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ANIMAL HUSBANDRY & VETERINARY SCIENCE | RESEARCH ARTICLE

An assessment of pig feed diversity amongst smallholder pig farmers in Northern Uganda

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Abstract: Pig production has a high potential for increasing household incomes of both rural and urban smallholder farmers. However, this opportunity is constrained by the high cost of feeds and its scarcity. As such, farmers usually feed pigs on multiple feed resources within their reach. Although the diversity of pig feeds is important in overcoming the challenges, there is limited information on how this can be achieved, and the factors influencing it. Using a cross-section of 240 pig farming households, this study assessed how socio-demographic, technical and institutional factors influenced household pig feed diversity. Statistical analysis was performed at $p < 0.1$, $p < 0.05$ and $p < 0.01$), respectively. Results showed that marital status ($p = 0.012$), household size ($p = 0.085$), number of crop ($p = 0.008$) and other livestock enterprises ($p = 0.055$), ownership of mobile phone ($p = 0.091$), buying feeds ($p = 0.005$), and use of radio ($p = 0.032$) and friend as sources ($p = 0.002$) of agricultural information had a positive significant influence on household pig feed diversity. Additionally, age ($p = 0.042$), land size owned ($p = 0.085$) and breed [rearing local ($p = 0.009$) and crosses ($p = 0.000$) as opposed to exotic breeds] had a negative significant influence on household pig feed diversity. The study recommends that focus should be placed on improving access to farm inputs, agricultural and market information for smallholder pig farmers so as to

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PUBLIC INTEREST STATEMENT

Pig production is an economical important venture for most smallholder farmers in developing countries. Feeding however has remained a challenged, with feed scarcity and high cost of most feed resources discouraging many potential farmers. As away forward, many farmers use several different feeds resources acquired from different sources, mainly purchase, own production and gathering. It is therefore common for farmers to feed pigs on several feed resources. This study provides an assessment of pig feed diversity with focus on factors influencing the diversity of feed resources in smallholder farm. Pig feed diversity is critical in ensuring that pigs obtained a balanced combination of nutrients. Consequently, findings from this study will go a long way to inform investments in the sector, by providing critical information on pig feed diversity in a smallholder setting.

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improve pig feed diversity and subsequently enhance production and productivity. Radio and mobile phone technologies are opportunities that can support information sharing.

Subjects: Agriculture & Environmental Sciences; Agricultural Economics; Environment & Resources

Keywords: Smallholder pig production; feed resources; diversity; Uganda

1. Introduction

The pig sub-sector has recently gained prominence as a sector with potential to significantly improve the incomes smallholder farmers in sub-Saharan Africa. Consequently, the total pig populations in Africa has increased from about 17 million in 1990 to over 40 million pigs in 2018, with over 17 million in Eastern Africa (FAO, 2020). In Uganda, total pig numbers increased from 3.2 million in 2008 to over 4.1 million in 2017 (UBOS, 2009, 2019). The increase in pig populations in Uganda is attributed to many factors that make the enterprise more appealing to both rural and urban smallholder farmers. Pigs can be reared within a relatively small piece of land as opposed to other livestock including cattle, goats and sheep (Ndyomugyenyi & Kyasimire, 2015; Tatwangire, 2014). Pigs are also capable of farrowing over two times annually with an average litter size of at least 10 piglets per farrowing (Tatwangire, 2014), in addition to relatively low pre-weaning mortality rates of less than two, piglets per farrowing (Okello et al., 2015).

There has also been an increase in demand of pigs and pig products as a result of the increasing population, coupled with increased per capita consumption of pork. The current per capita consumption of pork for Uganda is 3.3 kg (FAO, 2020). This estimate is likely to increase given the projected increase in population. Uganda's population is projected to reach 63 million by 2030 and 105 million by 2050 (UN, 2017). Additionally, projections by the Organization for Economic Co-operation and Development (OECD) and the United Nations Food and Agriculture Organization (FAO) shows a deficit in pig production to meet increasing demand for pork in most developing countries (OECD/FAO, 2019). This projected increase in demand for pig products would require a considerable increase in production largely from smallholder farmers who are the majority of the pig producers in developing countries (Otte et al., 2012) including Uganda (Ouma et al., 2014; Tatwangire, 2014).

Despite the benefits of pig farming and its potential for improving incomes of smallholder farmers, the sub-sector has been faced with an enormous challenge of providing pigs with adequate feeds for optimal growth (Ouma et al., 2015; Tatwangire, 2014). As a consequence, a number of potential pig farmers have been discouraged from the sub-sector (Mbuthia et al., 2015), while, those who are already in sub-sector cannot competitively and sustainably expand their operations for fear of increasing production cost beyond their capacity (Tatwangire, 2014). As such, the prospects of increasing production to match the increasing demand is being eroded. Obtaining feeds in the right quality and quantity for optimal pig production is increasingly becoming a challenge for most smallholder farmers due to two main factors.

First, is the high cost of feeds (Katongole et al., 2012) which disproportionately affects differently capital constrained smallholder farmers (Otte et al., 2012; Tatwangire, 2014). Feeding accounts for over 60–80 % of the total cost of production in most pig production systems (Ouma et al., 2015) and this impacts on incomes from the sector. The high cost of feeds is further exacerbated by the market inefficiencies common in developing countries that do not allow smallholder farmers to compete favourably with traders (Otte et al., 2012), and the seasonality of most feed ingredients (Ouma et al., 2015; Tatwangire, 2014). Studies have showed that seasonal feed scarcity attributed to droughts is responsible for the variation in pig supply to markets (Atherstone et al., 2019; Roesel et al., 2019). Second, there is an increasing scarcity of pig feeds as a result of the increasing uses of

most conventional and commercial feed resources (Tatwangire, 2014). In addition to competing feed demand among livestock for most of the conventional feed resources (between piggery and poultry), there is also competing demand for feed resources between livestock and human uses (Katongole et al., 2012; Ouma et al., 2015) especially observed for maize, soybeans and fish. this is a concern as it drives feeds prices to levels that are usually not affordable to smallholder farmers for optimal feeding.

