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Evaluation of fish farming practices and utilization of rice milling byproducts as fish feeds in Kirinyaga County, Kenya

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Abstract
The challenge of expensive fish feeds in Kenya can be mitigated through utilization of agro-processing byproducts. A study was done to evaluate farmed fish management practices and assess rice milling byproducts' use within Kirinyaga County in Kenya. Data from 109 fish farmers (owning 184 fishponds) and 6 large scale and 50 small scale rice millers was collected using semi-structured questionnaires. Most (51.6%) of the farmers interviewed kept Tilapia in monoculture, 27.7% kept Tilapia and Catfish together in polyculture, 11.4% kept Ornamental fish and 9.2% kept Catfish in monoculture. Although 86% of farmers cited high cost of feed as a challenge, none of them fed fish based on their weight. In addition farmers did not quantify the amount of fertilizer prior to application to the pond. Rice bran produced from large mills had higher quality (14.7% CP and 12.1% CF) compared to that from small mills (8% CP and 27.9% CF).

Keywords: Catfish, feeds, fertilizers, rice bran, tilapia

1. Introduction
The fisheries and aquaculture industry in Kenya accounts for 0.5% of the Gross Domestic Product (GDP); aquaculture contributes approximately 14% while the fisheries sector contributes the rest [1]. This is a small portion of the country's GDP despite the heavy investment in fish farming in the country [2]. A recent initiative, the Fish Farming Enterprise and Productivity Program implemented under the Economic Stimulus Program (ESP) of 2009[3] constructed 28,000 ponds for farmers and distributed feeds and millions of fingerlings to the farmers. This resulted in an increase in fish farming output from 4,000 metric tons in 2008[4] to 24,096 metric tons in 2014[5] valued at 5.6 Billion Kenya Shillings (K Sh.). There is need to evaluate the post-ESP fish farming practices to identify the challenges and opportunities that farmers are experiencing after the end of the program.

Fish production in Kenya is dominated by the culture of Tilapia varieties (3,424 tons) followed by Catfish varieties (1,047 tons), Common carp, *Cyprinus carpio* (Linnaeus, 1758) (373 tons) and Rainbow trout, *Oncorhynchus mykiss* (Walbaum, 1792) (51 tons) as of 2009 [6]. These fish are cultured under extensive, intensive and semi-intensive production systems [7]. This depends on the investment requirements and the fish species that can be cultured in a certain production system [8]. The extensive production systems have the lowest investment requirements with little or no inputs introduced to the pond [9]. Tilapia, Catfish and Common carp (*Cyprinus carpio*) are cultured under this production system with an estimated production of 500-1,500 kg/ha/year [7, 10].

Intensive production systems have the highest investment requirements where the fish are fed diets that meet their full nutritional requirements [7]. The water is continuously aerated, filtered and recycled in order to maintain its quality for it to support high stocking densities of fish such as Tilapia and Rainbow trout (*Oncorhynchus mykiss*) in tanks and raceways respectively. This results in a production of 10,000-80,000 kg of fish/ha/year [10].

Most farmers in Kenya practice the semi-intensive system of fish production [10] which involves enhancing the natural productivity of ponds using manures and commercial fertilizers [9, 10]. Fish are also fed on cereal milling byproducts and other locally available feed resources [11]. Tilapia in monoculture and Tilapia in polyculture with either Catfish or Common carp are cultured under this system, with a production of 1,000-2,500 kg of fish/ha/year [7, 10].

In this production system, feeds account for approximately 70% of the total variable costs [12]. Agro-processing byproducts, such as those obtained from the milling of rice (*Oryza sativa* L.), have great potential for lowering the cost of feeds [11]. Kirinyaga County, one of the beneficiaries of the ESP (that resulted in a production of 701 metric tons of fish in 2014 valued at 169,111,000 KSh. [5]), is the main rice growing region in Kenya [13]. It produced 68,988.2 tons of rice in 2014[5]. It therefore has abundant rice milling byproducts for use in feeds for fish.

The main products of rice milling are polished rice (50-66%), husks/hulls (20%), bran (10-11%), broken rice (1-17%) and polishing (3%) [14, 15, 16]. Rice milling byproducts that can be used in fish feeds are bran and broken rice [16, 17, 18, 19]. However, these byproducts have not been fully exploited as fish feed hence the need to evaluate, quantify and analyze their nutritional composition in an effort to increase their utilization. The objectives of this study were therefore to evaluate fish farming management practices in Kirinyaga County in Kenya and determine the quantities and quality of rice milling byproducts which are abundant in the study area.

