Farmed fish value chain analysis with emphasis on value addition and traceability: case of Kirinyaga County in Kenya

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Fish farming contributes to the attainment of food and nutritional security by providing high-quality fish proteins and micro and macro nutrients thereby minimizing hidden hunger. Fish supply in Kenya is mostly from capture fisheries, particularly fresh water lakes that contribute more than 90 per cent of the total fish produced. Agri-food supply chains involve the flow of products and information, and activities from production through to processing and consumption. Through value addition, at each stage, the value is increased along the chain. Traceability enhances tracking and tracing of fish and fish products information in the supply chains. A situational assessment was conducted along the farmed fish value chain in Kirinyaga County in Kenya in June and July 2013. The objective of the study was to assess traceability along the farmed fish value chain. Data was collected using semi-structured questionnaires and data analysis was done using SPSS version 16 software. Most farmers stocked mixed sex tilapia in monoculture, which led to over-breeding and harvesting of small-sized fish, while the market demand was for table-sized fish. The high cost of inputs, especially feeds, increased the cost of production. Value addition was limited as most farmers did not have enough quantities of fish to facilitate value addition. Traceability was limited; only a few farmers kept operations records and most of them did not share production information with other stakeholders in the chain. The study recommends capacity building through training on value addition and traceability along the value chains.

Keywords: farmed fish, tilapia value addition, traceability, value chain

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VALUE ADDITION OF PRODUCTS can either be through innovation or coordination (Tilley, 1989). Innovations create value by improving on existing products and processes or by creating new ones. Coordination adds value by facilitating efficient arrangements among farmed produce and market farm products. Coordination can either be horizontal, which involves pooling/consolidation among stakeholders at the same level of the value chain, or vertical coordination, which involves making strategic alliances, contracting, agreements, licensing and single ownership of multiple market stages in different levels of the food chain (Peterson and Wysocki, 1997). Through coordination, production processes and product characteristics are linked to consumers' preferences (Royer, 1995).

Food safety markets are characterized by high information asymmetry since food safety is a credence attribute. Only partial information flows along the supply chain since product flow is usually delinked from information flow (Heyder et al., 2012). Food safety and quality are credence attributes which create imperfections in the supply chains. Traceability has been shown to improve information management along a value chain (Souza-Monteiro and Caswell, 2010). Traceability systems enhance tracking and tracing of products and processing information along the value chains. Linking traceability with the entire information flow and documentation effectively improves operational efficiencies and increases food safety and quality (Ruiz-Garcia et al., 2010).

In Kenya, fish farming has been popularized through the Fish Farming Enterprise and Productivity Programme which was funded by the government. It was funded through the Economic Stimulus Programme (ESP) in phase one, and the Economic Recovery, Poverty Alleviation and Regional Development Programme (ERPARDP) in the second phase. The aims of the project were to increase fish production, enhance food security, improve livelihoods of farmers, and provide employment for the youth (Charo-Karisa and Gichuri, 2010). Previous government initiatives in fish farming have not been sustained and there is a need to evaluate challenges and opportunities that exist along the farmed fish value chain in order to formulate policies that enhance sustainability of the sector.

Tracking and networking information systems along food supply chains provide information that could be used in risk assessment (Li et al., 2006) and to improve on food safety (Pouliot and Sumner, 2008). In addition, traceability reduces transaction costs to downstream actors (retailers or processors) by monitoring upstream activities (primary production and raw material supply) (Hobbs et al., 2005). Electronic traceability systems reduce labour costs when compared with paper-based systems. The main challenge of traceability systems is that they create additional costs for actors in the sector. These costs depend on the type of identification technology (which can either be paper-based or electronic) and the labour costs (Buhr, 2003; Alfaro and Rábade, 2009).

In Kenya, the demand for fish and fish products is high but the farming system is unable to meet the quality attributes demanded by the consumers. In addition, traceability strategies implemented are inadequate since there are improper records kept by stakeholders. There is limited empirical data on the strategies adopted by

stakeholders in the aquaculture sector to ensure product information flow along the chains. The main objective of this study was to examine the strategic options for design and implementation of a traceability system along farmed fish value chains in Kenya. Such knowledge can be used by players in the aquaculture sector to improve logistics along product value chains and record-keeping in developing countries.

Study methodology

Study design

Situational analysis was conducted along the farmed fish value chain to identify current practices in value addition and traceability along the chain. This was done using a cross-sectional study design where information was collected at two levels. The first level was the primary production which was carried out in Ndia Sub-county in Kirinyaga County in Kenya. The next level was with the traders which were conducted throughout Kirinyaga County.

Sampling

Data was collected from 109 households in Ndia Sub-county of Kirinyaga County, among farmers who owned at least one fish pond. Snowball technique was used to identify fish farmers and traders throughout the county. Twelve traders were identified using this technique and they all took part in the study. Stratified random sampling was used in selection of farmers to ensure that all categories of farmers from all locations in the sub-county were included in the study.

Data collection

A semi-structured questionnaire with both closed and open-ended questions was used as the survey instrument. Global positioning system (GPS) co-ordinates were taken for each homestead included in the study to facilitate follow-up. Secondary data were collected using documents from the Ministry of Fisheries Development headquarters in Nairobi and Fisheries reports from the Kirinyaga District Fisheries office.

