Value-added options: background research for development of appropriate adaptations to artisanal fisheries in the Três Marias area of Brazil

October 2005

Report prepared for

World Fisheries Trust

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Background research for development of appropriate methodologies for adding value to catch in artisanal fisheries in the Três Marias area of Brazil

Preface

It is generally agreed that fish stocks in the Sao Francisco River near Três Marias region of Brazil are being exploited at, or over, maximum sustainable levels. Plans to increase the revenue generated from the artisanal fisheries has therefore turned to increasing the value of the current catch either by better processing, or utilizing, portions of the catch that are currently being wasted.

The first section of the report deals with methods of improving handling of the fish to increase per unit market value, and preservations techniques that may permit access to more lucrative markets further afield. The second section of the report deals with further processing the catch, either through smoking or canning, or both, which could increase market value as well as enable transport to national and international markets. The third and fourth sections explore the options of utilizing fish parts that are currently discarded to generate added income. Section three reviews technologies and market potential for fish leather and section four reviews options for dealing with fish offal and converting it into usable fish fertilizer. Section five reviews the health and environmental effects of tanning. Parts of the report are written in "instruction manual" fashion so that they can be easily excerpted for use in training workshops.

In all cases the emphasis is on low-tech methodologies applicable for rural regions but where possible, I have also briefly reviewed much larger mechanized operations worldwide as options for further development in the region. This report presents preliminary research prior to the assessment mission to Brazil. Information gathered on the mission will be used to guide recommendations for appropriate technology adaptations in the Três Marias Region.

Stephen Price, PhD.

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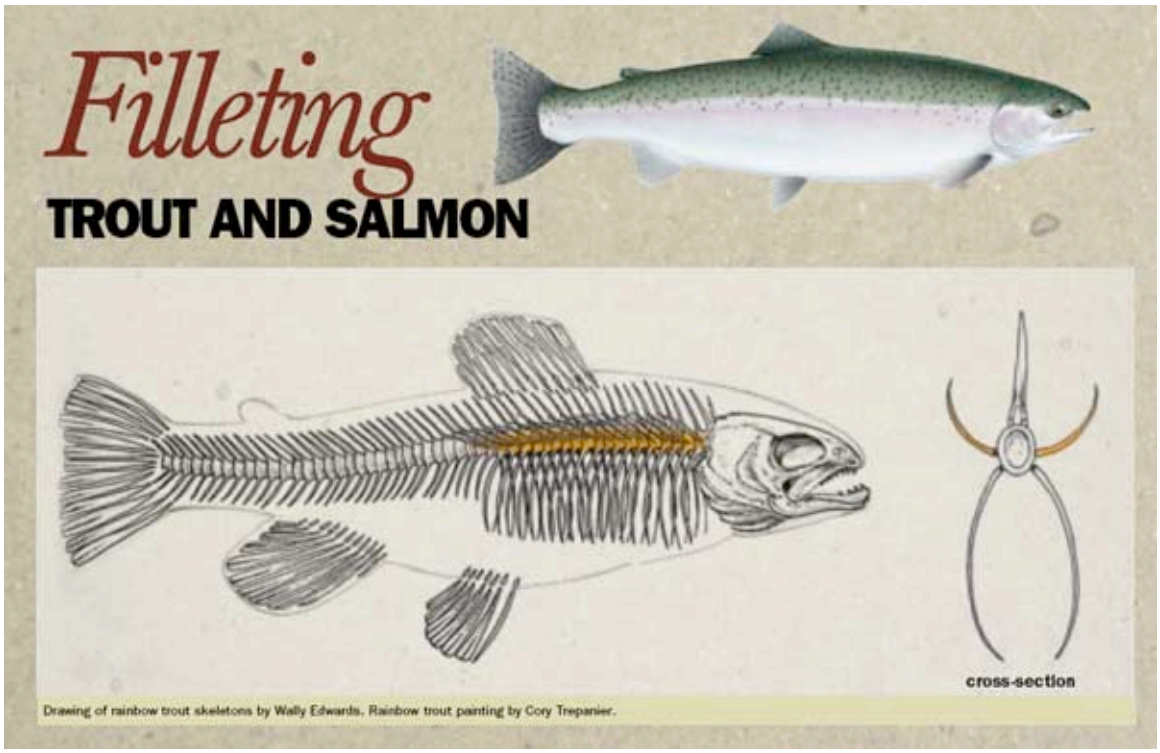
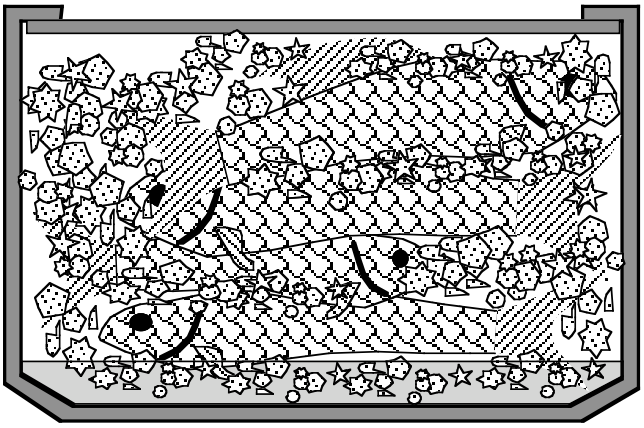
Part I

Fish Processing:
Handling and Market Presentation





Landing, Handling, Spiking, Bleeding, Icing,
Dressing, Filleting, De-boning, Packing and Freezing

Introduction and Market Expectations

This first section of the report reviews some of the common procedures used by fishers to maintain quality of the fish. It is always best for a fisher to take advantage of the greater price offered by buyers when his catch is in the best possible condition. Handling fish properly and well presented to purveyors is particularly important in the tropics where fish spoil quickly. Better handling and icing of fish may permit access of town or city markets where higher unit prices could be obtained compared to local village or rural markets.

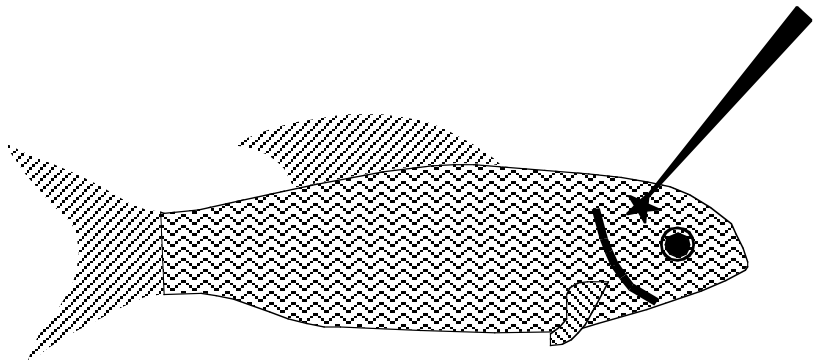
On a national or international scale, fish are most commonly marketed either whole or as fillets. Fish are almost always sold “dressed”, whether this is sold as a whole fish, minus the head and entrails, or as fillets. The value of the fish species, the distance from the point of sale or distribution, and climate, are all factors that will dictate whether the product presented requires icing, flash freezing, hot smoking, or canning. The following are some of the guidelines for landing and handling fish that should be followed by fishers.

A. Handling

Immediately after catching a fish it should be calmed to reduce bruising to the flesh and even loss of scales. Care must be taken when handling the fish as it is removed from a net, or a hook is removed from its mouth. Fish caught on a line should be lifted into the boat in a net to avoid it thrashing violently, and gaffs should not be used to handle the fish as this often injures the fish and increases possibility of spoilage. If there are no holding tanks in the boat, or the fish is large, it should be killed as quickly as possible.

1. Spiking (pithing)

Spiking is a quick and effective method to humanely dispatch a fish. This is done by driving a pointed rod, or knife, into the brain of the fish. This will kill the fish instantly and prevent the stress conditions that occur when the fish is left to die in a normal way. Spiking can be done from the top of the head or through the gill cover, or the spike is driven into the brain from the side of the head.



2. Bleeding Fish

To ensure high quality, it is best to bleed fish as soon as they are removed from the water and may be done at the same time as spiking. For small boat operators this is safest, easiest, and most consistently done ashore.

Effective bleeding will reduce discoloration of the flesh, spoilage, and bruising. Bleeding is done by cutting the gill-rakers or a main artery, and for larger fish a caudal tail artery. While fish are being bled, they can be either held in water contained in plastic bins in the shade or immersed in separate ice slurry. The use of an ice slurry is the preferred method. Slurries should be maintained as close to freezing (0°C) as possible, but not below, as partial freezing will occur and bleeding will not be as effective.

Tests have shown that excessive soak time in the slurry will cause bleaching of the skin, especially in red fish, and cloudiness of the eyes. In tropical areas, fish 1 kg or less should be processed within one hour of being placed in the slurry. Fish larger than 3 kg can be left for up to two hours.

3. Icing Fish

Icing fish is necessary if the fish are to be transported over any distance or length of time before they are sold retail. For two man fishers in a small boat, ice is a significant expense and space used by an insulted storage box to keep it on board may be limiting. Crushed, chipped or shaved ice works best for packing around fish and preserving quality. It may be feasible to carry crushed ice in coolers that is made available from larger volume power grinders set up at a central facility. However, since ice will remain frozen longer if it is in block form, it might be best to shave or crush ice after the fish are landed.

There are a variety of manual and automated ways to crush ice. There are manual ice shavers and battery operated ice shavers that can be used even in a small open boat. Perhaps the cheapest and most common way is simply break of chunks of ice from a main block using an ice pick. These chunks are then placed into a durable canvas bag, which is swung

against a solid surface such as a rock or tree. A small sledgehammer may be as effective and afford better control. The impacts fragment the chunks into very small pieces, which can then be emptied into the insulated box. Alternatively using an ice shaver produces more fine and consistent size of ice pieces and reduces bruising from larger chunks. A variety of hand (A) and electric (B) ice shavers are shown below.

A. Hand Ice Shavers

A-1.

ARCTIC Cast Iron Ice Shaver. This is a traditional hand held shaver used generally to make “snow cones”. It would probably be of use only for small catches.

A-2.

This hand ice shaver is 17cm long – 8 cm wide at widest and has a 5 cm deep pocket. The handle hollow yet made of a heavy metal is molded to fit a hand. There is a blade on the front of shaver. It is probably too small for any application for fishermen.

A variety of ice small-scale ice shavers are available ranging in price from $US500 to $US2000 (below). These are mainly designed for restaurant operations. They are limited by the size of the ice block that they can accept, usually < 30 cm in height. Various models can shave from100 to 300 lbs of ice in an hour. The *Gold Medal Products Co.* makes models that can be operated using 12 V batteries or be attached to a hand or bicycle crank arm.

B. Electric Ice Shavers

A

Cheng Huei Machinery Corp., Taiwan
Retail: $US500

B

Olde New Orleans Block Ice Shaver, Brand 1087
Retail: $US1695.00

C

Gold Medal Products Co.
Retail: Models from $US400 to $US1679

Another option would be for a central shore based facility (e.g., a fisherman's cooperative) to purchase a commercial communal ice-making machine as shown below.

