tuna fish species.

Results – Estimated amounts of FPW generated and broken down and defined by category, to help define its average composition

Pelagic fish average out to be 94.3 percent of the total fish landings, nonpelagic fish averages out to be 5.3 percent; combined they make up 99.5 percent of the commercial fishery landings. In the pelagic and nonpelagic fish category we can also separate the fish landed into 60 percent tuna and 40 percent non-tuna fish. We will assume that the FPW being generated will on average consist of this 60:40 ratio of tuna to non-tuna in the FPW that is being generated.

Results – Objective 1c. Additional questions in Summary Questionnaire Survey

1. What is the cost of FPW disposal? Grinder or No grinder?

The cost of FPW disposal was the greatest concern for all of the fish and seafood dealers and processors. According to them this is a critical cost issue for their business. While many would not disclose their cost or where their FPW was being taken for disposal, some fish wholesalers on Oahu reported the cost of disposal as reaching a high of $10K per month, and several companies were spending over $100K/year for FPW disposal. It is estimated that there are ten companies on Oahu paying over $40K/ year and up to have their FPW removed. Due to this high disposal cost it is estimated that approximately $820K is being spent by Oahu fish processors alone to remove their waste. However only $740K of this can be accounted for by the two largest hauling companies taking away their waste. There may be several unidentified companies that are also servicing the industry. Some of the fish processing companies have become innovative and have developed alternative ways to reduce the cost of disposing their FPW: switching waste disposal haulers that pick up FPW or fish wholesalers trucking their own FPW to farmers for composting and by using a meat grinder (Appendix 3, figures 8 and 9) to compact the FPW, thereby increasing the amount of FPW filling a container for disposal by a factor of 2x and greatly reducing the amount containers that is being hauled away. There are only five companies on Oahu that have made the $40K plus investment in a purchasing and installing a grinder in their facility.

There are two major haulers of FPW. Disposal Company 1 is a rendering plant that charges $35 to pick up a 64-gallon container of ground or unground FPW for disposal (personal communication fish processor). It has several different size containers that they use; we will use the 64-gallon as the standard size container for this study. Disposal Company 2 will pick up the 64-gallon container but only accepts ground FPW and charges $25 per container. The difference in the container weight between ground and unground FPW is approximately 200 pounds more with the ground FPW (Appendix 3, figures 10 and 11). The container cost is the same whether filled with ground FPW (approximately 400 pounds per container) or unground FPW (approximately 200 pounds per container). The cost of grinding the FPW to get more FPW into a container with a meat grinder is shown in Appendix 3, figures 8 and 9. A grinder like the AUTIO GH (Gear Head) Grinder, model 1101 GH, with a 1” hole die plate, notched feeder screw, grinder weight 2,400 pounds, equipped with a 50 HP motor, and a maximum grinding capacity of 25,000 pounds per hour costs approximately $36,500. A soft start is needed for the 50 HP motor, which costs another $4,000, add in shipping and handling for about $2,000. Total cost of grinder is approximately $42,600 plus the cost of installation: a very large investment for a lot of companies.

2. How was the FPW handled and stored prior to disposal?

Appendix 3 (Fish processing waste generation and storage prior to disposal) reviews figures 1 through 12, which gives a pretty good picture of how fish and FPW are handled and processed at a fish wholesaler's facility.

3. Was the FPW mixed with other garbage?

During the visits and interviews with fish wholesalers and retailers all FPW were kept separated from other garbage waste that was produced. The FPW was kept separated and refrigerated because if not refrigerated it quickly breaks down, causing odors and attracting flies. Board of Health requirements for no odor, no pests, and regular disposal rules for garbage must be met. However on the day of or night before the garbage pickup some of the retailers will at that time combined the FPW with other items for disposal. The majority interviewed would keep the FPW separated if it was requested to be used as a feed or fertilizer.

4. Where did their FPW go when disposed of?

For the Outer islands of Molokai, Maui, Kauai and the Big Island, the FPW was either being hauled to the landfill by a commercial hauler or by the fish wholesale company. Some companies had isolated plots of land and dumped and buried the FPW for composting, or it was picked up by a farmer for composting or picked up by a pig farmer as feed. However, several long time pig farmers commented FPW is not a desirable feed as it causes the pig meat to smell fishy and the fish bones, if not ground down to small pieces, can perforated the stomach or intestines or get stuck in the pig's throat, causing mortalities. Most pig farmers are picking up mixed waste from a supermarkets or retail food outlets, but generally not from fish wholesalers.

From the visits and interviews with seafood wholesalers and retailers it was found that there are problems with the free pickups of FPW by crop farmers for composting and by pig farmers for feed. There was the lack of consistency of regular pickups for disposal, and many times they would not take all the FPW available for disposal. There was also another big problem in the lack of due care in sanitizing FPW bins after used in the pickup and exchange process. The return of unsanitized bins was not a practice the fish processor can tolerate to be in compliance with Board of Health regulations. To date the most reliable and consistent disposal service is the commercial garbage disposal companies that pick up on a regular schedule and take the FPW to the landfill.

On Oahu most FPW is mainly collected by two companies. From our interviews and from answers to our questionnaire it was determined that they collect approximately 86 percent or 2,219 tons of the FPW per year. The other 14 percent or 471 tons per year are disposed through other means. Company 1 is part of a large rendering group of more than 21 facilities across the United States that converts animal by-products into commercial commodities such as high protein ingredients for poultry feed and pet food, and tallow, used as an ingredient in soaps, paints, and cosmetics. They also convert used cooking oil from restaurants into "yellow grease," a key ingredient in biodiesel fuels. The FPW that is collected is mixed with other protein meals from the slaughter houses (beef and pork), and meat scraps and fish waste from retail food establishment. Because of the Bovine Spongiform Encephalopathy, or mad cow disease, risk, any product processed by the rendering plant cannot be sold back as a feed ingredient to ruminants (beef, dairy, goats and sheep). The rendering plant cooks (renders) FPW and other meat products through a high temperature process into a product called Meat and Bone meal (MBM), any oil rendered from the process is collected and sold as tallow or yellow grease. The MBM is mostly sold locally as an Organic Soil Amendment for $.21 per pound ($420 per ton), and the yellow grease is sold to Pacific Biodiesel Inc., which converts the yellow grease to biodiesel, according to the plant manager.

Interviews with the local rendering plant manager also revealed that not all FPW was being collected on Oahu: there is that 14 percent, or 471 tons per year of FPW going somewhere. According to the IC plant manager, he has lost several substantial commercial accounts of FPW disposals because the company producing the FPW qualifies as a small business, and since the City and County of Honolulu has no rules for refuse and recycling for small businesses under 5,000 square feet, it allows them to dispose of FPW through their commercial trash hauler. This may go to the landfill, or most likely to H-power (http://www.opala.org/solid waste/food waste recycling.html). He also commented on losing large accounts to commercial garbage disposal services that are picking up meat and fish scraps FPW from the military bases for disposal; their disposal destinations were unknown to him.

The second largest hauler of FPW is a locally owned company that picks up and transports FPW to various commercial farms for composting. However, they have expressed a keen interest in diversifying their services and would like to convert the FPW they are now transporting into a liquid fish fertilizer or higher value product(s) and are looking for and actively pursuing opportunities that will meet these company objectives.

5. Did they have the capability of making ice or access to ice?

FPW transport for disposal is where deterioration of the FPW starts. The cold chain is broken when FPW is transported by an open, uninsulated or by a non-refrigeration truck. FPW is now in ambient air temperature when it leaves the fish processor's cold room and is transported for disposal. (Appendix 3, figure 12) To mitigate this deterioration process, FPW containers can be packed with ice supplied by the fish wholesaler to keep the FPW cold during transport prior to processing. This would help maintain FPW quality for finished feed ingredients (fishmeal, fish silage, fish oil, fish solubles, or a ground raw frozen fish blocks). For fertilizer products from FPW, a cold chain is not required for an acceptable finished product.

4.2 Objective 2. Determine the general average quality and nutrient content of FPW material that can be processed into various potential feed ingredient and fertilizer products

Background Sampling Rationale

To determine the general average quality and nutrient content of FPW at the wholesale and retail levels prior to disposal, accurate sampling procedures to determine quality and nutrient content were initiated. Samples that were collected had specific protocols of collecting only tuna FPW samples and non-tuna FPW samples separately and analyzing these samples separately. This was due to the lack of predictability when taking small, random samples of mixed FPW being generated by the fish processors; these showed extremely high variability of FPW composition on a day to day basis. All laboratory analyses (Appendix 4) were run on only samples that were sorted tuna FPW samples and on non-tuna FPW samples. These samples were collected over a three-year period. The data on quality and nutrient analysis determined for the sorted tuna FPW samples and on non-tuna FPW were combined in a 60:40 ratio to obtain an average quality and nutrient profile of the FPW called “mixed,” which simulated the general FPW being generated. The sorting of FPW samples also enable an assessment to be made if the separated tuna and non-tuna samples could obtain a higher market value from an improved quality and nutrient content.

There are three categories of FPW shown in Table 2 and 3 with data analysis on the quality and nutrient content of the FPW: 1) mixed, a 60/40 ratio of tuna + non-tuna FPW, 2) tuna only FPW and 3) non-tuna only FPW. The mixed sample of tuna and non-tuna FPW at the 60/40 ratio simulated the actual FPW average composition being generated over the year. These actual and calculated average values of quality, and nutrient content of the mixed, tuna and non-tuna samples are shown in Tables 3a, b, c and 4a, b, c. Table 4a, b, c shows the Amino Acid content of the three categories of FPW as compared to Menhaden Select a fishmeal with a commodity price of $1,650 per ton or $1,815 per metric ton (mt).

Objective 2a. Quality of FPW (total volatile basic nitrogen and free fatty acids values)

Generating a high quality product is determined by how this FPW is handled by the fish wholesalers and retailers (see Appendix 3). To determine this issue of handling, onsite visits with fish wholesalers and retailers were scheduled to see and speak with them about how the fresh fish and the FPW was handled. Regulations by the Board of Health §§ 11-12-46 Garbage and Refuse section of the; Hawai‘i Administrative Rules. Title 11. Department of Health. Chapter 12. Food Establishment Sanitation (http://gen.doh.hawaii.gov/sites/har/AdmRules1/11-12.pdf), enable the preservation of a high quality FPW. The Board of Health (BOH) has established rules of control that mandate no odor, no pests (flies) and regular disposal. To abide by these rules the fish wholesalers and retailer all store their FPW in cold storage (<400° F), refrigerators or freezers and schedule regular pickups for disposal. By storing the FPW under low temperatures to comply with the no odor, no pest, and regular disposal rules the Board of Health has set forth, the wholesale and retail company must by law maintain the quality of this FPW product and not let it spoil, smell or attract flies, if they want to stay in business. What was observed was that the larger fish wholesalers held their FPW in cold storage areas where all the incoming fish from the auction was stored prior to going into the cutting room (see Appendix 3). Visits to fish wholesaler and retailers and seeing how and where the FPW was stored prior to disposal confirmed our lab results on total volatile basic nitrogen (TVN) values that showed the high quality of the raw FPW, and low free fatty acids (FFA) values that was being maintained at the fish wholesalers and retailers.

Table 2 Fish processing waste – quality and nutrient content of mixed tuna and non-tuna, only tuna and only non-tuna.

MIXED FPW - Tuna + Non-Tuna

		Tuna	Tuna	Tuna	Non -Tuna	Non -Tuna	Non -Tuna	Non -Tuna	Tuna	Tuna	Tuna	MIXED	
		10/4/2008	10/10/2008	10/17/2008	10/4/2008	10/10/2008	10/17/2008	calculated	3/12/2012	3/12/2012	4/29/2013	**60 / 40**	
Feed Ingredient		**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	
		sample 1	**sample 2**	**sample 3**	**sample 4**	**sample 5**	**sample 6**	**AVE**	**sample 7**	**sample 8**	**sample 9**	**AVE**	
Specifications													
Total Volatile Nitrogen (TVN)	mg/100g	76	94	109	60	49	48	52	18	17	35	**62**	
Protein	% min	68	69	76	64	47	53	55	70	70	57	**63**	standard
Fat	% max	13	12	11	16	33	28	26	6	7	18	**17**	standard
Moisture	% max	7	6	8	6	6	6	6	1	1	2	**5**	
Ash	% max	12	10	6	15	12	14	14	23	22	21	**15**	
Salt & Sand	% max	na	na	na	na	na	na	na	na	na	na	**na**	
FFA	% max	na	na	na	na	na	na	na	na	na	4.8	**5**	
Histamine	ppm max	na	na	na	na	na	na	na	na	na	na	**na**	
Digestibility	% min	na	na	na	na	na	na	na	na	na	pending	**pending**	
Soluble protein	% min	na	na	na	na	na	na	na	na	na	15	**15**	

Table 2 Fish processing waste – quality and nutrient content of mixed tuna and non-tuna, only tuna and only non-tuna.

ONLY TUNA FPW

		Tuna	**Tuna**	**Tuna**	**Tuna**	**Tuna**	**Tuna**	**TUNA**	
		10/4/2008	10/10/2008	10/17/2008	3/12/2012	3/12/2012	4/29/2013	**100%**	
Feed Ingredient		**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	**FPW**	
		sample 1	**sample 2**	**sample 3**	**sample 7**	**sample 8**	**sample 9**	**AVE**	
Specifications									
Total Volatile Nitrogen (TVN)	mg/100g	76	94	109	18	17	35	**58.2**	super/aqua/prime
Protein	% min	68	69	76	70	70	57	**68.3**	super/aqua/prime
Fat	% max	13	12	11	6	7	18	**11.2**	
Moisture	% max	7	6	8	1	1	2	**4.2**	super/aqua/prime
Ash	% max	12	10	6	23	22	21	**15.7**	super/aqua/prime
Salt & Sand	% max	na	na	na	na	na	na	**na**	
FFA	% max	na	na	na	na	na	4.8	**4.8**	super/aqua/prime
Histamine	ppm max	na	na	na	na	na	na	**na**	
Digestibility	% min	na	na	na	na	na	pending	**pending**	
Soluble protein	% min	na	na	na	na	na	15	**15.0**	

Table 2 Fish processing waste – quality and nutrient content of mixed tuna and non-tuna, only tuna and only non-tuna.