Consequently, smallholder farmers have devised ways of addressing this challenge by adopting the use of locally available feed resources in addition to conventional and commercial feeds. Smallholder farmers feed their pigs with feeds that they can afford through purchase, production or simply gathering (Carter et al., 2017; Katongole et al., 2012; Lumu et al., 2013; Mutua et al., 2012; Roesel et al., 2019). The smallholder pigs' feed profile which includes conventional feeds, leftover food (swill), plant products and by-products of agro-processing are thus highly diversified. This feed diversification is important in addressing the feeding challenge especially among resource constrained smallholder farmers. Studies conducted by Middelkoop et al. (2018); (2019)) showed that pig feed diversity was seen to improve pig performance post weaning. Feed diversification is important in ensuring that farm animals are supplied with nutrients in the right quality and quantity for better growth and productivity (Kaufmann et al., 2016). Jarrett and Ashworth (2018) observed that providing pigs with diverse sources of fibre improved their reproductive performance. Additionally, using diverse feeds on farm is seen as a sustainable strategy of reducing feed cost while ensuring that pigs obtained adequate nutrients (Levy et al., 2014).

Whereas pig feed resource diversification is important, there has been limited attention to its socio-economic and institutional drivers, and yet there are several feed resources that can be utilized for feeding pigs by smallholder farmers (Katongole et al., 2012; Lumu et al., 2013; Roesel et al., 2019). Understanding these socio-economic drivers is specifically important since there are several pig feeds resources that may be equally available to most smallholder farmers, and yet different farmers choose to use different combinations of feed resources. This study assessed these socio-demographic, technical and institutional determinants of smallholder pig feed diversity.

2. Materials and methods

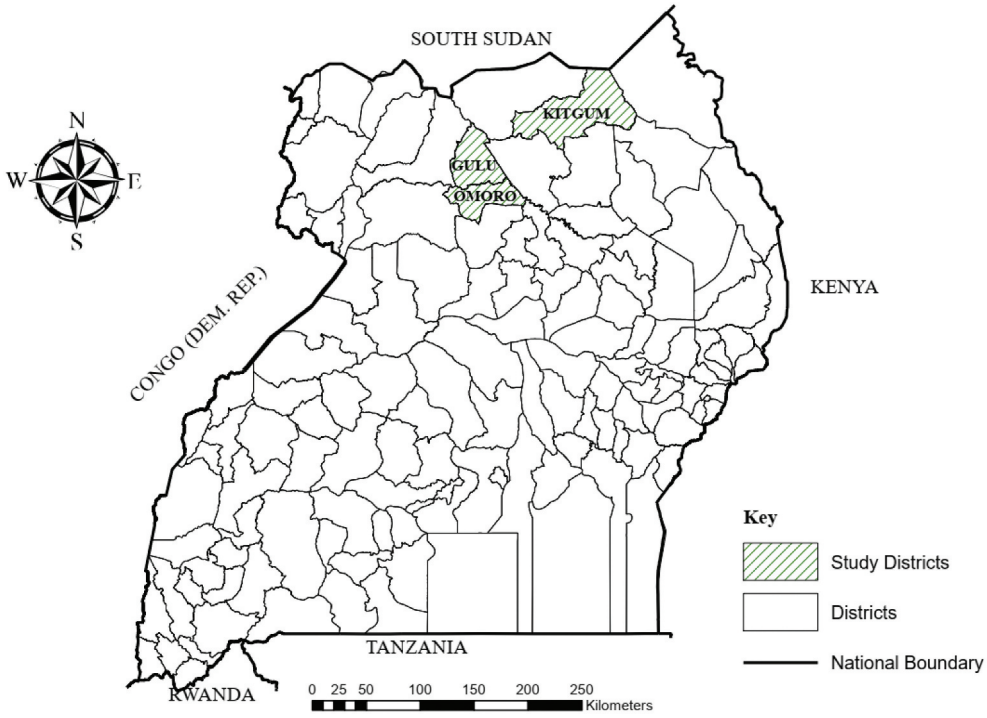
2.1. Study area

This study was conducted in Gulu, Kitgum and Omoro districts in the Acholi sub-region of northern Uganda (Figure 1). Over 80% of households in these districts derive their livelihood from agriculture (UBOS, 2016). The three districts were purposively selected given the potential of the piggery sub-sector in improving incomes of smallholder farmers. In all these districts, piggery is undertaken by most farmers as a commercial enterprise. The districts are home to 16% of pigs (UBOS, 2019), and 13% of all pig rearing households (Tatwangire, 2014) in Northern Uganda. Northern Uganda is home to only 13% of the total pig population in Uganda (UBOS, 2019).

2.2. Data collection

The study adopted a cross-sectional design with a sample of 240 smallholder pig producing households. This sample size was determined following recommendations of the district production officers on sub counties with high concentration of pig farmers in the study area and on pig farmers who met the inclusion criteria. The inclusion criteria were that the pig farmer must have been consistently rearing pigs for at least the last one year. This was important in that smallholder pig farmers tend to drop out of pig rearing and drop in again after a period of rest. The study was interested in those who had pigs at the time of data collection, and had been rearing for at least one year. The sampling followed a multi-stage approach. From the purposively selected study districts, eight sub-counties were purposively selected to be included in the study. Prior to the interviews, each respondent was taken through a brief on why the study was being conducted before being asked to give consent.

