ADOPTION AND INTENSITY OF IMPROVED FISH FEEDS USE IN WESTERN KENYA

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ABSTRACT

Improved fish feeds are considered to be paramount input for increased agricultural productivity and enhanced food security, however, its adoption in Western Kenya remains very low. This study utilized double hurdle model to analyse determinants and intensity of adoption of improved fish feeds in Western Kenya using cross-sectional survey data of 400 fish-farming households. A multi-stage sampling technique was used to identify the adopters and non-adopters of improved fish feeds. The study revealed that 51.5% households utilized improved fish feeds. The results of the study indicated that there were differences regarding factors that determine adoption and intensity of adoption of improved fish feeds. It was found that government subsidy, type of labour, credit access, age, and growing crops significantly influenced the probability of adoption of improved fish feeds but had no significant influence on intensity of use. The findings further revealed that group membership, access to extension services, experience, and non-farm activity significantly affected the intensity of use of improved fish feeds but did not explain probability of adoption. However, market access, household size, fish income, education, livestock ownership and farm-gate price of fish significantly influenced both adoption and intensity of use of improved fish feeds. To enhance adoption and intensity of use of improved fish feed technology, policy interventions such as availing market information, reducing transaction costs, improving resource endowment of farmers, improving education through trainings to reach many farmers and increasing price of fish yield are recommended.

Key words: double hurdle, adopters, non-adopters, determinants, technology

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INTRODUCTION

Aquaculture is the fastest growing industry in Africa with high potential and accounts for 17% of total fish production while contributing 2.5% to global production (FAO, 2018). Kenya is ranked the fourth producer of aquaculture in Africa with the sub-sector contributing 0.8% to the Gross Domestic Product. It also provides direct employment opportunities to over half a million people and indirectly supports over two million people (KMFRI, 2017). Improved agricultural technologies are crucial for increasing food security, household income, and agricultural productivity as well as reducing poverty (Yigezu *et al.*, 2018) There are potential direct benefits of improved aquaculture technology such as gains from productivity which lead to increased fish income and reduction in poverty for technology adopters (Kassam, 2013).

Improved fish feed technology reduces poverty by increasing fish income among fish farmers who adopt the technology (Amankwah and Quagrainie, 2019). The improved feed type is smooth, pelleted and floating compared to the coarse, powdery and sinking farm-made feed (Awity, 2013). Improved fish feeds are nutritionally balanced fish feeds which have a protein content ranging from 28-35%, are extruded to float, pelleted and dry which ease feeding and improve digestibility reducing wastage (Amankwah *et al.*, 2018). Ansah (2014) found out that adoption of the commercial floating fish feed led to an increase of 100% fish growth and yield compared to the sinking farm made fish feed. In addition, profitability analysis further showed that use of the commercial floating fish feeds brought about higher probability of profitability (45%) unlike the farm made feed (25%).

Improved fish feeds are considered to be paramount input for increased agricultural productivity and enhanced food security, however, adoption of improved fish feeds in Western Kenya remains very low. The scale of aquaculture technology uptake is very slow (30% of fish farmers) hence inadequate for the achievement of the envisaged transformational change in the vision 2030 agenda for sustainable development (Obiero *et al*., 2019) The adoption of the aquaculture technologies including improved fish feeds is still very low, the farmers still use locally formulated fish feeds yet this formulation is not nutritionally balanced leading to poor growth (Awuor *et al*., 2021).

The local feeds are badly formulated due to inadequate manufacturing equipment and the farmers lack knowledge on how to use the feeds for lack of technical expertise (Cocker, 2014). The locally available agricultural by-products (corn meal, cassava meal, rice bran, and wheat bran) contain high crude fibre which reduces digestibility and palatability and also are deficient in micro and macro nutrients hence leading to low fish yields (Charo-karisa *et al*., 2014). Awity, (2013) show that some of the farm made fish feeds are wasted as a result of poor ingestion due to the varied inappropriate pellet sizes and would not satisfy the fish nutritional requirements. This study therefore contributes to the literature by analysing the factors which influence adoption and intensity of use of improved fish feeds among smallholder farmers in Western Kenya. There is no empirical study which specifically analyses the adoption and intensity of use of improved fish feeds in Western Kenya.

Studies such as: (Yaw and Frimpong, 2015; Awity, 2013; Charo-karisa *et al*., 2014), investigated various aspects on fish feed technologies within the broader aquaculture context. Although (Amankwah and Quagrainie, 2019) examined the determinants and extent of adoption of improved fish feeds, this study was done in Ghana. (Amankwah *et al*., 2018) analysed the impact of improved feed technology on income from fish and poverty in Kenya, a study in which intensity of adoption was not investigated. This study fills the gap in knowledge for policy makers and researchers on the factors that influence the decision making of farmers towards adoption and the extent of adoption of aquaculture technologies.