ONLY NON-TUNA FPW

		Non-Tuna	Non-Tuna	Non-Tuna	NON-TUNA	Oil	NON -TUNA	
		10/4/2008	10/10/2008	10/17/2008	100%	Extraction	100%	
Feed Ingredient		**FPW**	**FPW**	**FPW**	**FPW**	Fishmeal	**FPW**	
		sample 4	**sample 5**	**sample 6**	**AVE**	Plant	**AVE**	
Specifications								
Total Volatile Nitrogen (TVN)	mg/100g	60	49	48	**52.3**		**52.3**	super/aqua/prime
Protein	% min	64	47	53	**54.7**	54.7	**64.81**	standard
Fat	% max	16	33	28	**25.7**	10	**11.85**	standard plus
Moisture	% max	6	6	6	**6.0**	6	**7.11**	
Ash	% max	15	12	14	**13.7**	13.7	**16.23**	
Salt & Sand	% max	na	na	na	**na**		**na**	
FFA	% max	na	na	na	**na**		**na**	
Histamine	ppm max	na	na	na	**na**		**na**	
Digestibility	% min	na	na	na	**na**		**na**	
Soluble protein	% min	na	na	na	**na**		**na**	
						84.4		

Table 2 Fish processing waste – quality and nutrient content of mixed tuna and non-tuna, only tuna and only non-tuna

		$1880-1900	$1860-1880	$1860-1880	$1820-1840	$1750-1760	$1720-1730
Fish Meal Ingredient		**Super**	**Aqua**	**Prime**	**Standard**	**Standard**	**FAQ**
Commodity Market		**Prime**	**Prime**		**Plus**		
Specifications							
Total Volatile Nitrogen (TVN)	mg/100g	100	120	120	150	na	na
Protein	% min	68	68	67/68	66/67	65/66	64/65
Fat	% max	10	10	10	10/12	12	12
Moisture	% max	10	10	10	10	10	10
Ash	% max	16	16	17	17	NA	NA
Salt & Sand	% max	4	4	4	4	5	5
FFA	% max	7.5	10	10	10	na	na
Histamine	ppm max	500	1000	na	na	na	na
Digestibility	% min	na	94	na	na	na	na
Soluble protein	% min	na	20	na	na	na	na

Menhaden Fish Meal in the Gulf: Select Quality was steady from $ 1,650 - 1,677.5 /mt

Menhaden Fishmeal on the East Coast: Select Quality was steady from $ 1,650 - 1,677.5 /mt

Table 3 Fish processing waste – amino acid content of mixed tuna and non-tuna, only tuna and only non-tuna.

MIXED FPW - Tuna + Non -Tuna

Amino acid profile of Tuna and Non -Tuna fish samples (freeze dried basis) 60/40 ratio

									62.5/37.5	
Sample date	10/4/2008	10/10/2008	10/17/2008	10/4/2008	10/10/2008	10/17/2008	3/19/2012	4/29/2013	**MIXED**	
Amino Acid (g/100g)	Tuna	Tuna	Tuna	Non -Tuna	Non-Tuna	Non -Tuna	Tuna	Tuna	**AVE**	MFM
Non-Essential Amino Acids										
Alanine	4.42	3.28	3.63	4.27	3.16	2.64	2.2	6.2	3.72	4.57
Aspartic Acid[1]	7.71	7.32	7.79	4.1	5.02	5.71	6.6	4.17	6.05	5.64
Cysteine	0.73	NA	0.03	0.8	NA	NA	1.2	0.34	0.39	0.34
Glutamic Acid[2]	7.07	7.25	7.92	6.65	6.72	6.18	6.0	5.83	6.70	6.49
Glycine	5.74	2.85	2.98	5.19	3.08	2.51	5.4	11.19	4.87	4.79
Proline	3.33	2.28	2.58	3.46	2.11	2	5.0	4.45	3.15	2.61
Serine	2.53	2.08	2.39	2.68	1.96	1.76	3.3	2..69	2.09	2.11
Tyrosine	2.6	2.46	2.67	2.77	2.34	1.93	3.1	0.96	2.35	2.06
Taurine	0.96	1.01	1.26	0.78	0.81	0.78	0.53	0.44	0.82	0.58
Essential Amino Acids										
Arginine	4.88	3.68	5.41	4.79	4.3	3.9	4.55	3.04	4.32	5.41
Histidine	4.13	4.12	4.69	3.59	4.43	3.51	1.97	1.12	3.45	1.73
Isoleucine	4.05	3.99	4.34	4.5	3.68	3.01	3.55	1.64	3.60	2.74
Leucine	5.19	5.06	5.14	6.02	4.31	3.66	4.37	3.13	4.61	4.42
Lysine	5.22	6.52	6.04	5.2	6.33	5.02	6.03	3.07	5.43	5.66
Methionine	1.75	1.69	1.65	1.5	0.97	1.01	1.46	1.49	1.44	0.95
Phenylalanine	3.21	2.79	3.68	3.83	3.02	2.63	3.09	1.47	2.97	2.89
Threonine	4.58	3.13	4.58	5.2	3.31	2.71	3.51	2.81	3.73	2.78
Tryptophan	NA	NA	NA	NA	NA	NA	NA	NA	0.00	NA
Valine	4.42	3.95	4.32	4.64	3.52	2.83	3.11	2.30	3.64	3.43
Total (g/100g)[3]	72.52	63.46	71.1	69.97	59.07	51.79	64.9	53.65	**63.31**	59.2

NA – not available . [1] Value includes Asparagine. [2] Value includes Glutamine.

Table 3 Fish processing waste – amino acid content of mixed tuna and non-tuna, only tuna and only non-tuna.

ONLY TUNA FPW

Amino acid profile of Tuna samples (freeze dried basis) 100%

						100%	
Sample date	10/4/2008	10/10/2008	10/17/2008	3/19/2012	4/29/2013	TUNA	
Amino Acid (g/100g)	Tuna	Tuna	Tuna	Tuna	Tuna	AVE	MFM
Non-Essential Amino Acids							
Alanine	4.42	3.28	3.63	2.2	6.2	3.94	4.57
Aspartic Acid[1]	7.71	7.32	7.79	6.6	4.17	6.71	5.64
Cysteine	0.73	NA	0.03	1.2	0.34	0.46	0.34
Glutamic Acid[2]	7.07	7.25	7.92	6.0	5.83	6.82	6.49
Glycine	5.74	2.85	2.98	5.4	11.19	5.64	4.79
Proline	3.33	2.28	2.58	5.0	4.45	3.53	2.61
Serine	2.53	2.08	2.39	3.3	2..69	2.06	2.11
Tyrosine	2.6	2.46	2.67	3.1	0.96	2.36	2.06
Taurine	0.96	1.01	1.26	0.53	0.44	0.84	0.58
Essential Amino Acids							
Arginine	4.88	3.68	5.41	4.55	3.04	4.31	5.41
Histidine	4.13	4.12	4.69	1.97	1.12	3.21	1.73
Isoleucine	4.05	3.99	4.34	3.55	1.64	3.51	2.74
Leucine	5.19	5.06	5.14	4.37	3.13	4.58	4.42
Lysine	5.22	6.52	6.04	6.03	3.07	5.38	5.66
Methionine	1.75	1.69	1.65	1.46	1.49	1.61	0.95
Phenylalanine	3.21	2.79	3.68	3.09	1.47	2.85	2.89
Threonine	4.58	3.13	4.58	3.51	2.81	3.72	2.78
Tryptophan	NA	NA	NA	NA	NA	0.00	NA
Valine	4.42	3.95	4.32	3.11	2.30	3.62	3.43
Total (g/100g)[3]	72.52	63.46	71.1	64.9	53.65	65.13	59.2

NA – not available. [1] Value includes Asparagine. [2] Value includes Glutamine

Table 3 Fish processing waste – amino acid content of mixed tuna and non-tuna, only tuna and only non-tuna.

ONLY NON

Amino acid profile of Non Tuna fish samples (freeze dried

				100%	
Sample date	10/4/2008	10/10/2008	10/17/2008	**Non -Tuna**	
Amino Acid (g/100g)	Non -Tuna	Non -Tuna	Non -Tuna	**AVE**	MFM
Non-Essential Amino Acids					
Alanine	4.27	3.16	2.64	3.36	4.57
Aspartic Acid[1]	4.1	5.02	5.71	4.94	5.64
Cysteine	0.8	NA	NA	0.27	0.34
Glutamic Acid[2]	6.65	6.72	6.18	6.52	6.49
Glycine	5.19	3.08	2.51	3.59	4.79
Proline	3.46	2.11	2	2.52	2.61
Serine	2.68	1.96	1.76	2.13	2.11
Tyrosine	2.77	2.34	1.93	2.35	2.06
Taurine	0.78	0.81	0.78	0.79	0.58
Essential Amino Acids					
Arginine	4.79	4.3	3.9	4.33	5.41
Histidine	3.59	4.43	3.51	3.84	1.73
Isoleucine	4.5	3.68	3.01	3.73	2.74
Leucine	6.02	4.31	3.66	4.66	4.42
Lysine	5.2	6.33	5.02	5.52	5.66
Methionine	1.5	0.97	1.01	1.16	0.95
Phenylalanine	3.83	3.02	2.63	3.16	2.89
Threonine	5.2	3.31	2.71	3.74	2.78
Tryptophan	NA	NA	NA	0.00	NA
Valine	4.64	3.52	2.83	3.66	3.43
Total (g/100g)[3]	69.97	59.07	51.79	60.28	59.2

NA – not available . [1] Value includes Asparagine. [2] Value includes Glutamine

Table 3 Fish processing waste – amino acid content of mixed tuna and non-tuna, only tuna and only non-tuna

Amino Acid (g/100g)	MFM
Non-Essential Amino Acids	
Alanine	4.57
Aspartic Acid1	5.64
Cysteine	0.34
Glutamic Acid2	6.49
Glycine	4.79
Proline	2.61
Serine	2.11
Tyrosine	2.06
Taurine	0.58
Essential Amino Acids	
Arginine	5.41
Histidine	1.73
Isoleucine	2.74
Leucine	4.42
Lysine	5.66
Methionine	0.95
Phenylalanine	2.89
Threonine	2.78
Tryptophan	NA
Valine	3.43
Total (g/100g)	**59.2**

NA – not available

1 Value includes Asparagine

2 Value includes Glutamine

Results Objective 2a. Laboratory values of TVN and FFA

TVN is an indicator of protein degradation or spoilage and represents the sum of ammonia, DMA (dimethylamine), TMA (trimethylamine) and other basic nitrogenous compounds volatile under the analysis conditions. Analyzing FPW raw samples from fish wholesalers over time and determining total TVN of the raw FPW is a way of determining quality (freshness). The TVN values for nine FPW samples collected over time from two of the largest fish wholesalers on Oahu ranged from a low of 16.1 to a high of 108.6mg/100g, with an average value of 62mg/100g indicating a low degree of protein degradation or a high degree of freshness or quality of this raw FPW (Table 2a).

For a super prime grade of fishmeal product, the TVN should be less than 100mg/100g (Table 4). The TVN value for the nine raw FPW samples taken over a three-year period (2008, 2012 and 2013) averaged out to be 62mg/100g for a 60/40 ratio of mixed FPW, 58.2mg/100g for a 100 percent tuna only FPW, and a 52.3 mg/100g for a 100 percent non-tuna only FPW, indicating a low degree protein degradation or spoilage or a high degree of quality freshness of this raw FPW for all samples (Table 2a, b, c).

Table 4a Commodity fishmeal specifications according to grade.

Fish Meals		*Super Prime*	*Aqua Prime*	*Prime*	*Standard Plus*	*Standard*	*FAQ*
Standard Specifications							
Total Volatile Nitrogen (TVN)	mg/100g	100	120	120	150	-	-
Protein	% min	68	68	67/68	66/67	65/66	64/65
Fat	% max	10	10	10	10/12	12	12
Moisture	% max	10	10	10	10	10	10
Ash	% max	16	16	17	17	-	-
Salt & Sand	% max	4	4	4	4	5	5
FFA	% max	7.5	10	10	10	-	-
Histamine	ppm max	500	1000	-	-	-	-
Digestibility	% min	-	94	-	-	-	-
Soluble protein	% min	-	20	-	-	-	-
		$1880/1900 m/t	**$1860/1880 m/t**	**$1860/1880 m/t**	**$1820/1840 m/t**	**$1750/1760 m/t**	**$1720/1730 m/t**

Super Prime. This is the best quality obtainable, insofar as the protein content and freshness = TVN value of the raw (FPW) feedstock. This super Prime is used principally in aquaculture (for salmon, eels) and in the early stages of life of pigs and chickens. This quality fetches the best market prices. $1880/1900 m/t (Table 2).

Aqua Prime. This quality is similar to Super Prime, but the fish used is not quite as fresh. This quality is determined by a higher histamine content and although it is employed in the same sector of the market, the prices are marginally lower than those of Super Prime. $1860/1880 m/t (Table 2).

Prime. This meal is known in the market as "Taiwan Quality". Although it contains a high protein level, it is not employed in feeding salmon or eels, because these species require a strict control of the histamine level. It is used in shrimps sectors. $1860/1880 m/t (Table 2).

Standard Plus. This quality is marketed at lower prices than the Prime meals since the freshness is on the borderline of what is considered acceptable. It is recommended only when an investment in a quality product is not justified and is not recommended for breeding purposes. In Thailand and Indonesia it is much used in chicken and shrimp farming. $1820/1840 m/t (Table 2).

Standard. This quality does not guarantee freshness and is used principally in beef and dairy farming, also in rustic piggeries and chicken farms, but only for adult animals/birds. Prices obtainable are notably lower. $1750/1760 m/t (Table 2).

FAQ (Fair Average Quality). This is similar to Standard Quality, except the protein content is at the minimum level. The market it reaches is the same as Standard and the prices are even lower. Most of this meal is exported from Peru and is flame dried. The high temperatures produced deteriorate certain amino acids resulting in a reduction of the digestibility of the protein. $1720/1730 m/t (Table 2).

Table 4 Current commodity fishmeals and fish oil values according to different quality grades and type of fish (as of 8/16/14).

Hammersmith Marketing Ltd - Grain Trading (http://www.hammersmithltd.blogspot.com/)

WEEKLY FEED GRAIN AND PROTEIN REPORT. August 16, 2014,
PERU "INDICATION" FISHMEAL PRICES: ALL PRICES SHOWN ARE IN CONTAINER, ON VESSEL, AT ORIGIN --- US DOLLARS. Minimum shipment of 200 m/t for fishmeal.

Specification	Price per m/t FOB vessel Peru port
65 protein	1720/1730 m/t
65/66 protein	1750/1760 m/t
67 protein standard steam	1800/1820 m/t
67 protein SD 150 TVN	1820/1840 m/t
67 protein SD 120 TVN	1840/1860 m/t
67 protein SD 1000 hist., 120 TVN	1860/1880 m/t
68 protein SD 500 hist., 120 TVN	1880/1900 m/t
Fish oil, crude bulk	1900/2000
Fish oil, crude drums	2100/2200
Fish oil, flexi tank	2050/2150
Fish oil, Omega 3: 28%EPA/DHA	2500/2700

INFORMATION: TVN = total volatile nitrogen, hist. = histamine,
FAQ = fair average quality (normally flame or hot air dried), SD = steam dried

European fishmeal prices – FOB North German port (8/16/2014).