Figure 1. Map of Uganda showing the study districts.



Data was collected using a structured interviewer-administered questionnaire. The questionnaires were administered to only those who consented to participate in the study. The questionnaire contained questions related to socioeconomic characteristics, pig production related variables including feeds resources used and feeding management, and factors that can influence pig feeding on farm. The questions focussed on information from the previous one year of production. The questionnaire was pretested before data collection and appropriate adjustments made before producing the final version. Data was collected between March and April, 2018.

2.3. Data analysis

The collected data was entered into SPSS spreadsheet and cleaned prior to analysis. The SPSS dataset was later exported to STATA v14 where inferential and econometric analysis was conducted. Pig feed diversity was defined as the physical count of the number of pig feed resources used by a given farm household. Using the median as mid-point, a binary dependent variable for feed resource diversity was generated, categorizing the feed diversity as low and high, respectively. The mean comparison t-test was used to assess differences in means of various farmers characteristics with respect to low and high pig diversity categories. Similarly, the chi-square test of association was used to assess significance of association between categorical farmers characteristics and the pig feed diversity categories. In order to assess the determinants of smallholder pig farming household pig feed diversity, a Poisson Regression Model (PRM) was estimated.

The PRM was appropriate since it models count dependent variables (in this case, the physical count of feed resources used on farm) against several explanatory variables (which in this study included a number of socio-demographic, technical and institutional factors). Studies with similar specifications of the dependent variable have also previously used the PRM approach. For example, Mwololo et al. (2019) estimated the effects of extension type on farm diversity using the PRM approach, while, Sibhatu et al. (2015) used it to assess the association between production diversity and dietary diversity. In both cases, the dependent variables were count variables.

Table 1. Description of variables for the Poisson Regression Model

Variable	Description	*A priori*
Feed resource diversity	Dependent variable, physical count of pig feed resources used on farm	NA
Socio-demographic factors		
Location	Dummy for location of farmer (1 = urban, 0 = rural)	
Age	Age of farmer (years)	±
Experience	Pig production experience (years)	-
Land size	Total land size own/accessible to farmer in acres	+
Education	Number of years of formal education	±
Married	Farmer is married (1 = yes, 0 = no)	±
Household size (farm)	Number of household members involved in farming	+
Dependency ratio	Ratio of non-earning household members to total household size	
Technical factors		
Pig herd size	Number of pigs on farm	+
Crop enterprises	Number of crop enterprises on farm	+
Others livestock	Tropical livestock units (TLUs) (TLU conversion factors: Cattle = 0.5, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01, other birds = 0.03, and rabbits = 0.02 (Tatwangire, 2014)).	+
Local breed	Farmers rears local breed (1 = yes, 0 = no)	
Cross breed	Farmers rears cross breed (1 = yes, 0 = no)	+
Exotic breed	Farmers rears exotic breed (1 = yes, 0 = no)	+
Institutional factors		
Extension	Access to Extension (1 = yes, 0 = no)	+
VSLA	Membership to a village savings and loan association (VSLA) (1 = yes, 0 = no)	+
Bought feeds	Farmer bought feeds and/or feed ingredients in the last one year (1 = yes, 0 = no)	±
Telephone	Farmers owns a mobile phone (1 = yes, 0 = no)	±
Radio	Farmers source of agricultural information is radio (1 = yes, 0 = no)	
Farmers' organization	Farmers source of agricultural information is farmers organization (1 = yes, 0 = no)	±
Friends	Farmers source of agricultural information is friends and other farmers (1 = yes, 0 = no)	+
Government and NGOs	Farmers source of agricultural information is Government and NGO staff (1 = yes, 0 = no)	±

According to Cameron and Trivedi (2005), count data have the characteristic of being concentrated within a small discrete range, are highly skewed (usually to the right) and are usually "intrinsically heteroskedastic". Such data therefore follows the Poisson distribution instead of the Standard Normal Distribution as required for the OLS estimator (Wooldridge, 2016). The Poisson distribution is specified as in equation (1).

$$\Pr[Y = y_i|x_i] = \frac{e^{-\mu_i}\mu_i(x)^{y_i}}{y_i!}, y = 0, 1, 2, 3, \ldots\ldots. i = 1, 2, \ldots\ldots\ldots., N \quad (1)$$

Where; Pr is the conditional probability of y given x, μ is the rate parameter with an equidispersion property. y represents the count of the dependent variable which is number of pig feed resources used by the ith farm household. N represents the sample size. By parameterizing the relation between μ and the regressors x, the PRM is derived as specified as in equation (2).

$$E(y_i|x_i) = var(y_i|x_i) = \mu_i = \exp(\alpha + X'\beta + u) \quad (2)$$

Where α is the regression coefficient, β is a vector of parameters to be estimated, u is the error term and X represents a vector of explanatory variables that can influence the dependent variable. Table 1 describes the explanatory farm specific variables used in this study and their *a priori* expectations. The PRM was estimated using the maximum likelihood estimator (MLE) with the assumption that conditional probabilities are independent. The log likelihood function estimated is thus specified in equation (3).

$$lnL(\beta) = \sum i = 1Ny_iXi\beta - \exp XiB - lny_ii. \quad (3)$$

Since the PRM is estimated using the MLE, its coefficients do not reflect the direct effect of changes in the explanatory variable on the dependent variables (Cameron & Trivedi, 2005). To obtain the direct effect of changes in the explanatory variable on pig feed diversity, the marginal effects were estimated following equation (4).

$$\frac{\partial E[y|X]}{\partial x_j} = \beta_j \exp(X'B) \quad (4)$$

An assessment of the model was done using post-estimation diagnostics. Following a significant post estimation test for heteroskedasticity, the PRM was estimated with robust standard errors to control for heteroskedasticity (Wooldridge, 2016). On the other hand, post estimation test for unequal dispersion assumption which requires that the mean to variance ratio should equal to one, and the Pearson statistics were all not significant which makes the model appropriate. To show significance, the actual p-values were presented in the table of results. However, the interpretation of the p-values was at three alpha levels of $p < 0.1$, $p < 0.05$ and $p < 0.01$ which ever was appropriate.