Data was collected through interviews using two sets of semi-structured questionnaires specifically designed for the target respondents (farmers and traders). The questionnaires provided a guide to the interviewer, covering details of the post-harvest handlings, handling of waste and rejects and record-keeping. The data was collected in July 2013.

All data were cleaned, edited, sorted and entered into the computer. Descriptive statistics consisting of frequencies, means and modes were computed for different data categories to facilitate comparison. Data were analysed using the Statistical Package for Social Sciences (SPSS) version 16.0.

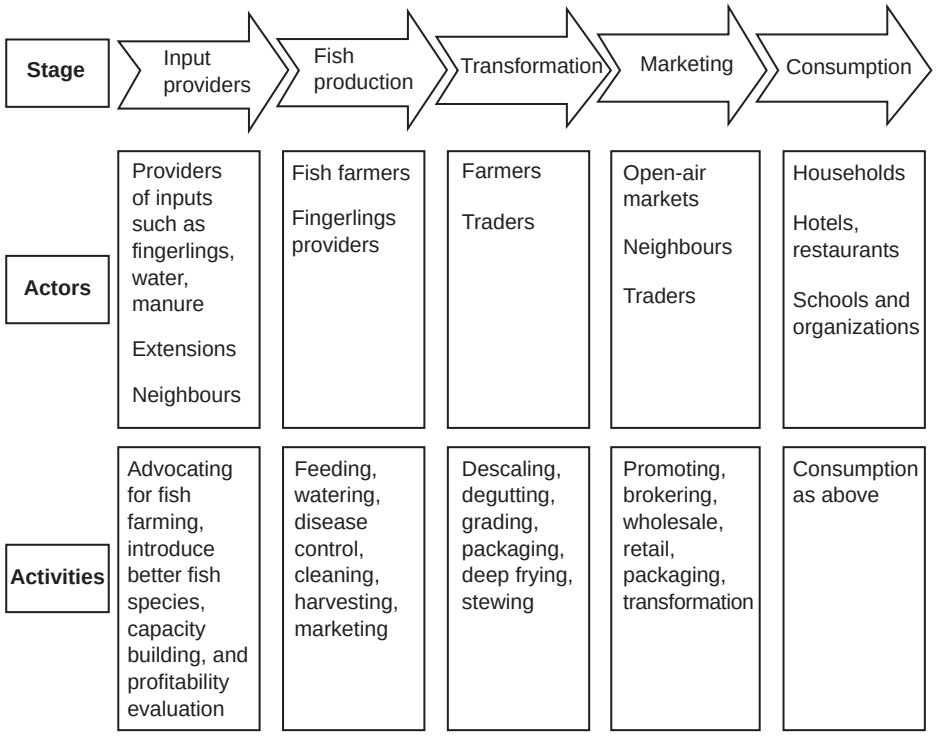

Figure 1 Farmed fish value chain in Kirinyaga County

Results and discussion

Farmed fish value chain mapping in Kirinyaga County

The farmed fish value chain is made of several actors, namely primary input providers, fish farmers, processors, traders and consumers as shown in Figure 1.

Input providers. Most of the primary inputs were from social networks and the government. The government, through the Fish Farming Enterprise and Productivity Program (FFEPP), provided feeds, extension services, and start-up capital (ponds, liners, and fingerlings). Social networks such as neighbours provided animal manure for use in fertilization, advice and information, and a ready market for the harvested fish.

Fish producers. Most of the producers were small-scale farmers owning at least one fish pond measuring 300 m^2, and stocked with tilapia in monoculture or tilapia and catfish polyculture. Most were concerned with daily pond management practices such as feeding, water management, pond fertilization, hygiene, and sales. Fish were sold immediately after harvesting with minimal preservation; some techniques used in preservation were smoking, sun-drying, and freezing.

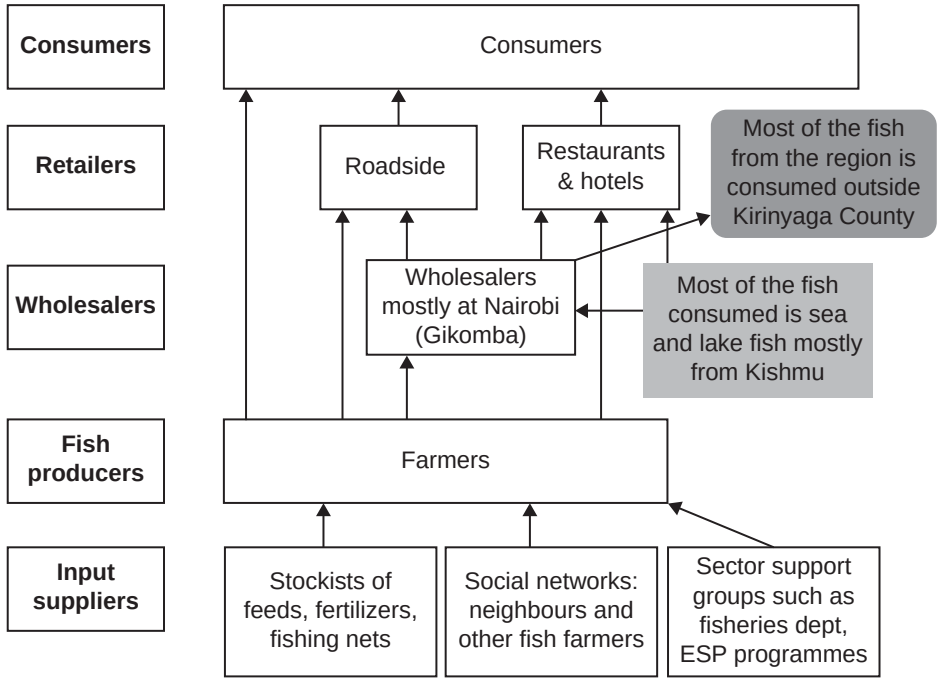

Figure 2 Farmed fish supply chain in Kirinyaga County

Transformation. The most popular product transformation activities carried out were gutting (42 per cent), descaling (37 per cent), and sorting (14 per cent). Other transformation processes included packaging, salting, sun-drying, smoking, deep frying, and stewing, which were done to a limited extent.