2. Materials and methods

2.1 Study site and sample size

This study was done in Kirinyaga County, Kenya, located between the longitudes 37° and 38° East and latitudes 0° 1' and 0° 40' South[20]. The study targeted a random sample of fish farmers (from 15th-19th July, 2013) and all rice millers (from 5th-9th August, 2013) in the county. Data on the total number of farmers of fish in Ndia constituency, Kirinyaga County was provided by the Divisional Fisheries Development officers in Ndia. A total of 325 fishponds were constructed under the ESP but only 290 were active at the time of the survey. This number was used in the Yamane formula of 1967 [21] to determine the required sample of farmers and the respondents were identified using stratified random sampling. Fish farmers from the following locations of Ndia, Kirinyaga County were interviewed using a semi structured questionnaire: Mwerua (50), Kariti (38), Kiine (11) and Mukure (10). Small scale rice millers in five locations of Kirinyaga County namely, Mutithi (15), Mwerua (8), Nyangati (13), Tebere (11) and Thiba (3) were interviewed. Large scale rice millers in two locations of Kirinyaga County namely, Mutithi (1) and Tebere (5) were also interviewed.

2.2 Data collection and chemical analysis

Semi structured questionnaires were used to collect data from fish farmers and rice millers. Among the information collected were fish farming management practices and the challenges faced by respondents, who either owned the fishpond or managed it. Questionnaires were administered through face to face interviews done by trained enumerators. The rice millers were categorized as small scale (single-pass rice mills) and large scale (multiple-pass rice mills) for purposes of the study. Data collected included the amounts of rice milling byproducts produced through the year. Rice bran samples were collected from randomly selected 4 small scale mills and 3 large scale mills. They were analyzed for CP, CF, EE, ash and moisture according to AOAC (1998) [22] procedures.

2.3 Data analysis

The data collected was cleaned, sorted and entered into the computer program Microsoft Excel of Windows 7 Professional and exported to the software, Statistical Package for Social Sciences (SPSS) for analysis. This generated descriptive statistics consisting of frequencies, means, standard deviations and percentages that facilitated inferential analysis using t-test to compare large scale and small scale mills.

3. Results and Discussion

3.1 Social and economic factors affecting fish farming practices in Ndia, Kirinyaga County

Table 1 below shows the gender, age, education levels, other sources of income and source of start-up capital (to start fish farming) of the respondents. Only 109 out of the 169 targeted fish farmers were interviewed which was due to the fact that most farmers had abandoned fish farming by the time of the study. Majority of the farmers (70.6%) were male with 29.4% being female. A similar trend was reported in Meru[23] (72.7% male and 27.3% female) and in Kisumu[24] (84.1% male and 15.9% female), both in Kenya. The rights to land in many countries worldwide are determined by socio-cultural frameworks such as through spouses, the community allocating the land to an individual, or individuals inheriting land from parents [25]. As for inheritance, it is the men who mainly inherit land and will therefore have more fishponds. In the study area, most of the land (except leasehold land in Mwea) is ancestral land [26] resulting in a higher number of men owning fishponds.

Majority of respondents (49.5%) were aged between 36 and 60 years (Table 1). In other studies, it was observed that fish farming was mainly practiced by farmers aged below 50 years [2, 24, 27, 28]. This was attributed to the energy levels and willingness to take risks by this age group leading to higher adoption of the relatively new enterprise of fish farming [29]. A majority of the fish farmers (43.7%) had attended secondary school. Fish farming adopters have high levels of education because it enables them understand and adopt new technologies [29]. Farmers had other sources of income as shown in Table 1. The major source of income (88.1%) was from mixed livestock and crop farming. Similar findings were reported for fish farmers in Kiambu and Machakos Counties [27].