3. Results

3.1. Feed resources used by smallholder pig farmers

Twenty-two different feed resources and/or ingredients were identified (Table 2). Fresh cassava tubers were being fed to pigs by about 73% of the farmers (n = 240). Similarly, over 68% of the farmers fed their pigs with fresh sweet potato vines. Additionally, rice bran, amaranth, wondering Jew and Maize bran each had more than 45% of the farmers using them as feeds for their pigs. Only 7% of the farmers reported using formulated feeds.

3.2. Source of feeds resources

In this study, three sources of pig feeds were identified, namely: market purchase, own production and gathering. Most of the feeds were acquired from more than one source. Maize bran, rice bran, fish and blood meal, cabbage, sunflower seed cake as well as formulated feeds were mainly

Table 2. Feed resources reported by pig farmers

Feed resource	Description/scientific name	Percent (*n* = 240)
Cassava	Fresh Cassava tubers, *Manihot esculenta*	72.9
Sweet potato vines	Fresh sweet potato vines, *Ipomoea batatas*	67.9
Rice bran	By-product of rice (*Oryza sativa*) milling	61.3
Pig weed	*Amaranthus retroflexus*	52.5
Wondering Jew	*Tradescantia zebrina*	51.7
Maize bran	By-product of maize (*Zea mays*) milling	45.8
Sweet potato	Fresh sweet potato tubers, *Ipomoea batatas*	32.5
Kitchen waste/food residues	Household human food residue	19.2
Sunflower seed cake	By-product of sunflower (*Helianthus*, spp.) milling	13.8
Brewers waste	By-product of alcohol brewing	13.3
Cassava peels	Fresh cassava peels, *Manihot esculenta*	10.4
Formulated feeds	Formulated feeds, purchased or otherwise	7.1
Cassava leaves	Fresh cassava leaves, *Manihot esculenta*	4.2
Cabbage	*Brassica oleracea*	4.2
Whole maize	*Zea mays*	2.9
Succulent grass	Consist of different grass species that are in succulent stage	2.9
Fish and blood meal	Silver fish (*Lepisma saccharina*) and dried blood from other livestock	2.9
Pawpaw (fruit/leaves)	Fruits and leaves of *Carica papaya*	2.1
Milk weed	*Asclepias syriaca*	2.1
Mineral premix	Mineral premix	1.7
Chicken droppings	Chicken droppings from chicken houses	0.4

acquired through market purchase, although some farmers formulated their feeds from home. On the other hand, fresh cassava and its leaves and peels, fresh sweet potato and vines, whole maize and kitchen waste were obtained from the farmer's own production. Similarly, milk weed, succulent grass, chicken droppings, wondering Jew, and amaranth were acquired through gathering from the homestead and nearby bushes (Figure 2).

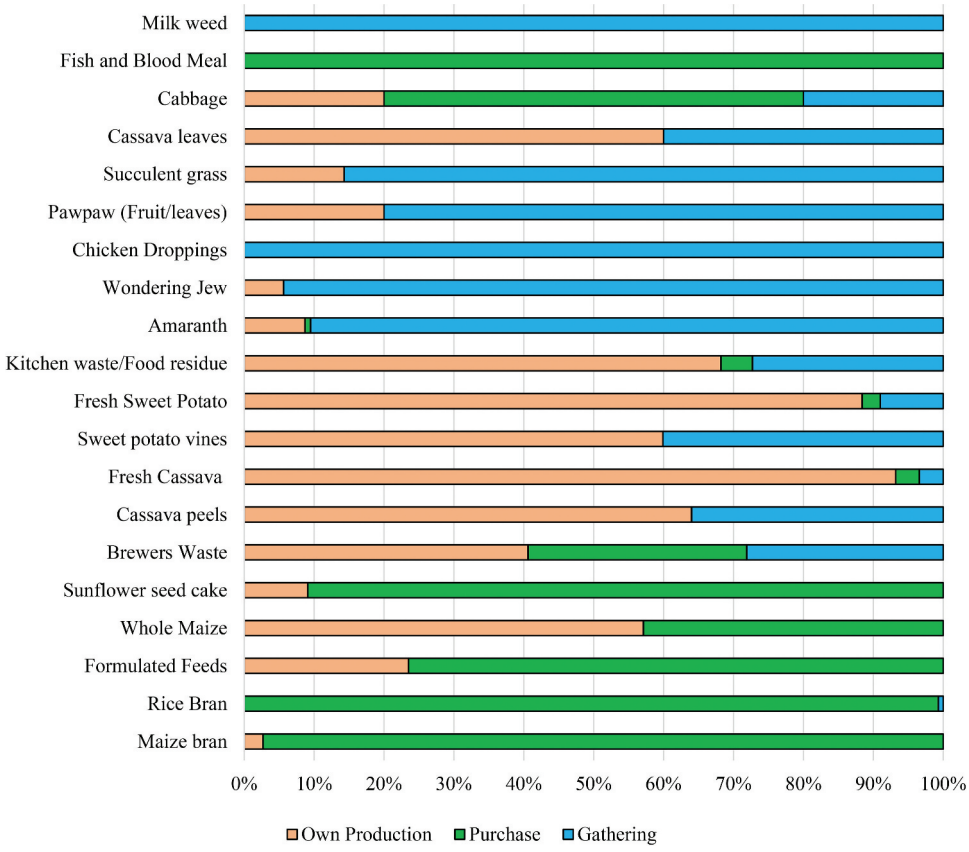
3.3. Feed resource diversity

The number of feed resources used by smallholder pig farmers in this study (pig feed diversity) is presented in Figure 3. Over 31% of the household were using four different types of pig feed resources. Over 19% and 17% of the households were using five and three different types of pig feed resources, respectively. Pig feed diversity ranged from 1 to 12, with a median of four.