Marketing. Fish for home consumption were harvested throughout the production cycle, usually on a weekly basis. In this way, fish farming contributed significantly to household food security. The main fish harvests were done at the end of the production cycle (usually nine months). During this time, traders from the main towns and trading centres came to the fish farms to purchase fish. Fish harvested in bulk from Ndia Sub-county were sold in nearby towns while some were sold in Nairobi (Gikomba and Baba Ndogo markets).

Consumption. Farmed fish were consumed at home and also sold to traders and institutions such as schools, hotels, hospitals, and government institutions among others. Most of the bigger (heavier) fish were sold to large hotels and restaurants in Kirinyaga County with most of them going to Sagana town.

Farmed fish supply chain in Kirinyaga County

The farmed fish supply chain in Kirinyaga County has input suppliers, fish producers, wholesalers, retailers and consumers. Figure 2 summarizes the actors along the supply chain.

Social demographic characteristics of fish farmers

Social-demographic characteristics of fish farmers in Ndia Sub-county in Kenya are summarized in Table 1. More than two-thirds (71 per cent) of the respondents were men. Most of them (51 per cent) were more than 51 years old, 30 per cent were 61 years or older (Table 1). Only 9 per cent were below 30 years. More than 60 per cent of the respondents were household heads, who were the main decision-makers in the household, with only about 20 per cent being spouses of the household heads.

Most respondents (43.7 per cent) had completed secondary education, while only 24 per cent had tertiary education. From this group, 19 per cent and 5 per cent had attended colleges and university, respectively. More than 30 per cent of respondents had not attained secondary school education.

Approximately 13 per cent of respondents owned less than 1 acre of land, 20 per cent owned more than 1 acre but less than 2 acres, and about 17 per cent owned 2–3 acres. Only 1 per cent owned land greater than 10 acres. This is an indication that fish farming was mainly done by small-scale farmers. More than 75 per cent of the farmers had liner ponds while 24 per cent had earthen ponds. There were no farmers using concrete ponds or fish tanks in the area.

Fish farming practices

Fish farming practices of farmers in Ndia sub-county in Kirinyaga County are summarized in Table 2. Experience in fish farming was assessed using the number of years the respondents had been in the practice. Fish farming was a relatively new venture in that area and more than 80 per cent of respondents were funded through the Fish Farming Enterprise and Productivity project (FFEPP). This was a project funded by the government to stimulate fish farming in the country. It started in the 2008–09 financial year and was funded under the Economic Stimulus Programme (ESP) in the first phase and the Economic Recovery, Poverty Alleviation and Regional Development Programme (ERPARDP) in the second phase. Under this programme, the government gave funds to farmers for construction of fish ponds and also supplied other inputs such as fingerlings and feeds.

Most of the respondents (90.9 per cent) had been in fish farming for less than three years. This was because most of them (over 80 per cent) were funded through the FFEPP. Only 11 per cent of respondents used their own funds to start fish farming and most of them had started the venture before the start of the FFEPP. Nine per cent of respondents were funded through the FFEPP, but also used their own funds to increase the number of fish ponds.

Most farmers (50 per cent) kept mixed-sex tilapia in monoculture, while 37.8 per cent had both catfish and tilapia in polyculture. Very few respondents (less than 1 per cent) kept ornamental fish. More than 86 per cent of the farmers produced mature fish while less than 5 per cent produced fingerlings only. The rest produced both fingerlings and mature fish.

Only 41 per cent of the farmers were organized into active groups. When asked the reasons for forming groups, 48 per cent of respondents said it was for easier access to inexpensive fish feeds, which were pelleted using a community pelleting

Table 1 Social demographic characteristics of fish farmers in Kirinyaga

Characteristics	*Percentage*	*Characteristics*	*Percentage*
Location		**How do you predict your tilapia and catfish production for the next 3 years?**	
Kariti	34.9	Increase	44.6
Kiini	10.1	No change	33.7
Mukure	9.1	Decline	21.7
Mwerua	45.9	Respondent gender	
No. of years as fish farmers		Male	70.6
1 year	9.2	Female	29.4
2 years	36.7	**Respondent position in household**	
3 years	45	Household head	63.3
4 years	5.5	Spouse	20.4
5–10 years	2.7	Child	1.5
> 10 years	0.9	House-help	1.5
Source of funds		Others	13.3
Own savings	11.0	**Respondents' age group**	
ESP	78.9	Less than 30 years	9.0
Both ESP and loan	9.2	30–40 years	19.0
Other	0.9	41–50 years	21.0
Other income-generating activities		51–60 years	21.0
Fish traders	5.2	Greater than 60 years	30.0
Livestock/crop farmer	83.6	**Respondents' educational level**	
Employed	4.3	Less than primary	1.9
Other business	5.2	Primary	30.1
Only fish farming	1.7	Secondary	43.7
Main reasons for fish farming		College	19.4
Extra income	53.6	University	4.9
Main income source	5.0	**Organization into groups**	
Home consumption	25.4	Individual	58.5
Health conscious	16.0	In groups	41.5
Other income-generating activities for respondents		**Land size holding**	
Fish farming	11.1	Less than 1.0 acre	13.5
Livestock farming	26.5	1.0–2.0 acres	19.8
Crops farming	51.9	2.1–3.0 acres	16.7
Business	3.1	3.1–5.0 acres	20.8
Employment	6.2	5.1–10.0 acres	28.1
Other	1.2	Greater than 10 acres	1.1