This study employed the random utility theory proposed by (Hanemann *et al*., 1991) and following De Janvry and Sadoulet (2002) to analyse household's decision whether to adopt improved fish feeds or not . Let U_{ia} U_{ia} to denote the utility achieved by household i from adopting improved fish feeds and U_{in} be the utility realised by household i from not adopting improved fish feeds. Let V_i be a vector of household socioeconomic and institutional characteristics affecting adoption decisions and ε_i be the error term. Thus, the household i utility is defined as shown in equation (1) and (2)

$$U_{ia}=f(V_i\ )+\varepsilon_i \quad \textbf{(1)}$$

$$U_{in}=f(V_i\ )+\varepsilon_i \quad \textbf{(2)}$$

A household i will adopt improved fish feeds only and only if the utility derived from adopting improved fish feeds, U_{ia}, is greater than the utility obtained from not adopting improved fish feeds, U_{in}, that is $U_{ia} > U_{in}$. The above utilities are not observable and therefore, expressed in the following latent structure of adoption decision;

$$y_i^{*}=\beta V_i+\varepsilon_i \quad \textbf{(3)}$$

$$y_i = \begin{cases} 1\ if\ y_i^{*} > 0 \\ 0\ if\ y_i^{*} < 0 \end{cases}$$

Where; y_i= is a binary response indicator taking the value of 1 if household i adopts improved fish feeds and 0 otherwise.

METHODOLOGY

Study area

The study covered five counties in Western Kenya namely: Kakamega, Bungoma, Busia, Siaya and Kisumu. Kakamega County covers an area of 3050.3 km^2 and has two major ecological zones: Upper Medium (UM) and Lower Medium (LM). Altitude ranges from 1,240- 2,000 metres above sea level. It receives rainfall that ranges from 1280mm- 2214mm in a year. The temperatures range from 18-29 ^{0}C (Government of Kenya, 2018b). Bungoma County covers an area of 3032.4 km^2 and lies between latitude 00 28' and latitude 10 30' North of the Equator, and longitude 340 20' East and 350 15' East of the Greenwich Meridian (Government of Kenya, 2018a). Busia County covers an area of 1,694.5 km^2 and lies between latitude 0º and 0^0 45 North and longitude 34º 25 east. The altitude rises from 1130 metres-1500 metres above sea level. (Busia County, 2018). Siaya County covers a land surface area of 2,530 km² and water surface area of 1,005 km^2 that is part of Lake Victoria. It lies between latitude 0º 26´ South to 0º 18´ North and longitude 33º 58´ and 34º 33´ east. The altitude rises from

1,140m to 1,400m above sea level. It spreads across agro-ecological zones (Republic of Kenya, 2018). Kisumu County lies between longitudes 33^0 20'E and 35^0 20'E and latitude 0^0 20' South and 0^0 50' South and covers a total land area of 2085.9 km^2 and 567 km^2 covered by water as part of Lake Victoria (Government of Kenya, 2018c).

Data collection, sampling technique and sample size

The study employed cross-sectional survey to obtain data by use of a structured questionnaire which was administered to smallholder fish pond farm households. The questionnaire solicited for information on socio-economic and institutional characteristics of smallholder fish pond farmers. The study used a multi-stage sampling technique to identify the households of adopters and non-adopters of improved fish feeds. A sample size of 400 households was randomly selected. This study used Anderson's formula of estimating sample size of unknown population as follows:

$$n = \frac{p(1-p)Z^2}{E^2},$$

where n = sample size

p = proportion of target population that is not known

Z = confidence interval

E = allowable margin of error

$$n = \frac{0.5(1-0.5)1.96^2}{0.049^2} = 400$$

Method of Data Analysis

The methods of data analysis used were descriptive statistics and double hurdle model. This study employed a double hurdle model with an assumption that the adoption of improved fish feeds and the intensity of use are independent decisions. The double hurdle model involves two step decisions which are the participation and the quantity decisions (García, 2013; Cragg, 1971).

The adoption and intensity of adoption of improved fish feeds may be modelled to involve two decision steps. First, a household head determines whether he or she wants to adopt the improved fish feeds technology known as the participation decision. Second, the same farmer determines the amount of use of the improved fish feeds in case he or she adopts, known as the quantity decision.

In the first hurdle, the probit model was used to identify the factors determining the decision to adopt improved fish feeds. The probit regression was estimated using a dummy value of 1 if the household head adopted and 0 otherwise. The probit model equation which was used in this study is given by:

$$Y_i^* = \beta_i X_i + \varepsilon_i \text{..................................(4)}$$

$$Y_i = \begin{cases} 1 \text{ if } Y_i^* > 0 \\ 0 \text{ if } Y_i^* \leq 0, \end{cases}$$

where subscript i is the i^th^ household, Y_i^* is a latent discrete adoption choice variable, Y_i is the observed adoption variable which takes a value of 1 if the household head adopted improved fish feeds and 0 otherwise, ε_i is the error term which is independent from X_i that is a 1 by K vector of factors which determine the adoption of improved fish feeds by the i^{th} household and β_i is a 1 by K vector of the parameters to be estimated.

The probit model above is only adequate for analysing adoption decisions that occur over a discrete range such as yes or no. It does not handle adoption choices that have a continuous value range. The intensity of use is an important aspect of technology adoption because it's not only about the choice to use but also the level of use.

In the second hurdle, a truncated regression model was used to identify the determinants which influence the intensity of use of improved fish feeds among the households which adopted improved fish feeds. The truncated regression model equation is given by:

$$I_i^* = \alpha_i X_i + \mu^i \quad \mu_i \sim N(0, \delta^2) \text{ ....(5)}$$

$$Ii = \begin{cases} I_i^* \text{ if } I_i^* > 0 \text{ and } Y^i = 1 \\ 0 \text{ otherwise)} \end{cases}$$

where I_i is the intensity (level of use measured in kg/ha) of improved fish feeds' adoption and depends on I_i^* the latent variable being greater than zero on condition that a decision is made to adopt the improved fish feeds, α_i is a vector of parameters to be estimated for the intensity of adoption, X_i is a vector of factors which affect the intensity of use of improved fish feeds, and μ_i is the error term which has normal distribution.

$$Y_i \text{ or } I_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 +, \dots\dots\dots, + \beta_{21} X_{20} + \varepsilon_i$$

where Y_i is the improved fish feed adoption which takes the value of 1 for adopters and 0 otherwise, I_i is the intensity of use of improved fish feeds measured in kg/ha, β_i is a vector of parameters to be estimated, X_i is a vector of the explanatory variables and ε_i is the error term. The average marginal effects for both models were estimated since the coefficients do not represent the magnitude of change in the explanatory variables.