3.3.1. Feed resource diversity and farmers characteristics

A summary of the farmer characteristics is presented in Table 3, for the overall sample (n = 240) as well as by the pig feed diversity levels of high (n = 111) and low (n = 129). The overall mean age

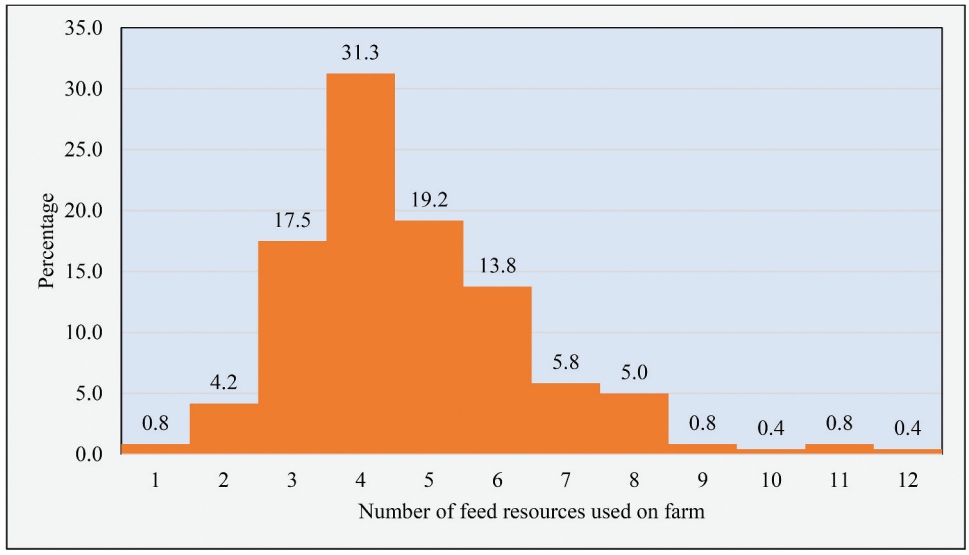
Figure 2. Sources of feed resources for smallholder pig farmers.



was 37.6 (SD = 13.6) years. Farmers that did not diversify their pig feeds were much older (mean = 39.1 years, SD = 14.7) than those who diversified (mean = 35.9 years, SD = 12.1) ($p = 0.03$). The pig farmers had on average 4.0 (SD = 3.6) and 17 (SD = 12.6) years of pig production and farming experiences, respectively. Pig production experience is experience associated with pig production, while farming experience is experience associated with involvement in all primary agricultural activities including both livestock and crop production. Although there was no significant difference in pig production experience for both categories, farmers with low pig feed diversity had significantly ($p = 0.003$) higher farming experience than those with high pig feed diversity by a difference of 4.5 years. The mean land size owned was 6.7 (SD = 8.7) acres. Farmer that did not diversity their pig feeds had significantly more land (mean = 7.8 acres, SD = 10.9) than those that diversified (mean = 5.5 acres, SD = 4.8) ($p = 0.024$).

The mean household dependency ratio (the ratio of non-earning household members to total household size) was 0.41, with, households in the low pig feed diversity category with average dependency ratio of 0.44 (SD = 0.19) having significantly (p = 0.018) higher dependency ratio than those in the high pig feed diversity category that had average dependency ratio of 0.38 (SD = 0.21). The average pig herd consisted of five pigs with no significant difference pig farmers in the high or low pig feed diversity. All the households were involved in production of crop enterprises. The mean number of crop enterprises on each farm was 6 enterprises. Households in the low pig feed diversity category had a significantly ($p = 0.000$) lower number of crop enterprises being cultivated on farm by an average of 1.2 crops, than those in the high pig feed diversity category. Pig farmers were also involved in rearing other livestock breeds including cattle, goats, chicken and ducks, with mean TLU of 1.52 units. Households in the low pig feed

Figure 3. Frequency distribution of pig feed diversity.



diversity category had a significantly (p = 0.041) lower TLUs that those with high pig feed diversity category, by an average of 0.51 units.

About 59% of the households were located in the rural areas, 75% of the household heads were married, while, 85% of the households were male headed. More than half of the households were rearing local pig breeds. There was a significant (p = 0.000) association between pig breed reared and pig feed diversity. Specifically, farmers rearing local pigs were less likely to diversify their pigs. Over 35% of the households reared pigs extensively, with a significant association (p = 0.053) between pig feed diversity and production system. Over 85% of households did not have access to pig production-related agricultural extension services, while over 59% of the farmers were members of a farmers' association. Access to extension (p = 0.052) and membership (p = 0.010) to an association had significant relationship with pig feed diversity. Households who did not have access to extension services were more likely to belong to the category with low pig feed diversity, while, farmers who were members of an association were more likely to belong to the category of high pig feed diversity. Results also showed that over 82% of the households were purchasing some or all of the feed resources used for feeding their pigs, with a significant association between buying feeds and feed diversity (p = 0.029). Households with low pig feed diversity were less likely to buy feeds.