Table 2 Fish farming practices in Kirinyaga County

Types of ponds		**Type of fish grown by farmers**	
Earth ponds	23.8	Tilapia only	50.9
Liner ponds	76.2	Catfish only	0.9
Concrete	0.0	Both tilapia and catfish	37.8
Type of product from fish ponds		Tilapia and other species	3.8
Fingerlings only	4.7	Catfish and other species	1.0
Mature fish only	86.0	Tilapia, catfish and other species	4.7
Both fingerlings and mature fish	9.3	Other fish species	0.9

Table 3 Reasons why fish farmers were affiliated in groups

Reasons for group formation	*Frequency*
Feeds: mostly group ownership of pelletizing machine for production of cheaper feeds	48.2%
Marketing: for collective advantage for access to markets	24.1%
Training: group activities to facilitate training to group members	19.9%
Sharing ideas, knowledge, and inputs	7.8%

machine. Another 24 per cent formed groups to access fish markets, while 20 per cent reported that it was for easier access to training. Eight per cent of respondents formed groups to share ideas and inputs. The reasons for group formation are summarized in Table 3.

Most fish farmers in the region (about 84 per cent) practised mixed (crops and livestock) farming with only 2 per cent who were strictly fish farmers only. About 51 per cent of the households were arable farmers while around 26 per cent were livestock farmers. Less than 10 per cent had sources of income other than farming.

Approximately 54 per cent of respondents kept fish as a source of extra income while 25 per cent kept them primarily for home consumption. This latter group reported that they were aware of the health benefits of eating fish.

Approximately 44 per cent of respondents said they would increase their production over the next three years, while 34 per cent would maintain production at the current levels. Twenty-two per cent of respondents reported that they would reduce their tilapia and/or catfish production in the next three years. On further probing, most respondents in the latter group wanted to change to ornamental fish farming which was considered to be more profitable than food fish farming.

Post-harvest handling of farmed fish

Post-harvest handling practices of farmed fish in Kirinyaga County in Kenya are summarized in Table 4. During major end-of-year harvests, most of the farmers (81.7 per cent) sold harvested fish immediately. Thirty-six per cent preferred to sell

Table 4 Post-harvest handling of farmed fish in Kirinyaga County

Characteristics	*Percentage*	*Characteristics*	*Percentage*
Preferred marketing channel by farmers during major harvests		**Means of transportation from pond to market**	
Traders at pond	36.1	On foot	39.0
Traders at market	6.0	Using bicycles, motorbikes, etc.	6.3
Customers at markets	16.9	Using vehicles without refrigerators	43.7
Neighbours at pond	30.1	Using vehicles with refrigerators	4.7
Other channels	7.2	Other means	6.3
Do not sell	3.6	**Possession of a refrigerator**	
Quality parameter demanded by traders		Yes	17
Length	35.1	No	83
Weight	60.5	**Time taken to deliver fish to market after major harvest**	
Age	0.9	Sold at pond	34.9
Colour	1.8	Delivery time ≤ 2 h	53.9
Any other	1.8	Delivery time 2–5 h	4.8
Storage of fresh harvested fish after major harvest		Delivery time 5–10 h	4.8
Not stored, all sold immediately	81.7	Delivery time ≥ 24 h	1.6
Stored at room temperature	2.4	**Product transformation process**	
Frozen	4.9	No value addition	0.7
Sun-dried	3.7	Descaling	37.4
Smoked	1.2	Gutting	41.5
Other	6.1	Filleting	0.0
Usage of fish processing waste		Packing	2.7
Used as manure	3.5	Sun-drying	0.7
Feed for chickens	16.1	Salting	1.4
Feed for fish	16.1	Cooking/stewing	0.7
Feed for pets	17.3	Deep frying	0.7
Thrown away	23.0	Smoking	0.7
Feed for other livestock	24.1	Sorting	13.6

their fish to traders who came to the farm on harvesting days, while 30 per cent preferred selling to neighbours. The rest of the fish were sold in markets near the farms. Only 5 per cent of the harvested fish were stored under reduced temperature conditions, 4 per cent were sun-dried, 1 per cent smoked, and approximately 6 per cent preserved using other preservation techniques. Fish for home consumption was harvested regularly, usually on a weekly basis. During these minor harvests,

only a few fish were caught and they were consumed by the household. Only 17 per cent of the farmers had a refrigerator at home although most farmers said they have never used it to store harvested fish waiting to be sold; it was used for domestic purposes. Most of the homesteads were not connected to electricity which explains why they did not have refrigerators.