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Manitowoc Ice Maker Machine $1,285
Produces up to 52 Lbs. Ice/24 hrs

Manaitowoc Commercial Restaurant Ice Machine $1600
Produces up to 325 Lbs. Ice/24 hrs

B. Dressing Fish

1. Gilling and Gutting

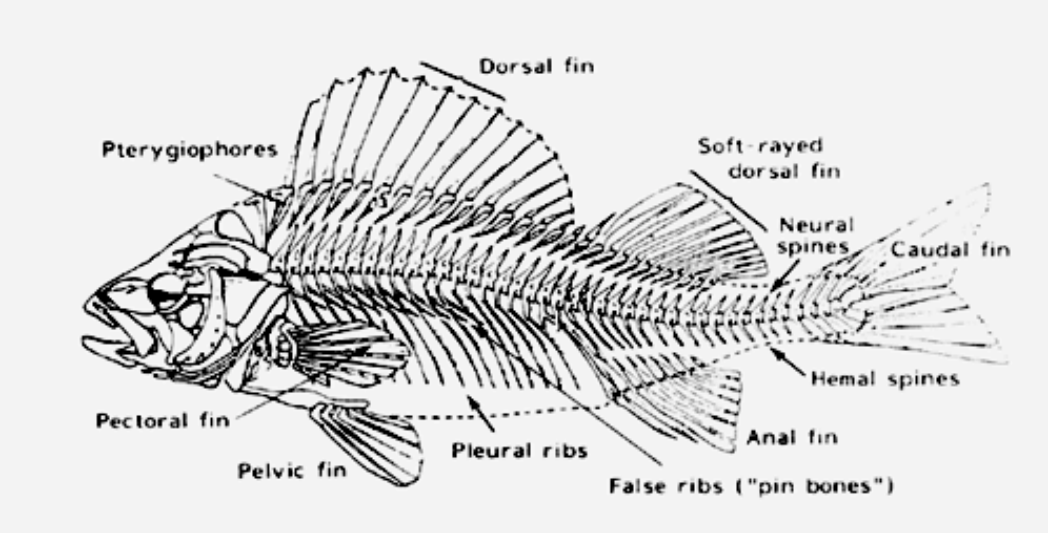
If it is decided that fish are to be ”dressed”, they must be gilled, gutted (eviscerated), and washed very clean. Usually the head is removed as well. These operations should also be carried out as soon as possible after bleeding. All gills, internal organs, gut contents, air bladders and the blood-line (simple kidney) along the backbone should be removed completely. Care should be taken not to cut or damage the inside skin of the gut cavity or to spill gut contents on to any cut surfaces, as this will make the fish spoil more rapidly. A stiff brush or a high-pressure spray can be used to remove the blood-line. All excess blood, mucus slime, body fluids, and fecal matter should then be washed from the fish, as there are usually pathogenic bacteria associated with them. The body cavity of the fish must be absolutely clean.

Scales are not usually removed from gutted or whole fish, unless the market requires their removal.

A high quality flash frozen B.C. salmon in -27°C storage. The body cavity is absolutely clean of all kidney tissue or blood.

2. De-boning Fish

Boneless fish fillets are the most common cut, and for the consumer there is the significant convenience of not having to deal with the disposal of the smelly skin, bones, and internal organs. However, whole fish holds its shape and flavor better than fillets and is preferred by some markets.



3. Filleting Fish

Filleting fish requires that all bones and fins be removed. It is also one of the first steps in preparing fish for "smoking", or if the skin is to used as leather. Tools required are a cutting board or table, clean fresh water, and a thin very sharp filleting knife.

Place the dressed fish on a cutting surface. Hold the fish by the head (if the head is still attached; it doesn't need to be) and slice into the fish behind the gill until the knife touches the backbone as if to cleave the fish into its two halves.

Work the knife along backbone. Turn the knife so it is flat against the backbone, touching the ribs. Cut along the backbone through the fish from head to tail, under the fillet. Make long, even strokes rather than sawing motions, which result in a jaggedly cut.

Turn fish over and repeat. Lay the fish out, skin side down. Take your sharp fillet knife and run the knife all the way down the fillet. Keep the knife along the skin.

Cut away the fillet from the skin, so that the skin has not been nicked, or any flesh remains on it.

At this point two sets of bones will remain in the fillet. These are the *rib cage bones* and *pin-bones*. Cut away the *rib cage bones*, which will be visible, by sliding the edge of the knife between the rib bones and the meat of the fillet.

Slide the knife close under the rib bones from the top to the bottom, cutting rib bones free. Also cut away the "comb" of tiny bones that will edge your fillet. Rinse off the fillet

4. Pin-boning

Pin bones are the fine, unattached "False ribs" bones found in the mid section of the fish extending more or less horizontally into the muscle tissue. These bones cause a great deal of trouble when fish are being filleted or otherwise prepared for food.

Rubbing fingers over the fillet to find the pin bones above the main ribs. Then grabbing each pin bone with a pair of needle-nosed pliers or surgical forceps and pulling them out. This technique leaves an intact, uniform-thickness fillet.

A stainless steel Japanese tool is specifically made for pulling bones.

***FTC's* Cordless Pinboner**
Ergo-Light Pin Bone Remover ($2600)
2.4v NiCD Battery .85 kg

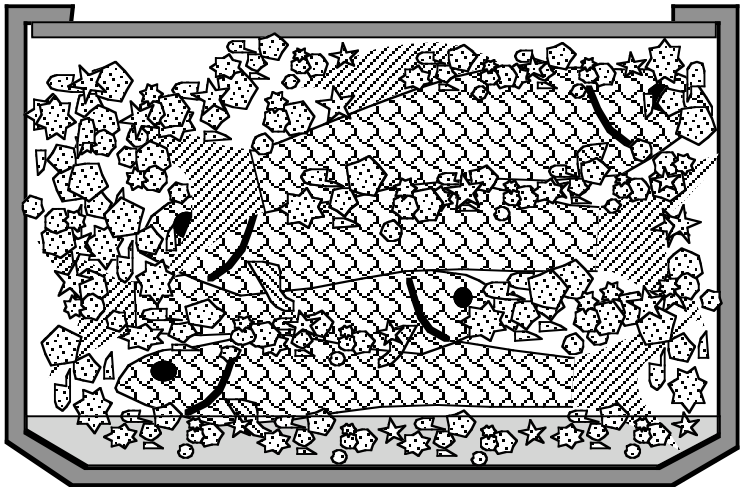
Pin-bone removal is labour intense, although for highly valued fish, removal of pin bones with pliers is still profitable as evident in the many salmon processing plants British Columbia. Swedish engineers of the *FTC Company* have come out with a variety of machines that greatly shorten the time in the removal of pin bones. These range from the hand held rechargeable units, the *Ergo-Light Pin Bone Remover* pictured above to the tabletop conveyer belt units suited for large-scale operation (Appendix). For application to artisanal fisheries, it would seem that manual removal of pin-bones is still economically feasible, although the handheld automated units may be useful in the peak fishing season.

An alternative to removing each pin-bone individually is to cut along each side of the bones and pull out the section of meat containing them. Cut on either side of the row of pin-bones in a shallow “V”, and remove this narrow strip of meat with the bones embedded within. Although quicker, this technique leaves a deep cut, which reduces the market value.

C. Transport, Refrigeration and Storing

After the fish are dressed, they can be either sold locally that day, or must be transported to other markets. It is important to minimize temperature changes during transport and ideally, fish should be unloaded into a well-insulated, refrigerated transport vehicle. However, these trucks are expensive and may not be available to artisanal fishers. Catches should at least be well protected from the sun and the ice replaced in the transportation containers when it melts.

The preferred way to pack fish in ice is to use the "soldier" method, in which they are packed in freshwater ice in boxes with the belly downwards or upwards. The box must be big enough so fish can be laid in straight, or without being forcibly bent, as they will retain this position as *rigor mortis* sets in.



Fish packed in the “soldier” method in icebox.

The fish may also be transported to a central cold storage or to a processing facility where they may be smoked or cured and further processed for national and international markets.

In deciding the appropriate processing procedure it should be remembered that many markets for high-quality fish give higher prices for fresh, unfrozen fish. This is especially true if there is a local clientele. Other considerations, especially in the tropics, is the capital cost of refrigeration equipment, as well as the power it will consume. In addition, there is maintenance. If the freezer does not operate correctly or at the correct temperatures, the product will deteriorate rapidly.

Minus 28 holding facility in Victoria, B.C. (3 million kg storage)

D. Packaging and Preserving

1. Vacuum Packaging

Vacuum packing removes air from around the food item and seals it in a plastic wrap. Removing the air and sealing it out enables food to stay fresh up to five times longer than conventional storage methods. In addition moisture and flavours are sealed in and odours are eliminated. Vacuum packing eliminates freezer burn, a common problem with long-term storage of food in the freezer.

Vacuum packaging of fresh or smoked fish has now also become a very popular marketing method. In addition to attractive and unique packaging design, it is also convenient to display food inspection information, barcodes and pricing necessary for non-local markets.

There are several brands of vacuum packing machines now available, from small home units that can be conveniently placed on a counter-top, to the larger commercial fully automated units that stand alone, and flush out any remaining oxygen around the meat with inert nitrogen, and

incorporate all packaging design and information. Smoked fish packed in vacuum packs with nitrogen flushing can even be stored and marketed without freezing.

Home/Counter-top machines
FoodSaver® Professional II
Retail: $300
Max packaging size: 16”

Commercial unit with Nitrogen flushing. *Packaging Aids Corp Fresh Pac Vacuum/Gas flush*
Retail: $12000
Max packaging size: 18”

2. Canning

Canning was a very poplar method of preserving salmon amongst the fishing communities in British Columbia. However, with the advent of refrigeration this method has become much less important. It is still popular as a home method of preserving fish in remote areas and in First Nations communities. Commercial canneries on Vancouver Island also custom can salmon for sport fisherman. *St. Jean’s Cannery* in Nanaimo for example, will process salmon in a variety of ways and can it for individual sport fisherman with their name and other specifications on the label (www.stjeans.com).

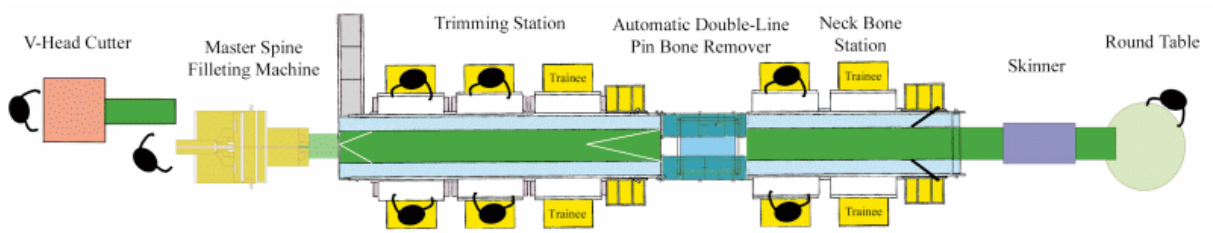
Canning may have only a limited application for production of a value added product in the Três Marias region for the following reasons, but the market potential needs to be assessed during the field mission.

1. The primary reason may be the lack of culinary preference for canned fish in the region. Although canned fish is used extensively in western cooking, it is not popular in many countries.
2. Glass jar home canning is labour intensive and needs special pressure canning equipment and jars that may not be easily available in Três Marias.

3. Unless done with extreme care, canned products can pose a serious health hazard from *C. botulinum* poisoning.
4. Large-scale commercial canning operations require a large capital investment but may be an option if a good market potential exists for canned fish in the region.

E. Large-scale Fish Processing

Fish processing has become highly automated for those species landed in large quantities, whether these be "wild" caught, or from aquaculture operations. While repetitive tasks were automated long ago, some aspects such as fish inspection still required human insight.



Ergonomically designed *FTC-Sweden* flowline processing workstations for visual inspection of fish from whole to packaged fillets (www.ftc-sweden.se)

However, with the advent of digital imagery and image-analysis technology even these functions are rapidly being automated. Automation to such a degree is still far removed from the reality of Três Marias but I have included some images from these automated factories for completeness.

At the *Samherji* processing plant, Dalvík, Iceland this flowline is equipped with high-resolution display terminals. They highlights in colour the location of any remaining bones that have not been automatically removed.

About the only remaining task for people is to remove any remaining pin-bones. Bones as small as 0,3 mm in diameter and 4 mm in length are located with the aid of an X-ray and displayed in colour in front of each worker.

Part II

Fish Smoking: Techniques and Potential

Small family operated custom fish smoking business in British Columbia, Canada

Introduction

This second section reviews methods of further processing the fish catch in ways to increase value of the final product. There are many ways in which this can be done, and depends on locality, culture, and socio-economic status of the target market. In the developed world, fish is pre-prepared at a retail outlet to facilitate cooking (e.g., marinated fish steaks, fish kabobs, stuffed fish cutlets). In many tropical countries, the catch of the day is often spiced and cooked as snacks and treats for sale in the evening and night at street markets. Although the settings are very different, both practices increase the per-unit value of the fish.