RESULTS AND DISCUSSION

Description of variables, summary statistics and mean difference tests

Table I presents a descriptive summary of selected variables that were used in the analyses. Household heads were 47 years of age on average and 79 percent of the households were headed by males. On average the number of years of education of household heads was 11 and household heads who were married were 90 percent. The household heads who practiced farming as their main occupation were 15 percent on average. The households mean size was 6 persons with a mean of 6 years of experience. The means of households who engaged in non-farm activities and family labour were 32 percent and 74 percent respectively.

On average, 83 percent of the households accessed the market and average land size was 1.8 acres which suggest that the farmers who were surveyed were smallholders. The average farm size for fish owners was 0.3 acres and about 69 percent of the farmers owned livestock on average. The mean cost of fish feeds was KES.125 per kg while the mean unit price of fish was KES144. About 95 percent of the households perceived that improved fish feeds would increase their fish yield. The households that accessed extension services and credit were about 70 percent and 13 percent on average respectively. About 32 percent of the total households were members of farmer groups and 24 percent accessed government subsidy.

TABLE I - DESCRIPTIVE STATISTICS AND MEASUREMENT OF VARIABLES

Variable		Sample mean	Std. dev
Age	Age of household head in years	47.2	13.767
Gender	1 if household head is male, 0 otherwise	0.797	0.402
Education	Years of schooling of household head	11.83	2.805
Marital status	1 if household head is married, 0 if single	0.902	0.297
Occupation	1 if household head's occupation is agricultural, 0 otherwise	0.152	0.36
Household size	Number of people residing in a household	6.42	2.773
Experience	Fish farming experience in years	6.344	5.172
Non-farm activity	1 if farmer engages in non-farm activities, 0 otherwise	0.318	0.466
Type of labour	1 if family labour, 0 if hired labour	0.735	0.442
Market access	1 if farmer has access to market, 0 otherwise	0.833	0.466
Land size	Total household farm land in acres	1.785	0.790
Land Fish production	Total fish farm land in acres	0.295	0.184
Livestock ownership	1 if household owns livestock, 0 otherwise	0.685	0.465
Price fish feeds	Cost of improved fish feeds per kg	125.043	76.571
Farm-gate price fish kg	Price of a kg of fish at farm-gate	432.075	101.621
Perception fish yield	1 if farmer perceives yield as a result of improved fish feeds as superior to local, 0 otherwise	0.953	0.213
Extension access	1 if household had access to fisheries extension provider, 0 otherwise	0.7	0.459
Credit access	1 if household had access to credit, 0 otherwise	0.128	0.334
Group membership	1 if farmer belonged to a farmers' group, 0 otherwise	0.323	0.468
Government subsidy	1 if farmer received improved fish feed subsidy, 0 otherwise	0.24	0.428

Table II presents the mean differences between adopters and non-adopters of improved fish feeds. The results reveal significant differences between adopters and non-adopters with respect to various household characteristics. An estimated 51.5 percent (206) of all the surveyed fish farming households used improved fish feeds in the year 2021. The other 48.5 percent (194) used traditional fish feeds. About 76 percent of non-adopters were married compared to 83 percent of adopters and this difference was significant. There was a significant difference between the adopters and non-adopters in the number of years of education. There was a significant difference between adopters and non-adopters in terms of the type of labour employed. About 83 percent of non-adopters employed family labour compared to 65 percent of adopters. The analysis of adoption of improved fish feeds by market access revealed that there is a significant difference between adopters and non-adopters of improved fish feeds. On average, 88 percent of non-adopters accessed the market compared to the 79 percent of the adopters.

The results also revealed a significant difference in total land acreage between adopters and non-adopters of improved fish feeds. The adopters and non-adopters averagely owned 1.9 and 1.7 acres of land respectively. The bigger land size could have been an incentive for the households to consider fish farming thereby adopting improved fish feeds. In addition, there was a significant difference in terms of livestock ownership between adopters and non-adopters of improved fish feeds. The results reveal that 77 percent of the adopters owned livestock compared to 60 percent of non-adopters. Owning livestock could have been an asset for availability of cash to afford improved agricultural technologies.

There is significant difference in the cost of fish feeds between adopters and non-adopters. The adopters bought improved fish feeds at KES142 per kg on average compared to KES 107 per kg of the local feeds for the non-adopters. This showed that improved fish feeds are expensive compared to the local feeds. The results further revealed that adopters sold one kilo gram of fish at KES 455 compared to non-adopters who sold at KES 408 which showed that adopters received more fish income compared to non-adopters.

The analysis of adoption of improved fish feeds by access to credit revealed a significant difference between the adopters and non-adopters whereby 17 percent of adopters had access to credit compared to 8 percent of non-adopters. The results further revealed that about 28 percent of adopters received fish feed subsidy compared to 20 percent of non-adopters. This difference was significant and it’s attributed to the reduced cost of fish feeds by the government subsidy which encourages more households to adopt improved agricultural technologies.