3.3.2. Determinants smallholder pig feed resource diversity

Poisson regression was run to determine factors associated with smallholder pig feed diversity (Table 4). Results showed that a number of socio-demographic, technical and institution factors had significant influence on household pig feed diversity at different levels of significance. Specifically, marital status of household head (p = 0.012), number of household members involved in farming (p = 0.085), crop enterprise diversity (p = 0.008), other livestock species measured as tropical livestock units (p = 0.055), dummy for buying feeds (p = 0.005), ownership of mobile phone (p = 0.091), radio as source of agricultural market information (p = 0.032) and friends as a source of agricultural and market information (p = 0.002) had a positive and significant influence on pig feed diversity in the household.

Contrarily, age of household (p = 0.042) and land size owned (p = 0.085) had negative significant influence on pig feed resource diversity (Table 4). Breed of pigs kept on farm also had a significant influence on feed diversity with farmers with local (p = 0.009) and cross (p = 0.000) breeds having a relatively low feed diversity as opposed to those with exotic breeds. Factors including farmers location (urban/rural), pig production experience, education, pig herd size, access to extension,

Table 3. Comparing farmers characteristics based on level of pig feed diversity

Variables	Category/ units	Mean (SD)/frequency (percentages)			t/χ^2 statistic	*p*-value
		Overall	Low diversity (*n* = 129)	High diversity (*n* = 111)		
Age	Years	37.60 (13.63)	39.06 (14.72)	35.90 (12.09)	1.794**	0.037
Education	Years	7.66 (4.17)	7.47 (4.09)	7.89 (4.26)	−0.790	0.215
Pig production experience	Years	3.98 (3.63)	4.24 (3.67)	3.68 (3.56)	1.198	0.116
Farming experience	Years	17.23 (12.62)	19.31 (13.80)	14.82 (10.65)	2.787***	0.003
Land owned	Acres	6.73 (8.72)	7.76 (10.95)	5.54 (4.79)	1.984**	0.024
Household size	Number	8.25 (4.31)	7.98 (3.74)	8.55 (4.90)	−1.012	0.156
Dependency ratio	Ratio	0.41 (0.20)	0.44 (0.19)	0.38 (0.21)	2.100**	0.018
Pig herd size	Number	5.33 (4.20)	5.01 (4.14)	5.69 (4.26)	−1.263	0.104
Crop enterprise diversity		6.43 (2.37)	5.89 (2.26)	7.05 (2.36)	−3.865***	0.000
Other livestock	TLU	1.52 (2.20)	1.29 (2.09)	1.78 (2.30)	−1.742**	0.041
Location	Rural	141 (58.75)	81 (33.75)	60 (25.00)	1.879	0.170
	Urban	99 (41.25)	48 (20.00)	51 (21.25)		
Marital status	Otherwise	60 (25.00)	35 (14.58)	25 (10.42)	0.676	0.411
	Married	180 (75.00)	94 (39.17)	86 (35.83)		
Sex of household head	Male	203 (84.58)	105 (43.75)	98 (40.83)	2.174	0.140
	Female	37 (15.42)	24 (10.00)	13 (5.42)		
Breed	Local	123 (51.25)	82 (34.17)	41 (17.08)	33.257***	0.000
	Crosses	48 (20.00)	30 (12.50)	18 (7.50)		
	Exotic	69 (28.75)	17 (7.08)	52 (21.67)		
Production system	Extensive	84 (35.00)	54 (22.50)	30 (12.50)	5.886*	0.053
	Semi-ntensive	75 (31.25)	35 (14.58)	40 (16.67)		
	Intensive	81 (33.75)	40 (16.67)	41 (17.08)		
Access to extension	No	204 (85.00)	115 (47.92)	89 (37.08)	3.763*	0.052
	Yes	36 (15.00)	14 (5.83)	22 (9.17)		
Membership to association	No	99 (41.25)	63 (26.25)	36 (15.00)	6.625**	0.010
	Yes	141 (58.75)	66 (27.50)	75 (31.25)		
Farmer buys feed	No	42 (17.50)	29 (12.08)	13 (5.42)	4.792**	0.029
	Yes	198 (82.50)	100 (41.67)	98 (40.83)		

In the case of continuous variables, means are presented with standard deviation in brackets, while the case of categorical variables, frequencies are presented with percentages in brackets.

*, **, and *** implies significance at $p < 0.1$, $p < 0.05$ and $p < 0.01$ level of significance, respectively.

VSLA membership, household dependency ratio, and farmers organization, government and non-governmental organizations (NGOs) as source of agricultural and market information had no significant ($p > 0.1$) influence on household pig feed diversity.

Table 4. Determinants of smallholder feed resource diversity

Feed resource diversity	Poisson regression			Marginal effects		
	Coef.	SE	*p* > *z*	dy/dx	SE	*p* > *z*
Socio-demographic factors						
Location (1 = urban)	0.071	0.043	0.099	0.330	0.202	0.102
Log age	−0.105**	0.051	0.042	−0.482**	0.236	0.041
Log pig production experience	−0.016	0.039	0.681	−0.073	0.179	0.681
Log land size owned (acres)	−0.058*	0.034	0.085	−0.267*	0.155	0.085
Education	−0.008	0.006	0.186	−0.037	0.028	0.187
Married	0.111**	0.044	0.012	0.498**	0.192	0.010
Household members involved in farming	0.153*	0.089	0.085	0.706*	0.410	0.085
Household dependency ratio	−0.157	0.108	0.144	−0.725	0.496	0.144
Technical factors						
Pig herd size	0.002	0.005	0.686	0.009	0.023	0.686
Crop enterprise diversity	0.024***	0.009	0.008	0.113***	0.043	0.008
Others livestock (TLU)	0.071*	0.037	0.055	0.327*	0.171	0.056
Breed (base = exotic)						
Local breed	−0.147***	0.056	0.009	−0.679***	0.260	0.009
Cross breed	−0.248***	0.052	0.000	−1.063***	0.209	0.000
Institutional factors						
Access to extension	0.020	0.057	0.729	0.092	0.267	0.731
VSLA membership	0.008	0.040	0.839	0.038	0.185	0.839
Bought feeds	0.162***	0.058	0.005	0.711***	0.239	0.003
Ownership of phone	0.071*	0.042	0.091	0.324*	0.191	0.090