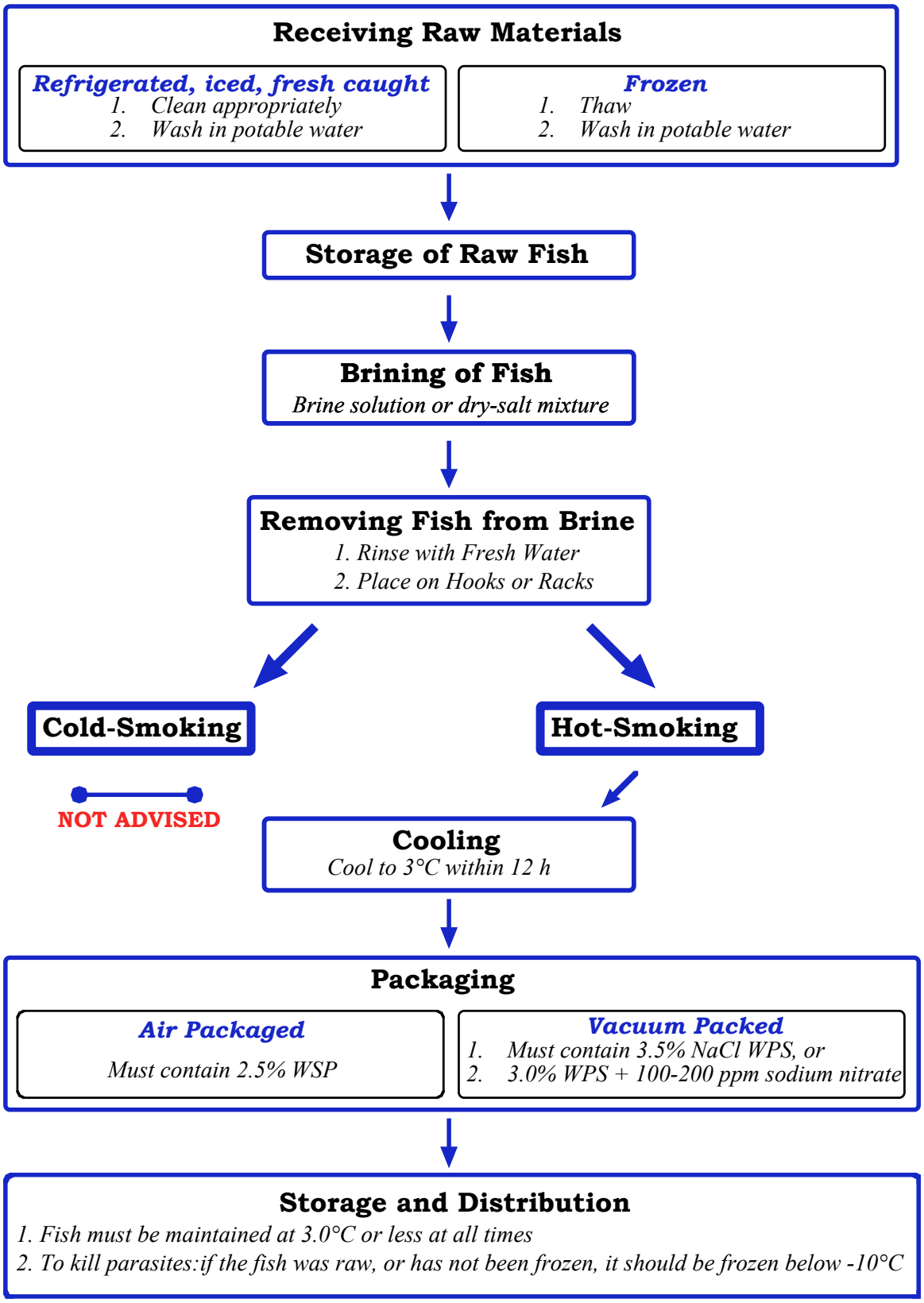
Another reason that fish is additionally processed is to deal with excess catch or for preservation for long-term storage. Historically, salting, drying, and smoking fish have been extremely important techniques for preserving fish. First-nations in North America used smoked fish extensively for surviving through lean times and as sustenance for long distance travel. After European colonization, salt-cod for example, played a pivotal role in the trade between the Caribbean and North America.

Traditional First-Nations drying frames for whole salmon. http://collections.ic.gc.ca/pacificfisheries /techno/img_tech/780636a.jpg

Now, salting, drying, and smoking are no longer used for preservation because efficient and inexpensive refrigeration enables fish to be preservation in prime condition. Even if these techniques are no longer used for preservation, there is market potential for these products in the gourmet market. Although dried and salted fish have fallen out of favour with epicureans, smoked fish is increasing in popularity and may have potential for development in the Três Marias region as a value added fisheries product.

A. Fish Smoking Procedures and Table

The following flow chart provides a generalized description of the smoking process but individual details depend on the fish species, methods used for brining and smoking, culinary preference, and procedure to reduce health hazards.


Receiving Raw Materials
Refrigerated, iced, fresh caught
1. Clean appropriately
2. Wash in potable water
Frozen
1. Thaw
2. Wash in potable water
Storage of Raw Fish
Brining of Fish
Brine solution or dry-salt mixture
Removing Fish from Brine
1. Rinse with Fresh Water
2. Place on Hooks or Racks
Cold-Smoking
NOT ADVISED
Hot-Smoking
Cooling
Cool to 3°C within 12 h
Packaging
Air Packaged
Must contain 2.5% WSP
Vacuum Packed
1. Must contain 3.5% NaCl WPS, or
2. 3.0% WPS + 100-200 ppm sodium nitrate
Storage and Distribution
1. Fish must be maintained at 3.0°C or less at all times
2. To kill parasites:if the fish was raw, or has not been frozen, it should be frozen below -10°C

1. Preparing Fish

Any fish can be smoked, but species high in fat (oil) are recommended because they absorb smoke faster and have better texture than lean fish, which tend to be dry and tough after smoking. Fresh caught or previously frozen fish can be used.

For optimizing the quality of a smoked fish product, only fish that have been kept clean and cold should be smoked. Fish that have been handled carelessly or stored under improper conditions will not produce a satisfactory finished product. Ideally, once a fish has been caught it should almost immediately be cleaned and iced. As in other market products to achieve maximum value, it should not have bruised, broken, or otherwise damaged flesh.

The fish should be scaled, gutted, de-boned, and then cut into uniform pieces. However, small fish can be smoked in one piece. Although in modern smoking operation large fish like salmon are often cut into pieces, First Nations in the Pacific Northwest traditionally used wooden frames to spread and dry whole salmon. The skin can be removed or left on. The skin is usually easier to remove at the end of the smoking procedure.

2. Brining Fish

Fish are soaked in a salt solution, *brine*, to preserve the fish and kill bacteria and parasites, especially *Clostridium botulinum*. Such curing is a two-way process; it takes some moisture out of the fish while simultaneously putting some salt and other spices into the fish. There is no precise salt concentration or soak time because these vary depending on fish size and condition and dietary preference. Stronger brine solutions reduce the immersion time but weaker solutions result in a more uniformly salted product. A good compromise is 80 ° brine (brineometer degrees) or 30 to 40 salimeters (211.2 g salt/litre water or equivalently one litre of salt in 4 litres of water).

Fish marinating in brine and spice solution.

http://www.3men.com/Images/Fish_brining.jpg

Amount of Brine to Fish Weight: Approximately 2 litres of brine are needed for each kilogram of fish. During the brine period the fish should be completely covered, and not too tightly packed so that the brine cannot circulate around each piece.

Spices and Sugar: Spices such as black pepper, bay leaves, seafood seasoning, or garlic, may be added to the brine depending on preference. Sweetening smoked fish is common in which sugar is an equivalent quantity as salt. The recipes for brining smoked fish abound on the Internet and below are two examples.

Honey Smoked fish (http://www.justsmokedsalmon.com/alderrecipes.htm**)**

¾ cup honey
10 allspice berries
2 bay leafs
½ cup salt
4 oz rum
15 peppercorns
10 cloves
¼ lime juice
1 quart water

3 Men's Recipe (http://www.3men.com/threemen1.htm**)**

1 US gallon water at room temperature
2 cups salt
1 cup brown sugar
1/3 cup lemon juice
1 tbsp garlic juice or garlic powder
1 tbsp onion powder
1 tbsp all spice
2 tsp white pepper

Rate of Brining: There is no precise time that is right for all fish under all conditions. Curing, or *brining*, times vary because fish condition and size affects how quickly and how much salt will be absorbed. However, below are guidelines, which can be modified to suit the fish species and other conditions. Muscle fibers of freshly caught fish, as opposed to frozen fish, are still intact. Intact muscle fibers absorb salt slowly and these fish will require longer brining. Below is a rough guide to brining times

Weight of each piece of fish	**Time to brining**
Under 500 grams	45 minutes
500 grams to 1 kg	2 hours
1 kg to 2 kg	4 to 5 hours

If the fish is brined whole, if the skin is left on, and for oily fish, the brining time should be increased by at least 25%. Some procedures require brining for as long as 24 hours. During longer brining times the

fish should be turned over once or twice in the solution to ensure uniform brining.

For short durations brining is done at room temperature in temperate regions of the world. However, in the tropics brining may require refrigeration or bags of ice placed in the brine mixture to keep temperatures cool.

3. Drying Fish After Brining

After curing, the fish is rinsed with cold running water to remove the excess salt and other seasonings from the surface. They are then dried on hangers or racks in a smokehouse, or a protected area, with heat and air circulation. The same racks as those used in the smoke house can be used for drying. The racks should be lightly wiped with oil to prevent the fish from sticking to it.

Fish drying prior to smoking.

http://www.3men.com/Images/Fish_Drying.jpg

The meat should be wiped with vegetable oil, and the surface allowed to dry. A shiny skin-like *pellicle* (glaze) will form on the fish surface, which seals the surface and prevents loss of natural juices during smoking. The *pellicle* also aids in the development of colour and flavour during the smoking process. Fish generally require approximately 1/2 hour of drying at 20-25°C, but this time is affected by air circulation and humidity. An electric fan can be used to aid air circulation and to keep flying insects away from the fish.

4. Smoking Brined fish

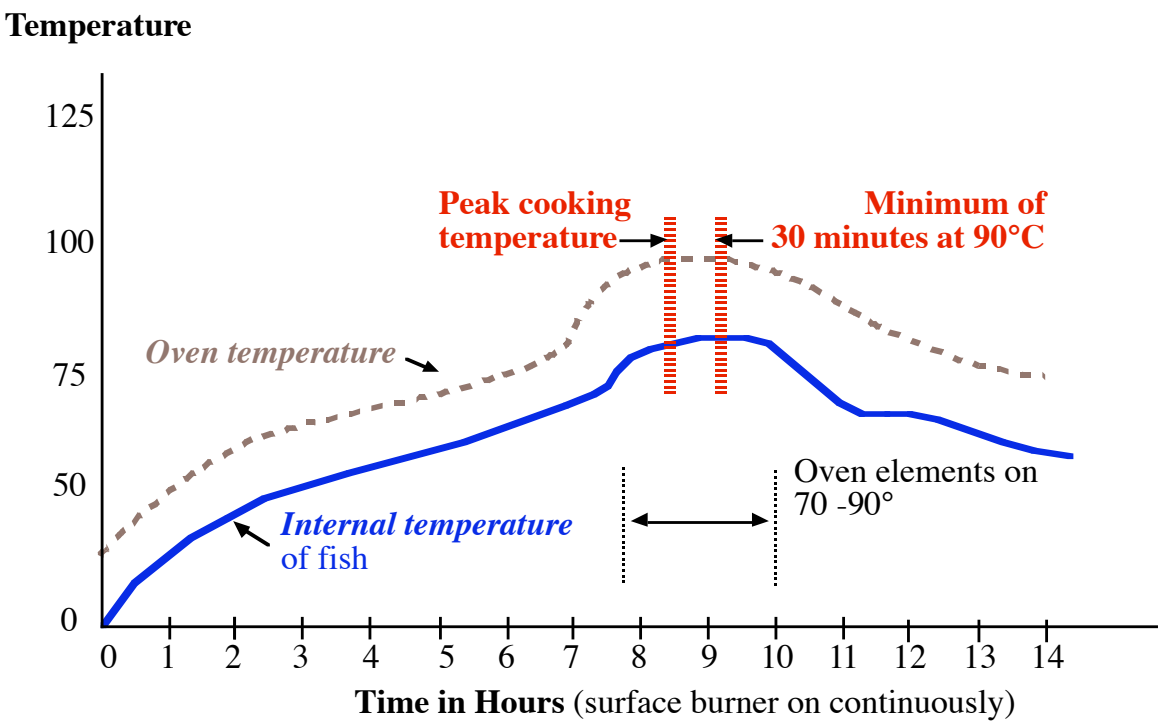
Fish smoking is done in many different types of smoking equipment but in general there are two different methods of fish smoking.