TABLE II - MEAN DIFFERENCE OF SOCIO-ECONOMIC AND INSTITUTIONAL CHARACTERISTICS OF ADOPTERS AND NON-ADOPTERS OF IMPROVED FISH FEEDS

Variable	Non-adopters = 0		Adopters = 1			t-test
	Mean	Std. dev	Mean	Std. dev	Mean diff	
Age	46.34	13.012	48.01	14.427	-1.6695	-1.2
Gender	0.762	0.426	0.830	0.376	-0.067*	-1.65
Education	11.34	2.953	12.291	2.582	-0.951***	-3.45
Marital status	0.897	0.305	0.908	0.29	-0.011	-0.35
Occupation	0.144	0.352	0.16	0.368	-0.016	-0.45
Household size	6.629	2.927	6.223	2.6111	0.406	1.464
Experience	6.168	5.516	6.510	4.834	-0.342	-0.65
Non-farm activity	0.294	0.457	0.340	0.475	-0.046	-1
Type of labour	0.830	0.377	0.645	0.479	-0.184***	4.25
Market access	0.881	0.324	0.786	0.411	0.095**	2.55
Land size	1.682	0.801	1.884	0.763	-0.202**	-2.5754
Land Fish production	0.310	0.190	0.280	0.177	-0.030	1.6108
Livestock ownership	0.598	0.492	0.767	0.424	-.169***	-3.7
Price of fish feeds	107.35	76.34	141.71	131.66	-34.36***	-4.6
Farm-gate price fish	408.09	108.37	454.66	89.36	-46.57***	-4.7
Perception fish yield	0.948	0.222	0.958	0.205	-0.008	-0.35
Extension access	0.691	0.463	0.709	0.455	-0.018	-0.4
Credit access	0.083	0.276	0.17	0.376	-0.0875***	-2.65
Group membership	0.32	0.468	0.325	0.47	-0.005	-0.1
Government subsidy	0.196	0.398	0.282	0.451	-0.086**	-2

* p<0.10, ** p<0.05, *** p<0.01 denotes significance at 10%, 5% and 1% respectively, t-test and/ chi-square are used for continuous and categorical variables, respectively.

Econometric Results

Table III presents the maximum log likelihood estimates of the independent double-hurdle model. The Tobit model results were presented together with the double hurdle results for robustness check. The log likelihood ratio of -640.7 for both adoption and intensity equations is significant at 1% hence confirms the reliability of this model. The first hurdle coefficients show how a decision variable influences the probability of adoption of improved fish feeds. The coefficients in the second hurdle specify how decision variables affect the level of use of improved fish feeds. The first hurdle results indicate that market access, household size, fish income, government subsidy, education of household head in years, livestock ownership, type of labour, access to credit, age of household head in years, farm gate price of fish and growing of crops were statistically significant decision variables which influenced the probability of adoption of improved fish feeds. The marginal effects indicate changes in the probability of adoption of improved fish feeds for any additional unit increase in the independent variables.

Access to market negatively and significantly influenced the probability of adoption of improved fish feeds by 69%. This finding suggests that farmers may be accessing the market but not necessarily for purchase of improved fish feeds. This finding might also be due to lack of market information, long distance to the market and high market transaction costs. This result conforms to that of Ogeto *et al*., 2020, who found a negative effect of market access to adoption of improved potato varieties in Ethiopia. However it contradicts the finding of Beshir, 2014, who found market access to have had a positive and significant influence on adoption of improved forages technology.

The results indicate that household size negatively and significantly influenced the probability of adoption of improved fish feeds by 7.4%. The possible reason could be that increase in household size increases the family basic needs expenditure hence reducing on farm expenditure. This could also be attributed to the labour intensiveness of the fish farming enterprise at excavation stage of the fish ponds. This finding is consistent with the findings of Akpan *et al*.(2012) and Adewale Isaac *et al*. (2020) who found out that household size negatively and significantly influenced the probability of fertilizer adoption and adoption of improved technologies and profitability of catfish processors in Ondo State Nigeria respectively. However, the result is contrary to the finding of Mignouna *et al*.(2011) a study that identified a positive and significant influence on adoption of imazapyr-resistant maize for striga control in Western Kenya. A shilling increase in fish income increases the probability of adoption of improved fish feeds by 83.2%. The possible reason for this is that the more the income, the more the money available for farmers to afford and implement new technologies which are quite expensive. This result is consistent with study by Khonje *et al*.(2018) a study which identified increased income to have had a positive relationship with the decision to adopt multiple agricultural technologies.

Availability of government subsidy increased the probability of adoption by 34.1%. The justification for this finding is that government subsidies reduce on the cost incurred on purchase of inputs hence encourage farmers to adopt new technologies. Similar finding was found by Amankwah *et al*.(2018) who found out that subsidy feed positively influenced adoption of fish feed technology. The results indicate that a unit increase in the years of education of the household head increases the probability of adoption of improved fish feeds by 4.2%. The justification for this is that increase in the years of education increases the farmers' ability to obtain knowledge and information on the importance of improved agricultural technologies. This finding is consistent with the finding by Amankwah *et al*.(2018); Amankwah and Quagrainie, 2019; Salau *et al*.(2014), who found a positive relationship between adoption of fish feed technology and education level of household heads. This finding is also consistent with what Alabi *et al*. (2014) found out.