Table 1: Social and economic factors affecting fish farming practices in Ndia, Kirinyaga County

Gender of the respondents	Frequency	Percentage
Male	77	70.6
Female	32	29.4
Total	109	100
Age of the respondents		
18- 35 years	20	20.6
36- 60 years	48	49.5
Over 60 years	29	29.9
Total	97	100

Education level		
Below primary	2	1.9
Primary	31	30.1
Secondary	45	43.7
College	20	19.4
University	5	4.9
Total	103	100
Other sources of income		
None	3	2.8
Fish trader	3	2.8
Livestock/ crop farmer	96	88.1
Business person	3	2.8
Factory worker	2	1.8
Casual labourer	2	1.8
Total	109	100
Source of start-up capital		
Own saving	13	11.9
Government (ESP)	86	78.9
Own saving and Government funding	10	9.2
Total	109	100

The start-up capital for majority of fish farmers (78.9%) was provided through the Government of Kenya (Table 1) under the Economic Stimulus Program (ESP). The other farmers either used their savings (11.9%) or savings in addition to the ESP subsidy (9.2%). In Gucha, Meru and Taita-Taveta Counties, the same trend was documented where 92% of the respondents had individually owned ponds in an area of communal land ownership, attributed to the ESP [30]. A similar trend was observed in Kiambu and Machakos Counties where 85.3% and 75% of fishponds respectively were owned by fish farmers recruited through the ESP [27]. The ESP fully funded the Fish Farming Enterprise Productivity Program (FFEPP) and the Economic Recovery, Poverty Alleviation and Regional Development Program which funded the construction of more than 48,000 fishponds in 160 constituencies countrywide [3, 31].

3.2 Fish species cultured

The different species of fish cultured in the study area is shown in Table 2. The number of ponds owned by the 109 fish farmers was 184. The culture of monosex Tilapia alone was the most common (51.6%) among the farmers interviewed whereas 27.7% kept mixed sex Tilapia with Catfish. A few farmers (11.4%) kept Ornamental fish while only 9.2% kept Catfish in monoculture. The same tendencies were observed in Mwea area, adjacent to the study area [2]. A study in western Kenya found that Tilapia culture was the most dominant (56.8%) followed by Tilapia and Catfish polyculture (37.3%) [28]. During the initial stages of the Economic Stimulus Program (ESP), the Government of Kenya, through its extension workers, distributed mixed sex tilapia fingerlings to farmers. Tilapia reach sexual maturity before reaching market weight and quickly reproduce thus overpopulating ponds [9]. This leads to increased competition for feed and oxygen among the fish resulting in stunted growth of the fish. The government then attempted to offset this challenge by introducing the African Catfish (*Clarias gariepinus*) to control Tilapia numbers by feeding on the unwanted Tilapia fingerlings and fry [9, 32]. This is what increased the culture of Tilapia and Catfish together. The Government of Kenya, through the ESP, also distributed monosex tilapia fingerlings obtained through sex reversal [9, 32] resulting in the high numbers of Tilapia in monoculture observed in this study. Under the ESP, the Government of Kenya did not distribute Catfish and Ornamental fish resulting in the low numbers of these fish species among the farmers. The *C. gariepinus* is a popular fish species in Africa, only second to tilapia with the exception of Nigeria where the reverse is true [33]. This is despite the fact that *C. gariepinus* grows faster and is more tolerant to poor water quality conditions than tilapia [9].

Table 2: Fish species cultured in Ndia, Kirinyaga County

Fish culture	Number of ponds	Percentage
Tilapia monoculture	95	51.6
Tilapia and Catfish polyculture	51	27.7
Ornamental fish culture	21	11.4
Catfish monoculture	17	9.2
Total	184	100

3.3 Fish feeds

The different types of fish feeds used by fish farmers is shown in Table 3. For purposes of this study, commercial feeds were defined as complete feeds that were purchased from retailers while home-made feeds were mixed on the farm using available ingredients. Some farmers fed the fish with only one type of feedstuff (single ingredient feeds). The common ingredients for the home mixed feeds were agro-processing byproducts such as rice bran, wheat bran and maize bran. The single ingredient feedstuffs used were sweet potato vines, rice bran, maize germ, wheat bran and cassava leaves. Most of the farmers (70% of those who stocked Catfish in monoculture, 58.2% of farmers who stocked Tilapia in monoculture, 73.5% of those who stocked Tilapia and Catfish together and 70% of Ornamental fish farmers) fed their fish on commercial feeds. This could be attributed to commercial feeds being one of the inputs distributed to fish farmers under the ESP [3]. The use of commercial fish feeds was also reported among fish farmers under the ESP in Kiambu and Machakos Counties [27].

The second most popular feeds were home-made feeds used by 30% of Catfish farmers, 17.9% of farmers keeping Tilapia in monoculture, 20.6% of farmers who kept Tilapia and Catfish together and 30% of Ornamental fish farmers. This was also observed in Gucha, Meru and Taita-Taveta Counties where 93.4% of farmers fed their fish commercial feeds while 6.6% made their own feeds [30]. Home-made rations are inexpensive compared to commercial feeds but they are often nutritionally incomplete. Only 6% and 2.9% of farmers

keeping Tilapia in monoculture and Tilapia and Catfish in polyculture respectively used single ingredient feeds to feed their fish. Fish farmers used home-made and single ingredient feeds to reduce cost since feeds account for approximately 70% of total variable cost in fish production [12].