(http://www.hammersmithltd.blogspot.com/)

Type	Protein %	Price per m/t $US
Herring fishmeal	72 protein	1,965
Danish fishmeal	64 protein	1,737
Peru fishmeal	64 protein	1,795
Chile fishmeal	65 protein	1,815

Free fatty acids (FFA) in the FPW fat can affect the sensory properties and oxidative stability of the fat. FFA is an indication of hydrolytic rancidity, but other lipid oxidation processes can also produce acids. This free fatty acid is a measure of the chemical decomposition of fats, oils and other lipids. For a super prime grade of fishmeal fat quality, the FFA specifications have a maximum percent of 7.5. Based on the results of a 100 percent tuna FPW, the FFA test that was run in 2013 resulted in only 4.8 percent FFA in the sample, which was well below the acceptable high level of 7.5 percent FFA in the super prime grade of a fishmeal.

Summary

The current FPW that is being generated in Hawai‘i, if maintained under temperature controlled conditions (<40° F), can meet or exceed the fishmeal quality standards for TVN and FFA in comparison to the various top grade fishmeals sold on the commodity market today.

Objective 2b. Nutrient content of FPW fishmeal, fish oil and FPW fertilizer.

Data collected from laboratory analysis (Appendix 4, lab methods) of FPW from the Aquatic Feeds and Nutrition Department at the Oceanic Institute on FPW for nutrient content are shown in proximate and mineral analysis (Table 2a, b, c and 3a, b, c). Samples of FPW taken from commercial fish wholesalers during the years 2008, 2012 and 2013 are shown. In addition, visual observations of fish processing operations (Appendix 3) made during visits and interviews with seafood and fish wholesalers and retailers were recorded on the 2014 questionnaire that covered the five main Hawaiian Islands; Molokai, Kauai, Maui, Big Island and Oahu.These laboratory analysis of nutrients of the mixed, tuna and Non-tuna FPW categories determined how the fishmeal would be rated.

Results – Objective 2b. Laboratory values of crude protein, fat, ash, moisture and amino acid for FPW fishmeal and fish oil.

1. The mixed 60:40 sample tuna and non-tuna FPW rated with the specifications for a standard and standard plus fishmeal shown in Tables 1 and 2.

2. The tuna fishmeal rated with the nutrient specifications for the top quality fishmeals of super prime, aqua prime and prime as shown in Tables 1 and 2.

3. The non-tuna fishmeal rated with the nutrient specifications for a standard, standard plus fishmeal shown in Tables 1 and 2.

Results – Objective 2b. Nutrient content of FPW fertilizer

Laboratory nitrogen, phosphorus, potassium (NPK) values of FPW fish fertilizer with 50 percent solids (liquid) had a NPK value of 5.1:1.4:0.4, with 95 percent solids (dry) fertilizer the NPK value was 10.1: 2.4:0.7 (Table 5).

Table 5 Nutrient content of mixed tuna and non-tuna.

Using Proximate and Mineral analysis of FPW		FPW sample 1	FPW sample 2	FPW sample 3	FPW sample 4	FPW sample 5	FPW sample 6	FPW sample 7	FPW sample 8	FPW sample 9	AVE
Protein (N)	%	68	69	76	64	47	53	70	70	57	63.8
Fat	%	13	12	11	16	33	28	6	7	18	16
Moisture	%	7	6	8	6	6	6	1	1	2	4.8
Ash	%	12	10	6	15	12	14	23	22	21	15
Phosphorus (P)	%	1.3	0.95	0.45	1.3	1	1.15	1.75	NA	3.4	1.4
Potassium (K)	%	0.5	0.35	0.4	0.4	0.25	0.3	0.45	NA	0.25	0.4

Nitrogen X 6.25 = protein

Converted to:

Fish Processing Waste (FPW)

Fertilizer	N	P	K
sample 1	5.5	1.3	0.5
sample 2	5.5	0.95	0.35
sample 3	6	0.45	0.4
sample 4	5	1.3	0.4
sample 5	4	1	0.25
sample 6	4	1.15	0.3
sample 7	5.5	1.75	0.45
sample 8	5.5	NA	NA
sample 9	4.5	3.4	0.25

50% solids - Liquid FPW Fertilizer

Average	**5.1**	**1.4**	**0.4**

95% solids - Dry FPW Fertilizer

Average	**10.1**	**2.4**	**0.7**

Summary

For the current FPW that is being generated in Hawai‘i, if maintained under temperature controlled conditions and segregated into tuna and non-tuna FPW and when processed separately, the quality and nutrient content of the tuna meal can meet or exceed the fishmeal quality market standards for the top quality fishmeals; super prime, aqua prime and prime fishmeals that are sold on the commodity market. The non-tuna FPW and the mixed FPW will meet the nutrient specifications for a Standard or Standard Plus fishmeal that are sold on the commodity market. Amino acid content of the FPW fishmeal are not shown in the commodity market specifications for the different grade pf fishmeals, however using only the protein and amino acid values of the FPW as shown in Table 3a, b, c., the amino acid profile and protein content of all the three categories the mixed, tuna and non-tuna fishmeal were all not that different in amino acid profile and 65-60 percent crude protein content as a menhaden select fishmeal (Table 3d). FPW fertilizer NPK values with 50 percent solids (liquid) was 5.1:1.4:0.4 and with 95 percent solids (dry) was 10.1:2.4:0.7 (Table 5).

4.3 Objective 3. Values of the potential FPW products in Hawai‘i

Commodity market checked for general quality standards as shown in Table 4a and b and values of the potential FPW products were determined. Table 6 show estimates of the dollar value of a FPW fish fertilizer or fishmeal and fish oil from each island and the State if all the

FPW was converted to these products.

Table 6 Commodity market values of fish fertilizer, fish silage, fish oil and fishmeal from fish processing waste by Island and State from 2014 questionairre estimates.

Fish Fertilizer, Fish Silage, Fishmeal & Fish Oil quantities and values

		2014 FPW / tons Year	fish fertilizer $3.5/gal	fish silage $545/ton	fish oil 6% $1,818/ton	fishmeal 33% $1,635/ton
MAUI COUNTY	FPW tons / year	223.0				
	Total	gallons	55,750			
	Total	ton			13.4	73.6
	Total	$ value	195,125	121,535	26,760	120,319.7
KAUAI & NIHAU	FPW tons / year	159.0				
	Total	gallons	39,750			
	Total	ton			9.5	52.5
	Total	$ value	139,125	86,655	19,080	85,788.5
HAWAII	FPW tons / year	689.0				
	Total	gallons	172,250			
	Total	ton			41.3	227.4
	Total	$ value	602,875	375,505	82,680	371,750
OAHU	FPW tons / year	3,367.0				
	Total	gallons	841,750			
	Total	ton			202.0	1,111.1
	Total	$ value	2,946,125	1,835,015	404,040	1,816,664.9
		2014 FPW / tons Year	fish fertilizer $3.5/gal	fish silage $545/ton	fish oil 6% $1,818/ton	fishmeal 33% $1,635/ton
STATE of HAWAII	FPW tons / year	4,215.0				
	Total	gallons	1,053,750			
	Total	ton			252.9	1,391.0
	Total	$ value	3,688,125	2,297,175	505,800	2,274,203.3

ASSUMPTIONS USED IN PROCESSING FISH MEAL AND FISH OIL
Using tuna fish oil and fish meal yields for all species of fish landed.
Estimating 40%, fish processing waste (FPW) generated from fish landed.
Raw material from fresh tuna yields ~6% fish oil and ~33% fishmeal from industry standards.
Estimated Fish oil, top quality ~ $2,000 m/ton, or $1,818/ton (Table 1b commodity values)
Fish meal top quality ~$1,800 m/ton or $1,635/ton (Table 1b commodity values)
ASSUMPTIONS USED IN PROCESSING FISH FERTILIZER AND FISH SILAGE
Course Ground FPW estimated at 6.25 lbs / gallon (Appendix C Oahu)
Estimate that 1 gallon of liquid fish fertilizer = 8 lbs ($3.5-4/gal wholesale, personal communications 9/2014).
UK and European market fish silage trades for $600/mt or $545/ton, personal communications 9/2014.

Results – Objective 3. Fishmeals

Tables 4a and b contain specifications and grades of fishmeals: super prime, aqua prime, prime, standard plus, standard and FAQ (fair average quality). If the FPW on Oahu could be processed by a fishmeal plant, fishmeals that are able to meet the specifications shown in Table 4 a and b it would have a current selling price in today's commodity market of a high of $1,900 per mt to a low of $1,840 per mt (Table 4b).

A fishmeal plant producing a fishmeal from the three categories of FPW shown in Tables 2a, b, c and 3a, b, c of mixed, tuna and non-tuna could produce a fishmeal of the following values:

1. Mixed 60:40 tuna and non-tuna mix (standard, standard plus) is valued at $1,760 to $1,750 per mt.

2. Tuna fishmeal (super prime, aqua prime and prime) is valued at $1,900 to $1,860 per mt.

3. Non-tuna fishmeal (standard, standard plus) is valued at $1,840 to $1,750 per mt.

4. Using only the protein and amino acid values of the FPW as shown in Table 4a, b, c., the amino acid profile and protein content of the mixed, tuna and non-tuna fishmeal amino acid profiles and 65 to 60 percent crude protein content were not that different from a menhaden select fishmeal valued at $1,650 to $1,677.50 per mt or $1,845 per mt. (USDA Market News, National Feedstuffs Market Review. Wed, Sept 10, 2014)

The fish oil extracted would be a crude oil, sold as bulk, drums and flexi tank which range in price from $1,900 to $2,200 per mt (Table 4b). If the fishmeal plant has a more sophisticated oil processing system for cleaning and separating the long chain omega-3 oils, the omega-3 oils collected would have a market price $2,500 to 2700 per mt (Table 4b).

If the concentrated fish solubles (50 percent solids), were not added back to the fishmeal and dried it would sell for $12.35 per ton in 55-gallon barrel, $12.15 per ton in 1-ton tote bags and $8.65 per ton in bulk containers (4,500-gallon tanker truck), FOB plant TX, (9/2014, personal communication, Omega Protein sales).

Results – Objective 3. Fish silage

Current market values for fish silage. There is very little information available on the price structure for these products. The only current information on fish silage sold is on the internet (http://www.unitedfisheries.co.nz/content/rural-products) however no price listed on the company website. In the UK and European market it usually trades for $600 per mt. Only salmon, now available as hydrolyzed acidified salmon, is $120 to 180 per mt. (Personal communication, John Blackett/Peter Hutchinson, ENH Ltd. NZ.)

Results – Objective 3. Fish Fertilizer

Fish Hydrolysates are the whole of the fish when processed. Fish Emulsions = Fish Solubles that comes from a fishmeal plant where fish and fish scraps are heated to denature proteins, rupture fat cells and release water from tissue. The proteins removed is fishmeal, the fat removed is the fish oils and the water remaining is the fish solubles that contains soluble proteins (amino acid), small particles fish tissue and fat.

NZ Fertilizer (http://www.unitedfisheries.co.nz/content/rural-products) Retail market values of 9/2014 shipping included delivered in NZ:

1. Organic liquid fish fertilizer @ 1000L min order – $2.95/liter (3.785) = $11.17/gallon.

2. Biological Liquid fish fertilizer @ 1000L min order – $3.11/liter (3.785) = $11.77 gallon.

3. Fish Hydro lysate @ 1000 L min order – $2.56/liter (3.785) = $9.69/gallon.

USA Fertilizer (http://www.ebay.com/itm/like/380885230501?lpid=82) Retail market values of 9/2014: with and without shipping in US.

1. Organic Liquid Natural Fish Hydrolysate Fertilizer – $39.95/ 2 gallons free ship in US.

2. Fish Soluble liquid Organic Hydrolysate fertilizer – $29.95/gallon free ship in US.

3. Fish Soluble liquid Organic Hydrolysate fertilizer – $12.95/gallon FOB Plant.

Wholesale market value: (9/2014 personal communication)

1. Fish Hydrolysate fertilizer in bulk – $3.50 to 4.00/gallon

4.4 Objective 4. Basic technologies that can be applied to stabilize the raw FPW material as a feed ingredient or as a fertilizer

A basic description of a simplified process and back ground information that is involved in manufacturing fishmeal, fish oil, fish silage and fish fertilizers and the potential product produced.

Fishmeal Plant - fishmeal, fish oil and fish solubles

The raw materials (FPW, whole fish) in fishmeal and fish oil manufacture are composed of three major fractions: solids, oil and water. The purpose of the fishmeal plant is to process and separate these fractions from each other as completely as possible, with the least possible expense and under conditions that will produce the best product values possible. In a typical fishmeal plant whole fish and/or FPW is weighed or measured by volume before it is transported to a grinder to be reduced to a uniform size, so that when it is passed to the cooker, uniform cooking and equal temperature distribution in the cooked material can be assured. Whole fish or fish scraps can be reduced to meal and oil by the following processing steps: whole fish and/or fish scraps are heated by a cooker, which coagulates the protein, ruptures the fat deposits and liberates oil and bound water. The coagulated, cooked solid material is then prestrained where liquids (oil and water) are drained from the cooked solid material before entering a twin screw press. Pressing removes a large fraction of the liquids from the solid material. Removed liquids separate into oil and water where the oil fraction is processed, cleaned and polished and sold as fish oil. The water fraction is evaporated to form a concentrated liquid called fish solubles. Drying the solid meal with the added concentrated fish solubles forms a whole dry fishmeal, or the concentrated fish solubles can be sold as a fish emulsion which is used in the fish fertilizer industry. Fish solubles contain small amounts (less than 0.1 percent by weight) of an acid that is added to drop the pH of the fish solubles to 4.5 or below. Without this acid addition to the fish solubles, microbial growth would proliferate creating gases and smelly odors. Fish solubles, also call fish emulsion, is purchased by fertilizer plants that turn them into liquid fish fertilizer (Windsor and Barlow 1981).

Note: The cost of a Thai fishmeal plant with a one mt per hour production capacity with oil extraction capability will cost about $1 million plus USD for equipment (personal communication). The fishmeal plant with a one mt per hour (2,200 pounds per hour) production capacity of raw tuna FPW will yield about 33 percent of a dry fishmeal (726 pounds), 6 percent oil (132 pounds) and 61 percent water (1,342 pounds of stick water = solubles) per mt of FPW.