A unit increase in the number of livestock owned increased the probability of adoption of improved fish feeds by 35.8%. This is because livestock is an asset for availability of cash to buy new technologies and it acts as a collateral to access credit which finances the adoption and implementation of the new technologies. This result is similar to the finding of Beshir, 2014, who showed that ownership of livestock was significant and positively influenced the probability of improved forages technology. The result also concurs with the finding of Ogeto *et al*. (2020) who found livestock ownership to have positively influenced adoption of improved potato varieties in Ethiopia. The type of labour (1=family, 0=hired) negatively and significantly influenced the probability of adoption of improved fish feeds by 47.2%. The possible reason is that family labour

TABLE III: DETERMINANTS OF IMPROVED FISH FEEDS' ADOPTION AND INTENSITY OF USE

	Double hurdle				Tobit	
	Hurdle 1		Hurdle 2			
	Probability of adoption: Probit estimator		Intensity of adoption: Truncated estimator		Intensity of adoption: Tobit estimator	
Variable	dy/dx	Std Err	dy/dx	Std Err	dy/dx	Std Err
Market access	-0.687***	0.218	-3.770***	0.792	-2.921***	0.547
HH size	-0.074**	0.031	-0.187*	0.098	-0.172**	0.074
Fish income	0.832***	0.225	1.757**	0.674	1.732***	0.416
Government subsidy	0.341**	0.174	-0.591	0.503	-0.038	0.44
Education	0.042*	0.027	0.163**	0.072	0.132**	0.065
Livestock ownership	0.358**	0.162	1.313**	0.555	1.175***	0.407
Type of labour	-0.472***	0.176	-0.250	0.549	-0.559	0.43
Group membership	-0.223	0.171	-0.886**	0.385	-0.662	0.419
Credit access	0.376*	0.241	-0.115	0.484	0.006	0.567
Marital status	-0.094	0.278	0.311	0.562	0.053	0.67
Extension access	0.048	0.171	1.155***	0.365	0.418	0.427
Age	0.016**	0.007	0.026	0.020	0.033*	0.017
Gender	0.167	0.179	0.400	0.417	0.396	0.434
Experience	-0.022	0.017	-0.114***	0.038	-0.081**	0.04
Land size	-0.007	0.033	-0.065	0.082	-0.04	0.086
Perception fish yield	0.339	0.341	-0.061	0.785	0.611	0.862
Farm gate fish price	0.002***	0.001	0.011***	0.003	0.008***	0.002
Non-farm activity	-0.022	0.162	-0.777**	0.308	-.456	0.393
Grow crops	0.270*	0.164	0.559	0.484	0.777*	0.414
_mill	0		4.245**	1.931		
Observations	400		206		400	
Log likelihood	-640.70232		-640.70232		-1053.6548	
Pseudo R^2	0.1919[a]		0.0674[a]		0.053	
LRChi2	168.39812		149.22183		118.398	
Prob>chi2	0.000		0.000		0.000	

*p<0.10, **p<0.05, ***p<0.01 denotes significance at 10%, 5% and 1% respectively, t-test and/chi-square are used for continuous and categorical variables, respectively; a: represents pseudo R2 from the Double Hurdle first stage results

could have been inadequate hence hired labour required especially at excavation stage which is labour intensive.

Access to credit increased the probability to adopt improved fish feeds by 37.6%. The justification for this is that technologies require heavy funding which the farmers may not afford and therefore farmers who get more access to credit are more likely to adopt because they can now afford to purchase the improved fish feeds. This is consistent with the findings by Jerop *et al*. (2018); Danso-Abbeam *et al*. (2019); Amankwah and Quagrainie, 2019; Thinda *et al*., 2020 on adoption of improved variety of finger millet and conservation tillage, zai technology for soil fertility management, fish feed technology and climate change adaptation strategies respectively. However this result is contrary to the finding of Alabi *et al*. (2014), who found out the credit access negatively influenced adoption of agrochemical inputs.

For each additional year of age, the probability of adoption of improved fish feeds increased by 1.6%. The possible reason for this is that additional years translate into more experience in fish farming making it easy for farmers to understand the benefit of adopting new technologies and hence more experienced farmers are more likely to adopt improved fish feeds. This result conforms to that of Mignouna *et al*. (2011), a study that found a positive and significant effect of age on adoption of imazapyr-resistant maize for striga control in Western Kenya. It is also consistent with the study of Adewale Isaac *et al*. (2020), who found age to have had a positive influence on adoption of improved technologies and profitability of catfish processors in Ondo state, Nigeria. Chen *et al*. (2020) also found a positive effect of age on the intensity of tea consumption among men and women in China. However, this result is inconsistent with the finding of Thinda *et al*. (2020), a study that identified a negative and significant influence of age on adoption of climate change adaptation strategies.

A unit increase in the farm gate price of fish per kilo gram increased the probability of adoption of improved fish feeds by 0.2 %. The justification for this result is that an increase in farm gate price attracts more farmers to adopt improved fish feeds technology knowing that if they adopt they will fetch more money per kilo gram of fish. This finding concurs with the finding of Adewale Isaac *et al*. (2020), a study in which price of fish was found to have positively influenced adoption of improved technologies and profitability of catfish processors in Ondo state, Nigeria. Growing of crops increased the probability of adoption of improved fish feeds by 27%. The possible reason for this could be that crop yields could be easily converted in to cash so as farmers could afford the improved fish feed technology.

