Ozone and chlorine baths – Outside of Pakistan, most plants run their trimmed fillets through a water bath at this stage. In the past, some plants used a mild chlorine solution in the water to reduce bacteria and lengthen shelf life. Most plants have now replaced chlorine with ozone gas that is bubbled into the tank. Ozone does not have the disinfection by-products that chlorine does, nor does it leave any disagreeable taste that can be discerned by some consumers. Most plants use an on-site ozone generation system that supplies the small amounts of ozone needed effectively disinfect. Lab studies at the University of Arizona demonstrated that bacterial counts could be lowered by several degrees of magnitude and shelf life could be extended by several days.

Carbon monoxide and liquid smoke – Carbon monoxide (CO) gas has been used in some countries, but apparently not Pakistan, to maintain the appearance of freshness (bright white and red) on the fillet. It appears that the gas is absorbed by the flesh and reacts with myoglobin in the muscle tissue. By binding the myoglobin, fillets maintain a fresh, bright red color in the myomeres for extended periods. In the simplest method, carbon monoxide gas is applied by placing fillets on a tray, which is placed into a large plastic bag. The bag is inflated with gas, tied off and allowed to absorb for 5 to 10 minutes. This method exposed workers to large amounts of carbon monoxide which can cause health problems with extended exposures. An alternate method is to place the trays of fillets into a large cabinet that is filled with the gas. This still exposed workers to CO as the cabinets were opened. Eventually a safer method was developed placing fillets into a retort vessel with high pressure to infuse the CO quickly. The gas could also be evacuated from the vessel and replaced with air before the removal and refilling stage. Several countries do not allow the treatment of fish fillets with carbon monoxide and will not accept imports that have been so treated. The U.S. has reviewed the practice and requires labeling or notification of the procedure on the packaging. Many of the major

buyers of fillet products in the U.S. will not accept fillets that have been treated with carbon monoxide. Liquid smoke is a product which is sometimes used to impart a smoked flavor to fish rather than going through the actual smoking process. Smoke from a wood fire is condensed, often with a small amount of water sprayed into the condensing tube and chilled air. The condensed liquid is then is sprayed or injected on a fillet to impart the smoked flavoring. Small amounts of carcinogenic compounds may be present in the liquid.

Freezing – Rapid freezing of the fillet or whole fish is critical to maintain the product quality. Fillets are normally placed on large trays that ride on a conveyer through a tunnel freezer. Often the fish are given a quick dip or hand-sprayed with water to form a glaze over the fillets. This avoids freezer burn (and adds weight). The percent glaze on a fillet is a constant topic of negotiation on the value chain. Glaze extends freezer life by reducing oxidation and freezer burn (drying), but also obviously adds weight, which someone is paying for, even though it is just water that melts away. Whole or gutted fish may go through a tunnel freezer or a blast freezer. Seafood processors in Pakistan have this capability but so far are purchasing very little fish from farmers.

Trimmed tilapia fillets

Individually quick frozen fillets ready for packing

Packaging – Packaging is still in its infancy in Pakistan as is branding and marketing. However, some growers and retailers have begun branding and packaging with marks on boxes and labels. This can be expected to increase as stakeholders attempt to differentiate their products from competitors. When most of the fish in domestic trade are sold whole there is little to differentiate, however as fish are treated better than the average and especially with more processing, the packaging and branding will be more and more important. In the early stages of international trade whole or gutted, product frequently are often transported in large containers holding hundreds of individually quick frozen (IQF) fish. This might be an initial format for selling carps and/or tilapia into Gulf countries. The next typical processing and packaging format might be simply filleting the fish. For domestic markets these might be sold fresh, while for international trade they more likely would be IQF. These would be placed onto individual styrofoam trays with plastic wrap for retail sales. Today, with more sophisticated processing in the producing countries, virtually any style of packaging is available. Many fillets and even whole fish are now packed into individual bags that are heat-sealed or vacuum packed. The bags are normally put into a five or ten pound cardboard or plastic box. These boxes may be placed into an insulated master pack. Fresh fillets are normally packaged in five or ten pound plastic packs that can be resealed, and are preferred by the restaurant trade.

For **tilapia,** the fillets themselves are normally graded by size. Most common grades are 3 oz and under, 3-5 oz, 4-6 oz, 5-7 oz, 6-8 oz,

7-9 oz, and over 9 oz . Many plants have automatic sorting machines that separate fillets by size. In developing countries hand sorting is common and highly accurate with scales used only for checking. The variety of fillet and value added products continue to grow with size variations, skinning variations and various treatments available. Breaded and marinated preparations are the most popular, but new stuffed, baked, broiled and grilled products appear on a regular basis.

Multi-function machines – There are several automated fillet machines that are capable of accepting a whole fish at one end and discharging finished fillets at the other. Many processors feel that the machines are still not cost effective, primarily because they do not recover as much as hand filleting and cannot compete with the low labor costs in most of the major producing countries. Additional innovations should eventually close the gap. There are also several machines that will conduct one or more processing functions. These are also finding their way into processing plants around the world as even the lowest cost labor markets move more toward automation.

C. Value chain models

In Pakistan the majority of carp farmers sell their fish to haulers who then bring the fish into urban brokerages or distribution locations. The prices paid to the farmers by the haulers in April 2014 were in the range of US$ 1.60 to $2.40 per kilo. The variation is due to quality of fish, average size of the fish, and distance from the market. The distributors/brokers will pay the fish haulers from $2.00 to $3.00 per kg. The distributors/brokers will then charge the small retailers US$2.60 to $3:60 per kg for the product delivered to the small shops in urban areas who in many cases have limited space and refrigeration. Consumers for the most part purchase

whole fish for US4.00 to $6.00 per kg, which they prepare at home, or have the fish seller head and gut the fish at the store or stand.

Carp Value chain as of April 2014

Farmers - US$1.60-$2.40/kg - Fish Haulers - $2.00-$3.00/kg - Distributor/Broker - $2.60-$3.60 / kg - Small retailer / Grocery - $4.00-$6.00/kg - Consumer