Hot smoking requires a short brining time and smoking temperatures of 32°C for the first 2 hours and 60-80°C for an additional 4-8 hours. Hot-smoked fish are moist, lightly salted, and fully cooked.

Cold smoking requires a longer brining time, lower temperature (25-32°C) and extended smoking time (1-5 days or more of steady smoking). Cold-smoked fish contain more salt and less moisture than hot-smoked fish.

Although cold smoking is used extensively in colder northern climates, it is not very practical for the hot humid tropics. Hot smoking may be the only practical option for the Três Marias region in order to avoid health hazards.

Hot Smoking Temperature Graph



For safe product, the fish must be cooked at 90°C external temperature for at least 30 minutes at some time during the smoking "cycle". It is best to wait 3-5 hours before elevating the fish to 60 to 80°C internal temperature. This is easier to do after most of the moisture is gone out of the fish, and there will be less tendency for a "baked" fish flavour. In addition, there will be less "curd" formation cased by the juices boiling out of the fish. A standard meat thermometer can be used to check this temperature.

B. Smokers and Smokehouses

There are a variety of smokers and smokehouses and although they vary in size and shape, they all have two essential features: a source of heat and a source of smoke. In traditional designs a wood fire meets these two requirements.

1. Types of Wood

Seasoned non-resinous wood from "hard" deciduous tree is best, and the soft woods, such as pine, fir, spruce, etc., or green woods, should be avoided. Logs, wood chips, pellets or sawdust can be used as a source of smoke. Common hardwoods used for smoking are alder, oak, hickory, pecan, cherry and mesquite. The logs damped with wet sawdust gives a lot of heat and smoke. Heat and humidity are both important to give the final product the golden brown colour and silky sheen. Smoked fish is done it flakes easily when pressed lightly with a fork.

Basically a smokehouse is simply an enclosed space where heat and smoke can be regulated. The inside arrangements of a smokehouse can be as varied as one might feel necessary for individual situations. Before electricity, smokehouses were large freestanding structures with a fire pit with racks and hooks to vertically hang fish or meat.

Image © Hilary Stewart. Indian Fishing: Early Methods on the Northwest Coast. p. 105.

A traditional wooden community smokehouse
http://www.endtimesreport.com/smokehouse.html

Today many people require only a smaller unit simply convert an old discarded refrigerator into a small "hot" smokehouse. All that is required fro this conversion is to remove all rubber gaskets, interior plastic moldings, as well as the motor and compressor. There are many ingenious designs for home built smokers available on the web. The degree of sophistication of heat control, airflow, and smoke, is up to the creativity or needs of the inventor.

This smoker was built out of an old oil tank and drum.
http://www.eaglequest.com/~bbq/smokehouses.html

This smoker was built out of 18" steel pipe with 3/8" wall thickness and 1/4" plate.

A small semi-commercial small unit that has excellent reviews is the *Bradley Smoker*. This a unique smokehouse, sold complete with its accompanying smoke generator, in which flavor briquettes are burned for 20 minutes each so that the temperature does not fluctuate. This system eliminates the high temperature gases, acids and resins that can distort the flavor of smoked food. It is light enough to carry and is about the size of a small fridge.

Bradley Smoker Model BT1S1 ($400)
Bradley Smoker and Grill Company

As with most processes in commercial fisheries, large fully automated smokers are available. However, they require large capital investment, skilled labour to operate and high maintenance costs. Two examples are shown below.

All stainless and automated commercial smokehouse

Friedrich walk-in smokehouse. 200 – 7000 kg capacity

However, given minimal budgets, ingenuity, and simple welding skills, commercial size smokehouses can be fabricated by an individual or small group. Ideas and plans are found in abundance on the Internet.

Cooling

Hot smoked fish has to be allowed to cool at least to room temperature before packing. An electric fan helps to cool the fish down and to keep flies away. Fish packed too warm will have reduced shelf life and moulds will readily grow on them. It is best not to cool smoked fish in a refrigerator or chill room prior because condensation will form inside the packaging and decrease presentation value and shelf life.

Smoked fish steaks cooling on a drying rack in a cool, dry area.
http://www.3men.com/Images /smoked_rack.jpg

3. Storage of Smoked Fish

It is important to emphasize that smoking fish adds flavor but does little to increase its preservation. Smoked fish spoils almost as easily as fresh fish. These days, all smoked fish for commercial sale are vacuum packed (see Part I).

Packaged hot smoked fish vary considerable in shelf life. In general, white fish keep better than fatty fish. In a refrigerator (below 2°C) smoked with fish can keep up to 8 days and fatty fish for about 6 days. For longer storage the fish should be frozen (below -10°C) immediately after smoking.

C. Smoked Fish Products

There are several varieties of smoked fish that can be marketed. The fishing industry in B.C. has developed a very successful smoked savory or sweet salmon ("candied smoked salmon") market. Here small family run-businesses to large commercial operations successfully market locally and internationally. The target market is tourists in local towns and key areas at in airport store outlets. A feature that is very popular is directed towards sports fishermen who will have their own catch custom smoked and sent to them at home (Photos cover Part II)

As with most retail products, packaging is important to maximize sales volume. Usually the items are vacuum packaged and often frozen. If the product is well brined, and the vacuum packaging is done with nitrogen to replace any possible trace of oxygen, freezing is not necessary. Some of the B.C. salmon items are shown below: -

Various salmon smoked products Smoked Salmon Products – BC

D. Health Hazards associated with smoked fish

Occasionally illnesses are associated with *hot-smoked* fish that have been traced to the incorrect handling, or processing. Surprisingly *hot-smoked* fish products should be considered to pose a greater health risks than normal fish for the following reasons.

- Smoked fish products are perceived by the public to be capable of safely tolerating temperature abuse and eaten without further cooking.
- Spoilage is not readily apparent because of the sheen and colour of smoked fish and the packaging.
- Processors sometimes use poor quality fish since the smoke and brine flavour and colouration can mask an unhealthy product.

There are three serious illnesses associated with improperly prepared fish due to bacterial activity: Listeriosis, Scombroid poisoning, and Botulism.

1. Listeriosis

The bacteria *Listeria monocytogenes* that is commonly found in soil and water causes listeriosis. The disease symptoms range from a flu-like illness to death under rare conditions in susceptible individuals. This hardy bacteria can survive and grow for long periods even when the temperature is as low as -1°C in vacuum packed foods. Since the minimum number of bacteria required to cause the illness in unknown, regulations in North America and the EU state that no *L. monocytogenes* should be present in a 25 g sample of smoked fish.

2. Scombroid Poisoning (Histamine Contamination)

Scombroid poisoning is specially a concern in certain species of fish whose flesh contains high levels of the amino acid histidine. Some bacterial species found on the surface of these fish secrete enzymes capable of decarboxylating the amino acid histidine to histamine. High levels of histamine cause symptoms are similar to allergic reactions; sharp metallic or peppery taste, facial swelling, skin rash, itchy skin, headache, nausea, and vomiting. Fortunately the symptoms appear almost instantly, but disappear within 24 hours. Once formed the histamine is thermally stable and subsequent heating or freezing does not destroy it. Therefore fish not properly chilled after catching and during storage should not be hot-smoked as the final product may still contain unacceptable levels of histamine. The US Food and Drug administration sets a histamine guidance level of 50 ppm and the European Union regulation sets it at 100 ppm.

3. Botulism

It is caused by the group of bacteria *Clostridium botulinum*, which is often common in fresh water sediments and even in the mouths of some healthy fish. There are many types of this bacteria but the one of primary concern is the strain that produces the Type E toxin and also the Type A, B and F toxin strains. These are neurotoxins and are associated with high levels of mortality. These bacteria can live and grow in temperatures from 3° - 45°C, and so is relatively heat resistant. It is important for all parts of the smoked fish to be raised to sufficiently high temperatures to kill these bacteria and its spores. The toxin is destroyed only when heated to > 80°C for more than 10 minutes. The dangerous property of this group of bacteria is that they are anaerobic and so require no oxygen to live. This is of particular concern in vacuum packed products where, freed from competition from aerobic spoilage bacteria, *C. botulinum* can increase to very high levels.

Other illnesses

The extensive handling required in hot-smoking procedures also provides opportunity for contamination by pathogens such as *Escherichia coli*, *Staphylococcus aureus, Salmonella, Clotridium perfringens, Bacillus cereus, Vibrio parahaemolyticus,* and *Vibrio cholerae*. These pathogens are not specific to smoked fish and result from improper sanitary conditions and safe food preparation standards.

E. Guidelines for Safe Preparation of Hot-smoked Fish

Paying close attention to temperature control in the stages from fish capture to consumer consumption can control most health hazard associated with hot-smoked fish.

1. Fish must be quickly chilled after harvest and maintained chilled until smoked. The core temperature of the fish should be 10°C or less within 6 hours of death, then lowered to 4°C within 42 hours. Chilled fish should not be exposed to temperatures above 4°C for more than a 4 hours cumulatively after the initial chilling. Chilled fish should not be stored for more than 14 days at 0°C or more than 7°C before smoking. Frozen fish (e.g. stored for 24 weeks or longer) should not be exposed to temperatures above 4°C for more than 12 hours cumulatively after initial chilling.
2. Parasites are killed by the hot-smoking procedure but cold-smoked products need to be frozen at -20°C for 24 hours (EEC,1991) or 7 days (FDA, 1998) or at -35°C for 15 hours (FDA, 1998) prior to processing.
3. During smoking the core temperature of the fish must reach at least 63°C for at least 30 minutes to eliminate bacterial hazards.

4. In addition a salt concentration of 3.5% water phase or 3% salt and 100-200 mg/kg sodium nitrate is required by FDA regulations.
5. Sanitary conditions and safe food handling procedures have to be maintained at all times during the smoking and packaging operations.
6. Smoked fish can be refrigerated if it to be consumed within a few days. It should be maintained at below 3°C through out distribution, retail storage and consumer consumption during this period. For longer periods, all smoked fish has to be frozen and remain frozen during distribution, storage and retail sale.
7. The only way for smoked fish to be distributed without refrigeration is when the product has been flushed and vacuum packed with inert gas (usually nitrogen). Machines that can do this are very expensive and this method most likely not available to artisanal fishers.

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Part III

Fish Skin:
Potential and Development

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are needed to see this picture.

Left to right, top row: Pacific chum salmon purse, $US 270; spotted wolf fish wallet, $100. Middle row: Stingray handbag, $155; stingray purse, $280. Bottom row: Atlantic salmon belt, $89; masked water snake handbag, $125.

Introduction

This section examines the potential for development of value added products from fish skins, primarily the development of fish leather products. It is evident that the current leather market demands a high degree of specialized skills, technological sophistication and marketing savvy. Therefore, technical know-how for the development of true fish leather in the Três Marias region is beyond the scope of this review. However, I have summarized organizations involved in research, development and marketing of fish leather in the region as potential sources of collaboration and assistance. I have also included a section on the utilization of fish skins in the production of value added craft products that may be more appropriate for the Três Marias region.

A. Fish Leather History and Current Markets

For millennia humans have used mammal, birds, and reptiles to make leather products out of their skins. As a result we have an extensive cultural knowledge of leather preparation and use of specific animal skins, best suited for a variety of applications. The earliest records of wide scale use of fish skins appear to have been used by the Japanese Ainu culture in the 5th century. Inuit and some southern maritime cultures have used fish skins, especially salmon, since the Middle Ages for their clothing accessories such as jackets and outer lining of shoes.

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Salmon skin shoes 5th Century
http://www.hmh.pref.hokkaido.jp/english/E_jouten/E_theme2/E_theme2.htm

Salmon shoes 21st Century

Yet it has not been until relatively recent times that Western culture has utilized more than a few species of fish to make leather. Sharks, for example, have been used for their strong, rough lenticular abrasive surface, that is ideal for military boots, and non-slip sword handles. Eels on the other hand have extremely smooth, thin, skin, but it too is very strong and consequently used in the high-end shoe and purse/wallet markets. During World War II, Norwegians covered their feet with salmon skins.