Table 3: Types of feeds used by fish farmers in Ndia, Kirinyaga County

Feed type	Catfish		Tilapia		Tilapia and Catfish		Ornamental fish	
	N	%	N	%	N	%	N	%
Commercial	7	70.0	39	58.2	25	73.5	7	70.0
Home-made	3	30.0	12	17.9	7	20.6	3	30.0
Single ingredient	-	-	4	6.0	1	2.9	-	-
Commercial and single ingredient	-	-	7	10.4	1	2.9	-	-
Commercial and home-made	-	-	5	7.5	-	-	-	-
Total	10	100	67	100	34	100	10	100

3.4 Feeding Challenges

The main challenges of feeds encountered by fish farmers are summarized in Table 4. Majority (86%) reported that the high cost of feeds was their major challenge. This was also identified as a challenge by 33.6% of farmers in Siaya County, Kenya [34]. In Kakamega, Kisii and Siaya Counties [28], the high cost of feeds was identified by fish farmers as the main challenge (compared to lack of finances, expertise and high quality fingerlings) that they faced in fish farming. Other challenges reported in the current study were market place unavailability of feeds (8%) and low quality feeds (6%). Feed related challenges such as high cost, unavailability in the market and low quality impact heavily on fish farming because feeds account for approximately 70% of total variable cost of semi-intensive culture of fish [12]. The profitability of fish farming can be enhanced if there is availability of high quality, low cost feeds accompanied by appropriate management practices [35].

Table 4: Feeding challenges faced by fish farmers in Ndia, Kirinyaga County

Feeding challenges	Frequency	Percentage
High cost of feeds	43	86
Unavailability of feeds in the market	4	8
Low quality feeds	3	6
Total	50	100

3.5 Fishpond Fertilization

Fertilization of ponds was done using fertilizers that were either inorganic (purchased from local shops) or organic (obtained from livestock (manure) on the farm or bought from neighbouring farms. The fertilizer application frequency in fishponds is shown in Table 5. Most (27.4%) of the farmers used inorganic fertilizers in their fishponds before stocking them with fish and none of them measured the amounts used. Urea and DAP use are common among Kenyan fish farmers because they are the cheapest sources of nutrients, from a nutrient supply perspective [9, 36]. The recommended application rates for urea and DAP are 3g/m^2/week and 2g/m^2/week respectively for warm areas and half these rates for cooler areas [9, 36].

Most farmers (38%) used organic fertilizers once a month while 28% of farmers applied it only when the pond water was clear indicating there was little algal growth. None of the farmers weighed the manure prior to application. The manuring schedule for most farmers in Kenya is determined by monitoring algal blooms instead of following the recommended manuring rate of 500kg dry manure/ha/week [9, 36]. There are also recommended manuring schedules for specific sources of manure such as chicken manure which should be applied two weeks before stocking at 25 kg dry weight/100 m² and thereafter 3 kg dry weight/100 m² every 10 days [37]. The fish farmers under the ESP were using fertilization frequencies based on monitoring algal growth as was recommended by government extension officers.

Several challenges associated with fishpond fertilization were identified. The main challenge (56.3%) was the high cost of inorganic fertilizers. In addition, fish farmers did not follow the recommended fertilization regimes and water quality problems such as too much algae growth (37.5%) and fish diseases (6.3%) due to over-fertilization were also challenges faced.

Table 5: Frequency of fertilization of fishponds in Ndia, Kirinyaga County

Frequency of use	Inorganic fertilizer		Organic fertilizer	
	N	%	N	%
Before stocking only	32	27.4	12	12
When the water clears	29	24.8	28	28
Daily	-	0	1	1
Once a week	-	0	4	4
Every two weeks	8	6.8	1	1
Once a month	28	23.9	38	38
After more than a month	20	17.1	16	16
Total	117	100	100	100

3.6 Rice milling byproducts

The total rice bran production from both large and small scale millers in the study area was 702 and 6388 tons/year respectively (Table 6). The average cost of the bran was 13.1 and 6.9 KSh/kg (103.85 KSh= 1US$) with average CP of 14.7 and 8% for large and small scale mills respectively (Table 7). Wheat bran having a CP of 17.1% costs 6.72 KSh/kg and maize bran having a CP of 11.8% costs 21 KSh/kg [11]. As such, rice bran from large scale mills can replace maize bran but not wheat bran in fish diets (considering cost and CP only).