(*Continued*)

Table4. (*Continued*)

Feed resource diversity	Poisson regression			Marginal effects		
	Coef.	**SE**	***p > z***	**dy/dx**	**SE**	***p > z***
Radio is source of information	0.093**	0.044	0.032	0.426**	0.197	0.031
Farmers organization	0.016	0.046	0.717	0.076	0.212	0.719
Friends	0.126***	0.040	0.002	0.578***	0.184	0.002
Government and NGOs	0.051	0.057	0.375	0.239	0.274	0.383
Constant	1.531	0.256	0.000			
Log pseudolikelihood	−449.630					
Wald chi2(21)	177.39		0.000			
Deviance goodness-of-fit	92.067		1.000			
Pearson goodness-of-fit	93.488		1.000			

N = 240; Mean VIF = 1.39; Highest VIF = 2.04, Exotic breed was base category during analysis; SE = standard error, dy/dx = change in feed diversity as a result of a unit change in the x–variable (the marginal effect). *, **, and *** implies significance at $p < 0.1$, $p < 0.05$ and $p < 0.01$, respectively.

4. Discussion

This study measured pig feed diversity as a physical count of the number of feed resources given to the pigs on a given farm. An alternative to this approach was an index that accounts for the quantity of each feed resource used (a weighted index), but this could not be possible given that, in most smallholder production systems, farmers do not usually weigh feed given to pigs. Such detail is usually unavailable for most smallholder operations. Additionally, there is evidence that a simple count index when estimated with the PRM, gives results consistent to estimates of weighted indices estimated using the appropriate technique (Islam et al., 2018; Pellegrini & Tasciotti, 2014; Sibhatu et al., 2015; Sibhatu & Qaim, 2018). Consequently, using the PRM, the findings of this study presents critical insights into pig feed diversity and its determinants in a smallholder setting of a developing country.

4.1. Pig feed resources and their source

Farmers usually have several types of feed resources available for their use (Katongole et al., 2012; Ouma et al., 2015; Tatwangire, 2014). This study identified 22 different feed resources that were mainly by-products of crop and livestock processing. These feeds are however given to pigs in different forms and combinations. Similar observations were made in previous studies (Dione et al., 2015; Kagira et al., 2010; Levy et al., 2014). In this study, the use of formulated feeds was very low. Most farmers prefer feeding pigs with locally available feed resources due to the cost involved with the use of formulated feeds (Katongole et al., 2012; Ouma et al., 2015). With qualitative and quantitative availability of most of these feed resources exhibiting significant seasonal variation (N. Carter et al., 2015), farmers' use of this feed resources also follows a seasonal trend.

Farmers usually obtain feeds and/or feed resources from various sources depending on their availability, nutritional requirements and the farmers ability (Lumu et al., 2013). In this study, three sources were identified. These include purchase, own production and gathering. The different feed resources are usually obtained from different sources. There are feed resources that were being obtained only through purchase such as mineral premix and rice bran, while, there are those that can only be obtained through gathering. Similarly, there are feed resources that can be obtained from all three sources such as cabbages that can be obtained from gathering as market waste, production and purchase. Farmers usually select the source of feeds according to how easy it is (in terms of cost and availability) to obtained the respective feed resource for feeding their pigs. For instance, in most urban areas, pig farmers are reported feeding pigs more on swill, farm residue and market waste due to the ease of accessing them (Muthui et al., 2019; Nantima et al., 2016; Ouma et al., 2015).

4.2. Determinants of smallholder pig feed resource diversity

4.2.1. Socio-demographic factors

The socio-demographic factors considered in this study were farmers location, age, experience in pig production, land size owned, farmers level of education, marital status, and household dependency ratio. Results showed that pig feed diversity did not significantly vary with farm location, pig production experience, farmer's level of education and the household dependency ratio. It however varied significantly with farmer age, size of land owned, marital status and number of household members involved in farming. Specifically, with other factors held constant, a percentage increase in age would reduce pig feed diversity by about 48%. This is attributed to challenges that older farmers tend to have. As farmers age, they become less energetic to look for feed resources from different source hence reducing the diversity. Older farmers have also been shown to be less innovative than younger farmers (Läpple et al., 2015). In case of feed scarcity, farmers need to be innovative to come up with alternative feeding strategies for their feeds.

Similarly, a percentage increase in land size owned would reduce pig feed diversity by about 26%. Land is required for producing most of the feed resources identified in Table 3. More land allows farmers to produce more of crops that form the conventional feed resources that are later used to feed

pigs. With reduction in land size, farmers would produce less quantities of the conventional feed resources and would thus require alternative feed resources. This means that the few farm produced feed resources would be supplemented by other non-farm produced feed resources thereby increasing feed diversity. Such farmers would have their pig feed diversity reduced as they tend to rely on few feed resources that can be obtained through farm production. According to Tatwangire (2014), pig farmers usually adopt intensive feeding practices as a result of land scarcity. Such systems require farmers to obtain feeds from various sources thereby increasing pig feed diversity.

Results also showed that married farmers had a 50% higher pig feed diversity as opposed to single, divorced and widowed farmers combined. Farmers marital status influences a number of household farming aspects including decision making with respect to household agricultural and marketing activities. According to Carter et al. (2017), marital status is important in household pig production and marketing decision. Married household heads are also likely to get support from their spouses when it comes to looking for feeds for pig production. Marital status is also important for provision of labour for agricultural production and for decision making. In pig production, labour is an important input that determines feed diversity. In this study, results have shown that, an increase in the number of household members involved in farming would increase pig feed diversity by about 70%. In provision of feeds to pigs, households with more members involved in farming may have the capacity (financial or otherwise) to obtain feeds from different sources and this can more likely increase their pig feed diversity.