Fish Silage Plant

Converting FPW into an acceptable protein supplement for the animal feed industry is a challenge. FPW (fillet scraps, head, tails, gill and guts, undersized or damaged fish, and bycatch) are high protein materials that are often underutilized or even discarded at sea or disposed at the land fill. There are a number of problems that have prevented the full-scale use of this FPW resource; a variable supply and quality, lack of nutritional data on its value in animal feeds, and inadequate economical methods of handling, storage, and conversion into an acceptable feed ingredient. The passage of the Magnuson-Stevens Fisheries Conservation and Management Act of 1976, which is intended to encourage further development of fishing activity, has probably resulted in increased quantities of FPW products. Ensiling and co-drying may be one way to convert this waste material into a usable by-product for incorporation into animal feeds (Hardy and others 1984). Ensilaging of fish wastes as a method of preservation was developed in northern Europe and has been used commercially since 1948 (Tatterson and Windsor 1974).

Fish silage is a liquid product made from whole fish, combinations of whole fish and fish wastes, or waste alone. It is liquefied by the action of endogenous enzymes in the presence of added mineral and/or organic acids such as sulfuric, phosphoric, formic or propionic and can be prepared by the following methods:

1. Acid Fish Silage – The liquefaction of fish tissue by enzymes naturally present in the FPW raw material. Addition of acid, inorganic and/or organic acid which lowers the pH of the silage sufficiently to prevent microbial spoilage.

2. Fermented Fish Silage – Bacterial fermentation with lactic acid bacteria, which are naturally present in the FPW raw material. It may be advisable, however, to add a starter culture of proper lactic acid bacteria. This will favor the growth of these bacteria. It is essential to add a fermentable sugar because FPW raw material contains little free sugar. The lactic acid bacteria and the reserve of fermentable sugar suppress amino-acid degradation.

Fish Silage Versus Fishmeal

According to Raa and Gildberg (1976), fish silage is a means of utilizing waste fish in situations where conventional fishmeal production is inappropriate or unavailable. Such situations are characterized by scattered and irregular landing of fishmeal plant. Fish silage has some advantages over fishmeal:

1. Acid preserved fish silage does not putrefy, retaining a fresh acidic smell even after storage for weeks at tropical temperatures.
2. There are not the same environmental problems with silage production as with fishmeal manufacture.
3. A fish silage is almost sterile and pathogens like Salmonella are efficiently killed in it.
4. The scale of production of fish silage can be varied at will without the economy of the process being greatly affected. The capital investment in equipment may be anything from a homemade drum with a chopper to a commercial plant designed for the de-oiling of large quantities of fish silage.
5. The energy requirements of silage production are very low compared with fishmeal.
6. Mixture of acid-preserved fish silage and carbohydrate filters can be dried in open trays under tropical conditions without fly infestation because flies are repelled by the evaporating acids
7. Fishmeal has the advantages of concentrated nutrients and is less bulky and thus cheaper to transport.

Fishmeal is the common product made from waste fish, but it is not suitable for small-scale production because of the high capital costs involved, and the need for trained engineers and other technical staff. Fish silage, on the other hand, can be made in any quantity as little as one drum at a time; the process can be quickly learned by unskilled labor and the capital outlay is minimal. The basic equipment required consists of a grinder for macerating the fish, a pH meter, a supply of drums or other containers and a balance for weighing the ingredients. Disadvantages of silage compared to fishmeal are that it is bulkier and more costly to transport, and that its protein content is only about 20 to 25 per cent of that of meal. The latter is an important consideration when evaluating the comparative costs of the two products, also there is some compensation in the lower energy input of silage, compared to the high energy input of a fishmeal production process (Batista and Irineu 1986).

The nutritional value of fish silage as an animal feed can be increased significantly by limiting the extent to which proteins and polypeptides are hydrolyzed to free amino acids. Studies have shown that the majority of the protein nitrogen ingested by humans (Mathews 1972; Silk 1980; Silk and others 1985) is absorbed by the intestinal mucosa as di- and tri-peptides while a lesser portion is absorbed as free amino acids. Similarly, plasma levels of essential amino acids remain at elevated levels for longer periods when trout (Yamada and others 1981) and carp (Plakas and others 1980; Plakas and Katayama 1981) are fed a diet containing intact protein (casein) rather than an equivalent diet containing free amino acids as the protein source. Rainbow trout had higher weight gains, protein efficiency ratios (Hardy and others 1983), net protein utilization, and apparent digestibility coefficients (Hardy and others 1984) when fed silages in which autolysis was terminated after 3 to 7 days or restricted by temperature and pH (Hardy and others 1983; Stone and Hardy 1986) than when autolysis was permitted to continue until high levels of free amino acids appeared in the silage (Stone and others 1989).

Silages that contained more intact protein and less free amino acids than diets made with conventional silage have been utilized more efficiently because the absorption of peptides and free amino acids was prolonged as digestion progressed in the gastro intestinal tract, resulting in more efficient conversion of dietary protein to fish flesh. The silage diets, however, were inferior to those containing fishmeal in supporting fish growth in part because they contained a higher proportion of essential amino acids in the free form. It is clear that the autolysis of fish silage should be restricted to preserve nutritional value.

Note: Two commercial fish hydrolysate fertilizer manufacturers were contacted but no cost estimates have been received to date. The cost of a fish silage or fish fertilizer plant with a 0.5 to 4 tons /day capacity including equipment that was requested is still pending. However these plants are simple and far less costly in equipment, to setup, install, maintain and simple to operate when compared to a fishmeal plant. Estimated yield of products fish silage or fish fertilizer plant is input of feedstock, which is then liquefied by enzymes and stabilized w/ acids into a liquid fish silage or a liquid fish fertilizer. A ton of FPW (2,000 pounds) will yield 250 gallons of product at ~8 pounds per gallon.

Fish Fertilizer Plant

A complete review of fish fertilizer by Vernon Sato (MS, Algal Specialist) is in Appendix 5. The review on fish fertilizer covers: 1) use of fish as a fertilizer, 2) product forms, 3) seaweeds as fertilizers, 4) benefits of organic fertilization, 5) organic fertilization in terrestrial agriculture and 6) algal biomass for biofuels.

A fish fertilizer plant and a fish silage plant are essentially the same plant with the same equipment and very similar processes (Ward and others 1985). The difference between the two are the freshness or quality of the raw FPW as feed stock and the length of the enzymatic digestion process. A fertilizer plant will take any grade of raw feeds and through the enzymatic digestive process break the FPW down to it basic elements of NPK; the addition of an acid lowers the pH, which stops microbial growth. It is important note that fish guts in FPW contain endogenous enzymes that are important for the enzymatic digestion process of the breakdown of FPW that is needed to be converted into fish silage and/or fish fertilizer in the manufacturing process.

4.5 Objective 5. Identify potential commercial suppliers of the FPW as a feed ingredient or fertilizer on each Island

Results

A list (company name, address, phone #s and contact person spoken with) of all the major commercial producers of FPW by Island, on the wholesale and retail level in Hawaii (Appendix A). A summary was compiled of information gathered from the questionnaire on visits to companies on the list. Summary data on how much FPW is being generated by the commercial wholesaler or retailer by Island, and where it being disposed of.

Potential manufacturers of feed silage or a liquid fish fertilizers on the various Islands that were met and interviewed and expressed interest in creating a business with FPW:

- Kauai, Mr. Mark Oyama, Contemporary Flavors Catering
- Maui, Mr. Darrel Plimpton, Maui Seafoods LLC
- Molokai, Mr. Noah Freeman, Freeman Farms
- Big Island, Ms. Jennica Lowell, Kona Blue
- Oahu, Mrs. Maryann Songsong, Pacific Pure Technologies

4.6 Objective 6. Identify the potential users of the FPW as a feed ingredient or fertilizer on each Island

Results

The Department of Agriculture, Aquaculture and Livestock Support Services Branch (ALSS) (http://hdoa.hawaii.gov/ai/aquaculture-and-livestock-support-services-branch/) can provide information on Objective 6 to identify potential users, they are also able to provide a wide range of support for new and existing aquaculture and livestock businesses through planning and coordination, business counseling, information dissemination efforts. ALSS supports profitable and sustainable industry growth by encouraging a diversity of products and offers assistances in: 1) starting a new business in Hawai‘i; 2) introducing best management practices and new technologies; 3) providing direct assistance with regulations and disease prevention; 4) assisting market development at home and abroad; 5) facilitating expansion of offshore aquaculture development on species, systems and potential leases; and 6) helping securing resources including leaseholds, water and processing facilities required to maintain and promote the local production of aquaculture and livestock.

Animal feed ingredients contact:

- Todd Low, Dept. of Agriculture, Aquaculture and Livestock Support Services, phone: (808) 483-7130, fax: (808) 483-7110, email: todd.e.low@hawaii.gov
- Liz Xu. Economic Development Specialist, Dept. of Agriculture, Aquaculture and Livestock Support Services, phone: (808) 483-7104, fax: (808) 483-7110, email: jing.xu@hawaii.gov

Plant fertilizer contact:

- The Department of Agriculture (http://hdoa.hawaii.gov/add/md/) Hawai‘i Department of Agriculture Agricultural Development Division, Market Development Branch, 1428 South King Street, Honolulu, HI, 96814-2512, phone: (808) 973-9595, fax: (808) 973-9590, email: hdoa.md@hawaii.gov

4.7 Objective 7. Determine if FPW can be collected economically and converted to a feed ingredient or a fertilizer on each island

Results

Results for each Island were determined by the data collected and compiled. The data suggested viable options for the recycling and utilization of this co-product (FPW), on Island as an eco-friendly sustainable product for a feed and/or fertilizer.

Kauai

A fish silage or a fish fertilizer are possible for the Island of Kauai. There is an estimated 0.5 tons of FPW going to landfill per day. This FPW has a high quality and nutrient content that can be used for animal feed, both as a raw material FPW and as processed fish silage. These are the least expensive capital investments to manufacture a product that can be made and sold on Island. The bones in the FPW needs to be finely ground to eliminate pig mortalities caused by internal punctures and cuts in the gastrointestinal tract by unground fish bones in the feed consumed by pigs. Pig farmers need to be taught that FPW needs to be fed in limited quantities, or withdrawn from the feed several week prior to slaughter if used as a feed ingredient (raw FPW and/or fish silage), to minimize a fishy odor that can occur in the pig flesh, which will influence the product quality and value of a slaughtered animal.

A liquid fish fertilizer is also a possible product to produce using the same equipment and processing methods as in making a fish silage. It is important the guts of fish that contain the endogenous enzymes is retained and added to the process for it is an important component for the digestion of the FPW that is needed in the fish silage and the fish fertilizer manufacturing process. However the FPW quality need not be optimal for a fertilizer and the enzymatic digestion process for a fertilizer is left for a longer period of time to optimize the breakdown of the FPW tissues and to increase the mineralization of the bones in the liquid fertilizer. A finished liquid fish fertilizer needs to be passed through a 200 mesh screen before it is sold as a fish liquid fertilizer to eliminate, small stone, metal and bone that can clog irrigation drip pipes and spray nozzles.

Table 6 shows that if all the FPW on Kauai was converted into fish oil and fishmeal by a fishmeal plant it would have an estimated commodity market value of $19,080 for fish oil and a market value of $ 85,788 for fishmeal. As an alternative if all the FPW on Kauai was converted into a fish silage it would have an estimated a retail value of $86,655. But if all the FPW on Kauai was converted into a liquid fish fertilizer it would have an estimated wholesale value of $139,125 or a retail value of 2X or $278,250.

Maui County (Maui and Molokai)

A fish silage or a fish fertilizer are possible on the islands of Maui and Molokai. There is an estimated 0.7 tons of FPW going to landfill per day. Recommendations for Maui County are the same as above for Kauai.

Table 6 shows that if all the FPW on Maui County was converted into fish oil and fishmeal by a fishmeal plant it would have an estimated commodity market value of $26.760 for fish oil and a market value of $ 120,319 for fishmeal. As an alternative if all the FPW on Maui County was converted into a fish silage it would have an estimated a retail value of $121,535. But if all the FPW on Maui County was converted into a liquid fish fertilizer it would have an estimated wholesale value of $195,125 or a retail value of 2X or $390,250.

Big Island

A fish silage or a fish fertilizer are possible for the Big Island in Hilo and Kona. There is an estimated 1.0 tons of FPW going to landfill per day from Kona and 1.0 tons of FPW going to landfill per day from Hilo. Kona and Hilo are towns on opposite sides of the island about 80 miles apart. Recommendations on how the FPW should be handled is the same as Kauai, with the possibility of 2 FPW facilities because transporting the FPW across island may not be economical. Recommendations for the Big Island are the same as above for Kauai.

Table 6 shows that if all the FPW on Big Island was converted into fish oil and fishmeal by a fishmeal plant it would have an estimated commodity market value of $82,680 for fish oil and a market value of $371,750 for fishmeal. As an alternative if all the FPW on Big Island was converted into a fish silage it would have an estimated a retail value of $375,505. But if all the FPW on Big Island was converted into a liquid fish fertilizer it would have an estimated wholesale value of $602,875 or a retail value of 2X or $1,205,750.

Oahu

A fishmeal, fish oil, fish silage, and fish fertilizer are all possible on Oahu. There is an estimated 12 tons/day of FPW being produced but 6 tons/day are collected by the local rendering plant that is currently processing about 32 tons of FPW/wk. Slaughterhouse by-products (cattle, hogs, and goats) are added and mixed with the FPW from Kalaeloa slaughterhouse that is operated by the Hawaiʻi Livestock Cooperative. The meat and bone meal (MBM) by-product ingredient is sold locally as an organic soil amendment @ $.21/lb. or $420/ton. The rest of the estimated 6 tons are being composted by farmers, taken to the landfill or H-power.

A potential small fishmeal plant if constructed (1mt/hr. capacity) will have to collect more than the 6 tons of the 12 tons of FPW that is estimated to be available today; the rendering plant is collecting about 6 tons/day. There is no commercial animal feed manufacturing industry in Hawaiʻi at this time so the fishmeal that could be produced will be a potential exported commodity.

The estimated value of a fishmeal at $1,800/mt (~.81/lb. or $1,636/ton) and the estimated value of fish oil at $2,000/mt (~.91/lb. or $1,818/ton) that could be exported or used as a feed ingredient on Oahu. Currently disposal companies collect 2,912 tons/ year, and 3,367 tons is estimated from the questionnaire summary. For ease of calculation we have used 3,000 tons per year of FPW, of which 50 percent goes to the rendering plant to make MBM @ $420/ton. If the other 50 percent or 1,500 tons goes to a fishmeal plant using the estimated yields of tuna fishmeal (33%) and fish oil (6%) this will result in (1,500 FPW(33%) = 495) 495 tons of fishmeal and (1,500 FPW (6%) = 90) 90 tons of fish oil. The value of the 495 tons of fishmeal @ $1,636/ton would yield $809,820. The value of the 90 tons of fish oil @ $1,818/ton would yield $163,620. Total $973,440 /year, from fishmeal and fish oil, and no shipping cost added to the products made in Hawaiʻi.