The second hurdle results indicate that market access, household size, fish income, education of household head in years, livestock ownership, group membership, access to extension services, experience, farm-gate price of fish and non-farm activities significantly influenced the intensity of using improved fish feeds. The marginal effects show change in the intensity of use of improved fish feeds for any additional unit increase in the independent variables. Market access negatively influenced the intensity of using of improved fish feeds at 1% significant level. This could be due to high transaction costs and lack of market information. This finding is consistent with Beshir, 2014, a study in which market access had a negative influence on intensity of use of improved forages technology.

Household size negatively influenced the intensity of using improved fish feeds by 18.7% at 10% significance level. The possible reason for this could be that the fish farming is labour intensive at initial stages of pond construction. Another reason could be the higher food requirements of the household members which could have been given priority rather than the adoption of improved fish feeds. This result supports the finding by Beshir, 2014; Ketema and Kebede, 2017, who found out that household size had a significant negative influence on intensity of use of improved forages technology and adoption intensity of inorganic fertilizers in maize production, Eastern Ethiopia respectively. This result also concurs with the finding of Adewale Isaac *et al*. (2020), in a study that revealed that household size had a negative and significant influence on adoption of improved technologies and profitability of catfish processors in Ondo state Nigeria. However, this finding is contrary to that of Ogeto *et al*. (2020); Danso-Abbeam *et al*. (2019); Mignouna *et al*. (2011), who found out that household size had a positive influence on the intensity of adoption of improved potato varieties, zai technology for soil fertility management and imazapyr-resistant maize for striga control respectively.

The results show that a unit increase in fish income increased the intensity of using improved fish feeds at 5% significance level. The reason for this could be due to the availability of cash by farmers to buy the improved fish feeds technology. This result is consistent with the finding by Chen *et al*. (2020), who found income to have had a positive and significant effect on the intensity of tea consumption among men and women in China. For each additional year of education, the intensity of using improved fish feeds increased by 16.3%. This could be attributed to the knowledge and information gained through education. This result is consistent with that of Danso-Abbeam *et al*. (2019), that found positive and significant influence of education on intensity of adoption of zai technology for soil fertility management. This finding also concurs with the finding of Chen *et al*. (2020), a study in which education was found to have a positive influence on the intensity of tea consumption among men in China.

Owning livestock by a household, positively influenced the intensity of using improved fish feeds at 5% significance level. This result is consistent with Ketema and Kebede, 2017, a study in which ownership of livestock positively influenced adoption intensity of inorganic fertilizers in maize production. The finding is also consistent with that one of Ogeto *et al*. (2020), a study in which livestock ownership positively influenced the intensity of adoption of improved potato varieties. The possible reason for this could be due to availability of cash through sale of livestock or use of livestock as collateral to acquire credit to purchase the improved fish feeds.

Group membership, negatively influenced the intensity of use of improved fish feeds by 88.6% at 5% significance level. The reason for this could be that farmers join agricultural based groups for other farming enterprises and not necessarily fish farming. This result is consistent with Yigezu *et al*. (2018), who found a negative relationship between cooperative membership and intensity of adoption of agricultural technologies. This result is contrary to the finding of Ogeto *et al*. (2020), who found that membership to a cooperative positively influenced intensity of adoption of improved potato varieties.

Access to extension services positively influenced the intensity of use of improved fish feeds at 1% significant level. This result is similar to the finding of Amankwah and Quagrainie, 2019, in determining the intensity of use of aquaculture feed technology. Diiro (2013) also found out that extension services significantly and positively influenced intensity of use of improved seed. Adewale Isaac *et al*. (2020) also found out that extension services positively influenced the decision to adopt improved technologies and profitability of catfish processors. The possible reason for this finding is that when the farmers get access to extension services which is a major source of information for farmers, they get more informed about improved agricultural technologies.

Experience negatively influenced the intensity of using improved fish feeds by 11.4%. This result does not follow a priori expectation of a positive impact with intensity of use of improved fish feeds. This meant that the farmers used less quantities of improved fish feeds as the years of experience increased. The possible reason for this could be that older farmers did not find it useful to increase the amount of improved fish feeds for lacking motivation any longer leaving it for young people were more valid to intensify the use of improved fish feeds. This results conforms to Mahoussi *et al*. (2021) and Amankwah and Quagrainie, 2019, studies in which experience in years was found to negatively influence the intensity of use of improved maize seeds in Benin and improved fish feeds in Ghana respectively. However it is contrary to that of Adewale Isaac *et al*. (2020), a study in which there was a positive relationship between experience and the intensity of using improved fish processing technologies.

Farm gate price of fish positively influenced the intensity of using improved fish feeds by 1.1%. The possible justification for this result is that increased farm gate price is an incentive for increased income in the farmers' pockets hence motivating them to use improved fish feeds. This finding supports that of Adewale Isaac *et al*. (2020), who found price of fish to have had a positive and significant influence on adoption of improved technologies and profitability of catfish processors in Ondo state, Nigeria. Non-farm activity had negative and significant effect on the intensity of using improved fish feeds by 77.7%.

CONCLUSION AND RECOMMENDATIONS

This study analysed the factors influencing the probability of adoption and intensity of use of improved fish feeds using 400 fish pond farmer households from Western Kenya. Descriptive analysis suggested differences in observed household socio-economic and institutional characteristics between adopters and non-adopters of improved fish feeds, however, these differences were insufficient to explain the factors that influence adoption and intensity of use of improved fish feeds. Therefore, rigorous analysis was done using double hurdle model to estimate the adoption intensity of improved fish feeds. This model showed that the adoption of improved fish feeds and the intensity of use were independent decisions hence treated separately.