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Cod leather back pack $320

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Bikini $300 and up

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Atlantic salmon belts $90

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Pacific salmon belt $70

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Atlantic salmon wallet $120

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Atlantic salmon bill-fold $60

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Wolf Fish cardholder $30

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Key-fobs $20 & cash clips $20

Most of these items were listed at www.oceanleather.com

In the last decade, however, the skin of farmed fish, Tilapia and salmon, has stormed into the global designer fashion industry for clothing and small items such as belts, purses, wallets, and bikinis. The skins from fish are now considered the principal residual by-product of this aquaculture business. *Christian Dior* is now marketing a line of pink salmon shoes $US800; *John Galliano* has produced a US$800 purse in its boutiques during the spring season; *Bottega Veneta* showed a stingray clutch for $ $US1,180; *Givenchy* had a small evening stingray purse for $ US1,620; and both the Scottish fashion company *Skini*[5], and *Irish Salmon Skin Leather Co.*[6] have launched lines of expensive bikinis. In the USA, Jim Bates, Founder/owner of *Upscale Leather*[3], and Jean-Charles Grenon-Andrieu has *Ocean Leather* are producing a wide selection of fish-skin wallets, boots, and other products

The *haute couture* fashion has embraced fish skin leather because of not only its novelty but also praises its softness, strength, and versatility. Part of the reason for not using fish leather has been that up until recently few tanneries had managed to get rid of the "fish" smell completely. With modern tanning procedures, this is no longer an issue. Fish tanners in New Zealand, Ireland, Canada, and France, maintain the skins are as strong as crocodile leather and have the strength and durability of a manmade fiber.

The high-end market also aligns itself with the current politically correct marketing strategy as "environmentally friendly alternative exotic leather" because they use an otherwise wasted product. The fish leather market trend is a spin-off from the dramatic increase in fish farming around the world of Atlantic salmon and Tilapia. These operations, which up until recently discarded the skins as waste, or added them to fertilizer, are in the convenient position to supply cheap, and physically consistent skins to leather tanners. Almost all the leather in the high-end market is tanned using chemical (chromium) processes. It is important to point out that the claim of "eco-friendliness" is mainly because a previously wasted product in used and does not encompass the source fishery of the fish skins or the environmental and toxicological standards of the leather processing methods. The chemical tanning procedures used in most fish tanning operations also pose a high health hazard to workers (http://www.ilo.org/encyclopaedia/?print&nd=857200646).

B. Processing of Fish Leather

The leather companies in Europe and North America have been suffering from the pressure of cheaper leather coming out of Asia. To counter this trend, the European Union has poured large funds into supporting projects to perfect the process of curing salmon skin. As with land animals the physical properties of fish skin varies between species, and these differences require different tanning processes. The

uniqueness of each fish species is determined by the surface lenticular patterns due to scales.

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are needed to see this picture.

Surface pattern of *salmon* leather

The *grain* or *surface pattern* of the scales, or their absence, is important because the variation in roughness and density of scales is critical to product appeal. The collagen fibers of the dermis and the orientation, disposition, and composition as these factors affect stretch, strength, and tear resistance of the leather. The age and size of a fish will also affect the leather quality. This variation makes the development of fish leather from new species in artisanal fisheries time consuming and difficult.

Before fish leather products can be developed for commercial manufacture, samples of tanned skins should first be classified and ranked using standardized methods. This requires specialized knowledge in leather technology, laboratory facilities and multi-year research funding. New technologies in the processing and tanning of fish skins have been developed in Brazil and around the world. The details of these procedures are guarded as trade secrets and not sufficient details of these procedures are known for ready adaptation to species in the Três Marias region.

C. Major Fish Leather Researchers and Manufactures

This section lists potential sources of information and collaboration for the development of commercial fish leather production in the Três Marias region. Most of the manufactures use chemical tanning process except for the operation in France and Ireland.

1. Brazil

Brazil has become the World's largest exporter of leather and shoes. Although, this is predominantly from beef cattle, their marketing infrastructure continues to find new outlets because of the leather quality and the country's production capabilities. As fish leather products become increasingly popular throughout the world, especially in the high-end fashion markets, it would seem that most the marketing infrastructure is already in place for large scale production.

There is one fish leather manufacturer and two researchers who may be excellent collaborators for the further development of fish leather in the Três Marias regions.

1.a. Tania Pedracini

The Brazilian businesswoman Tânia Pedracini, from Maringá, Paraná, has established a tannery to process Tilapia leather in 2003. Recently the

company started producing a line of ladies shoes, which are being sold in Austria, Germany and the United States and new markets opening in Canada and Holland. The company employs some 25 people producing 15 styles in 20 different colours. Part of the appeal of the Tilapia leather is that it is difficult to be simulated synthetically and it has no environmental impact, as the fish are bred in captivity.

Tânia Pedracini's company purchases unprocessed fish skins from cold storage houses in the state of Paraná, São Paulo and Minas Gerais that make fillets out of the fish. Up until recently all the fish skins have been discarded as waste, so their cost is negligible to the tanners. From the information available on the Internet, I was unable to ascertain whether the tanning process was ecologically sound but it can be assumed that chemical tanning methods are being used. The tannery now supplies Tilapia leather for garment, belt and wallet factories in the state of Paraná.

If fish leather production is to be developed further in the Três Marias region, it may be best to collaborate with Ms. Tânia Pedracini as she already has a fish leather tanning and dying process in place, as well as marketing infrastructure. Perhaps the initial step in Três Marias is to develop the technology to skin and de-scale fish suitable for an identified market. Then next step would be to develop the infrastructure for collection, storage (freezing), and shipment of the skins to the processing facility.

Contact

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Site: www.annapedracini.com

1. b. Maria Luiza Rodrigues de Souza, (Ph.D.)

Dr. de Souza has recently written a report on the development of fish skin technology in Brazil (Appendix 1). In this paper she says that new technologies have been developed in the past decade for the utilization of the skin of Pacu, Tambaqui, Carp, Catfish, Giant Catfish, Bocachico and Tilapia from artisanal fisheries. She would be a good person to contact for research into the potential of development of fish leather from species in the Três Marias region. She may also be knowledgeable about the use of ecologically friendly processes for the tanning of leather using local materials.

Contact

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2. Spain, Pinchomania S

A M. De Torres, for example, approached *Inescop,* a Spanish centre for shoe technology in Alicante, and secured more than $450,000 from the EU to research the use of salmon skin from shoes. Ms. De Torres has reported from his efforts that fish-curing technology is complex, labour intensive and costly, especially when done on a small scale. Also, he had been unable to find adequate fish tanners to support his grand marketing plans.

Comment [SP1]: Do you have her report? A contact address?

Contact

José Ignacio DE TORRES VILLAGR - Pinchomania S (Organization)
C Emilio Hurtado, 29004 Málaga, ESPAÑA
Tel: +34-95-223-64-10 ignacio@vensy.es

3. Canada

FineExoticLeather: Since 1990, the Canadian company *Great's Holdings Co., Ltd.* and Japanese company *BiddyLeather Products Co.*, Ltd. have partnered to develop and market a unique line of superior exotic leather products. While G*reat's Holdings* specializes in the design of trendy fashions incorporating the latest styles, *BiddyLeather Products* focuses its energy in researching high-quality and environmentally-friendly manufacturing techniques using only the finest North American salmon skins. Together, they service the Chinese and Japanese retail industry and are expanding into other international markets. *Pacific Leather Tanners* tan cow, deer, elk and moose leathers and claim to be specialist tanners of aquatic **fish** skins.

Contact

FineExoticLeather c/o Great's Holdings Co., Ltd.
12839-114A Avenue Surrey, BC, Canada V3R2N1,
Tel: 001-604-825-0636 Fax: 001-604-580-1120 E-mail:
sales@FineExoticLeather.com http://www.fineexoticleather.com/company.html

Pacific Leather
1789 East 22 Avenue Vancouver, B.C. Canada V5N 2P6
Tel: (604) 874-5526, Fax: (604) 874-8886,
E-mail:info@pacificleather.com http://www.pacificleather.com

4. USA

Upscale Leather. Partners Jim and Kim Bates founded *Upscale Leather* in 1991 from their home in Massachusetts. They were looking to market a product characteristic of their northeast Atlantic coast. Considering the cod's impact on the prosperity of early New England, they launched their company with products made from the tanned skins of commercially caught codfish. Reaction to the quality of the tanning and finish work was so favorable, they then expanded to include the skins of wolf fish and farm-raised salmon.
http://www.upscaleleather.com

5. France

M. Vaudelle. M. Vaudelle of rural Callac, Brittany (France), has started and runs a small very successful artisanal operation by himself. He is a self-taught leather tanner, who calls fish skin "the leather of the 21 Century". Every month he, and three other tanners, turn 5000 smelly fish skins, costing $0.03 to 0.05 each, into supple and odorless strips of soft and supple leather that bring between $4 and $5 from wholesalers or leather-goods makers. He sells some of his skins to the workshop of a M. Dobe, who lives in the same town. M. Dobe then turns the skins into handbags that sell for about US$200 in his local shop. In a testimonial from one of their customers, after four years of daily use of a handbag "it looks as if it were new – other than the cowhide strap and lining".

M. Vaudelle's operation has demonstrated that artisanal fish skin tanning is possible, and that a large financial commitment is not necessary. He, and only three workers are able to cure, stretch, spray and press skins, using precise formulas that vary with each species of fish. However, he considers all his recipes as guarded precious trade secrets, so details of the artisanal processing are not common knowledge. Perhaps M. Vaudelle should be contacted to assist in the technology transfer of a comparable operation to small communities in the São Francisco Basin.
http://www.reveries.com/coolnews/2003/july/jul_9.html

6. England

SKINI. The concept of using salmon skin leather for clothes was born out of a 4 years-long national study concerning the ecological use of natural materials. The result is *SKINI* London, by designer Claudia Escobar, a line of perfectly crafted bikinis made entirely of salmon skin. Ms. Escobar is quoted in a newspaper interview as saying that she is looking at importing salmon skins from the Canadian fish farms and from salmon farms in Chile to her processing plants. This company seems to specialize almost exclusively in salmon skins.
http://www.SKINILondon.com

7. Ireland

The Irish Salmon Skin leather. This company was incorporated in 2000. After four years of intensive research and qualitative refining, the final processes yielded a leather of outstanding strength and durability, which were awarded the full quality mark from the Craft Council of Ireland. The company claims to use an ecologically friendly tanning process with a highly skilled workforce of craftspeople.

Contact
The Irish Salmon Skin Company
Unit 3a, Ossary Court, Ossory Road, Dublin 3, Ireland.
Email:salmonleather@gmail.com www.irishsalmonskinleather.com

D. Artisanal Marketing of Fish Leather in Três Marias

As described above the development of fish leather is a technically challenging procedure. I tried the *LEM* do-it-yourself tanning kits and some other low-tech methods. The end product in all cases was inflexible and hard and resembled cardboard rather than leather. Since all the experts in the field emphasize that tanning procedures are species specific, further experimentation should be tried using local fish in Três Marias. Also, expertise in fish leather tanning seems to have been developed in Brazil.

1. Fish Skin Craft Products

In contrast to commercial fish leather, fish skin craft products are easy to develop. In British Columbia, I have found one individual artist using unprocessed salmon skin make souvenir drum rattles, or tambourines.

I have tried this technique in which scales are removed and the skin cleaned of any meat. The wet skin was stretched taught over the drum, secured with elastic band, and dried in the sun (25-30°C) for a day. Once dried, the skin adheres to the clay surface and the elastic band can be removed. *Neat's-foot* oil was rubbed into the surface prevents cracking. The skins did not smell "fishy" after this procedure. This technique can be easily adapted to other crafts such as lampshades, picture frames, key fobs etc. The skins could also be imprinted using leather dyes.

The other avenue that may be worth developing would be to use fish scales for the manufacture of jewelry and trinkets.