The quality attributes demanded by most of the fish traders were the length and weight of harvested fish. Most traders (60 per cent) only bought fish that exceeded 180 grams while 35 per cent of the traders demanded fish exceeding 20 centimetres. Other quality factors demanded were colour and age of fish. Most of the harvested fish did not attain the quality parameters demanded by traders; hence they were sold at reduced prices.

Farmers who delivered fish to markets usually used vehicles that had no cold storage facilities to transport fish and fish products, while others just walked to the marketing centres, most of which were less than 5 kilometres from the homesteads. Only 5 per cent of respondents used vehicles that had cold storage facilities while 6 per cent used other preservation facilities such as cool boxes to transport the fish; these were used when large quantities of fish had been harvested and were to be taken to the market. About 35 per cent of the fish was sold at the pond while 54 per cent was delivered to the market places within two hours of harvesting. Only 2 per cent of respondents delivered fish to the market 24 hours after harvest.

Value addition along the chain was limited; only simple technologies had been adopted with 41 per cent reporting that they removed the gut contents, 37 per cent removed scales, and 14 per cent graded based on weight and size. Preservation techniques used by farmers were sun-drying, salting, smoking, deep frying, and stewing. Filleting was not done at farm level although it had potential to add value and increase income for farmers since a good proportion of consumers preferred buying fish fillets rather than whole fish.

Rejected fish and waste management

Most of the harvested fish were rejected by traders since they were less than plate size in length, that is, less than 150 grams. They also did not meet the desired quality attributes as some of them had bent tails, or appeared sickly.

Bones and fish guts formed the majority of the solid wastes from fish processing operations at the farm, while effluent water from fish ponds formed the liquid waste. The major wastes and by-products from fish farms in Ndia Sub-county are summarized in Table 5.

After processing, 28 per cent of fish farmers used the solid waste as feed for other livestock, 20 per cent fed the waste to their pets, notably dogs and cats, 19 per cent used the waste as feed for catfish, 19 per cent fed the waste to chickens, while 4 per cent used the waste as manure. Almost 27 per cent of respondents said that the waste was of no use to them. Most of the liquid waste from the ponds was used to irrigate the farms.

Table 5 Usage of fish processing waste and by-products

Type of by-product or waste	*Usage*
Length: less than plate size (less than 150 grams)	Consumed at home Sun-dried and used as animal feed Sold for lower price
Weight: less than 150 grams	Consumed at home Sold for lower price
Sickly, e.g. bent tails	Consumed at home
Bones	Thrown away as garbage Crushed and used as animal feeds
Water from pond, slurry after cleaning pond	Irrigation
Wild fish	Drained to river

Losing fish to predators was the main challenge with more than 80 per cent of the farmers reporting that they experienced the challenge at least once in a production cycle. The most common fish predators were birds such as kingfisher and cormorants, and ducks, dogs, and wild animals, among others. Water availability was the other challenge faced: the fuel cost for pumping made it expensive. Other challenges included parasites and diseases, and human theft, among others.

Record-keeping and traceability along the farmed fish value chain

Information on record-keeping practices by farmers is summarized in Table 6. Almost 57 per cent of fish farmers did not keep records on a regular basis. Among those who did, the main types of records kept were on harvesting (11 per cent), sales (9 per cent), fish stocking (7 per cent), feeding (6 per cent), pond construction (5 per cent), and sampling (4 per cent). Other types of records kept were on pond fertilization/liming records, water pumping, water temperatures, and pond draining records. Almost 47 per cent of those who kept records used the records for planning, 27 per cent used them to analyse the trends for input and production management, 13 per cent for daily controls, and 7 per cent for lending institutions both formal and informal. Five per cent of respondents used records to calculate the enterprise's profitability while 2 per cent used them for comparing performance among seasons. Almost 57 per cent of the fish farmers had undergone training on documentation. However, most of them said that record-keeping in aquaculture was not a major emphasis of the training. Other farmers reported that although they had been trained on record-keeping, there was no motivation for them to keep proper records, as they felt it didn't improve their performance. On chain traceability, only 35 and 44 per cent of the farmers shared production information with their immediate customers and immediate input providers, respectively. This was an indicator of the inadequacy of current traceability systems. Table 6 summarizes the record-keeping and traceability by farmers along the chain.

Table 6 Summary of the record-keeping and traceability by farmers

Characteristics	*Percentage*
Types of records kept by fish farmers in Ndia Sub-county	
No records	56.5
Pond construction	5.0
Stocking	7.1
Feeding	5.7
Harvesting	10.7
Sales	8.6
Sampling	4.3
Others: pumping, liming, draining, fertilizing	2.1
Training on record-keeping	
Yes	56.6
No	43.4
Sharing records with immediate suppliers	
Yes	44.0
No	56.0
Sharing records with immediate customers	
Yes	35.0
No	65.0
Reasons for record-keeping by farmers in Ndia Sub-county	
For daily controls	13.3
For planning	46.7
Lending institution requirement	6.7
To analyse the information	26.7
To evaluate profitability	4.7
For comparison between seasons	2.0

Variable costs and approximate gross margin analysis from small-scale fish farming

Table 7 shows the variable costs and profits for rearing fish in an earthen pond measuring 300 m^2, stocked with tilapia and catfish in polyculture. This was the most frequent size of pond used by farmers. It was also the size provided by the government through the ESP.

The main costs incurred by fish farmers include the cost of pond construction, purchase of fingerlings, pond fertilization, fish feeds, and labour costs.