The findings indicate that there are differences regarding the factors that determine the two decisions. The factors that influenced the decision to adopt are not necessarily the factors that affected the decision on the intensity of adoption. The results revealed that availability of subsidy, type of labour, access to credit, age of household head in years, and growing of crops significantly influenced the likelihood of improved fish feeds' adoption but had no significant influence on the intensity of use of improved fish feeds. The findings further revealed that group membership, access to extension services, experience, and non-farm activity significantly affected the intensity of use of improved fish feeds but did not explain the likelihood to adopt. The factors that significantly influenced both adoption and intensity of use of improved fish feeds were: market access, household size, fish income, education of household head, livestock ownership and farm-gate price of fish.

Access to market negatively influenced both adoption and intensity of use of improved fish feeds. Farmers could be accessing market but lack information pertaining improved fish feeds and facing the challenge of high market transaction costs. Therefore, efforts that aim at availing market information and reducing market transaction costs are necessary to boost the uptake of improved agricultural technologies. Livestock ownership as a resource endowment of farm households had a positive and significant influence on both adoption and intensity of use of improved fish feeds. This implies that improvement of resource endowment of farmers is likely to boost uptake of improved agricultural technologies.

The positive effect of education on both adoption and intensity of adoption of improved fish feeds imply that government policies which aim at improving education to enhance impartation of knowledge through trainings and capacity building should be reinforced to help more farmers acquire knowledge on the improved agricultural technologies. Policy interventions to increase the price of fish would enhance adoption intensity of improved fish feeds and would increase the fish income for farmers.

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REFERENCES

Adewale Isaac, O., Ibidun Comfort, A., Amos Igbekele, A., and Taiwo Timothy, A. (2020). Adoption of improved technologies and profitability of the catfish processors in Ondo State, Nigeria: A Cragg's double-hurdle model approach. *Scientific African*, *10*. https://doi.org/10.1016/j.sciaf.2020.e00576.

Akpan, S., S. Nkanta, V., amd Essien, U. (2012). A Double-Hurdle Model of Fertilizer Adoption and Optimum Use among Farmers in Southern Nigeria. *Tropicultura*, *30*(4), 249–253.

Alabi, O. O., Territory, F. C., Lawal, A. F., Services, E., Coker, A. A., Technology, E., Awoyinka, Y. A., and Commission, N. P. (2014). *Probit model analysis of smallholder 's farmers decision to use agrochemical inputs in Gwagwalada and Kuje area counsils of federal capital territory , Abuja , Nigeria Omotayo Olugbenga Alabi Department of Agricultural-Economics and Extension , Faculty o*. *2*(1), 85–93.

Amankwah, A., and Quagrainie, K. K. (2019). Aquaculture feed technology adoption and smallholder household welfare in Ghana. *Journal of the World Aquaculture Society*, *50*(4), 827–841. https://doi.org/10.1111/jwas.12544

Amankwah, A., Quagrainie, K. K., and Preckel, P. V. (2018). Impact of aquaculture feed technology on fish income and poverty in Kenya ABSTRACT. *Aquaculture Economics & Management*, *0*(0), 1–21. https://doi.org/10.1080/13657305.2017.1413689

Ansah, Yaw B., and Frimpong, E. A. (2015). Impact of the adoption of BMPs on social welfare: A case study of commercial floating feeds for pond culture of tilapia in Ghana. *Cogent Food and Agriculture*, *1*(1). https://doi.org/10.1080/23311932.2015.1048579.

Ansah, Yaw Boamah. (2014). *Enhancing Profitability of Pond Aquaculture in Ghana through Resource Management and Environmental Best Management Practices*. PhD Dissertation, Virginia Polytechnic Institute and State University

Awity. (2013). On-farm feed management practices for Nile tilapia in southern China. *FAO Fisheries and Aquaculture Technical Paper No. 583*, *1958*(Figure 1), 71–99.

Awuor, F. J., Opiyo, M. A., Obiero, K. O., Munguti, J. M., Abwao, J., Nyonje, B. M., Nevejan, N., and Stappen, G. V. (2021). Aquaculture extension service in Kenya : Farmers and extension officers perspectives. *Journal of Agricultural Extension and Rural Development*, *13*(March), 14–22. https://doi.org/10.5897/JAERD2020.1203

Beshir, H. (2014). Factors Affecting the Adoption and Intensity of Use of Improved Forages in North East Highlands of Ethiopia. *American Journal of experimental Agriculture 4*(1), 12–27.

Busia County. (2018). Integrated Development Plan 2018-2022. *County Government of Busia*, *5*(1), 86–96.

Charo-karisa, H., Munguti, J. M., Musa, S., Orina, P.

S., Kyule, D. N., Opiyo, M. A., Charo-karisa, H., and Ogello, E. O. (2014). An overview of current status of Kenyan fish feed industry and feed management practices , challenges and opportunities. *International Journal of Fisheries and Aquatic studies 1*(6), 128–137.