Gar Fish Scale Jewlery
http://www.ccss.us/

QuickTime™ and a
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Appendix I Fish Skin Technology: Tanning Process

Maria Luiza Rodrigues de Souza[1]

The increasing need to use the sub-products generated by fish culture is mainly because of the high percentage of filleting residues - a problem both to the producer and to the butchers' shop. The residues of fish processing are considered to be the head, fins, skin and guts, which, depending on the species, represent up to 66% of the total body weight (Contreras-Guzmán, 1994). The skin is considered the principal residual sub-product.

The teleost fish skin percentage ranges from 5 to 10 percent according to the species and its way of collection (filleting method). In Nile Tilapias there are observed values varying from 4.8 to 8.5 percent (Macedo-Viegas et al., 1997; Souza e Macedo-Viegas, 2000; Souza 2003). For Sharptooth Catfish *(Clarias gariepinus)*, from 4.4 to 6.5 percent, depending on the weight category (Souza et al., 1999); for Pacu *(Piaractus mesopotamicus)*, there is a skin percentage of 5.1 (Faria et al., 2002), and for Mirror Carp *(Cyprinus carpio specularus)*, the percentage is about 4.65 (Souza et al., 2003).

However, the skin can be processed and transformed into quality raw material of unique and peculiar aspect after tanning, due to its resistance and drawing on its surface, mainly skin of fish with scales. According to Ingram e Dixon (1994), the skin of fish are considered an exotic and innovative leather, being accepted in different clothing industry segments.

It has been verified that in the fish skin commercialization and industrialization there are problems associated to its small size and apparent fragility. However, because of the need to know and test the quality of this raw material, some works have been developed to test its resistance by physical-mechanical tests.

The after-tanning exotic drawing of the skins of fish with scales compensates its reduced size. The original drawing of these skins, which can hardly be imitated by impression plates on other leathers, hinders the falsification of this type of product, mainly if the lamellas of insertion of the scale are more elongated.

The physical-mechanical tests confirm that the skins of fish present variable resistance in function of a series of factors such as: the species of fish and composition of collagen fibers, the fish dimensions, technique of tanning employed, region of the skin and orientation or direction of the

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leather (longitudinally and transversally to the length of the fish), among others.

As for the species, the resistance of the skin is related to its architectural histology, e.g., the disposition, orientation and composition of the collagen fibers. According to Junqueira et al. (1983), the structural arrangement of the collagen fibers of the compact dermis, as well as the thickness of its stratus, allows for the skin to present great resistance to different traction forces. Therefore, the skin of some species of fish can be used commercially in the confection of leather devices.

Besides the histological structure of the skin and fish size, there is the matter of the formation of collagen fibers. According to Hoinacki (1989) and Sanches and Araya (1990) the skin presents high concentration of proline, hydroxyproline, and of glycine (mainly) and low concentration in aromatically amino acids. Paces (2002) also confirms that the most abundant amino acid in the constitution of the collagen is glycine. Sanches and Araya (1990) state that the collagen of different species differ in their amino acids sequence, the major part containing around 35% of glycine, 12% of proline and 9% of hydroxyproline. The hydroxyproline is rarely found in distinct proteins of the collagen. According to the same authors, the amount of hydroxyproline in the collagen of the skins of fish differ between the species, intervening with the temperature of retraction or shrinking of the skin, where the rupture of hydrogen bonds of the collagen chain occurs in an irreversible form. Therefore, the protein dehydration occurs and, particularly in the collagen, there is the coagulation, which morphologically manifests through a strong contraction of the fibers in the longitudinal direction, also becoming transparent and elastic. In hot water fish, the temperature of retraction of the skin is bigger than that of cold water fish. Consequently, it needs a greater control of the temperature during the stages of the *ribeira process* (wet part of the tanning process, where skin is prepared to receive the tanning agent). Thus, the composition of the skin in relation to amino acids has great influence during the processing; otherwise, it would not be possible to get a quality leather, which is soft and flexible. The lipids in the skin also interfere in the process of tanning and in the resistance and final product quality (leather). In this case, if the lipids are not removed during the initial stages of the tanning process they make it difficult the penetration and reaction of the chemical products with collagen fibers.

As for the size of the fish it is directly related to the thickness of the skin: as the fish grow, the skin proportionally thickens due to the increasing amount of collagen fibers, which will react with the tanning agents and give the characteristic resistance to the leather. According to Craig et al. (1987) it has been verified in the skins of some species the distribution of collagen fibers in accordance with their size. The

parameters that indicate the traction (load of force, tension of traction and elasticity) can be correlated with the amount and orientation of collagen fibers. The dermis thickness being mainly determined by the collagen fibers ratio in the skin (Fujikura et al., 1988).

The tanning technique applied influences the results of the resistance of the raw substance transformed into leather. The concentration and types of tanners, the amount and types of oils, added in the stage of shine (at the end of the tanning process), act directly in the result of the final product (leather). In a general way, the physical-mechanical characteristics can be improved by the action of shine, because it provides greater resistance to tearing, and the leather becomes softer and more elastic due to presence of the oils that contain collagen fibers—the oils function as a lubricant and they prevent the aglutination of the fibers during drying (Hoinacki, 1989; Gutterres, 2001). It can be inferred that the technique used for tanning influences the determination of the traction of the leather.

In general, the resistance of the Tilapia leather presents greater values for resistance to traction and gradual tearing in the transversal direction; while in the longitudinal direction presents better stretching results. For Pacu, the transversal direction of the leather presents greater resistance to traction and stretching than the longitudinal direction. In this same species, the leather possesses greatest resistance to the gradual tearing in the longitudinal direction.

The skin of some species of fish like Pacu, Tambaqui, Carp, Catfish, Giant Catfish, Bocachico and Tilapia of the Nile are being already processed in artisan tanneries. Amongst the species of fish that are being cultivated, the skin of the Tilapia is the one with increasing importance due to its advantage in the processing of devices and clothes. However, for better exploitation of the skin for the leather industry, it must be considered the species, size, quality of skin, besides its beauty, specially for the fish that have scales, since the characteristic drawing formed by lamellas of protection of the insertion of these scales, resulting in a typical and hard aspect to be imitated, guarantees an exclusive high visual impact standard.

This raw material allows the confection of devices in general, like keychains, folders, belts, wristwatches bands, t-shirt collars, applications in clothes, rafts, pencil cases among others. However, for the confection of clothes (manufacture of jackets, vests, dresses, skirts) and footwear it is important the realization of resistance tests as means to guarantee the quality of this processed leather. According to Hoinacki (1989), the values of reference of the resistance of the leather tanned in chromium, based on the "United Nations Industrial Development Organization's Acceptable levels of quality in the leather industry (1976)", for the traction are of, at the very least, 9.80 N/mm2, stretching until the 60%

rupture and gradual tearing of 14.72 N/mm for clothes confection. While, for the manufacture of shoes, the resistance test for traction must be of at least 17,65 N/mm2 or 180 kgf/cm and the gradual tearing of 80 kgf/cm or 78.43 N/mm. Thus, in a general way, the leathers of fish can be used in the confection of shoes coated with another type of leather.

For the transformation of the skin into leather, an unputrefiable product, it becomes necessary to tan it. In this way, the fibrous nature is kept after being previously separated, for the removal of the interfibrillar material makes it easy for chemical products to act. After this preparation of the skin, they are treated with tanning substances, which transform them into leathers or processed skins (tanned), preserved from autolitic processes or microbial attacks (Hoinacki, 1989). Thus, the skin is transformed into an unputrefiable material with characteristic softness, elasticity, flexibility, and traction resistance. In sum, it has specific physical-mechanical qualities (tanning process).

The tanning process presents some stages: remolho, descarne, desencalagem, desengraxe, purga, píquel tanning and basificação, neutralization, re-tanning, dying, shine, drying and softening. It still can be submitted to the final finishing, through the application of a composition of chemical products that form a film over the leather surface, which is called finishing film.

The purpose of remolho is to wash and to hydrate the skins; the descarne removes remaining portions of fat tissue adhered to the skin. In the caleiro stage, there are the removal of scales and opening of the fibrous structure for interfibrillar material release through the intumescimento of collagen fibers. The desencalagem aims at the elimination of alkaline substances deposited in the skin during the caleiro, loosing the fibrilar structure a little, and the purpose of desengraxe is to remove lipids in the skin. The purga consists of a more refined cleaning, using proteolytic enzymes. In the piquel there is the acidification of fibers in order to facilitate the reaction of these with tanning substances, transforming it into an unputrefiable material, the leather. Depending on what is desirable as a final product it is possible to use chromium salts-based tanning substances, which would lead to a more flexible and elastic leather as well as a more hydrothermal stability. But, tanning can be done with synthetic tanning, resins, and glutaraldehyde, aluminum-based tanners, as well as organic, among others. For fixing the tanner in the leather, the basificação must be carried through, using soft alkaline substances, such as bicarbonate, forrniato or sodium acetate, among others.

In the stage of neutralization the skin pH is raised, eliminating existing free acids in the tanned leather using soft auxiliary products and without causing any prejudice to the leather fibers and to the flower. This stage must be well executed because it must give re-tanners, dyers, and

greases a bigger penetration capability as a consequence of the dermis pH increase. The re-tanning and dying are stages where the degree of desired softness and color in the leather is determined. According to Gutterres (2001), in shines some substances (natural and synthetic oils in watery dispersions) are introduced in the leather in humid state and will coat the surfaces of fibers and fibrils, providing for their slide and mobility. The main purpose of the process of shines is that of to guarantee leather softness after dried out. Following the drying process is the softening of the leather. In the softening stage, the collagen fibers are put into motion by mechanical action, in such a way that they slide over one another, which softens the leather if correctly lubricated with oils in the stage of shining.

During the tanning process, the skin goes under modifications due to the use of chemical products that react with the collagen fibers, giving the leather a greater resistance associated to the disposal and orientation of collagen fibers.

New technologies in the processing and tanning of exotic skins have been developed in Brazil, as well as studies analyzing the resistance of the leather, produced raw material, for the transformation of a problematic by-product, due to the elevated amount generated in the process of butchering, in a product of high commercial value. In a global analysis of the cost of the process of tanning of fish skins it must be taken into consideration everything from raw material availability to labour and necessary equipment. According to Almeida (1998), the costs of formulation of the tanning of skins of fish keep narrow proportionality with the ones of bovine skins because there is no specific equipment for skins of fish in the market. The processing of these skins is practically artisan, what causes a rise of the labour costs without making its production impracticable.

Based on the values calculated for unit of skins of fish, it is noticeable the existence of an really significant aggregate value to the fish because both sides of the fish body are considered (two units of leather)—in the half-finished form or finishing leather. However, the skin can be used by the industry of leather processing, after being taken of the fish correctly, followed by the application of an adequate conservation method, keeping them apt to be submitted to the tanning process. With the commercialization of fillets without skins, the sale of residues for production of silagens or proteic hydrolyzates, and the possible integral exploitation of the skins of fish, in the tanning process, the producer will economically optimize his fish activity.

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Part IV

Fish Waste Utilization: Disposal and Composting Techniques

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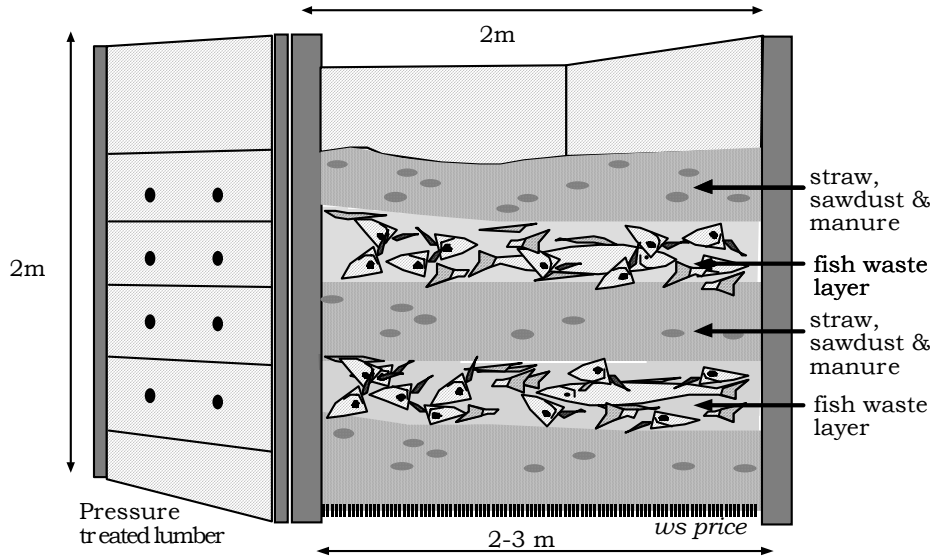
Windrow composting



Backyard bin composting

Introduction

Fish waste attracts flies and rodents, decays rapidly, smells badly and poses a health hazard if not disposed properly. At the same time fish scraps are rich in proteins and fats and can be profitably used in a number of ways. In large scale industrial fisheries operations, fish offal and waste fish are processed into fish emulsion and liquid fish fertilizer that are traded in the commodities markets, and valued as additives in animal feed, pet food manufacture and agricultural fertilizers. Although the scale is smaller in artisanal fisheries, similar uses can be found for fish offal generated by individual fishers and from small fish markets.