The majority of farmers (78.9 per cent) were funded through a government programme (FFEPP, funded through the Economic Stimulus Programme). For these farmers monies for construction of fish ponds were provided through the programme. The standard pond size constructed for farmers was 300 m^2. The

Table 7 Variable costs and gross margins in a pond with mixed tilapia and catfish (ratio catfish: tilapia = 1: 2.3)

Item	*Cost (Ksh)*	*Percentage of total cost*
Pond construction (300 m^2) earthen pond Depreciated at 20% per year (30,000 x 0.2)	6,000	10.6
Tilapia fingerlings (700 x Ksh3 each)	2,100	
Catfish fingerlings (300 x Ksh5 each)	1,500	6.41
Pond liming using agricultural lime	136	0.24
Pond fertilization using poultry manure (2 times in a production cycle)	840	1.50
Cost of feeds (tilapia): Kilograms of fish fed (0.2 kg/fish) x (700 x 0.85) = 119 kg Amount of feed = 2.4 kg of feed/kg of fish x 119 kg fish x 80sh/kg of feed.	22,848	57.00
Cost of feeds (catfish): 0.3 kg/fish x (300 x 0.85) x (1.5 kg feed/kg of fish x 80 Ksh/kg of feed)	9,180	
Cost of labour (9.0 months x Ksh1,508/month)	13,572	24.15
Total variable cost	**56,176**	
Revenue from sale of fish		**(% of revenue)**
Sale of **tilapia** (0.85 x 700 x 0.20 kg x Ksh300/kg)	35,700	60.87
Sale of **catfish** (300 x 0.5 kg x Ksh300/kg) (% of catfish harvested to those stocked = 85) (0.85 x 300 x 0.3 kg x 300)	22,950	39.13
Total revenue	**58,650**	
Total profit for a 300 m^2 earthen pond	2,474	

Note: Assumptions:
Feed: gain ratio for tilapia 2.4 and for catfish 1.5
Price of feeds – Ksh80 per kilogram
Both tilapia and catfish are fed on the same feeds
Mortality = 15%
Selling weight for tilapia = 200 grams
Selling weight for catfish = 300 grams
Price of tilapia and catfish = Ksh300 per kilogram
Percentage of tilapia harvested to the ones stocked = 85%
NB US$1 = Ksh87 (at time of survey)

market cost for construction of such a pond is Ksh30,000 (US$285), of which the government gave farmers Ksh26,000 ($247), and farmers provided the rest of the funds. The small size of the pond and the low stocking density were a challenge to fish farming because farmers could not take advantage of economies of scale.

Fingerlings were purchased mostly from government hatcheries and a few private ones which were accredited by the government. Catfish fingerlings were difficult to obtain which resulted in a situation where many farmers (50.9 per cent) stocked mixed sex tilapia in monoculture, a practice which is not recommended in commercial fish production (Shoko et al., 2014).

Pond fertilization is done to stimulate growth of phytoplankton, which increases oxygen concentration in a pond. The recommended rate of fertilization for tilapia ponds is 25 kg of manure per 100 m^2 and it should be before stocking and thereafter 5 kg of dry manure per 100 m^2 per week (Ngugi et al., 2007). Fish were harvested at nine months; therefore the total manure applied was 420 kilograms. Liming fish ponds is often done to achieve optimum pH. The recommended rate of liming depends on the pH of the soil. In the study area, the pH was between 6.5 and 7. The rate of application of agricultural lime was 1,000 kg per hectare (Ngugi et al., 2007). For a pond measuring 300 m^2, total amount of line applied was 13.6 kg at the cost of Ksh500 ($4.75) for a 50 kg bag.

By the time the survey was done, hired labour costs in the study area were Ksh200/day ($1.90/day). Hired labour worked for 7 hours in a day for 26 days in a month. The rest of the labour was provided by the family. Assuming they worked at the fish ponds for 2 hours each day, the direct cost of labour used in the fish pond was approximately Ksh58 per day and Ksh1,508 in a month ($0.55/day, $14.34/month).

According to the Food and Agricultural Organization (FAO, 2014), feed accounts for between 70 and 75 per cent of the total cost of production in grow-out ponds in tilapia/catfish polyculture systems in Cameroon under intensive systems of production. In Ndia, the main production system was semi-intensive, where fish were fed on commercial feeds, but the ponds were also fertilized to increase primary productivity.

The total cost of production was Ksh56,176 ($534). Feeds accounted for the highest percentage of production costs (57 per cent), followed by labour costs (24.15 per cent).

Of special interest was the fact that catfish accounted for 39.13 per cent of the total revenue from sale of fish, although they made up only 30 per cent of the fish in the pond. Catfish grow much faster than tilapia and have a higher feed conversion ratio. In addition, they feed on the fry and fingerlings of tilapia.