The large and small scale mills produced a total of 38 and 305 tons/year of chicken rice (a form of broken rice mainly fed to chicken) respectively that had an average cost of 32.5 and 42.7 KSh/kg respectively. Chicken rice is produced in small quantities and is expensive compared to rice bran. It also has a lower CP of 7.1% [19] compared to rice bran. Therefore, rice bran is a more suitable rice milling byproduct for inclusion in fish diets compared to chicken rice when considering cost and CP level only.

Table 6: Rice milling characteristics in Kirinyaga County

Production characteristics	Large scale millers				Small scale millers				Prob.
	N	Total	Mean	SD	N	Total	Mean	SD	
Rice bran production (tons/yr)	6	702	117	136	38	6388	168	312	0.697
Rice bran cost (KSh/kg)	5	-	13.1	2.12	47	-	6.9	2.13	<0.001
Chicken rice production (tons/yr)	2	38	19.0	26.2	25	305	12.2	27.3	0.737
Chicken rice cost (KSh/kg)	2	-	32.5	10.6	28	-	42.7	13.8	0.318

SD- Standard Deviation

3.7 Nutrient content of rice bran

The nutritional composition of rice bran from the two types of mills is shown in Table 7. The mean fiber content of bran from large scale mills was 12.1%, comparable to 13% reported in 2011 [38]. Several other authors [39, 40, 41, 42] reported values lower than this ranging from 6.3% to 9.1%. The mean fiber content of bran from small scale rice mills was 27.9%, comparable to 30.9% reported in 2007 [43]. Other studies found CF values of 42.3% [44] and 31.9% [41] in their rice bran samples. However, it is generally accepted that rice bran should have less than 13% CF [45]. This higher CF of bran from small scale mills could be due to mixing of the bran with rice hulls during the one-stage milling process where hulls and bran are removed together [14, 16]. On the other hand, multi-stage processing of rice in large scale rice mills removes hulls and bran in different stages [16] resulting in bran having low crude fiber.

Rice hulls are the hard outer layer of paddy (unmilled) rice with little feeding value due to high crude fiber and silica content and low crude protein [16, 40]. Therefore, the mixing of rice hulls with rice bran in small scale mills also led to the higher ash and lower CP of rice bran from small scale mills compared to large scale mills. In addition, there was also a high variability of CF, ash and CP among rice bran samples from small scale mills. This is due to the mixing of hulls and bran in varying proportions by the different machine types in different mills that carry out the one-stage milling resulting in large variations in the chemical composition [18]. The low fat content of bran from small mills could also be due to mixing of rice hulls with rice bran. Rice bran contains 14-18% oil [16]. In the current study, rice bran from large scale and small scale mills had 20% and 12% ether extract (oil) respectively.

Table 7: Nutrient content (%) of rice bran from rice millers in Kirinyaga County (DM basis)

Parameters	Mill scale	N	Minimum	Maximum	Mean	SD
Dry matter	Large	3	88.7	91.0	89.7	1.15
	Small	4	89.5	91.8	90.5	1.06
Crude fiber	Large	3	9.8	13.2	12.1	1.90
	Small	4	19.1	33.6	27.9	6.40
Crude protein	Large	3	14.1	15.5	14.7	0.72
	Small	4	3.5	11.5	8.0	3.47
Ether extract	Large	3	16.8	23.7	20.0	3.44
	Small	4	9.3	16.7	12.0	3.23
Ash	Large	3	10.7	11.2	10.9	0.26
	Small	4	14.8	18.1	16.4	1.42

SD- Standard Deviation

4. Conclusions

- Most of the farmers sampled kept Tilapia (*O. niloticus*) in monoculture.
- Polyculture of mixed sex Tilapia with Catfish was the second most common culture method.
- Most farmers did not feed their fish with the right feeds and at the recommended feeding rates.
- The fish farmers in Kirinyaga fertilized their ponds but did not follow fertilization recommendations
- Rice bran was the main rice milling byproduct found in large quantities in Kirinyaga County. However, the fish farmers in the County have not adequately utilized it to bring down their fish feed costs.
- The quality of rice bran from large scale rice mills was more suitable for use in fish diets due to its lower levels of crude fiber compared to rice bran from small scale rice mills.

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