Chen, L., Guan, X., Zhuo, J., Han, H., Gasper, M., Doan, B., Yang, J., and Ko, T. H. (2020). Application of Double Hurdle Model on Effects of Demographics for Tea Consumption in China. *Journal of Food Quality*, *2020*. https://doi.org/10.1155/2020/9862390

Cocker, L. *Strategic Review on African Aquaculture Feeds*. NEPAD Report March 2014

Cragg, J. G. (1971). Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods. *Econometrica*, *39*(5), 829. https://doi.org/10.2307/1909582

Danso-Abbeam, G., Dagunga, G., and Ehiakpor, D. S. (2019). Adoption of Zai technology for soil fertility management: evidence from Upper East region, Ghana. *Journal of Economic Structures*, *8*(1), 1–14. https://doi.org/10.1186/s40008-019-0163-1

De Janvry, A., and Sadoulet, E. (2002). World poverty and the role of agricultural technology: Direct and indirect effects. *Journal of Development Studies*, *38*(4), 1–26. https://doi.org/10.1080/00220380412331322401

Diiro, G. M. (2013). Impact of Off-farm Income on Agricultural Technology Adoption Intensity and Productivity. *Agricultural Economics*, 1–15. http://citeseerx.ist.psu.edu/ viewdoc/summary?doi=10.1.1.303.3390

FAO. (2018). The state of food security and nutrition in the world. *Fao Office for Corporate Communication*. *FAO PUBLIC*, ISBN 978-92-5-109888-2 128 pp. www.fao.org/publications

García, B. (2013). Implementation of a double-hurdle model. *Stata Journal*, *13*(4), 776–794. https://doi.org/10.1177/1536867x1301300406

Government of Kenya. (2018a). *CIDP Bungoma*.

Government of Kenya. (2018b). *Government of Kenya*.

Government of Kenya. (2018c). *Kisumu_CIDP_2018-2022_County-Integrated-Development-Plan*. 254.

Hanemann, M., Loomis, J., and Kanninen, B. (1991). Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation. *American Journal of Agricultural Economics*, *73*(4), 1255–1263. https://doi.org/10.2307/1242453

Jerop, R., Dannenberg, P., Owuor, G., Mshenga, P., Kimurto, P., Willkomm, M., and Hartmann, G. (2018). *Factors affecting the adoption of agricultural innovations on underutilized cereals : The case of finger millet among smallholder farmers in Kenya*. *13*(36), 1888–1900. https://doi.org/10.5897/AJAR2018.13357

Kassam, L. (2013). Assesing the contribution of Aquaculture to poverty reduction in Ghana .thesis University of London

Ketema, M., and Kebede, D. (2017). *Adoption Intensity of Inorganic Fertilizers in Maize Production : Empirical Evidence from Smallholder Farmers in Eastern Ethiopia Adoption Intensity of Inorganic Fertilizers in Maize Production : Empirical Evidence from Smallholder Farmers in Eastern Ethi*. *January*. https://doi.org/10.5539/ jas.v9n5p124

Khonje, M. G., Manda, J., Mkandawire, P., Tufa, A. H., and Alene, A. D. (2018). Adoption and welfare impacts of multiple agricultural technologies: evidence from eastern Zambia. *Agricultural Economics (United Kingdom)*, *49*(5), 599–609. https://doi.org/ 10.1111/agec.12445

KMFRI. (2017). *Kenya's Aquaculture brief 2017: Status, trends, challenges and future outlook*. 12. http://www.kmfri.co.ke/images/pdf/Kenya_Aquaculture_Brief_2017.pdf

Mahoussi *et al*. (2021). *Modeling the Adoption and use Intensity of Improved Maize*. *21*(4), 17931–17951.

Mignouna, D. B., Manyong, V. M., Mutabazi, K. D. S., and Senkondo, E. M. (2011). Determinants of adopting imazapyr-resistant maize for Striga control in Western Kenya : A double-hurdle approach. *Journal of Development and Agricultural Economics*, *3*(11), 572–580.

Obiero, K. O., Waidbacher, H., and Nyawanda, B. O. (2019). *Predicting uptake of aquaculture technologies among smallholder fish farmers in Kenya*.

Ogeto, M., Mohammed, J., and Bedada, D. (2020). Adoption of improved potato varieties in jeldu district, oromia region, Ethiopia: a double-hurdle model. *International Journal of Agricultural Research, Innovation and Technology*, *9*(2), 15–22. https://doi.org/10.3329 /ijarit.v9i2.45405

Republic of Kenya. (2018). County Integrated Development Plan Siaya county. *Encyclopedia of Public Administration and Public Policy, Second Edition (Print Version)*, 292.

Salau, E. S., Lawee, A. Y., Luka, G. E., and Bello, D. (2014). *Adoption of improved fisheries technologies by fish farmers in southern agricultural zone of Nasarawa State , Nigeria*. *6*(11), 339–346. https://doi.org/10.5897/JAERD13.0565

Thinda, K. T., Ogundeji, A. A., Belle, J. A., and Ojo, T. O. (2020). Understanding the adoption of climate change adaptation strategies among smallholder farmers: Evidence from land reform beneficiaries in South Africa. *Land Use Policy*, *99*(January), 104858. https://doi.org/10.1016/j.landusepol.2020.104858

Yigezu, Y. A., Mugera, A., El-Shater, T., Aw-Hassan, A., Piggin, C., Haddad, A., Khalil, Y., and Loss, S. (2018). Enhancing adoption of agricultural technologies requiring high initial investment among smallholders. *Technological Forecasting and Social Change*, *134*(April), 199–206. https://doi.org/10.1016/j.techfore.2018.06.006