Discussion

In developing countries, the market potential based on demand for fresh fish and value-added fish products is high (AllAfrica, 2007). At farm level, most farmers kept tilapia in monoculture or tilapia and catfish together in polyculture. Tilapia kept in monoculture systems have a tendency to over-breed which results in the production of small fish unsuitable for processing. In addition, tilapia are more susceptible to stress than catfish, which reduces their growth rates. For this reason, the quality of fish produced did not meet the attributes demanded by fish traders and consumers. In addition, the quantities produced were not sufficient to meet demand in terms of length and weight. The value chain

approach was used to capture stakeholders' interactions along the production and marketing channel when conducting the value chain mapping (Rich et al., 2011). The linkages at the vertical levels were generally weak because most actors (farmers and traders) were small scale with inadequate resources to make them participate and compete in the network. Market access for the harvested fish by most farmers was also a challenge as the produce did not meet quality attributes. Similar findings to those of Stuart (2009) were obtained on the main reason why the sector incurred substantial loss of harvested fish: the produce was of inferior quality when compared with wild harvested fish and thereby could not enter the fish supply chain. This was aggravated by lack of a structured marketing system among the smallholder production systems due to the small quantities produced; lack of organization in groups hence no aggregation; lack of proper transport and storage infrastructure; and inadequate market information among the smallholder farmers. Value addition within the county was minimal and supply of value-added products did not satisfy the demand.

Profits from fish farming using the standard ponds (300 m^2) were low. Feeds accounted for over 50 per cent of the cost of production. During the time of the survey, the government catered for most of the costs incurred by farmers. For fish farming to be sustainable, farmers should use bigger ponds, and improve on management practices so that fish reach mature weight at a shorter time. In addition, the prices of fish feeds are currently high.

Traceability systems should be based on procedures that guarantee accurate product/process information is recorded. According to Golan et al. (2004), traceability systems should provide, to some extent, product tracing information. From the study, based on the information traced by the systems, traceability of farmed fish was limited. In addition, there were variations in the information provided in terms of precision, depth, breadth, and accessibility of information by other actors in the supply chain. Products should be uniquely identified and recorded at each stage and these identifiers should be linked. Traceability is about record-keeping, documentation, and sharing information. Some actors had adopted a 'pen and paper' based system. Such systems were time and resource consuming, hence a major challenge to the small-scale actors with scarce resources (Wang and Li, 2006). The effectiveness of a traceability system is a factor of its ability to transfer necessary information through adequate record-keeping and information sharing along the chain (Bertolini et al., 2006). From the study, only a small percentage of the actors kept records and shared information, showing that traceability was not effective. Based on the study, the majority of the costs for implementing a record-keeping system are incurred during the design stage, system maintenance, and personnel training. Variable costs are incurred on a daily basis for data input and data sharing.

Conclusions

Most of the fish farmers in the county were funded through the government Economic Stimulus Programme and had less than three years, experience in fish farming. There is need to educate these communities on fish farming practices,

post-harvest value addition, and keeping and sharing information. Most farmers did mixed farming (crops and livestock) and fish farming was considered as a source of extra income. Since most farmers were funded through the ESP, they had ponds of similar sizes and with similar stocking capacities. The farmers had done little to repair the ponds and they said that they were waiting for support from the government to do that. Fish farming is not labour intensive; hence, there was minimal use of hired labour. More than 80 per cent of the farmers were more than 40 years old and most had not achieved a secondary education. Their low education level and relatively young age was the main reason why most of them had not adopted record-keeping and post-harvest value addition of the fish. Most actors in the chain were not adequately linked to one another; in particular, vertical linkages were weak. Post-harvest value addition was limited, with most farmers just descaling and gutting the harvested fish. Most of the fish were sold within two hours of harvesting. There was no standard way of using fish processing wastes and rejected fish; most farmers preferred to throw them away. Most of the harvested fish did not meet quality requirements demanded by consumers and traders in terms of weight and length. This can be attributed to the practice of keeping mixed sex tilapia in monoculture systems. In addition, the quantities entering the supply chain did not meet the demand from consumers and traders; hence they were insufficient to encourage value addition. The challenges create opportunities for design and implementation of appropriate value addition programmes and policies to support small-scale farmers and traders, individually or in groups, to improve market participation. Traceability was limited as most farmers did not keep proper production records. Traceability along the value chain was non-existent, with minimal sharing of information among actors. The study estimated the costs associated with fish production. During the time of the survey, the government met most of the costs of fish production in small sized ponds (300 m^2) through the Economic Stimulus Programme. From our analysis, the profit margins were very low from this size of pond and at the current stocking density and management levels. In addition, revenue from the sale of catfish was high, in proportion to the numbers stocked. Feed was the most expensive item accounting for 57 per cent of the cost of production.

Recommendations

Regular training programmes should be implemented to enhance the capacity of farmers in value addition, traceability and documentation, best aquaculture practices, good agricultural practices, and good hygienic practices. For farmers to take advantage of economies of scale, it would be necessary to increase the size of the ponds. They also need to improve pond management and stock more catfish, which grow faster and use feeds more efficiently in such a system.

Efforts that promote forward and backward linkages within the value chains are important in enabling the actors to embrace market dynamism and improve understanding of consumer preferences. Emphasis should be put on stakeholders to document production, transformation, and marketing information of farmed fish.

This will provide up-to-date information for other stakeholders interested in the promotion and development of the value chain now and in future. The private sector, which consists of traders/transporters, cooperatives, banks, and processors, has to be involved in the physical provision of inputs, credit, packaging, storage facilities, and transportation, etc. This will expand marketing opportunities for the farmers. Collective action through producer groups/farmer groups will bring about economies of scale thereby reducing transaction costs incurred by actors. In some cases producer groups exist but may require some level of empowerment through capacity building. Traders claimed that fish from capture fisheries (lakes and oceans) tasted better than farmed fish. There is a need to conduct sensory evaluation to substantiate or deny these claims. Some of the respondents reported that farmed pond fish were smaller in size, had a higher bone density, and had a muddy taste, and their meat was not as firm as that of wild fish.