Prior to development of value added products from fish waste a baseline assessment of the amount of wastes generated, methods of collection and disposal, current problems if any and future trends needs to be done. This will determine the most appropriate value added product that should be developed and the scale of the operation. There are three main value added products that can be manufactured from fish waste: fishmeal and oil, fish silage and fish compost fertilizer. Of these three the production of fish compost fertilizer may be the simplest and most versatile for adaptation to artisanal fisheries.

A. Fishmeal and Oil

Waste fish and inedible parts are minced and heated in fishmeal cookers to 95-100°C for 20 to 30 minutes and the cooked material is pressed to separate solids (press cake) from liquids (press liquor). The press liquor is further centrifuged to remove solids completely and the solids from this process are added back into the press cake. The press liquor is either evaporated or sometimes used in fish silage (below). The press cake can be used in the manufacture of aquacultural and animal feeds. Because the press cake contains very little water or oil and because it is subject to high temperatures in the cooking process it is considered virtually sterile but may be subsequently recontaminated by rodents or birds, which are attracted to it. Fishmeal and oil production requires capital investment in cookers and presses and may not be appropriate for an artisanal fishery with scattered waste generation. If a good waste collection infrastructure is in place then investment in a centralized fishmeal production facility may be considered.

B. Fish Silage

Fish silage is produced by acidification of fish waste using organic acids such as formic acid or mineral acids such as sulfuric acid at lower levels. A third method sometimes used in tropical countries involves the addition of simple sugars such as molasses and a lactic acid bacterial culture, which generates lactic acid through natural breakdown. The use of acid is necessary to inhibit spoilage bacteria, which produce trimethylamine or ammonia and toxins such as histamine. The final

silage product is a liquefied emulsion with a pleasant “malty” odour from the fermentation procedure. Fish silage is highly nutritious and is traditionally mixed with dry feed ingredients and fed as protein supplement to pigs and poultry. Fish silage production from artisanal fisheries have been developed and successful production depends both on the availability of non-fermentable products such as fish waste and fermentable sources such as molasses. The local market for silage supplements for animal feed is another factor that needs to be considered.

C. Fish Compost Fertilizer

Converting fish waste into clean smelling humus compost fertilizer for home gardens or agricultural applications is the third value added option for dealing with fish wastes in the Três Marias region. The composting process involving a series of related physical, chemical and biological events whereby detrital microorganisms efficiently convert complex fish proteins and lipids back to readily available nitrogen, carbon, and minerals to be assimilated by plants and animals. Understanding the nutritional requirements of these microorganisms forms the basis of composting.

1. Compost Ingredients

Three primary ingredients are required for compost production in addition to fish waste. These are carbon, water and oxygen. Carbon is the essential compound for energy production by microorganisms and maintaining the correct C:N ratio is the key to successful composting. The C:N ratio should be in the range of 20:1 to 35:1. Many different sources of carbon can be used and the choice is dependent on local availability. Wood fiber (cellulose) is extremely high in carbon (C:N is 400:1), and sawdust from wood processing plants are often used in the production of fish compost in British Columbia. Depending on the wetness of the fish waste, sawdust may clump together and not allow for air movement, which is necessary for decomposition of the fish. To avoid this condition sawdust is often missed with bark mulch, or larger pieces of chipped wood (0.5 to 2 cm), or horse manure. In small-scale operation by individual fishers, the carbon source can be kitchen vegetable waste, garden clipping and leaves. Caution must be exercised when using garden waste because small compost piles do not generate enough heat to kill weed seeds. Moderate scale operations may be able to utilize was stalks and post-harvest material from agriculture. No matter what the source of the carbon, the material should be chopped into small pieces to increase surface area contact with the fish waste and also to favour proper aeration.

Water is the second key ingredient for the multitude of microbial chemical composting reactions. The moisture content of the compost pile

should be maintained around 40 to 60%. If the mixture is too dry, microbial activity will cease. Too much moisture will result in nutrient leaching and possibly result in anaerobic conditions.

Oxygen is also critical for the survival of aerobic bacteria that are essential for successful composting. Poor aeration leads to the proliferation of anaerobic bacteria that convert fish material into volatile ammonium compounds, which gives off an unpleasant odor. Anaerobic decomposition also results in the loss of nitrogen from the compost. Regular turning of the compost is essential for aeration and also for maintaining appropriate moisture and temperature conditions.

2. Compost Temperature

Composting releases great quantities of energy that elevate temperatures in the compost. The term “hot” is used when the exothermic breakdown of the compost mixture causes the temperature within the compost pile to reach a temperature range of 40°- 60° that is ideal for the composting bacteria. Often in “hot” composting, steam will rise from the pile and the inner core of the compost will be too hot to touch. However, if the compost heat is not monitored and controlled temperatures can rise above 70° and the critical microbes are killed. After compost piles are constructed, temperatures will rise quickly and as a rule will reach 55°C in the first 3 to 5 days.

3. Compost pH

Best composting results are achieved in the pH range of 6.5 to 7.5. Maintaining the proper C:N ratio should keep pH in check. If the pH increases to 8 or higher, ammonia and other odours may become a problem especially in fish composting operation. High pH also results in the loss of nutrients through leaching. The addition of ferrous sulfate or aluminum sulfate (alum) can decrease pH if necessary. Peat moss is often used in British Columbia to decrease pH.

4. Odour and Pest Control

Foul odors are a real concern in fish waste disposal. It is a combination of the fish oils and protein which include volatile amines, amides, and ammonia and the incomplete oxidation of these compounds that cause the odours. For this reason, rotting fish presents a known attractant to flies, rodents, and other small insects. However, if the correct ratio of carbonaceous material (sawdust and litter) is mixed with the fish waste, the offensive odor of the fish waste disappears almost immediately. Actually the smell of the wood often masks the fish smell and if the composting is carried out in bins, nuisance problems with flies and rodents is greatly reduced. Once the compost piles are turned, only the faint smell of ammonia and oils can be detected. Eventually – usually no more than 2-3 months, these smells vanish as well.

D. Design of Fish Composters

1. Small-scale or Individual Operations

The design of the fish composter will depend on the scale of the operation. For a small-scale operation, a single fisher's family compost, compost may even start in a 20-litre bucket, to a small bin near a vegetable garden. The fish parts, to avoid the fishy smell is mixed with 80% high carbon sources like sawdust, leaves, or straw in the bucket. Liquid molasses, dry molasses powder, brown sugar, or corn syrup can be added as a source of quickly assimilated sugars for feeding and breeding the aerobic bacteria in composts. Similar to silage production, this speeds up decomposition by increasing microbial growth and controlling fishy odors. Molasses also contains sulfur, which acts as a mild natural fungicide also. This mixture should be allowed to decompose for at least a week or more before adding it to the garden hot compost pile. The aerobic bacteria will also kill pathogens in decaying fish meat.

For small individual operators composters such as the ones pictured below will work well. These designs are also fly and rodent proof, which minimizes health hazards. However, the compost generated by these operations will be sufficient only for home garden use and may not be sufficient to generate value added income.

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Commercial small plastic tumbling composter
www.cleanairgardening.com/tumcombincom.html

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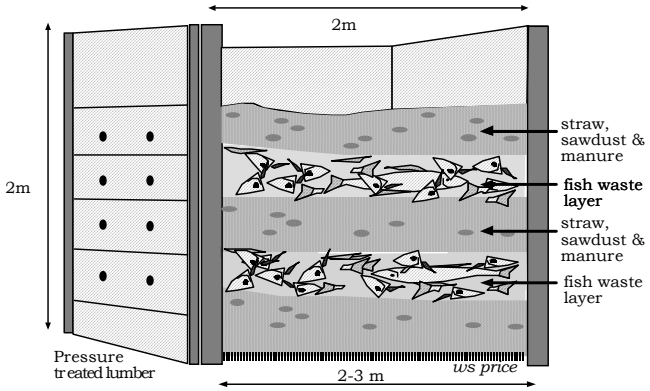
Home-made steel drum rotating composter.
Rotating barrel composter

The Rodale Guide to Composting, by Jerry Minnich, Marjorie Hunt, and the Editors of Organic Gardening Magazine, Rodale Press, Emmaus, PA

The bin systems featured below could still be run as a single family operations. They require more space for construction and are not as pest proof at the previous designs.



Schematic drawing of small compost bin with layers of fish and sawdust and manure.

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Garden-size wooden shipping pallet single compost bin

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Triplet compost bins from shipping pallets

Bag of Penninsula (BC) garden fish compost

Compost generated from these operations may be sufficient to sell in small sacks at local markets, similar to composted manure sold at the farm gate or at gardening stores in cities in British Columbia.

2. Moderate-scale Operations

There are also a number of designs available for moderate scale operations. Again, these designs can be modified for local conditions in

the Três Marias region to best utilize the building materials available and the carbon sources.

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Bins for composting fish mortalities in a 2-stage system at Buhl, Idaho.

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A three bin composting facility with moderate mechanization.

If the appropriate C:N ratio is maintained, the pile will get quite warm in a few days as the bacteria will work quickly and within 3 to 4 days the compost interior will have heated to above 40°C killing all harmful bacteria and eliminating the “fishy” smell. The mixture composts most quickly if it is turned after this initial period of 3 to 4 days, and the better mixed, the faster the bacteria will work. If the bin has vertical sides through which air can flow, the pile will compost faster and be neater. However, if the pile is left through a rainy season, it is best to cover it so nutrients won’t leach away. The composting should be finished in two or three weeks.

This moderate size operation may require some degree of mechanization for handling, mixing, and loading the compost materials. Usually a small farm tractor with a 1 yard (3/4 m^3) bucket may be useful for moving and mixing which are the most time consuming and labour intensive of the processes. A shredder for paper and a vegetation chipper may also be useful.

At this size, if adequate raw materials are available and suitable markets developed, it may be possible to generate revenue through the sale of fish fertilizer. A fisheries Cooperative may facilitate capital investment required for start-up and for developing the collection and distribution infrastructure.

3. Large-scale Fish Waste Operations

These operations are briefly reviewed here for completeness but such operations may be entirely unsuitable for artisanal fisheries applications. Large volumes of fish waste require larger areas, more automated systems, heavier equipment, with considerable capital investment and permanent staff. The C:N ratios and materials however, remain the same,

but the mechanics can be quite different. A common technique is to layer the carboniferous material and animal materials in long windrows. Depending on the size of the operation, or quantity of fish waste available, the amount of mechanization will increase rapidly in size ad cost.

In general this kind of operations range form a minimum of 500 tons to 100,000 tons per year capacity. There are two principle methods, the "turning" method which uses automated machines to turn the windrows regularly and the "static pile" compost methods where air is forced into the pile with pipes but the windrow is not turned until the end.

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A typical windrow compost system

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Mechanized mixing of compost

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A static compost pile with aeration pipes

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A blower forces air into a static compost pile.

Part V

Chromium Tanning

Health & Environmental Concerns

A Brief History of Tanning

Images of tanning leather are shown in Egyptian tomb paintings dating from 3000 BC. The ancient method of *vegetable tanning* relies on natural tannins found in tree bark, leaves, and nuts requires more than a month of processing, even with modern machinery and tanning liquors. Alum tanning is another ancient method but chrome tanning that began in the mid-1800s is the process most common today. Many heavy leathers, such as sole leather, are still vegetable tanned but the lighter leathers, especially fish skins, are chrome tanned. The great advantage of chrome tanning is that it requires only a few hours. Tanning processes have continued to evolve and now use many artificial agents (syntans).