4.2.2. Technical factors

Results showed that pig herd size did not significantly influence farm pig feed diversity. However, there was a strong relationship between pig feed diversity and presence of other agricultural enterprises. Specifically, an increase in crop enterprise diversity would increase pig feed diversity by about 11%. Most of the feed resources given to pigs can be obtain through production and purchase. With more crop enterprises, there are more opportunities for having more feed resources for feeding pigs. This is because most of crops cultivated by smallholder pig farmers including maize, rice, banana, cassava, sweet potato, soybeans and sorghum are those that are usually produced for multipurpose uses including household consumption, income and as animals with three categories.

Similarly, presence of other livestock species (cattle, goats, sheep, and poultry) influenced household pig feed diversity. In this study, results showed that an increase in the number of other livestock reared on farm measured as Tropical Livestock Units (TLUs) would increase pig feed diversity by about 32%. With many livestock species on farm, farmers maybe motivated to provide feeds to the different animals from various sources due to the complementarity of the different feed resources. For instance, cattle can be fed on maize stover and maize cobs, while, pigs and chicken feed on the maize and/or maize bran. Additionally, some farmers, also feed pigs with chicken droppings. This complementarity of feeds increases pig feed diversity.

The pig breed being reared by a farmer also had a strong bearing on the number of pig feed resources used. Results showed that farmers with local and cross breeds had a lower pig feed diversity as opposed to those with exotic breeds. Specifically, farmers keeping local breeds had a 68% lower pig feed diversity, while, those with cross breeds had a 106% lower pig feed diversity than those with exotic breeds. Differences in pig feed diversity across pig breeds is partly attributed to differences in nutritional requirements for the different breeds. According to Carter et al. (2016), in smallholder farms, the nutritional requirements of local pigs are significantly lower that those of exotic pigs. In livestock production, the breed chosen by a farmer is a strong indicator of the farmer's market orientation and resource endowment. This is important in that obtaining maximum benefits from the pigs requires an extra effort in feeding them. Farmers who rear exotic breeds usually have more income (Lemke & Zárate, 2008). Farmers with more income can afford diverse feed resources for feeding their pigs.

4.2.3. Institutional factors

Whereas access to agricultural extension and membership to a village savings and loan association (VSLA) were important to smallholder farmers, our results showed that they did not have any significant influence on household pig feed diversity. Farmers who bought feeds (had access to input markets) were however having a 71% higher pig feed diversity than those who did not. By having access to input market, farmers would be able to add on to the already available feed resources on farm thereby increasing feed diversity. Lumu et al. (2013) observed that in urban and peri-urban areas, livestock farmers usually rely on markets for feeds in form of conventional feeds or crop residues that are usually available throughout the year. Access to input markets including livestock feeds has been shown to improved farmers overall innovativeness (Chindime et al., 2017). According to Tatwangire (2014), improving market access to smallholder pig farmers leads to better access to productive inputs.

Source of agricultural and market information was also seen as important to smallholder pig farmers. In this study, results provided evidence of how access to agricultural and market information influences pig feed diversity. Specifically, the results showed that farmers organization and government and Non-governmental organizations as sources of agricultural and market information did not influence pig feed diversity. However, ownership of mobile phone, use of radio as source of agricultural and market information and access to market information from friends were found to be important for increasing pig feed diversity. Farmers who owned mobile phones were having significantly higher pig feed diversity as opposed to those who did not. Additionally, farmers who used radio as a source of their agriculture and market information also had a significantly higher pig feed diversity than those who did not, while, farmers who accessed agricultural market information from friends had a significantly higher pig feed diversity than those who did not.

According to Ouma et al. (2017) access to market information is associated with high levels of market integration. Improved access to agricultural and market information usually leads to improvements in farming practices as a result of increased adoption of farm inputs. Better agricultural and market information also reduces the uncertainty associated with access to input and output markets. Access to agricultural and market information is also important in creating awareness on the best practices that farmers do not. When farmers listen to radio, or talk to their friends either physically or on phone, they are informed of what other farmers are doing in other places and are thus able to adopt their best practices including identifying new feeding resources that other farmers are using and incorporating them into their own production. Access to agricultural and market information has been shown to improve access to agricultural extension with all its benefits including feeding practices (Daniso et al., 2020; Hilary et al., 2017). Similarly, associating with other pig farming friends is important is improving pig feed diversity through social influence. Social influence has been shown to influence farmers learning behaviour and formation of intentions with respect to improved agricultural practices (Kalule et al., 2019). It is thus expected that when a farmer associates with other farmers, there is a possibility of cross learning and sharing of best practices including use of unconventional feed resources.

5. Conclusions

Pig feed diversity is important in ensuring that pigs obtain a balanced nutrition. In this study, we investigated the socio-economic and institutional determinants of pig feed resources diversity. It shows how these farm specific factors can be harnessed to improve smallholder pig feed diversity. There is an inverse relationship between age and land size owned and pig feed diversity. The study also provides further evidence that exotic pig breeds require better nutrition which is a factor of pig feed diversity. Similarly, farm household crop and livestock diversities are critical in increasing pig feed diversity. Improving access to input markets would also increase access to more diverse feeds thereby increasing household pig feed diversity. Improving access to agricultural and marketing information through mobile phones and radio is also important for household pig feed diversity. It

is important for development practitioners to put into consideration these factors when designing messages aimed at improving smallholder pig production.

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Availability of data and materials
The datasets used and/or analysed in this study are available from the corresponding author on reasonable request.

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