A fish silage plant and/or a fish fertilizer plant are also possible recommendations and are the same as above for Kauai.

Table 6 shows that if all the FPW on Oahu was converted into fish oil and fishmeal by a fishmeal plant it would have an estimated commodity market value of $404,040 for fish oil and a market value of $1,816,664 for fishmeal. As an alternative if all the FPW on Oahu was converted into a fish silage it would have an estimated a retail value of $1,835,015. But if all the FPW on Oahu was converted into a liquid fish fertilizer it would have an estimated wholesale value of $2,946,125 or a retail value of 2X or $5,892,250.

State of Hawai‘i

Table 6 also shows that if all the FPW in the State of Hawai‘i was converted into fish oil and fishmeal by a fishmeal plant it would have an estimated commodity market value of 505,800 for fish oil and a market value of $2,274,203 for fishmeal. As an alternative if all the FPW in the State was converted into a fish silage it would have an estimated a retail value of $2,297,175. But if all the FPW in the State of Hawai‘i was converted into a liquid fish fertilizer it would have an estimated wholesale value of $3,688,125 or a retail value of 2X or $7,376,250.

Evaluating the dollar values of products that could potentially be developed from converting and stabilizing the FPW only highlights the importance of viewing what is now a costly waste disposal problem for the industry is an opportunity to develop an income stream. As reflected in the title of the WRPFMC study “Fish Processing Waste: A Valuable Co-Product of the Fishing Industry,” we need not accept the status quo of regarding this expensive disposal problem as just another cost of doing business.

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Appendix 1 Company list by island.

APPENDIX A : COMPANY LIST BY ISLAND

Deep 7 top buyers, top fish wholesalers & retailers, websearch for seafood and fish wholesalers

BIG ISLAND	KAUAI	MAUI	MOLOKAI	OAHU	
Crescent City Seafoods Inc - W	Garden Isle Seafood - KAUAI W	FRESH ISLAND FISH COMPANY - MAUI - W	FRIENDLY MARKET - MKT	DIAMOND HEAD SEAFOOD CO - W	Top Fish Auction Buyers
55 Holomua Street	2976 Aukele St # A3,	312 Alamaha St. Unit G	90 Ala Malama Ave.	966 Robello Lane	Fresh Island Fish Co.
Hilo, HI 96720	Lihue, HI 96766	Kahului, HI 96732	Kaunakakai, HI 96748	HONOLULU, HI 96817-4545	Tropic Fish Hawaii
Phone (808) 961-0877	(808) 245-4848	Phone: + 1 808 871 1111	(808) 553-5595	(808) 832-9500	Diamond Head Seafoods
Charles Umamoto	(808) 245 - 4949 Fax	Fax: +1 808 871 6511	Jeff or Judy Egusa	MICHAEL P IRISH CEO	Garden & Valley Isle Seafood
President - CMU&ASSOC. - W	Saber Kennedy - mgr	info@freshislandfish.com	Ph.# 553 - 5821	Gary T. Ishimoto, President	Norpac Fisheries
		4 locations - Big Island, Oahu, Maui, Kauai			Honolulu Fish Co.
HILO FISH COMPANY, INC. CMU&ASSOC. - W	TROPIC FISH KAUAI CMU & ASSOC - W		KUALAPUU MARKET - MKT	FRESH ISLAND FISH COMPANY - OAHU - W	Ham's Produce and Seafood
55 Holomua St.	Puhi Industrial Area	MAUI SEAFOOD LLC W	311 Farrington Hwy	1135 N. Nimitz Hwy	Wing Sing Seafood
Hilo, Hawaii, Hawaii 96720	1626 Haleukana Street. #103	800 Eha Street Unit 11& 12	Kualapuu, HI 96757	Honolulu, HI, 96817	Thomas Calvert & Associates
Tel: (808) 961-0877	Lihue, HI 96766	Wailuku, HI 96793	(808) 567-6243	Phone: +1 800 628 3329	Ashi (Western United)
Fax: (808) 961-3419	808-240-3474 Office; 808-240-1200 Fax	President & Owner	Sonya or Leslie Yuen	Toll-Free: +1 800 628 3329	Maguro International
Charles M. Umamoto	www.tropicfishkauai.com	Darrel Plimpton	Ph. #567-6243	Fax: +1 808 836 8762	John's Fresh Fish
Chairman/Chief Executive Officer	Mathew Lopez	6:00am-3:00pm daily		info@freshislandfish.com	Hawaiian Fresh Seafood
Email: charlie@hilofish.com	Regional Branch Manager	Tel: 808-242-4073	MISAKI'S - MKT	Bruce Johnson / President, CEO	
Kerry Umamoto	mlopez@tropicfishkauai.com	Fax: 808-244-7020	78 Ala Malama St.	Naoi Yuen /COO	
President and COO	808-755-5640	EMAIL: mauiseafoods1@gmail.com	Kaunakakai, HI.	Derek Higa / VP Operations	
Hilo Fish Company and Kona Fish Company	4 locations - Big Island, Oahu, Kauai, Maui		808-553-5505	4 locations - Big Island, Oahu, Maui, Kauai	
Email: kerry@konafish.com		TROPIC FISH - MAUI CMU&ASSOC. - W	Kevin or Marla Misaki		
Cell: (808) 640-7684	FRESH ISLAND FISH COMPANY - Kauai - W	124 Manea Place, #1	Ph # 553 - 5505	Garden & Valley Isle Seafood - Oahu W	
David D.M. Yee	1610 Haleukana St #8	Wailuku, HI 96793		225 N Nimitz Hwy # 3	
General Manager	Lihue, HI 96766	808-270-0770 Office	Independent Fish dealer	Honolulu, HI 96817-6349	
Email: davidyee@hilofish.com	Phone: +1 808 632 0363	808-270-0773 Fax	Shane Sumamap	(808) 524-484	
Cell: (808) 557-4084	Fax: +1 808 632 0812	www.tropicfishmaui.com	206-3074	Robert Fram and Dave Marabella	
6 locations - Big Island (3), Oahu, Kauai, Maui	4 locations - Big Island, Oahu, Maui, Kauai	Barry Masuda		4 locations - Oahu, Maui, Kauai & Kona	
		General Manager	Independent fisherman - Road side vendor		
KONA FISH COMPANY - CMU&ASSOC. W.	KOA TRADING W	bmasuda@tropicfishmaui.com	Henry	HAM PRODUCE & SEAFOOD W	
Kaloko Light Industrial Park	2975 Aukele St,	808-283-2710		916 Bannister Street new address	
73-4776 Kanalani Street #6	Lihue, HI 96766	4 locations - Big Island, Oahu, Kauai, Maui		Honolulu, HI 96819	
Kailua-Kona, Hawaii 96740	(808) 245-6981			Phone: (808) 842-7171	
PH: (808) 326-7708	kyukimura@koatradingcoinc.com	VALLEY ISLAND SEAFOOD - W & R		May Hugh (not english speaking) / Sam Hugh	
FAX: (808) 329-3669		475 Hukilike St		Owner	
EMAIL: sales@konafish.com	BEACH HOUSE RESTAURANT - R	Kahului, HI 96732			
General Manager	5022 Lawai Road,	(808) 873-4847		Hawaiian Fresh Seafood - W	
Wes Murakami	Koloa, HI 96756-9618	Victor Daubert - manager		2290 Alahao Place	
wes@konafish.com	(808) 742-1424	4 locations - Oahu, Maui, Kauai & Kona		Honolulu HI 96819	
808-960-5891				PH 808 845-8862	
	CJ'S STEAK & SEAFOOD, INC. R	Upcountry Fishery - W		Fax: 808 841-8862	
FRESH ISLAND FISH COMPANY - KONA - W	5-4280 Kuhio Hwy,	190 Alamaha St # E,		Frank Porcelli	
73-5677 Lawehana St	Princeville, HI 96722	Kahului, HI 96732		President & CEO	
Kailua - Kona, HI 96740	(808) 826-6211	(808) 871-8484			
Phone: +1 800 628 3329	Renie Bauder - Mgr			Honolulu Fish Company	
Fax: +1 808 331 2101		Eskimo Candy Inc - R & W		824 Gulick Avenue	
info@freshislandfish.com	THE FISH EXPRESS W&R	2665 Wai Wai Pl,		Honolulu, HI 96819	
4 locations - Big Island, Oahu, Maui, Kauai	3343 Kuhio Hwy	Kihei, HI 96753		Tel: (808) 833-1123	
	Ste 10	(808) 891-8898		Fax: (808) 836-1045	
Suisan Company, Ltd. W	Lihue, HI 96766			Email: sales@honolulufish.com	
1965 Kamehameha Avenue	(808) 245-9918	True World Foods - Maui - W		Website: www.honolulufish.com	
Hilo, Hawaii 96720	Alan Yamamoto / David Wada - Brothers	173 Alamaha St # 2,		Wayne Samiere - Owner	
Phone: (808) 935-8511		Kahului, HI 96732		Damon Johnson - Partner	
Fax: (808) 935-2737	HANALEI DOLPHIN CORP. MKT	(808) 877-2852			
Glenn T. Hashimoto	5-5016 Kuhio Highway			John's Fresh Fish	
President and CEO	Hanalei, HI 96714	THE FISH MARKET MAUI, INC. - R		????? Address	
KYLE SUMMER - mgr fish cutting	22.204830 -159.504660	3600 Lower Honoapiilani Rd		Kailua HI 96734-2232	
	Phone: (808) 826-6113	Lahaina, HI 96761		808 372-6773	
Wharton Seafood Sales (Paauilo, Hawaii) - W	Owner	(808) 665-9895		Web: www.johnsfreshfish.com	
43505 Belt Hwy	Doug Allen			John & Erin Hernandez - Owner	
Paauilo, Hawaii 96776, USA	Fish market manager: Brysen Sugihara &	HOTEL HANA MAUI name change to			
808 776 1087	Brother Byron	Travaasa Hana Hotel - R		Maguro International - M	
	Ara's Sakana-Ya - MKT	5031 Hana Highway		6 Wai Wai Loop	
True World Foods Inc - W	3-4301 Kuhio Hwy Ste 102	Hana, HI 96713		Honolulu, Hawaii 96819	
77-6425 Kuakini Hwy,	LIHUE, HI - Kauai County	(808) 248-8211		Phone: 808-865-7004	
Kailua-Kona, HI	(808) 245-1707	travaasa.com		Fax: 808-833-6036	
(808) 327-1360					
	Aloha Fish Company, Inc - MKT	FOODLAND-PUKALANI - MKT		Nobu Seafood Hawaii - W DHSF owned	

Appendix 1 Company list by island.

HAWAIIAN ISLE SEAFOOD -	4310 Waialo Road	55 Pukalani St.		1020 Auahi St Ste 2080
73-4156 Hulikoa Drive	Eleele, HI 96705	Pukalani, HI, 96768		Honolulu, HI
Kailua, Kona Hi 96740	Phone: (808) 335-0110	572-0674		(808) 591-2717
Phone: (808) 331-1535	Charles Gilbert			MIKE IRISH - CEO
Owner	Chief Executive Officer	FEARLESS FISH name change to		
James Kuwada		Mama's Fish House R		Norpac Fisheries Inc - W
	Koloa Fish Market	799 Poho Pl, Paia,		3140 Ualena St Ste 205,
KTA SUPERSTORE #2 MKT	5482 Koloa Road	Maui, HI 96779-9708		Honolulu, HI
Kona Coast Shopping Center	Koloa, Kauai HI 96756	+1 808-579-8488		(808) 528-3474
74-5594 Palani Road	(808) 742-6199	Mike Pascher - fish room mgr		Norpac Fisheries Export - W
Kailua-Kona, Hawaii 96740	Randy Matsukoa - owner			1535 Colburn St,
5:00 am to 11:00 pm (Daily)		OKI'S SEAFOOD CORNER * MKT		Honolulu, HI
808-329-1677	Kapaa, HI 96746	275 W Kaahumanu Ave,		(808) 842-3474
808-329-8404 (Fax)		Kahului, HI 96732		TJ Kraft / Dr. Charles Laidely
Store Manager	PONO MARKET	(808) 871-5922		
Arelene Reilly	4-1300 Kuhio Highway	Located in Foodland Kahului		Thomas Calvert & Associates - W
	Kaapa,HI 96746	Elisa Garcia - Mgr		834 Pohukaina St
KTA SUPERSTORE #3 - MKT	808 822-4581			Honolulu, HI 96813-5306
KTA Center				PO Box 1020 Haleiwa, HI 96712
50 East Puainako St.	Kilauea, HI 96754			Ph 808 534 0737
Hilo, Hawaii 96720				FAX 808 534 1309
5:30 am - Midnight (Daily)	Kilauea Fish Market			Email: Tom@tcaseafood.com
808-959-9111	4270 Kilauea Road			Web: TCAseafood.com
808-959-8064 (Fax)	Kilauea HI 96754			Thomas Calvert - Owner
Store Manager	Phone 828-6244			
Sanford Toma				TROPIC FISH HAWAII / CMU & ASSOC. - W
	Princeville, HI 96722			1020 Auahi Street, #3090
LA'AU'S FISHING - W & MKT	CJ'S STEAK & SEAFOOD, INC. R			Honolulu, HI 96814
Akoni Pule Highway	5-4280 Kuhio Hwy,			808-591-2936 Office;
Kamuela, HI 96743	Princeville, HI 96722			808-591-2934 Fax
Phone: (808) 882-1052	(808) 826-6211			www.tropicfishhawaii.com
Owner	Renie Bauder - Mgr			Shawn Tanoue—President/ COO
Edward La'au				stanoue@tropicfishhawaii.com
				808-478-3398
Garden Isle Seafood - Kona W				Shannon Tanoue—VP Operations
74-5626 Alapa St,				sstanoue@tropicfishhawaii.com
Kailua Kona, HI 96740				808-479-3938
(808) 329-3474				4 locations - Big Island, Oahu, Maui & Kauai
Robert Fram and Dave Marabella -Owners				
4 locations - Kona, Oahu, Kauai, Maui				Western United Fish Company - ASHI - W
				15110 NE 90th Street, Suite 110
SACK N SAVE #25 (KONA)				Redmond, WA 98052
75-5595 PALANI ROAD				Phone: 425-558-7809
KAILUA-KONA, HI 96740				Fax 425-558-7919
				info@westernunitedfish.com
KTA SUPERSTORE #7 - KEAUHOU				
78-6831 ALII DRIVE				Wing Sing Seafood Inc - W
KAILUA-KONA, HI 96740				230 Libby St,
				Honolulu, HI
KAWAIHAE HARBOR GRILL				(808) 847-2580
61-3642 Kawaihae Rd				Don Leong -Owner
KAWAIHAE, HI 96743				Owner
KONA SEAFOOD, INC.				UNITED FISHING AGENCY LTD - A
83-5308-A MAMALAHOA HIGHWAY				1131 N Nimitz Highway
CAPTAIN COOK, HI 96704				Honolulu, HI 96817
				Phone: (808) 538-2148
SACK N SAVE #26 (HILO)				Manager
250 KINOOLE STREET				Brooks Takenaka
HILO, HI 96720				
				Amor Nino Foods Inc - W
SACK N SAVE #21 (HILO)				1928 Homerule St,
2100 KANOELEHUA AVENUE				Honolulu, HI
HILO, HI 96720				(808) 845-1711
PUNA FRESH FOODS				Pacific Seafood Distribution - W
16-586 OLD VOLCANO RD #102				3170 Ualena St Ste B
KEAAU, HI 96749				Honolulu, HI
				(808) 836-8888
MALAMA MARKET				

Appendix 1 Company list by island.