References

Alfaro, J.A. and Rábade, L.A. (2009) 'Traceability as a strategic tool to improve inventory management: a case study in the food industry', *International Journal of Production Economics* 118(1): 104–10 <http://dx.doi.org/10.1016/j.ijpe.2008.08.030>.

AllAfrica (2007) 'Uganda: curb overfishing on Lake Victoria, Editorial' [online], New Vision <http://allafrica.com/stories/200709260037.html> [accessed 4 September 2013].

Bertolini, M., Bevilacqua, M. and Massini, R. (2006) 'FMECA approach to product traceability in the food industry', *Food Control* 17(2): 137–45 <http://dx.doi.org/10.1016/j.foodcont.2004.09.013>.

Buhr, B.L. (2003) 'Traceability and information technology in the meat supply chain: implications for firm organization and market structure', *Journal of Food Distribution Research* 34: 13–26.

Charo-Karisa, H. and Gichuri, M. (2010) 'Overview of the fish farming enterprise productivity program', in *End of Year Report Fish Farming Enterprise Productivity Program Phase I*, Nairobi, Kenya: Aquaculture Development Working Group, Ministry of Fisheries Development.

Food and Agricultural Organization (FAO) (2014) 'Cultured aquatic species information programme: *Clarias gariepinus* (Burchell 1822)' [online], Fisheries and Aquaculture Department <www.fao.org/fishery/culturedspecies/Clarias_gariepinus/en> [accessed 4 September 2013].

Golan, E., Krissoff, B., Kuchler, F., Calvin, L., Nelson, K. and Price, G. (2004) *Traceability in the US Food Supply: Economic Theory and Industry Studies*, Agricultural Economic Report 830, Washington, DC: ERS, USDA.

Heyder, M., Theuvsen, L. and Hollmann-Hespos, T. (2012) 'Investments in tracking and tracing systems in the food industry: a PLS analysis', *Food Policy* 37: 102–13 <http://dx.doi.org/10.1016/j.foodpol.2011.11.006>.

Hobbs, J.E., Bailey, D., Dickinson, D.L. and Haghiri, M. (2005) 'Traceability in the Canadian red meat sector: do consumers care?' *Canadian Journal of Agricultural Economics* 53(1): 47–65.

Li, D., Tang, O., O'Brien, C. and Wang, X. (2006) 'Improve food retail supply chain operations with dynamic pricing and product tracing', *International Journal Service Operations and Informatics* 1(4): 347–62 <http://dx.doi.org/10.1504/IJSOI.2006.012161>.

Ngugi, C.C., Bowman, J.R. and Omolo, B. (2007) *A New Guide to Fish Farming in Kenya: A Report of the Aquaculture Collaborative Research Program*. Corvallis, OR: Oregon State University.

Peterson, H.C. and Wysocki, A.F. (1997) *The Vertical Coordination Continuum and the Determinants of Firm-Level Coordination Strategy*, No. 11817, East Lansing, MI: Michigan State University, Department of Agricultural, Food, and Resource Economics.

Pouliot, S. and Sumner, D.A. (2008) 'Traceability, liability, and incentives for food safety and quality', *American Journal of Agricultural Economics* 90(1): 15–27 <http://dx.doi.org/10.1111/j.1467-8276.2007.01061.x >.

Rich K., Ross R., Baker, A. and Negassa, A. (2011) 'Quantifying value chain analysis in the context of livestock systems in developing countries', *Food Policy* 36: 214–22 <http://dx.doi.org/10.1016/j.foodpol.2010.11.018 >.

Royer, J. (1995) 'Potential for cooperative involvement in vertical coordination and value-added activities', *Agribusiness* 11(5): 473–81.

Ruiz-Garcia, L., Steinberger, G. and Rothmund, M. (2010) 'A model and prototype implementation for tracking and tracing agricultural batch products along the food chain', *Food Control* 21: 112–21 <http://dx.doi.org/10.1016/j.foodcont.2008.12.003 >.

Shoko, A.P., Limbu, S.M., Mrosso, H.D.J. and Mgaya, Y.D. (2014) 'A comparison of diurnal dynamics of water quality parameters in Nile tilapia (*Oreochromis niloticus*, Linnaeus, 1758) monoculture and polyculture with African sharp tooth catfish (*Clarias gariepinus*, Burchell, 1822) in earthen ponds', *International Aquatic Research* 6: 56 <http://dx.doi.org/10.1007/s40071-014-0056-8>.

Souza-Monteiro, D.M. and Caswell, J.A. (2010) 'The economics of voluntary traceability in multi-ingredient food chains', *Agribusiness* 26(1): 122–42 <http://dx.doi.org/10.1002/agr.20233 >.

Stuart, T. (2009) *Waste, Uncovering the Global Food Scandal*, London: Penguin.

Tilley, D. (1989) 'Value-added activities as a rural development strategy: discussion', *Southern Journal of Agricultural Economics* 1: 37–40.

Wang, X. and Li, D. (2006) 'Value added on food traceability: a supply chain management approach', presented at *IEEE International Conference on Service Operations and Logistics, and Informatics, 2006. SOLI'06*, pp. 493–8, Piscataway, NJ: IEEE.