The tanning is accomplished by the leeching of skins with toxic solutions of chromium compounds, vegetable tannin, metals salts, or formaldehyde. The overall purpose of the tanning process is to change the skin of an animal so that it is immune from natural degradation by physical and biological mechanisms. Inherent in this process is the rendering of the skin toxic to living microorganisms by altering DNA replication leading to death of the cells. Humans basically have the same biochemical reactions in their cells, and consequently organs affected by the tanning chemicals, also have disrupted cellular processes and DNA replication, often resulting in cancer. The post tanning coloration processes which use dyes and pigments and large quantities of auxiliary chemicals also pose a health and environmental hazard.

Hazardous chemicals found in leather and dyes treatments are:

1. Ammonium Bicarbonate,
2. Chromic Acetate,
3. Ethylene Glycol Monoethyl Ether,
4. Methylamine,
5. o-Nitrophenol,
6. Toulene Diamine,
7. 2,4,5-Trichlorphenol,
8. Zinc Hydrosulfite,

9. Zinc Sulfate,
10. tert-Butylamine,
11. Cadmium Nitrate,
12. Cadmium (II) Acetate,
13. Copper(2)Nitrate,
14. Chromium III compounds (Chromium sulfate)
15. 1,4-1,8 Dichloronaphthalene,
16. Nickel Sulfate,
17. o-Xylene,
18. Zinc Nitrate

And more!

Untreated tannery waste is one of the most hazardous and toxic wastes of our industrial society. Of these toxins, the most often discussed is chromium.

Chromium* – What is it?

*(*also known as Chrome, Chromate, Cr, Chrome(III), Chrome(IV), Hex Chrome, Tri Chrome)*

Chromium is an odorless, hard, steel-gray, lustrous metal available in crystals or powder. It has several different forms, the most common of which is the metal, chromium (0); chromium (III) compounds; and chromium (VI) compounds. Chromium (III) occurs naturally in the environment; types (0) and (VI) are produced by industrial processes.

Chromium (Cr) or metallic chromium(0) is used for steel and other metal production. Chromium compounds are also used for plating, paint dyes, and preserving wood.

"Trivalent" chromium Cr(III) occurs naturally and is essential for good health, and from food humans normally intake from 70-80 micrograms per day. It is essential to normal glucose, protein, and fat metabolism.

"Hexavalent" chromium (Cr VI) does not occur naturally, but is produced by certain industrial processes, such as tanning, and is the most toxic form of chromium, causing a variety of illness including cancer.

Concerns of chromium pollution

The concerns from chromium arise both from direct expose to the tanning chemicals during processing and also from disposal of the effluent from the processing plants. Human health concerns arise from the direct dermal contact with the tanning solutions, and also from the significant airborne particulate matter, which causes serious respiratory illnesses.

Calcium chromate, chromium trioxide, lead chromate, strontium chromate, and zinc chromate are known human carcinogens. EPA

classifies chromium as a *de minimis* carcinogen, meaning that the minimum amount of the chemical set by OSHA is considered to be carcinogenic. The potential hazards of chromium compounds are complex because of its many forms, and variable impacts on cellular activity.

1. Potential for Accumulation: *Positive*
2. Food Chain Contamination Potential: *Positive, can be concentrated in food chain.*
3. Etiologic Potential: *Chrome ulcer*
4. Carcinogenicity: *Potential carcinogen, high occurrence of lung cancer*
5. Acute hazard Level: *Extremely toxic if ingested or inhaled. Corrosive to living tissue.*

- *Organs:* The major acute effort from ingested chromium is acute kidney (renal tubular necrosis), as well as liver damage. Swedish studies have shown a 50% increase in pancreatic caner in leather workers, with a three-fold increase in pancreatic cancer mortality
- *Respiratory System:* Exposure to chromium, particularly in the chrome tanning where there is inhalation of chromium particles is associated with cancer of the respiratory tract.
- *Immune System:* Other vertebrate animal studies show immune system compromise.
- *Reproductive System*: Vertebrate animal studies show abnormal fetus development, as well as reduced sperm production.
- *Skin:* The leather-tanning workers in the USA have the highest incidence of dermatitis of any working group (Stevens 1979).
- *Eyes:* Direct contact with chromic acid can cause permanent eye damage.

It has been almost a century since it was noticed that workers in a German chrome ore industry had a high incidence of lung cancer, but we are still uncertain as to how it interferes with organism's cellular activity. There is controversy about the physiological pathways and effects of Cr(VI). According to the International Agency for Research on cancer (IARC), ingested Cr(VI) is largely converted to Cr(III) in the stomach, and this Cr(III) is not readily absorbed into the body. The saliva, gastric juice, intestinal bacteria, blood, liver, epithelial small intestine lining, lung alveolar macrophages all have been associated with eliminating Cr(VI)

from the body. Apparently major detoxification is accomplished by the red blood cells since they have extremely high capabilities of reduction.

It is hypothesized that in its trivalent form, Cr(III), chromium is unable to cross cellular membranes and hence has low toxicity. However, in its hexavalent form, Cr(VI), chromium is more easily transported across cell membranes. Once within a cell, chromium creates oxidative lesions and protein cross-links in the DNA. It may explain the carcinogenicity of Cr(VI).

Ground water near tanneries in developing countries such as Mexico and Bangladesh has become highly polluted by carcinogenic heavy metals. Occupational exposure to chromium can be two orders of magnitude higher than exposure to the general public, and people living within the vicinity of a tanning operation have a greater probability of elevated chromium levels in their bodies.

For the plant and animal communities there is no data on the long-, or even short-term effects of chromium to plants, birds, and land animals. There is some evidence of high chronic toxicity to aquatic life, although fish do not appear to take up or store chromium in their bodies.

Case Studies:

1. ***Bangladesh.*** *Tanning industry at its worst.*

In many developing countries environmental legislation and enforcement are hamstrung due to a host of issues. Bangladesh is a country, which has developed large numbers of unregulated tanneries over the past century. Tanneries in the city's Hazaribagh area discharge some 21,600 square meters of liquid wastes everyday. These harmful wastes, including chromium, lead, sulphur, ammonium, salt and other materials, are severely polluting the capital city and the river Buriganga. The people within these communities are producing sandal leather out of cow heads as a small cottage industry. They use waste tanning liquor from the modern tanners as their process liquor. But eventually all effluent is discharged into the streets, gutters and sewers, and these ultimately enter surface and ground water.

2. ***Mexico*** *– Care, concern, and progress.*

This country also has a very large tanning industry. A recent study (Blackman, 2005) of a sample of 137 small and medium size tanneries in Léon, Guanajuato indicates that there are serious environmental and health issues, but conventional environmental legislation has failed to mitigate the problem. This survey indicated that rather than top-down public-sector pressure and technical assistance, the key factor driving the adoption of clean tanning technologies was a bottom-up dissemination of information about the cost and quality of the benefits of the technologies.

Clean Tanning Technologies *(for technical details see UNEP 1991)*

The chrome-tanning process has been investigated extensively over several decades since its adoption by the tanning industry but, despite this, the exhaustion rates for the chromium reagents used in the process are commonly only around 70-80 per cent in conventional commercial practice. For centuries tanning was considered and art, and it has be only recently that sound science used in developing the *direct recycling technique* (developed in Australia) has shown that equally good leather can be obtained, and this process is now widely used. Also, not only are environmental impacts mitigated, but also, there are savings in production costs.

Chrome tanning has been a major focus for cleaner production and various systems have been developed and were recently reviewed in the Chennai *UNIDO Workshop on Cleaner Technologies for Tanners* (Mooney 1999)

1. High exhaustion – using special inputs and procedures to ensure that more of the tanning bath chrome actually affixes to the hide, and less ends up in waste streams. Although this technique requires a more expensive type of chrome (self basifying) and a longer soaking period, it offers significant cost savings due to reduces overall chrome use.
2. Enzymes in the dehairing bath – substituting biodegradable enzymes for lime and sodium sulfide. *(this may work for fish scales)*
3. Precipitation of chrome – using alkalis to precipitate out the chrome in the tanning bath, then collecting the resultant sludge and processing it with sulfuric acid to recover the chrome.
4. Recycling the dehairing bath – saving and reusing the contents of the dehairing bath instead of discharging it all into the sewer after a single use. The simple technology only requires the investment of a holding tank, pump, and filtering system to remove solids (screen).
5. Recycling the chrome tanning bath – reusing the contents of the tanning bath instead of discharging them into the sewer after a single use. As above only a simple holding tank and pump is required. This simple procedure results in approximately 20% less use of chrome. A total chrome liquor recycling system has been developed by CSIRO for reuse of all the chromium and salts in tanning liquors (Cranston et al. 1997). The liquors are concentrated before reuse. The capital cost of flash evaporation has been too high for commercial adoption; the challenge is to

reduce the capital and operating costs. Solar evaporation may be possible in some climates.

Using this direct recycling technique (Figure 1) it is as found that there were no observed changes over repeated cycles in the nature of the chromium complexes present in the liquors; either at the start after the chrome addition or at the finish of tanning. These techniques have been used in Australian tanneries ranging in size from the smallest (processing a few hundred hides per week) to the largest (processing around 12,000 hides per week) for several years.

In the USA, reduction of Cr(VI) to Cr(III) is now being used to remediate Cr(VI) contaminated sites and groundwater. One procedure suggests that iron filings mixed with quartz can completely reduce Cr(VI) to Cr(III) (Pratt et al., 1997). Some workers suggest that Cr(III) is practically non-toxic and environmentally benign (James !994, Powell, 1997).

Conclusion

Many international companies provide technical transfer on the use of tanning chemicals and machinery but they generally do not provide assistance to the treat toxic effluents. However, tanneries can be environmentally sustainable when chromium compounds are retained, reused, and ultimately eliminated from the tanning effluent. However, the health concerns to the workers within the industry still remain a significant concern.

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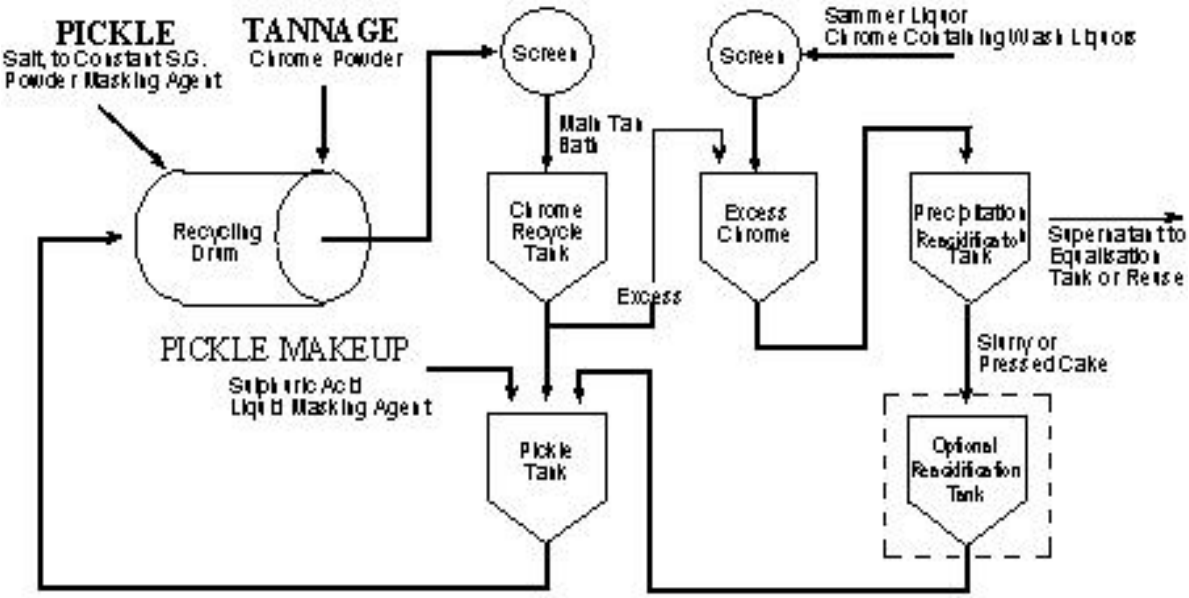

Figure 1: Direct chrome recycling and reuse of excess chrome liquors (adapted from Money 1999).