15-2660 Pahoa Rd				Fish 2 Go - W
PAHOA, HI 96778				1334 Young Street # 108
				Honolulu, HI 96814
OSHIMA STORE				Phone: (808) 593-0706
79-7400 Mamalahoa Hwy				
KEALAKEKUA, HI 96750				K Azama Fish Wholesale - W
				94-676 Farrington Highway
KAHUKU COUNTRY MARKET				Waipahu, HI 96797
525 Lotus Blossom Lane				Phone: (808) 888-2031
OCEAN VIEW, HI 96737				
				Dow Distribution - W
				524 Ohohia St
				Honolulu, HI
				(808) 836-3511
				True World Foods Inc Of Hawaii - W
				2696 Waiwai Loop
				Honolulu, HI
				(808) 836-3222
				808 Finest Seafoods - W
				690 Halekauwila St,
				Honolulu, HI
				(808) 521-6000
				Seafood Connection - W
				841 Pohukaina St Ste I,
				Honolulu, HI
				(808) 591-8550
				U Okada & Co Ltd - W
				1000 Queen St,
				Honolulu, HI
				(808) 597-1102
				Troy Enterprise - W
				135 N King St Spc 7B,
				Honolulu, HI
				(808) 531-6758
				Annasea International Hi LLC - W
				1151 Mapunapuna St,
				Honolulu, HI
				(808) 833-2222
				Wah Wah Seafood Co. - W
				157 N King St,
				Honolulu, HI
				(808) 533-3283
				Ohana Seafood
				255 Sand Island Access Rd # 2c,
				Honolulu, HI
				(808) 843-1844
				New Zealand Seafoods Of Hawaii - W
				524 Ohohia St
				Honolulu, HI
				(808) 836-3262
				Rite Selection Inc
				1325 Nuuanu Ave Ste 211
				Honolulu, HI
				(808) 585-6257
				Dmm International - W
				1430 Hart St,
				Honolulu, HI
				(808) 841-2882
				Da Seafood Store - M
				925 Maunakea St Unit B,

Appendix 1 Company list by island.

				Honolulu, HI
				(808) 526-1230
				Eskimo Candy Inc. - OAHU MKT
				2665 Wai Wai Place
				Kihei, HI 96753
				808-879-5686
				Fax: 808-874-0504
				PACIFIC SUPERMARKET - MKT
				94-300 Farrington Hwy,
				Waipahu, HI 96797
				(808) 678-2828
				TAMASHIRO MARKET - MKT
				802 N King Street
				Honolulu, HI 96817
				Cyrus Tamashiro
				President
				Phone: (808) 841-8047
				Web: Tamashiromarket.com
				MARUKAI WHOLESALE MART - MKT
				2310 Kamehameha Hwy
				Honolulu, HI 96819
				(808) 845-5051
				TRUE WORLD FOODS INC. OF HAWAII - W
				2696 Waiwai Loop,
				Honolulu, HI 96819-1938
				(808) 836-3222

Appendix 1 Company list by island.

MOLOKAI
KUALAPUU MARKET - MKT
311 Farrington Hwy
Kualapuu, HI 96757
(808) 567-6243
Sonya or Leslie Yuen
Ph . #567-6243
MISAKI'S - MKT
78 Ala Malama St,
Kaunakakai, HI.
808-553-5505
Kevin or Marla Misaki
Ph # 553 - 5505
FRIENDLY MARKET - MKT
90 Ala Malama Ave,
Kaunakakai, HI 96748
(808) 553-5595
Jeff or Judy Egusa
Ph.# 553 - 5821
Independent Fisherman - Selling out of truck
Henry
Independent Fish Dealer - No Store
Shane Sumarnap
206-3074

Appendix 1 Company list by island.

KAUAI
Lihue, HI 96766
Garden Isle Seafood - KAUAI W
2976 Aukele St # A3,
Lihue, HI 96766
(808) 245-4848
(808) 245 - 4949 Fax
Saber Kennedy -mgr
4 locations - Oahu, Maui, Kauai, Kona
TROPIC FISH KAUAI CMU & ASSOC. - W
Puhi Industrial Area
1626 Haleukana Street, #103
Lihue, HI 96766
808-240-3474 Office; 808-240-1200 Fax
www.tropicfishkauai.com
Mathew Lopez
Regional Branch Manager
mlopez@tropicfishkauai.com
808-755-5640
6 locations - Big Island (3), Oahu, Kauai, Maui
FRESH ISLAND FISH COMPANY - Kauai - W
1810 Haleukana St #8
Lihue, HI 96766
Phone: +1 808 632 0363
Fax: +1 808 632 0812
4 locations - Big Island, Oahu, Maui , Kauai
THE FISH EXPRESS W & R
3343 Kuhio Hwy
Ste 10
Lihue, HI 96766
(808) 245-9918
Alan Yamamoto / David Wada (owner)- Brothers
Ara's Sakana-Ya - MKT
3-4301 Kuhio Hwy Ste 102
LIHUE, HI - Kauai County
(808) 245-1707
Eleele, HI 96705
Aloha Fish Company, Inc - MKT
4310 Waialo Road
Eleele, HI 96705
Phone: (808) 335-0110
Chief Executive Officer Charles Gilbert

Koloa, HI 96756-9618
BEACH HOUSE RESTAURANT - R
5022 Lawai Road,
Koloa, HI 96756-9618
(808) 742-1424
Koloa Fish Market
5482 Koloa Road
Koloa, Kauai HI 96756
(808) 742-6199
Randy Matsukoa -owner
Kapaa, HI 96746
PONO MARKET
4-1300 Kuhio Highway
Kaapa,HI 96746
808 822-4581
Hanalei, HI 96714
HANALEI DOLPHIN CORP. MKT
5-5016 Kuhio Highway
Hanalei, HI 96714
Phone: (808) 826-6113
Owner: Doug Allen
Kilauea, HI 96754
Kilauea Fish Market
4270 Kilauea Road
Kilauea HI 96754
Phone 828-6244
Princeville, HI 96722
CJ'S STEAK & SEAFOOD, INC. R
5-4280 Kuhio Hwy,
Princeville, HI 96722
(808) 826-6211
Renie Bauder - Mgr
KOA TRADING W
2975 Aukele St,
Lihue, HI 96766
(808) 245-6961
kyukimura@koatradingcoinc.com

Appendix 1 Company list by island.

MAUI	MAUI	MAUI
WAILUKU	KAHULUI	HANA
MAUI SEAFOOD LLC W ***	VALLEY ISLAND SEAFOOD - W & R ***	HOTEL HANA MAUI name change to
800 Eha Street Unit 11& 12	475 Hukilike St	Travaasa Hana Hotel - R
Wailuku, HI 96793	Kahului, HI 96732	5031 Hana Highway
President & Owner	(808) 873-4847	Hana, HI 96713
Darrel Plimpton	Victor Daubert -mgr	(808) 248-8211
6:00am-3:00pm daily	Robert Fram and Dave Marabella -Owners	
Tel: 808-242-4073	4 locations - Oahu, Maui, Kauai, Kona	PAIA
Fax: 808-244-7020		FEARLESS FISH name change to
EMAIL: mauiseafoods1@gmail.com	OKI'S SEAFOOD CORNER - MKT ***	Mama's Fish House R ***
	275 W Kaahumanu Ave,	799 Poho Pl,
TROPIC FISH - MAUI CMU&ASSOC. - W ***	Kahului, HI 96732	Paia, Maui, HI 96779-9708
124 Manea Place, #1	(808) 871-5922	+1 808-579-8488
Wailuku, HI 96793	Located in Foodland Kahului	Mike Pascher - fish room mgr
808-270-0770 Office	Elisa Garcia - Mgr	
808-270-0773 Fax		
www.tropicfishmaui.com	AH FOOK'S SUPER MARKET **	
Barry Masuda	65 w Kaahumanu Ave	
General Manager	Kahului, HI 96732	
bmasuda@tropicfishmaui.com	808 877-8952	
808-283-2710		
6 locations - Big Island (3), Oahu, Kauai, Maui	FRESH ISLAND FISH COMPANY - MAUI - W ***	
	312 Alamaha St. Unit G	
KIHEI	Kahului, HI 96732	
Eskimo Candy Inc - R & W **	Phone: + 1 808 871 1111	
2665 Wai Wai Pl,	Fax: +1 808 871 6511	
Kihei, HI 96753	info@freshislandfish.com	
(808) 891-8898	4 locations - Big Island, Oahu, Maui , Kauai	
PHILMART ORIENTAL & FASTFOOD *	Upcountry Fishery - W	
300 OHUKAI ROAD	190 Alamaha St # E,	
Kihei, HI 96753	Kahului, HI 96732	
Rodrigo Rabang	(808) 871-8484	
Owner		
LAHAINA	CASH N' CARRY Warehouse	
FOODLAND FARMS *	90 Amala Pl	
345 Keawe Street Suite 304	Kahului, HI 96732	
Lahaina, HI 96761		
808 662-7088	HALIIMAILE	
	Hali'imaile General Store *	
THE FISH MARKET MAUI, INC. - R ***	900 Haliimaile Rd,	
3600 Lower Honoapiilani Rd	Haliimaile, HI 96768	
Lahaina, HI 96761	808) 572-2666	
(808) 665-9895		
	PUKALANI	
	FOODLAND ***	
	PAKALANI TERRACE CENTER	
	55 Pukalani St,	
	Pukalani, HI 96768	
	(808) 572-0674	

Appendix 1 Company list by island.

BIG ISLAND	BIG ISLAND
KONA	HILO
KONA FISH COMPANY - CMU&ASSOC. W. ***	Crescent City Seafoods Inc - W
Kaloko Light Industrial Park	55 Holomua Street
73-4776 Kanalani Street #8	Hilo, HI 96720
Kailua-Kona, Hawaii 96740	Phone: (808) 961-0877
PH: (808) 326-7708	Charles M. Umamoto
FAX: (808) 329-3669	President
EMAIL: sales@konafish.com	6 locations - Big Island (3), Oahu, Kauai, Maui
General Manager	
Wes Murakami	HILO FISH COMPANY, INC. CMU&ASSOC. - W
wes@konafish.com	55 Holomua St,
808-960-5891	Hilo, Hawaii, Hawaii 96720
6 locations - Big Island (3), Oahu, Kauai, Maui	Tel : (808) 961-0877
	Fax : (808) 961-3419
FRESH ISLAND FISH COMPANY - KONA - W ***	Charles M. Umamoto
73-5677 Lawehana St.	Chairman/Chief Executive Officer
Kailua - Kona, HI 96740	Email : charlie@hilofish.com
Phone: +1 800 628 3329	Kerry Umamoto
Fax: +1 808 331 2101	President and COO
info@freshislandfish.com	Hilo Fish Company and Kona Fish Company
4 locations - Big Island, Oahu, Maui , Kauai	Email : kerry@konafish.com
	Cell : (808) 640-7684
HAWAIIAN ISLE SEAFOOD ***-	David D.M. Yee
73-4156 Hulikoa Drive	General Manager
Kailua, Kona Hi 96740	Email : davidyee@hilofish.com
Phone: (808) 331-1535	Cell : (808) 557-4084
Owner	6 locations - Big Island (3), Oahu, Kauai, Maui
James Kuwada	
	SUISAN COMPANY, LTD. W
KTA SUPERSTORE #2 MKT ***	1965 Kamehameha Avenue
Kona Coast Shopping Center	Hilo, Hawaii 96720
74-5594 Palani Road	Phone: (808) 935-8511
Kailua-Kona, Hawaii 96740	Fax: (808) 935-2737
5:00 am to 11:00 pm (Daily)	Glenn T. Hashimoto
808-329-1677	President and CEO
808-329-8404 (Fax)	Fresh Seafood - HILO
Store Manager	93 Lihiwai Street
Arelene Reilly	Hilo, HI 96720
	Phone: (808) 935-9349
Garden Isle Seafood - Kona W	Fax: (808) 935-2115
74-5626 Alapa St,	Office Hours:
Kailua Kona, HI 96740	Monday – Friday 5:30 AM – 1:30 PM
(808) 329-3474	Saturday 5:30 AM – 12:00 PM
Robert Fram and Dave Marabella -Owners	
4 locations - Kona, Oahu, Kauai, Maui	KTA SUPERSTORE #3 - MKT
	KTA Center
LA'AU'S FISHING - W & MKT - Name changed	50 East Puainako St.
Malel'a Da Fish House	Hilo, Hawaii 96720
Akoni Pule Highway, Kamuela, HI 96743	5:30 am - Midnight (Daily)

Appendix 1 Company list by island.

Phone: (808) 882-1052	**808-959-9111**
Owner retired / Owner now daughter	**808-959-8064 (Fax)**
Edward La'au / Namoi Peck (daughter)	**Store Manager**
	Sanford Toma
Wharton Seafood Sales (Paauilo, Hawaii) - W	
43505 Belt Hwy	SACK N SAVE #26 (HILO)
Paauilo, Hawaii 96776, USA	250 KINOOLE STREET
808 776 1087	HILO, HI 96720
SACK N SAVE #25 (KONA)	SACK N SAVE #21 (HILO)
75-5595 PALANI ROAD	2100 KANOELEHUA AVENUE
KAILUA-KONA, HI 96740	HILO, HI 96720
KTA SUPERSTORE #7 - KEAUHOU	PUNA FRESH FOODS
78-6831 ALII DRIVE	16-586 OLD VOLCANO RD #102
KAILUA-KONA, HI 96740	KEAAU, HI 96749
KAWAIHAE HARBOR GRILL	MALAMA MARKET
61-3642 Kawaihae Rd	15-2660 Pahoa Rd
KAWAIHAE, HI 96743	PAHOA, HI 96778
KONA SEAFOOD, INC.	OSHIMA STORE
83-5308-A MAMALAHOA HIGHWAY	79-7400 Mamalahoa Hwy
CAPTAIN COOK, HI 96704	KEALAKEKUA, HI 96750
	KAHUKU COUNTRY MARKET
	525 Lotus Blossom Lane
	OCEAN VIEW, HI 96737

Appendix 1 Company list by island.

OAHU	Top Fish Auction Buyers
DIAMOND HEAD SEAFOOD CO - W	Fresh Island Fish Co.
966 Robello Lane	Tropic Fish Hawaii
HONOLULU, HI 96817-4545	Diamond Head Seafoods
(808) 832-9500	Garden & Valley Isle Seafood
MICHAEL P IRISH CEO	Norpac Fisheries
Gary T. Ishimoto, President	Honolulu Fish Co.
	Ham's Produce and Seafood
FRESH ISLAND FISH COMPANY - OAHU - W	Wing Sing Seafood
1135 N. Nimitz Hwy	Thomas Calvert & Associates
Honolulu, HI, 96817	Western United
Phone: +1 800 628 3329	Maguro International
Toll-Free: +1 800 628 3329	John's Fresh Fish
Fax: +1 808 836 8762	Hawaiian Fresh Seafood
info@freshislandfish.com	
Bruce Johnson	
President / CEO	
Naoi Yuen /COO	
6 locations - Big Island (3), Oahu, Kauai, Maui	
Garden & Valley Isle Seafood - Oahu W	
225 N Nimitz Hwy # 3	
Honolulu, HI 96817-5349	
(808) 524-484	
Robert Fram and Dave Marabella -Owners	
4 locations - Oahu, Maui, Kauai & Kona	
HAM PRODUCE & SEAFOOD W	
918 Bannister Street new address	
Honolulu, HI 96819	
Phone: (808) 842-7171	
May Hugh (not english speaking) / Sam Hugh	
Owner	
Hawaiian Fresh Seafood - W	
2290 Alahao Place	
Honolulu HI 96819	
PH 808 845-8862	
Fax: 808 841-8862	
Frank Porcelli	
President & CEO	
Honolulu Fish Company	
824 Gulick Avenue	
Honolulu, HI 96819	

Tel: (808) 833-1123
Fax: (808) 836-1045
Email: sales@honolulufish.com
Website: www.honolulufish.com
Wayne Samiere - Owner
Damon Johnson - Partner
John's Fresh Fish
United Fish Auction
Kailua HI 96734-2232
808 372-6773 /cell 630 7449
Web: www.johnsfreshfish.com
John & Erin Hernandez - Owner
Maguro International - M
6 Wai Wai Loop
Honolulu, Hawaii 96819
Phone: 808-685-7004
Fax: 808-833-6036
Nobu Seafood Hawaii - W DHSF owned
1020 Auahi St Ste 2080
Honolulu, HI
(808) 591-2717
MIKE IRISH - CEO
Norpac Fisheries Inc - W
3140 Ualena St Ste 205,
Honolulu, HI
(808) 528-3474
Norpac Fisheries Export - W
1535 Colburn St,
Honolulu, HI
(808) 842-3474
Thomas Kraft - managing member
NORPAC Fisheries Export
Honolulu:
1535 Colburn St
Honolulu, HI 96817
Tel: +1 (877) 855-7238 (toll-free)
Fax: +1 (808) 842-3474
Email: tkraft@norpacexport.com
A wholly owned subsidiary of Luen Thai International Group, a Hong Kong based conglomerate
Dr.Charles Laidley - compliance officer
Thomas Calvert & Associates - W

Appendix 1 Company list by island.

834 Pohukaina St
Honolulu, HI 96813-5306
PO Box 1020 Haleiwa, HI 96712
Ph 808 534 0737
FAX 808 534 1309
Email: Tom@tcaseafood.com
Web: TCAseafood.com
Thomas Calvert - Owner
TROPIC FISH HAWAII / CMU & ASSOC. - W
1020 Auahi Street, #3090
Honolulu, HI 96814
808-591-2936 Office;
808-591-2934 Fax
www.tropicfishhawaii.com
Shawn Tanoue—President/ COO
stanoue@tropicfishhawaii.com
808-478-3398
Shannon Tanoue—VP Operations
sstanoue@tropicfishhawaii.com
808-479-3938
6 locations - Big Island (3), Oahu, Kauai, Maui
Western United Fish Company - ASHI - W
15110 NE 90th Street, Suite 110
Redmond, WA 98052
Phone: 425-558-7809
Fax:425-558-7919
info@westernunitedfish.com
Wing Sing Seafood Inc - W
230 Libby St,
Honolulu, HI
(808) 847-2580
Don Leong
Owner
UNITED FISHING AGENCY LTD - A
1131 N Nimitz Highway
Honolulu, HI 96817
Phone: (808) 536-2148
Manager
Brooks Takenaka
Amor Nino Foods Inc - W
1928 Homerule St,
Honolulu, HI

(808) 845-1711
Pacific Seafood Distribution - W
3170 Ualena St Ste B
Honolulu, HI
(808) 836-8888
Fish 2 Go - W
1334 Young Street # 108
Honolulu, HI 96814
Phone: (808) 593-0706
K Azama Fish Wholesale - W
94-676 Farrington Highway
Waipahu, HI 96797
Phone: (808) 888-2031
Dow Distribution - W
524 Ohohia St
Honolulu, HI
(808) 836-3511
True World Foods Inc Of Hawaii - W
2696 Waiwai Loop
Honolulu, HI
(808) 836-3222
808 Finest Seafoods - W
690 Halekauwila St,
Honolulu, HI
(808) 521-6000
Seafood Connection - W
841 Pohukaina St Ste I,
Honolulu, HI
(808) 591-8550
U Okada & Co Ltd - W
1000 Queen St,
Honolulu, HI
(808) 597-1102
Troy Enterprise - W
135 N King St Spc 7B,
Honolulu, HI
(808) 531-6758

Appendix 1 Company list by island.

Annasea International Hi LLC - W
1151 Mapunapuna St,
Honolulu, HI
(808) 833-2222
Wah Wah Seafood Co. - W
157 N King St,
Honolulu, HI
(808) 533-3283
Ohana Seafood
255 Sand Island Access Rd # 2c,
Honolulu, HI
(808) 843-1844
New Zealand Seafoods Of Hawaii - W
524 Ohohia St
Honolulu, HI
(808) 836-3262
Rite Selection Inc
1325 Nuuanu Ave Ste 211
Honolulu, HI
(808) 585-6257
Dmm International - W
1430 Hart St,
Honolulu, HI
(808) 841-2882
Da Seafood Store - M
925 Maunakea St Unit B,
Honolulu, HI
(808) 526-1230
Eskimo Candy Inc. - OAHU MKT
2665 Wai Wai Place
Kihei, HI 96753
808-879-5686
Fax: 808-874-0504
PACIFIC SUPERMARKET - MKT
94-300 Farrington Hwy,
Waipahu, HI 96797
(808) 678-2828

TAMASHIRO MARKET - MKT
802 N King Street
Honolulu, HI 96817
Cyrus Tamashiro
President
Phone: (808) 841-8047
Web: Tamashiromarket.com
MARUKAI WHOLESALE MART - MKT
2310 Kamehameha Hwy
Honolulu, HI 96819
(808) 845-5051
TRUE WORLD FOODS INC. OF HAWAIi - W
2696 Waiwai Loop,
Honolulu, HI 96819-1938
(808) 836-3222

Appendix 2 Western Pacific Regional Fishery Management Council, Fish processing waste questionaire 2014.

WPRFMC, FPW Questionnaire 2014

ISLAND – Oahu ( ) Big Island ( ) Maui ( ) Kauai ( ) Molokai ( )

Fish wholesaler (FW) / Retailer (R) ______________________________
Address:
Phone #:
Person Contacted:

1. Estimate about how much fish processing waste (FPW) is generated per day or per week.
   a. Day _____ lbs,
   b. Week _____ lbs.
   c. Container or bin loads /day
2. What happens to the FPW now, how disposed of?
3. Is the FPW mixed with any other other garbage waste?
4. Who picks up the FPW now? Pig farmer, Truck farmer, Composter, Render or a Commercial garbage disposal carrier and hauled off and dumped in a landfill.
5. Picked up how many times per week. Cost of disposal.
6. Can and will the vendor separate and store FPW from other garbage.
7. Can FPW be kept refrigerated or not.
8. Are cold storage facilities available at site to store FPW. Will they allow storage?
9. Does vendor has Ice making capabilities. Block or flakes.

Appendix 3 Fish processing waste generation and storage prior to disposal.

Figure 1 A seafood/fish wholesaler's cold receiving room, where fish first enter from the auction and are held at temperatures that are less than 40°F. Proper handling of fish, and maintaining and processing them in clean, temperature-controlled conditions is the key to selling a high quality seafood (checking fish temperatures and making sure the fish are clean and well iced). This fish wholesaler's staff were always checking for signs of spoilage (appearance and odors) and working to keep the fish, clean and cold (less than 40°F) during processing.

Figure 2 Monchong (Sickle pomfret/Taractichthys steindachneri) stored under clean conditions and well iced for temperature control (less than 40°F).

Appendix 3 Fish processing waste generation and storage prior to disposal.

Figure 3 Opah (Moonfish/Lampris regius) stored under clean conditions and well iced for temperature control (less than 40°F).

Figure 4 Tuna from the fish auction >20 pounds had been gilled and gutted at sea. Head and tail were removed at fish wholesaler and stored in wholesaler's fish receiving cold room (less than 40°F).

Figure 5 Swordfish from the fish auction had head, tail, gill and gut removed at sea, stored in wholesaler's fish receiving cold room (less than 40°F).

Appendix 3 Fish processing waste generation and storage prior to disposal.

Figure 6 Fish heads and tails stored in wholesaler's fish receiving cold room (less than 40°F).

Figure 7 Fish trimmings from fish cutting room stored in wholesaler's fish receiving cold room (less than 40°F).

Figure 8 Autio GH (Gear Head) Grinder. Model 1101 GH, 1" holes die plate, notched feeder screw, weighs 2,400 lbs., with a 50 HP motor, max grinding capacity 25,000 lbs. per hour. The cost of a grinder like the Autio model 1101 GH is about $36,500. A soft start is needed for the 50 HP motor, which costs about $4,000, add shipping and handling about $2,000. Total cost of grinder is approximately $42,600 plus the cost of installation.

Appendix 3 Fish processing waste generation and storage prior to disposal.

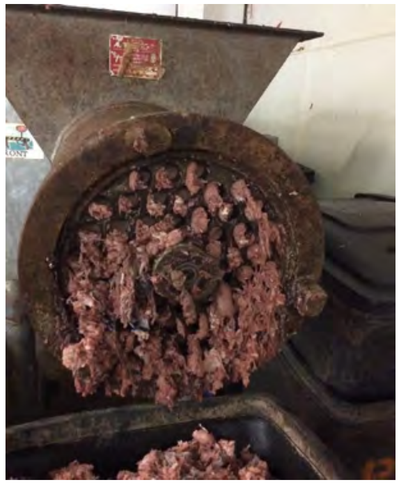

Figure 9 Autio Meat Grinder reducing heads, tails and fish cutting room trimmings to minimize disposal cost in a wholesaler's fish receiving cold room (less than 40°F).

Figure 10 64-gallon container filled with unground FPW. Weight of FPW in container ranges from 150 to 200 pounds. Island Commodities charges $35 per container.

Appendix 3 Fish processing waste generation and storage prior to disposal.

Figure 11 64-gallon container filled with ground FPW. Weight of FPW in container ranges from 350 to 400 pounds. Pacific Pure Technologies charges $25 per container. Island Commodities charges $35 per container.

Figure 12 FPW transport for disposal. Deterioration of the FPW starts when the cold chain is broken, when transported by an open uninsulated or by a non-refrigeration truck (shown above). FPW is now in ambient air temperature when it leaves the fish processor's cold room and is transported for disposal. To mitigate this deterioration process, FPW containers can be packed with ice supplied by the fish wholesaler to keep the FPW cold during transport prior to processing. and would help maintain FPW quality for finished feed ingredients (fishmeal, fish silage, fish oil, fish solubles, or a ground raw frozen fish blocks). For fertilizer products from FPW, a cold chain is not required for an acceptable finished product.

Appendix 4 Lab procedure for sample analysis.

Total volatile base nitrogen (TVBN) in raw fish sample was measured by AOAC (2002) method. Anisidine and peroxide values of fish oil were analyzed based on IAFMM methods recommended by International Association of Fish Meal Manufacturers /Marine Ingredients Organization (http://www.iffo.net). Free fatty acids in fish oil were determined according to a published method (Kail BW and others 2012).

Proximate composition of samples was analyzed following AOAC (2000) methods. Moisture was determined by drying a 1 to 2 gram (g) sample in an oven with air circulation at 105°C for 24 hours. Total nitrogen (N) was determined using a LECO FP-528 nitrogen analyzer (Leco Instruments, St. Joseph, Mo., USA) and crude protein was estimated by N x 6.25. Crude lipid was determined by ethyl-ether extraction with an accelerated solvent extractor (Dionex Corporation, Bannockburn, Ill., USA). Ash was calculated after combustion in a muffle furnace at 600°C for 6 hours. Gross energy was determined by bomb calorimetry (Parr 1261 Calorimeter, Parr Inst. Co., Moline, Ill., USA). Mineral content was analyzed by an inductively coupled plasma atomic emission spectroscopy (Model Atomscan 16, Thermo Jarrel Ash, Franklin, Mass., USA). Gross energy was determined using bomb calorimetry (Parr 1261 Calorimeter, Parr Inst. Co., Moline, Ill., USA).

The protocol used for amino acid analysis followed the modified AOAC method (994.12; 2000). Samples for most of the amino acid analysis were first digested at 110°C by 10 mL 6N HCl solution for 24 hours. For analysis of methionine and cystine, perfomic acid oxidation is performed prior to hydrolysis. Hydrobromic acid is then added to decompose extra performic acid. Individual amino acid components are separated and quantified by reverse-phase chromatograph (Ju and others 2008).

Soluble protein contents in raw fish and fishmeal were analyzed based on a published method (Araba and Dale 1990). The sample (0.75 g) was weighed into 100 ml beaker with 37.5 ml of 0.2 percent (0.36 normal, pH 12.5) potassium hydroxide solution added. The mixture was stirred for 20 minutes on a magnetic stir plate, and then centrifuged at 2,700 rpm for 15 minutes, followed by filtration through glass woo. The resultant liquid was further centrifuged to remove any particles. The supernatant was then used for nitrogen content analysis by LECO N-Determiner.

Fatty acids (FA) of fish meal samples were analyzed by using a Varian 3800 gas chromatograph (GC) (Varian Analytical Instrument, Walnut Creek, Calif., USA) equipped with a flame ionization detector using an Omegawax 320 column (Supelco, Inc., Bellefonte, Pa., USA) based our published method (Ju and others 2009). The conditions for GC analysis were as follows: helium as carrier gas at a flow rate of 60 cm s^{-1} and a constant head pressure of 347 kPa; FID set at 275°C; air and nitrogen makeup gas flow rates of 450 ml min^{-1} and 10 ml min^{-1}; sampling frequency of 50 Hz; autosampler injecΘons of 1 µl volume. FA profiles were identified by comparing their retention times with those of the FA standards. The amounts of individual FA were calculated using normalization technique. The relative response factor for each peak was determined based on a commercial standard composed of 28 fatty acids (462 Standard, Nu-Chek Prep, Elysian, Minn., USA).

Appendix 4 Lab procedure for sample analysis.

REFERENCES

[AOAC] Association of Official Analytical Chemists. Official Method 999–01. 2002. Volatile bases in fish, ammonia ion selective electrode method. In “AOAC Official Methods of Analysis of AOAC International.” 2(35):34–35.

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Araba M and Dale N. 1990. Evaluation of protein solubility as an indicator of over processing soybean meal. Poultry Science 69:76–83.

Ju ZY, Forster I, Conquest L, Dominy W, Kuo WC, Horgen FD. 2008. Determination of microbial community structures on shrimp floc cultures by biomarkers and analysis of floc amino acid profiles. Aquaculture Research 39:118–134.

Ju ZY, Forster I, Dominy W. 2009. Effects of supplementing two species of marine algae or their fractions to a formulated diet on growth, survival and composition of shrimp (Litopenaeus vannamei). Aquaculture 292:237–243.

Kail BW, Link DD, Morreale BD. 2012. Determination of free fatty acids and triglycerides by gas chromatography using selective esterification reactions. J Chromatogr Sci. 50:934–9.

Appendix 5 Review of fish fertilizers by Vernon Sato, MS, Algal Specialist.

Use of Fish as Fertilizer: One popular example of utilizing fish as a fertilizer can be found in the story of the Indians teaching the early American settlers to improve their farming of crops by placing fish in the soil to fertilize plants. The status of today's fisheries and the demand for fresh seafood does not allow the luxury of using whole fish in this manner. The major focus of this work is on the use of fishery waste products. Within the scope of the work being proposed the processed fishery products could be used as a fertilizer for growing terrestrial or aquatic plants. The fertilizer product can take two basic forms; as a liquid (e.g., fish emulsion or hydrolysate) or as a solid (dried and ground or composted with other materials to create a mulch). The method of processing fresh material will determine the ultimate quality, and therefore value, of the final product. Additional care in handling and processing of fresh material would be needed to achieve the highest quality product (e.g., a fish meal that could be used in producing feeds or to be used for human consumption). This section will focus primarily on processing to create fertilizer products.

Traditional fertilizers are primarily defined by the major nutrients N-P-K for nitrogen-phosphorus-potassium. Fish meals are normally high in nitrogen, moderate in phosphorus and, if bone material is included, the mixture can also be high in calcium (5-1-1) (www.faq.gardenweb.com). Fish-based fertilizers may be lower in potassium but offer the benefits of containing trace elements as well as organic compounds. This deficiency can be compensated for by including seaweed material (0-0-1) in the final fertilizer (www.faq.gardenweb.com). Seaweeds are generally lower in nitrogen and phosphorus but high in potassium. By combining processed fish and algae, the N-P-K ratios can then be normalized to a more balanced product.

There are additional benefits. Processing fish waste results in fish tissue being broken down to proteins, amino acids and carbohydrates. Many of these compounds can be taken up by plants when applied as a foliar fertilizer or by algae being grown in water. Seaweeds processed in a similar manner will also release vitamins, trace minerals and compounds that act as plant hormones. When used in feeds, seaweeds will also contribute binders such as alginate, agar or carrageenan (depending on the species of algae) and pigments.

As a fertilizer, a simple and effective method of utilizing the benefits of these compounds is to create a liquid fertilizer. Many plants and seaweeds are able to take up and utilize organic compounds directly. Foliar applications in which a liquid fertilizer is sprayed directly on the leaves of plants allows nutrient uptake through the leaves and incorporation of the compounds directly into the metabolic pathways of the plants.

Product forms: Liquid fertilizers produced from fish and seaweeds are sometimes called emulsions or hydrolysates interchangeably. When a distinction is made the hydrolysis is usually defined as a cold, enzymatic process to separate soluble and suspendable compounds from solids. Heat applied to fish hydrolysate denatures proteins and carbohydrates. After oils and proteins are removed the remaining liquid is referred to as fish emulsion.

Wyatt and McGourty (1990) described three basic preparation methods: 1) A crude mixture of fish soluble nutrients can be made. Boiling or cooking helps to extract compounds from cells but will also denature proteins, break down vitamins and pigments and result in a product of lower quality and value as a fertilizer. This type of fertilizer may be stabilized at the final stage by the addition of an acid. 2) Processing fish material by grinding and acid digestion will result in fish silage. Bones and other solids are screened out. Proteins will continue to break down to amino acids in storage. 3) A true fish hydrolysate is produced by grinding fish waste and digesting with papain. Any oil released is decanted from the liquid and solids are screened out. The resulting hydrolysate may be dried or dehydrated to produce a solid hydrolysate. This results in a fish protein powder that can be used in feeds or sold as a nutraceutical. If a "liquid" fish emulsion is desired the liquid can be stabilized with the addition of an acid or by heat pasteurization. Any solids (e.g., fishmeal or bonemeal) that may be desired as a part of the liquid fertilizer must be finely ground so that it can remain in suspension and flow through dispersion nozzles when dispensed through sprayers. There are a number of possible variations in these processes by incorporating different enzymes or probiotic bacteria to promote the breakdown of fish waste products.

Seaweeds as Fertilizers: Seaweeds can be processed by similar methods to produce seaweed emulsions and seaweed meal. They have been included in this part of the discussion because some native species and a number of invasive algae have become a problem in the near-shore environments around the Hawaiian Islands. Efforts to remove these algae are time consuming and often yield several tons of biomass that is soon replaced by new growth. At the present time the collected seaweed is being composted or taken to the landfill for disposal. Seaweed emulsions and seaweed based fertilizers have an economic value and the utilization of this biomass could encourage a greater effort to eradicate the invasives.

The Magnuson-Stevens Fishery Conservation and Management Act encourages the protection of near shore environments, especially when they have been identified as important spawning or nursery grounds for fish species. Restoring areas such as Kaneohe Bay (Invasive: Kappaphycus spp.), Maunalua Bay (Avrainvillea amadelpha), Waikiki Beach Reef (Gracilaria salicornia) and Maui shoreline (Hypnea musciformis) could generate sufficient algal biomass to support seaweed processing. Enchanted Lakes in Kailua was once a series of ancient Hawaiian fishponds that were fed freshwater from Maunawili Stream and passed through Kawainui pond. Seawater mixed with the freshwater through the stream mouth along Kailua Beach creating an important nursery habitat in the lake system that supported native species that migrated through the ponds and streams to populate Maunawili Stream. Enchanted Lake is currently being choked by the invasive Gracilaria tikvahiae.

An article in *Midweek* on Sept. 2, 2009, by Kerry Miller states that NOAA is contributing $3.4 million to support the removal of algae over 14 months from Maunalua Bay. Similar cleanup activities take place on the reef off Waikiki and in Kaneohe Bay and depends on volunteers to do a majority of the work. Enchanted Lakes holds regular algae removal days with community volunteers.

The removal of invasive algae is a part of restoring important larval and nursery habitats for fish as well as foraging areas for adults. It is an important aspect of restoring near-shore habitats and should continue in support of local fisheries. Such biomass should not be wasted and should be incorporated into recycling efforts being described in this document.

Appendix 5 Review of fish fertilizers by Vernon Sato, MS, Algal Specialist.

Benefits of Organic Fertilization: In the *Handbook of Phycological Methods* by Janet R. Stein, editor (1973), a number of different media for the isolation and culture of algae are discussed. This reference has been one of the major sources of techniques used in the culture of phytoplankton. It is a compilation of methods developed by phycologists over many decades of research. One algae culture medium described the use of soil to create a soil extract that is added to an inorganic fertilizer. This method became popular in the isolation and culture of certain algae that could only be grown on the organic/inorganic compounds that were extracted from rich garden soil.

The use of organic compounds in the culture of phytoplankton has led to the development of heterotrophic culture techniques for biomass production. It was realized that algal cells could be cultured in the complete absence of light. Bioreactor methods used in the industrial level production of bacteria and fungi were adapted to culture some species of algae. This has eliminated the need for carbon dioxide as a nutrient because the carbon sources are provided by organic compounds such as carbohydrates and sugars. The algae grown by this method still contain the chloroplasts but they are nonfunctional. In the absence of light harvesting pigments the cells appear to be pale and looking like yeast produced in bioreactors. When exposed to light the chloroplasts and other pigment producing organelles become active and the cells become photosynthetically functional. These observations suggest that the algae are very adaptable to the availability of nutrient sources in nature. The cells will take up nutrients needed from inorganic and organic sources, depending on what is available.

One aspect of these liquid emulsions that has not been adequately studied is its use in aquaculture. Phytoplankton blooms and/or thick growths of benthic algae is often produced in aquaculture ponds and tanks containing fish or shrimp. It is usually assumed that the nutrients excreted by the animals are cycled through the food web until the inorganic nitrates, phosphates or ammonia are produced. In reality the algae are responding to the waste products released by the fish or shrimp in the form of organic nitrogen, phosphorus as well as other fixed organic carbon waste products. These waste products are similar to the compounds present in the fish and seaweed emulsions.

Fertilization protocols utilizing organic compound mixtures can produce intense blooms of phytoplankton and are important in hatchery work. The use of organic fertilization has been used by shrimp farmers in Japan and Hawai‘i for decades. The extracts were obtained by chopping and blending squid or clams and adding the resulting liquid to a tank or pond. A bloom can be observed in a matter of hours. This kind of response is close to the concept of “instant algae.”

Currently, the industry in Hawai‘i is purchasing one-liter containers of concentrated frozen algae for up to $100 per liter for use in fish and shrimp hatcheries. While this product is convenient, the hatcheries must maintain some live algae as a nutritional supplement and to maintain water quality in the larval tanks. The liquid organic fertilizers being discussed can help smaller hatcheries located in more isolated areas to have phytoplankton production without having to maintain sterile cultures and extensive algae production facilities. It was estimated by Sato (1991) that nearly 140,000 liters of algae culture were required to support 50,000 liters of fish larval rearing tanks. Such facilities represent "Cadillac" dream facilities. It requires the dedication of land and manpower at a 3:1 ration of phytoplankton:fish larvae. The needs for algae can be met by purchasing frozen algae and supplementing it with fresh algae that can be produced when needed over a few hours by using the appropriate organic fertilizer.

Organic Fertilization in Terrestrial Agriculture: Websites such as www.gardenweb.com and www.ehow.com promote the use of liquid fish and seaweed fertilizers in terrestrial agriculture because they improve germination, root growth, transplant survival, flowering and/or fruiting.

Research studies by Brown and Davis (www.ces.ncsu.edu) have observed no significant difference when using emulsions vs. traditional fertilizers. Therefore, rather than promoting a "miracle" product the safer claim would be that fish and seaweed emulsions are an adequate substitute to be used in conjunction with or as a supplement to traditional fertilization methods. The North Carolina study described the N-P-K ration of fish emulsion as 2-4-1 with Ca, Mg, S, Cl and Na as being major elements also present. Seaweed extract was listed as 0-0-1. The fish plus seaweed blend tested out at 2-3-1. The cost of the product that they tested was $14 per quart and $30 per gallon. Application was at a rate of 0.5 to 1.0 oz. per gallon of water. The cost: benefit of utilizing the liquid fertilizer may not be great enough to justify it use as the sole source of plant nutrients for large scale farming unless some unique benefits can be documented.

The discussion of heterotrophic nutrient uptake in algae was presented because there may be a number of benefits in applying fish and seaweed extracts in large scale agriculture that have not been studied or properly documented. The North Carolina State University study was done with pepper and tomato plants. The claims found on internet searches about the benefits of emulsion fertilizers cover a much broader range of plants. The availability of organic compounds and trace elements in liquid form makes it desirable for foliar application as a supplement to traditional fertilization. Such products are important for agriculture producers who want to be certified as "organically produced". There are hobbyists and home gardeners who are more willing to purchase and use such products since a gallon may last an entire season. The production of liquid fertilizers may be profitable since they sell at a higher price than most traditional granular fertilizers. It should also be noted that the use of processed fish waste is just the first step in utilizing fishery by-products. In the waste stream cycle, smaller waste biomass and lower quality offals can be cycled into the fertilizer processing pathway. In time, the higher quality and larger quantity by-products would be preferentially processed into fishmeal.

Smaller communities that do not have easy access to offal disposal can generate their own emulsions for local consumption. The websites listed earlier along with a Google search will turn up a number of simple (though sometimes smelly) home techniques for creating fish and seaweed emulsions. Semi-moist or mash-type feeds can be created from small batches of fishery waste. This feed can be fed to fish or shrimp. Any additional fish waste can be placed in containers for processing into fish emulsion. The benefit of this activity is that the nutrients can be generated and stored for future use.

The current trend in aquaculture is to develop secondary crops through polyculture, co-culture and aquaponics; basically utilizing the waste products from fish and shrimp culture to produce another crop. Diatoms that bloom in fish and shrimp ponds are being used to grow clams and oysters. The effluent water in these systems may be cycled through macroalgae production channels to strip any remaining nutrients from the water prior to disposal. Macroalgae can be fed to herbivores, composted for fertilizer or processed along with fish waste to create an emulsion.

Algae Biomass for Biofuels: Diatoms and some phytoflagellates respond quickly to fertilization with organic nutrients. This water can then be used in aquaculture hatcheries. Phytoplankton biomass can also be processed for biofuel production. There have been projects on Maui and Hawai‘i to utilize carbon dioxide from power plants to grow algae, usually diatoms that produce high lipid concentrations that can then be extracted to produce biodiesel. The residue, after lipid extraction, can be utilized in feeds or sent through digesters to generate other potential fuels. One disadvantage being investigated is that algae produced on industrial waste may also accumulate toxic compounds and heavy metals. Such residue should not be used in producing any feeds. Growing diatoms on fish emulsions would not expose the algae to potentially toxic compounds.

Interested readers are referred to www.ainainstitute.org for a more detailed description of how the concepts described in this part of the report are an important step in attaining the kind of independence from imported energy and food products that has been contemplated for decades for Hawai‘i. All of the components of this network have been tested and documented or are being actively researched and applied in other parts of the world. What is needed is to initiate the portions of this work that are currently practical and to incorporate additional recycling and energy production technologies when it makes sense for Hawai‘i. The utilization of fishery waste products is an important first step in lessening the dependence of Hawai‘i on imported products.

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